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Implementation of Class-Based Storage for Warehouse Layout Optimization in Temperature-Controlled Raw Material Storage (Case Study: PT. XYZ)

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Abstrak

Ketidakefisienan pada gudang bahan baku bersuhu terkendali, khususnya di industri Fast-Moving Consumer Goods (FMCG), dapat menghambat kontinuitas produksi serta meningkatkan biaya operasional. PT XYZ, sebagai salah satu produsen kosmetik terkemuka, saat ini menggunakan sistem Dedicated Storage yang belum mempertimbangkan frekuensi perpindahan material. Kondisi ini menyebabkan keterbatasan slot penyimpanan, tingginya biaya penanganan material, serta ketidakefisienan dalam proses pengambilan. Untuk mengatasi permasalahan tersebut, penelitian ini menerapkan metode Class-Based Storage (CBS) dengan mengklasifikasikan material ke dalam kategori A (pergerakan cepat), B (pergerakan sedang), dan C (pergerakan lambat). Kontribusi utama penelitian ini terletak pada integrasi metode CBS dengan prinsip nearest location serta pemodelan simulasi guna menghasilkan solusi optimal dalam perancangan tata letak gudang yang lebih terstruktu. Melalui pendekatan kuantitatif, data pengeluaran bahan baku periode Januari–Desember 2024 dianalisis untuk menentukan frekuensi pergerakan serta menghitung biaya penanganan material. Perancangan ulang tata letak dilakukan berdasarkan klasifikasi tersebut dan disimulasikan menggunakan AnyLogic, disertai analisis terkait perhitungan jarak rektilinear serta estimasi biaya penanganan berdasarkan pengeluaran untuk operator dan peralatan. Hasil penelitian menunjukkan bahwa tata letak berbasis CBS mampu menurunkan total jarak tempuh sebesar 27,55% dan biaya penanganan harian sebesar 28,67%. Penempatan material berfrekuensi tinggi di dekat titik input/output juga meningkatkan aksesibilitas dan kecepatan pengambilan. Simulasi mengonfirmasi peningkatan efisiensi gudang, optimalisasi ruang, serta penurunan beban kerja operator. Dengan demikian, implementasi CBS secara signifikan mampu meningkatkan kinerja operasional dan menekan biaya logistik. Penelitian ini menjadi referensi perusahaan dalam pengelolaan inventaris bersuhu terkendali serta dasar pengembangan penelitian lanjutan, khususnya terkait pelacakan persediaan secara real-time dan penerapan sistem dynamic slotting.

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***Kata Kunci**: Biaya Penanganan Material, Class-Based Storage, Optimalisasi, Simulasi, Tata Letak Gudang*

Abstract

Inefficiencies in temperature-controlled raw material warehouses, especially in the Fast-Moving Consumer Goods (FMCG) industry, can hinder production continuity and escalate operational costs. PT. XYZ, a leading cosmetic manufacturer, currently uses a Dedicated Storage system that fails to consider material movement frequency, resulting in limited storage slots, high material handling costs, and ineffective retrieval processes. To overcome these challenges, this study applied the Class-Based Storage (CBS) method by classifying materials into A (fast-moving), B (medium-moving), and C (slow-moving) categories based on their movement frequency. The contribution of this research lies in integrating CBS with the nearest location principle and simulation modeling to provide a structured solution for warehouse layout optimization. A quantitative approach was used by collecting outbound raw material data from January to December 2024, analyzing material movement frequency, and calculating material handling costs. The redesign of the warehouse layout considered the frequency-based classification and used AnyLogic software to simulate the proposed configuration. The analysis also involved calculating rectilinear distances and estimating handling costs based on operator and equipment expenses. The results showed that the proposed CBS-based layout reduced the total travel distance by 27.55% and decreased daily material handling costs by 28.67%. Additionally, high-frequency materials were positioned closer to the input/output points, improving accessibility and retrieval speed. The simulation confirmed increased warehouse efficiency, better space utilization, and reduced operator workload. In conclusion, the implementation of the CBS method in warehouse layout design significantly improved operational performance and reduced logistics costs. This study serves as a reference for companies managing temperature-sensitive inventory and provides a foundation for future research incorporating real-time inventory tracking and dynamic slotting systems.

***Keywords**: Class-Based Storag,; Material Handling Cost, Optimization, Simulation, Warehouse Layout*

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1. Introduction

Warehouse management is a critical component in supporting the effectiveness of production processes in industrial companies, especially within the Fast-Moving Consumer Goods (FMCG) sector, which is characterized by high production intensity and sensitivity to inventory availability (E. A. Rahayu & Silitonga, 2024). Inventory is a vital asset for a company, comprising goods intended for sale within a specific period, materials used during the production process, or raw materials that are yet to be processed in ongoing or future manufacturing operations (Mikharani et al., 2022). In a company, inventory consists of raw materials, auxiliary materials, work-in-process goods, finished products, and spare parts that support both the production process and operational continuity (Anshar et al., 2023; Cahyani et al., 2019). According to Heizer and Render in (Seah & Ridho, 2020), raw material inventory refers to materials that have been purchased but not yet processed, serving to separate suppliers from the production process. Raw material inventory refers to the stock of primary materials that a company requires for its production process (Hidayat et al., 2023; Kadafi & Delvina, 2021) PT. XYZ, a cosmetic manufacturing company, manages a temperature-controlled raw material warehouse as a key facility in ensuring the stability and quality of raw materials used in production. However, the company currently applies a Dedicated Storage system that assigns fixed storage slots to each raw material type regardless of its movement frequency (Arifin & Andesta, 2024). This has led to several inefficiencies, including a lack of available storage racks, ineffective slot allocation, and delays in retrieval times due to the non-optimal placement of frequently moved materials.

