Optimization of Material Layout at the Warehouse Laboratory of PEM Akamigas through a Class Based Storage Approach

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Abstract

The PEM Akamigas Warehouse Laboratory serves as a vocational learning facility in oil and gas logistics, providing practical experience for students. However, the current warehouse layout is inefficient due to unstructured material placement and suboptimal movement flows. This research aims to redesign the warehouse layout using the *Class based storage* (CBS) approach, beginning with ABC-based classification of materials by movement frequency. Simulations were conducted using rectilinear distance analysis and evaluated across three storage modes: general storage, *Dedicated Storage*, and CBS. Results indicate that the proposed layout significantly reduces operational time, especially in CBS mode, which demonstrated uniform improvements in operator activity, run time, and transporter time. The CBS-based layout successfully streamlines material flow, optimizes warehouse space utilization, and enhances the realism of practical learning. Thus, the redesigned layout is not only more efficient but also supports educational objectives aligned with logistics industry standards.

Keywords: *Warehouse, Lay Out, Class, Based, Storage.*

A. INTRODUCTION

Warehouse is an integral part of a company's logistics system, serving the function of storing products (raw materials, spare parts, semi-finished goods, and finished goods), while also providing information regarding the location, arrangement, and condition of goods. The design and management of a warehouse must align with the production intensity and specific needs of the industry it serves. The layout of products within a warehouse significantly influences the flow of processes and activities. An effective and efficient warehouse layout is characterized by minimizing material damage and deterioration, as well as reducing material handling distances—since shorter distances result in faster processing times and lower transportation costs. Therefore, an optimized warehouse layout is essential to support customer satisfaction (Lambert & Stock, 2001).

A warehouse must be designed to meet all supply specification needs. According to Parji (2018), there are several main activities that take place within a warehouse, one of which is receiving. This activity includes unloading goods from incoming vehicles, inspecting purchase orders, and recording the received goods into the computerized system. After verification, goods are transferred into storage through a process known as putaway. The goods are then placed in the reserve storage area, which typically occupies the largest space in a warehouse as it holds the majority of stock inventory. Each item is stored at a location identified within the system to facilitate easy retrieval when needed. From this area, items can be directly retrieved and delivered upon request. Another critical activity is order picking. When the company receives a customer order, the system manages the picking process to ensure the correct quantity and timely fulfillment. This activity consists of several order lines, each representing a specific product item to be collected. If an order line corresponds to a full unit load such as a pallet, picking can be done directly from reserve storage. However, if the order is less than a full unit load, the items are usually retrieved from a primary storage area designed for small unit or volume picking. This distinction is important for ensuring efficiency in the distribution and order fulfillment process.

The Warehouse Laboratory at PEM Akamigas is one of the essential facilities owned by the Polytechnic of Energy and Mineral (PEM) Akamigas to support vocational education activities in the energy and mineral resources sector. This laboratory functions as a hands-on training center for students to understand logistics management concepts, material storage, and warehouse operations in accordance with industry standards—particularly in the oil, gas, and renewable energy sectors.

The Warehouse Laboratory not only serves as a storage area for educational materials but also acts as a practice center where students manage material inflow and outflow, arrange material layout, record inventory, and maintain material conditions. The materials available in the Warehouse Laboratory vary widely, including oil and gas production equipment, occupational safety (K3) tools, chemicals, and other laboratory supplies. Proper warehouse management aims to simulate real-world industrial conditions to enhance the practical learning experience.

As a learning facility, the Warehouse Laboratory at PEM Akamigas is designed to introduce students to the basic principles of warehousing systems, including receiving procedures, storage, issuing, and material distribution. Students are also taught the importance of accurate inventory recording, handling of hazardous materials, and the implementation of safety and security concepts within the warehouse environment.

However, despite functioning as a practice laboratory, the management and layout of materials at the PEM Akamigas Warehouse Laboratory are still under development. The current layout has not yet fully adopted a standardized or structured storage method. Additionally, there are several aspects of the existing layout that can still be optimized. Therefore, there is a significant opportunity to innovate the redesign of the material layout using a more systematic and efficient approach to support the effectiveness of the learning process and warehouse operations. As an innovation effort, the researcher proposes a new warehouse layout design using the Class Based Storage method in the PEM Akamigas Warehouse Laboratory.

B. METHOD

The research subject serves as the source of data and includes various variables under investigation, such as individuals (humans or animals), groups, companies, industries, places, or geographical areas. The subject of this research is the Warehouse

Laboratory of PEM Akamigas. The object of this research is the optimization of warehouse layout arrangements to facilitate operational efficiency, particularly in assisting stacker movement when transferring goods. In this case, the goods involved include cartons, jerry cans, and drums.

This study employs a quantitative research method, as all analyses are conducted using numerical approaches and data processing based on numerical values. The research measures the efficiency of the warehouse layout based on the calculation of material movement frequency and total travel distance using the rectilinear method. The data used were obtained from records of material inflows and outflows over one year at the Warehouse Laboratory of PEM Akamigas. Furthermore, materials were classified using the Pareto principle (ABC classification) to support the Class Based Storage (CBS) approach. The proposed layout design is developed based on the results of this classification and compared to the existing layout through movement distance analysis. Therefore, this study is quantitative in nature as it focuses on processing numerical data to provide recommendations for a more efficient warehouse layout.

In this research, the primary data refer to information obtained directly through field observation. The primary data were collected from the Warehouse Laboratory of PEM Akamigas. These data include the types and quantities of goods stored in the warehouse and the Material Handling Equipment (MHE) used. Secondary data in this research are obtained indirectly through literature reviews, internal documents, and relevant references to support analysis and discussion. These data complement the primary data that have been previously collected. The secondary data include literature and theories related to warehouse storage methods—specifically Dedicated Storage and Class Based Storage methods—standards and guidelines for warehouse layout design, and technical specifications of the Material Handling Equipment sourced from catalogs or product manuals.

The researcher conducted direct observations at the Warehouse Laboratory of PEM Akamigas to examine the warehouse conditions, flow of goods, types and quantities of materials stored, and the use of Material Handling Equipment. The purpose of this observation was to gain an accurate understanding of the layout and operational activities of the warehouse. The researcher also conducted informal interviews with personnel involved in warehouse management, such as warehouse staff and technicians. These interviews were casual but structured, aimed at gathering additional insights regarding work procedures, operational challenges, equipment usage, and storage arrangements. To enhance data validity and support the observations, the researcher also carried out visual documentation in the form of photos and videos. This documentation captured the actual conditions of the warehouse, storage positions, types of MHE used, and the overall warehouse layout during data collection.

A literature review was conducted to search and analyze relevant materials such as scientific journals, manuals, related research, articles, theses, and other documents related to the research topic. These sources were used to support the research arguments and conclusions.

Data processing in this study was carried out through a series of systematic stages to obtain valid analysis results that could be used as the basis for decision-making related to warehouse layout optimization. The stages of data processing are as follows:

1. Recording Inbound and Outbound Materials
   The first stage involved recording all material receipt (inbound) and dispatch (outbound) activities from January to December 2024. This data was collected from the operational logs of the Warehouse Laboratory and was used to calculate the frequency of movement for each material type. This information formed the basis for determining material flow patterns and storage space needs.
2. Calculating Material Movement Frequency
   This stage aimed to evaluate layout efficiency by calculating the total material movement distance. The rectilinear distance method was used, which measures the total horizontal and vertical distance between storage locations and warehouse entry/exit points. The total distance value served as an indicator to assess the efficiency of the existing and proposed layouts.
3. Material Classification
   The collected movement frequency data were used to group materials into three categories: Class A, Class B, and Class C. Class A includes materials with high movement frequency (fast-moving), Class B with moderate frequency, and Class C with low movement frequency (slow-moving). This classification was carried out using the Pareto approach, also known as the 80:20 principle, where most logistics activities generally arise from a small portion of material types. The results of this classification then served as the basis for assigning material placement in the proposed layout that adopts the Class Based Storage (CBS) method, ensuring that materials with higher movement frequencies are placed closer to the entry and exit areas to improve operational efficiency.
4. Proposing a New Layout
   Based on the ABC classification results and distance calculations, a new storage method using Class Based Storage was proposed. CBS organizes material placement according to its class, with Class A materials located closest to the access points, followed by Class B and C further away. The effectiveness of the new layout was then evaluated by comparing the total movement distance before and after the implementation of the CBS method.

The material movement distance calculation in this study used the rectilinear method, which estimates total travel distance based on the sum of horizontal and vertical components between points. This method is considered suitable for warehouse environments with straight aisles and movement restricted to perpendicular paths, such as in the Warehouse Laboratory of PEM Akamigas. In this study, the distance is calculated from the storage point to the activity point (inbound/outbound), then multiplied by the material movement frequency over the January–December 2024 period. The result of this calculation is used to evaluate the efficiency of the existing layout and compare it with the proposed Class Based Storage (CBS)-based layout.

C. RESULT AND DISCUSSION

1. Initial Condition of The Warehouse

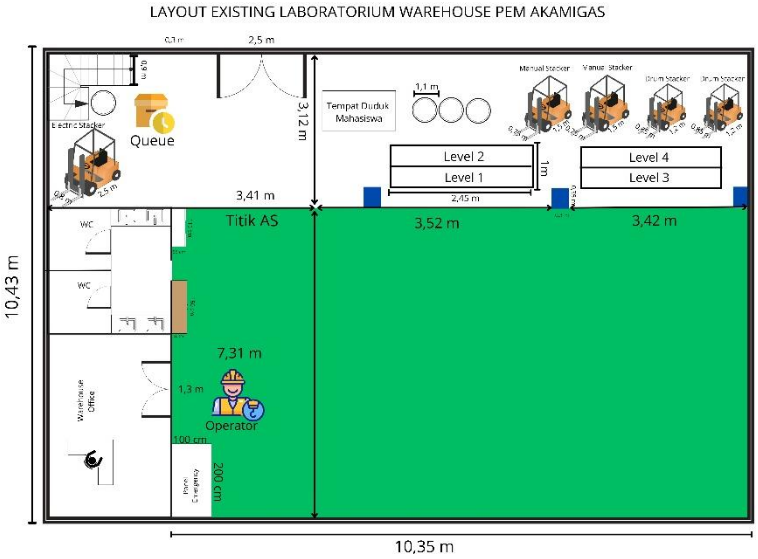

Figure 2. Initial Condition of Warehouse PEM Akamigas

The Warehouse Laboratory at PEM Akamigas is a storage facility designed as a practical learning environment for students of the Oil and Gas Logistics Study Program. This facility replicates real-world conditions commonly found in the oil and gas industry, enabling students to directly observe and engage in various logistics processes such as receiving, storing, picking, and dispatching materials. The warehouse has dimensions of 10.43 meters in length and 10.35 meters in width, covering a total area of approximately 107.99 square meters. Storage is facilitated using plastic pallet racks combined with material handling equipment in the form of an electric stacker, allowing for efficient simulation of goods movement processes.

However, the current condition of the warehouse reveals that items are arranged randomly without a standardized system. Products are stored without clear classification or grouping, leading to suboptimal storage and retrieval flows. This lack of organization has the potential to create inefficiencies in both the learning process and logistics simulations. The types of products stored represent materials typically found in the downstream oil and gas sector, including large cartons containing 4x6 liters, small cartons of 20x1 liter, white jerry cans, GIV Triple Layer red caps in pack form, and four drums used to simulate liquid storage. Given the unsystematic arrangement, a redesign of the warehouse layout is necessary to enhance storage efficiency and support a more effective learning environment that closely aligns with actual oil and gas industry standards.

2. Study Case at The Warehouse Laboratory of PEM Akamigas

The Warehouse Laboratory at PEM Akamigas plays an important role in supporting downstream oil and gas activities, particularly in the storage and distribution of materials. To ensure efficient warehouse management, an analysis was conducted on material receiving and dispatch data from January to December 2024. This analysis aimed to determine the movement frequency of each product type and to identify the ideal maximum storage capacity needed. The results also served as a basis for evaluating and optimizing the existing warehouse layout.

Based on the data, five main types of materials were identified: Karton PBK PL1 CKLT 4x5L, Karton PBK PL1 CSM 6x4L, Jerry Can White, GIV Triple Layer red cap (in pack form), and Drum. The number of items received and dispatched varied across materials—for example, Karton PBK PL1 CKLT 4x5L had 120 units received and 100 units dispatched, while Drum recorded 12 units received and 8 units dispatched throughout the year. These variations reflect differing levels of storage and handling activity, which influence placement strategies within the warehouse.

The difference between incoming and outgoing quantities forms the basis for calculating material movement frequency. This frequency is critical as it indicates how often a material moves in and out of storage. Materials with higher movement frequencies contribute more to overall warehouse activity and should therefore be placed in easily accessible locations to enhance handling efficiency and reduce time and labor efforts.

3. Inbound and Outbound Goods Handling

The data on product receiving and dispatch is utilized to determine the movement frequency of each product type and to calculate the maximum storage capacity required. This information is crucial for analyzing warehouse activity and planning an efficient storage layout. Table 4.1 presents the detailed record of material receiving and dispatch activities in the upstream oil and gas sector at the Warehouse Laboratory of PEM Akamigas during the period from January to December 2024.

Table 1. List of Material Receiving and Dispatch (January-December 2024)

Material	Received	Unit	Dispatched	Unit
Carton PBK PL 1 CKLT 4x5L	120	pcs	100	Pcs
Carton PBK PL1 CSM 6x4L	96	Pcs	80	Pcs
Jerry Can White	60	Pcs	50	Pcs
GIV Triple Layer Red Cap	48	pack	36	pack
Drum	12	pcs	8	Pcs

4. Product Movement Frequency

The movement frequency of each item can be calculated by summing the total number of items received and dispatched from the warehouse. Table 2 presents a summary of the calculated movement frequency for each product.

Table 2. Warehouse Material Movement Frequency Table

No	Material	Received	Dispatched	Frequency
1	Carton PBK PL 1 CKLT 4x5L	120	100	220
2	Carton PBK PL1 CSM 6x4L	96	80	176
3	Jerry Can White	60	50	110
4	GIV Triple Layer Red Cap	48	36	84
5	Drum	12	8	20

5. Initial Warehouse Layout and Product Movement Distances

The calculation of travel distance uses the **rectilinear method**, which considers both the frequency of material movement and the distance from the storage location to the warehouse's inbound and outbound points at the PEM Akamigas Warehouse Laboratory. This method is applied to evaluate the efficiency of the warehouse layout. As an example, the travel distance for **Carton PBK PL1 CKLT 4x5L** is calculated as follows:

Total Distance = (Frequency × Inbound Distance) + (Frequency × Outbound Distance)

Total Distance = (220 × 9.14) + (220 × 9.14)

Total Distance = 4021.6 Meters

Table 3. Total Material Travel Distance Calculation

No	Material	Frequency	Inbound Distance (m)	Outbound Distance (m)	Total	Grand Total
1	Carton PBK PL 1 CKLT 4x5L	220	9,14	9,14	18,28	**4.021,6**
2	GIV Triple Layer Red Cap	84	9,14	9,14	18,28	**1.535,52**
3	Jerry Can White	110	12,56	12,56	25,12	**2.763,2**
4	Carton PBK PL1 CSM 6x4L	176	12,56	12,56	25,12	**4.421,12**
5	Drum	20	6,53	6,53	13,06	**261,2**

6. Proposed Layout

Class-based storage is a storage policy that divides inventory into three categories—Class A, Class B, and Class C—based on the Pareto Principle, taking into account the level of storage and retrieval (S/R) activity within the warehouse. Materials are categorized into classes according to their movement frequency, with Class A representing the most frequently moved items, followed by Class B, and Class C for the least frequently moved items. The following is an example of how the percentage values are calculated based on the material movement activity in the Warehouse Laboratory of PEM Akamigas.

Movement frequency = 220

Total movement frequency = 610

Movement percentage = (movement frequency / total movement frequency) × 100%

= 220 / 610 × 100%

= 36.07%

Table 4. Material Classification Based on Movement Frequency

No	Material	Frequency	Frequency Percentage	Cumulative Percentage	Class
1	Carton PBK PL 1 CKLT 4x5L	220	36,07%	36,07%	A
2	Carton PBK PL1 CSM 6x4L	176	28,85%	64,92%	
3	Jerry Can White	110	18,03%	82,95%	B
4	GIV Triple Layer Red Cap	84	13,77%	96,72%	
5	Drum	20	3,28%	100,00%	C

The ordering of throughput and class formation is shown in Table 4.4. Following this, the travel distance of finished goods is calculated to determine the total material movement distance. Table 4.5 presents the total travel distance based on the improved warehouse layout. In this proposed layout, materials with the highest movement frequency are placed near the inbound and outbound doors, allocated across four horizontal storage racks. These four racks are then divided into three storage classes: Class A, B, and C.

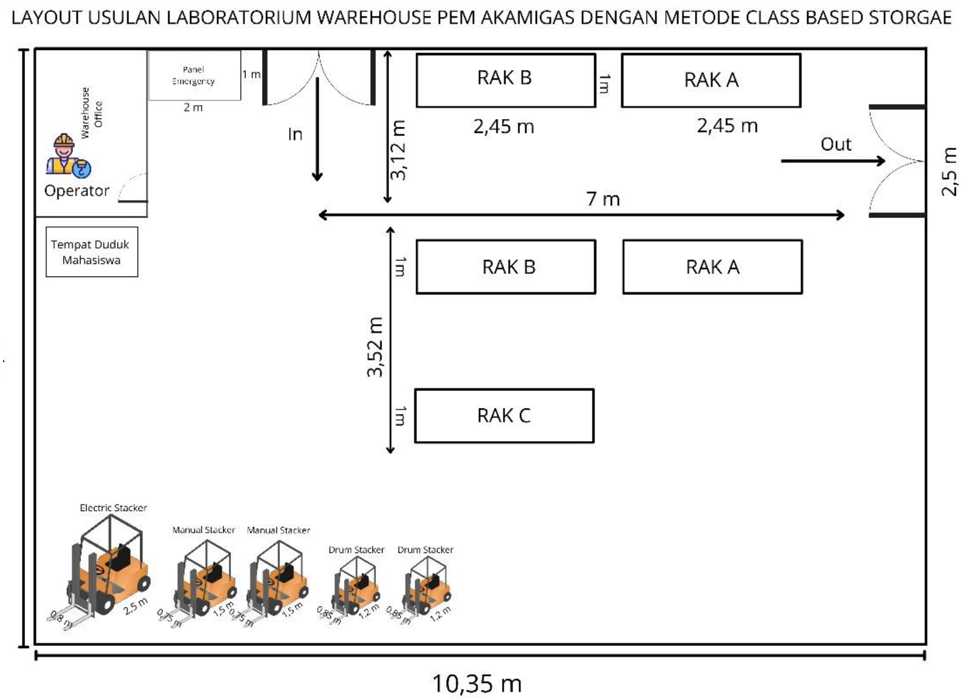

Figure 3. Purposed Layout of The PEM Akamigas Warehouse Laboratory

The PEM Akamigas Warehouse Laboratory serves as a logistics practicum facility designed to simulate an industrial warehouse in the downstream oil and gas sector. However, in its current condition, the arrangement of goods inside the warehouse is still random and lacks standardization. There is no classification system based on the characteristics or movement levels of the materials. As a result, items are placed without strategic consideration for accessibility or distance efficiency. With a warehouse area of 107.99 square meters, space utilization remains suboptimal due to an unplanned material flow, which may hinder the learning process and the effectiveness of logistics simulations conducted by students.

In response to this condition, an evaluation was carried out based on actual logistics activities using data on the receipt and dispatch of goods from January to December 2024. The analysis revealed an imbalance in material movement, where some items showed significantly higher levels of activity than others. To address this, a class-based storage approach was applied by grouping materials into A, B, and C classes using the Pareto principle (ABC Analysis). The objective is to position high-frequency items closer to the inbound and outbound areas in order to minimize travel distances and speed up material handling processes.

In the existing condition, the item with the highest movement frequency was Carton PBK PL1 CKLT 4x5L with a total frequency of 220, followed by Carton PBK PL1 CSM 6x4L with 176, Jerry Can White with 110, GIV Triple Layer Red Cap with 84, and Drum with 20. Based on the receiving and dispatch data, Carton PBK PL1 CKLT 4x5L was received 120 times and dispatched 100 times, while Drum was received only 12 times and dispatched 8 times throughout the year. Nevertheless, the placement of all these items did not account for their movement intensity, resulting in excessively high total travel distances. For instance, the total travel distance for Carton PBK PL1 CSM 6x4L reached 4421.12 meters, and Jerry Can White 2763.2 meters annually.

After performing class grouping using frequency percentages, it was found that Carton PBK PL1 CKLT 4x5L fell into Class A with a movement contribution of 36.07%, followed by Carton PBK PL1 CSM 6x4L with 28.85%, Jerry Can White with 18.03%, GIV Red Cap with 13.77%, and Drum with 3.28%. This classification process formed the basis for reorganizing the warehouse layout by placing Class A materials in the most strategic locations near the inbound and outbound areas. Travel distance was calculated using the rectilinear distance method with the formula: Total Distance = (Frequency × Inbound Distance) + (Frequency × Outbound Distance).

The results of implementing the proposed layout showed a significant reduction in the total travel distance for nearly all materials. For example, Carton PBK PL1 CKLT 4x5L, which previously traveled 4021.6 meters, now only travels 2534.4 meters, representing a 36.98% reduction. Carton PBK PL1 CSM 6x4L decreased from 4421.12 meters to 2027.52 meters (a 54.13% reduction), Jerry Can White from 2763.2 meters to 1498.2 meters (45.75% more efficient), and GIV Red Cap from 1535.52 meters to 1144.08 meters. Even the Drum, despite its low frequency, saw a slight increase from 261.2 meters to 393.2 meters due to its new storage location in alignment with the revised logistics flow.

From these results, it can be concluded that the implementation of the proposed layout using a class-based storage approach and the Pareto principle has successfully improved material movement efficiency within the warehouse. The placement adjustments based on activity frequency significantly reduced total travel distances, lowered workload, accelerated storage and retrieval processes, and created a more systematic logistics flow. This improvement positively supports the learning process in the PEM Akamigas Warehouse Laboratory by bringing it closer to real industry practices.

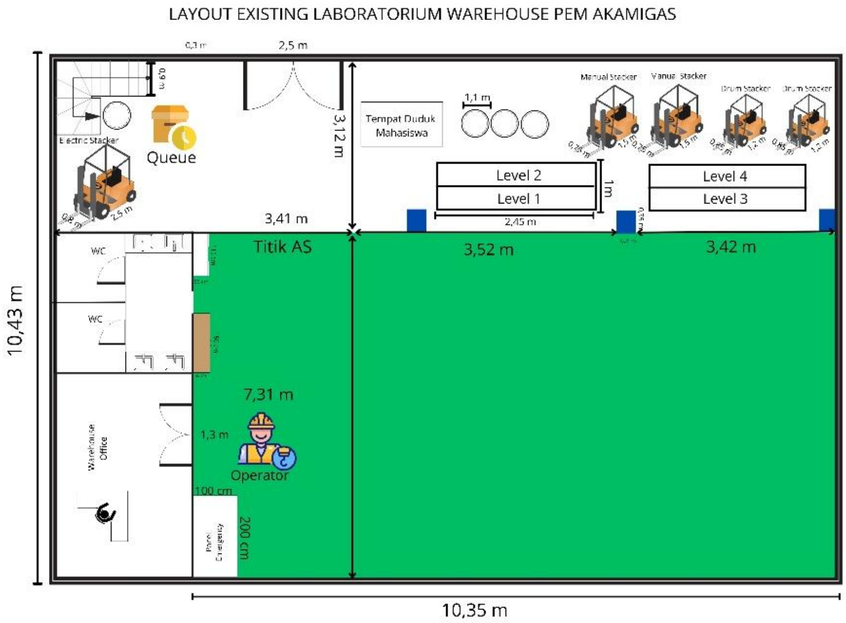

Figure 4. Existing Layout

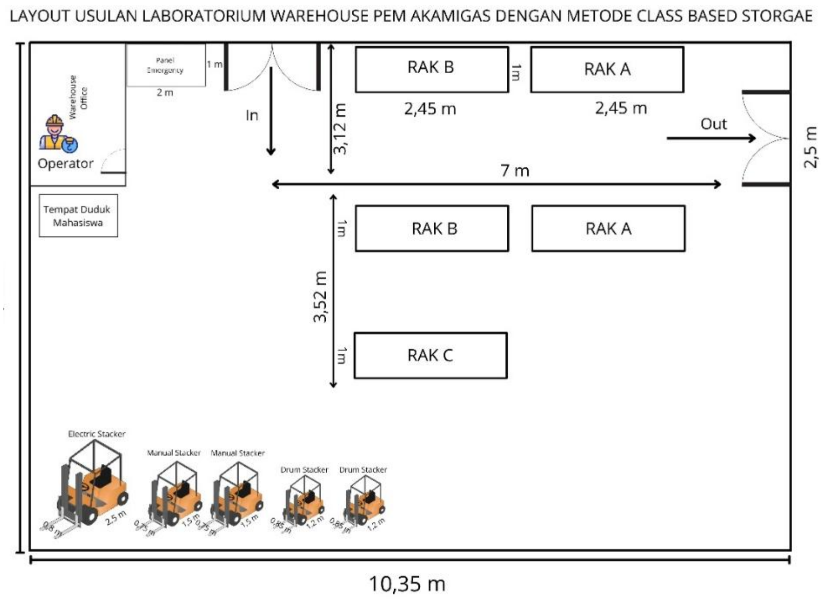

Figure 5. Proposed Layout

D. CONCLUSION

Based on the research findings on the evaluation and redesign of the warehouse layout at the PEM Akamigas Warehouse Laboratory, several conclusions can be drawn as follows. The existing warehouse layout remains suboptimal. Materials are stored without a clear classification system, resulting in longer travel times due to the mixing of high- and low-frequency items in the same storage area. The material flow does not take distance efficiency into account, leading to inefficiencies in handling and retrieval operations.

The method used to develop the new warehouse layout is the Class-Based Storage (CBS) method, which classifies materials using ABC analysis, based on the frequency of material movement data recorded over the one-year period from January to December 2024. This method allows for the placement of materials according to their movement rates (fast, medium, or slow moving).

The proposed layout was designed by placing Class A (fast-moving) materials closer to the inbound and outbound areas, while Class B and C materials were placed further away. The proposed layout also applies the rectilinear method to minimize travel distances and maximize accessibility for frequently moved items.

The proposed warehouse layout shows a time efficiency improvement of 24.78% compared to the existing condition. This was calculated based on the reduction in the total travel distance of materials, which decreased from 260.87 meters in the existing layout to 196.19 meters in the proposed layout.

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The author realizes that this report still contains shortcomings in both knowledge and writing. Therefore, the author kindly requests all readers to provide constructive feedback and suggestions. It is hoped that this Final Work Assignment report will be beneficial to everyone.

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