Observations at PT. XYZ found that some high-frequency raw materials did not receive specific rack space, even when there were empty slots available. This mismatch resulted in temporary storage of materials outside designated temperature-controlled zones, which could threaten the quality and compliance of raw materials with industry regulations (Sulaeman et al., 2024). Furthermore, raw materials located far from the input/output (I/O) area increased the operational workload of warehouse personnel and elevated material handling costs due to excessive travel distances (Gozali et al., 2020). In addition, the absence of layout policies that adapt to item movement behavior has caused space usage to become stagnant, with some racks consistently empty while others are over-utilized. As a result, the existing system at PT. XYZ fails to support operational efficiency, particularly in maintaining temperature integrity, rapid material access, and cost-effective material movement within the warehouse. In the FMCG sector, product turnover is rapid and the speed of production is paramount, effective warehouse management is a significant contributor to organizational success (E. A. Rahayu & Silitonga, 2024). One method that has been extensively applied in optimizing warehouse layouts is Class-Based Storage (CBS), a method that categorizes materials into three groups: A (fast moving), B (medium moving), and C (slow moving), based on their frequency of movement in and out of storage. This classification allows frequently accessed materials to be stored closer to the input/output (I/O) areas, minimizing retrieval times and reducing material handling costs (Gozali et al., 2020; Seah & Ridho, 2020). CBS is a warehouse storage policy that classifies items based on their movement frequency, allowing high-frequency materials to be stored closer to the input/output (I/O) area, while low-frequency items are placed further away. This structured allocation, commonly based on the Pareto principle, effectively reduces retrieval time and travel distance, minimizes material handling costs, improves space utilization, and enhances overall operational efficiency (Alfatiyah et al., 2021; Kharisma et al., 2024; Nursyanti et al., 2024; Silva et al., 2022). The proposed solution also integrates the nearest location Principle, which places the most frequently accessed materials in the most accessible areas, further optimizing warehouse workflows and improving operational performance by accelerate the transfer process and reduce distances from 10% to 25% compared to the previous warehouse layout (Rosihin et al., 2021).

CBS has proven effective in various industrial applications, particularly in the FMCG, automotive, and textile sectors. For example, implementation at supermarket distribution centers reduced logistics management costs by 30.15% (Lin & Ma, 2021). Studies by (Pratama et al., 2022) demonstrated that CBS implementation in automotive warehousing improved material transfer efficiency by 38.34%. (Isnaeni & Susanto, 2021) also applied CBS in a finished goods warehouse, achieving a 52% reduction in material handling distance over six months. Similarly, (Gozali et al., 2020) reported reductions in material handling times and retrieval distances, making CBS a widely used method for improving operational efficiency. Similarly, (Rosihin et al., 2021) demonstrated that CBS improves warehouse space usage by reducing travel distance within the facility, thereby increasing productivity and decreasing operational costs. (S. Rahayu & Pinasty, 2023) optimized part warehouse performance at PT XYZ by implementing an ABC-based class-based storage layout, resulting in significant efficiency gains with a 64.46% average reduction in product search time and a 55.07% reduction in part picking time. Another study by (Fadillah & Fahma, 2023) also applied CBS in a company engaged with the electricity sector, which shows 72.78% reduction in total travel distance compared to the existing layout.

In the textile industry, (Desiawan et al., 2024) explored CBS for raw material warehouse layout optimization. They found that CBS enhanced space utilization and reduced material handling costs, particularly for fast-moving materials like fabrics and threads. This approach minimized travel distance and improved retrieval speed, echoing the findings of (Ulum, 2022), who also reported improvements in warehouse efficiency through CBS implementation. In motor workshops, (Bahrudin & Herlina, 2025) applied CBS to optimize spare parts storage. This research highlights the significant advantages of CBS in environments with high product turnover, where efficient material handling is crucial. ABC analysis plays a crucial role in CBS by classifying inventory based on demand frequency. (Putra et al., 2024) used ABC analysis to optimize spare parts management at PT. Pupuk Kujang, which significantly improves the overall warehouse layout. The study by (Nursyanti et al., 2024) proposes an improvement in the placement of goods in the inbound inspection area of a logistics warehouse using the Class-Based Storage method, based on similarity and popularity principles. The result is an optimized block grouping layout that minimizes travel distance to 2,593.5 meters. (Febrianty et al., 2021) proposes the application of Class-Based Storage using ABC analysis by optimizing finished goods warehouse layout through quantitative evaluation of product movement frequency, slot capacity, and rectilinear distance, resulting in a 4.35% reduction in travel distance compared to the existing layout.

Additionally, a simulation-based approach using AnyLogic software will be employed to validate the new layout design. The simulation will model real-world operations, accounting for material movement frequency and warehouse activity, enabling the evaluation of various layout scenarios before implementing any physical changes (Mirzaei et al., 2021). By testing these scenarios virtually, the risk of errors in layout planning can be minimized, ensuring a smoother transition to the optimized warehouse design. The integration of real-time tracking systems enhances warehouse responsiveness by adjusting the storage layout based on demand shifts (Zarinchang et al., 2024). (McInerney & Yadavalli, 2022) proposed a dynamic class-based storage assignment algorithm incorporating ABC classification and product affinity, which successfully reduced average daily order-picking time by 3 hours and 20 minutes, thereby significantly increasing warehouse throughput and operational efficiency.

While previous research has explored CBS for general warehousing environments, studies specific to temperature-controlled storage (where environmental conditions must be preserved) remain scarce. Existing works do not sufficiently address layout optimization where material sensitivity to temperature is a key concern. Furthermore, few studies integrate CBS classification with simulation-based evaluation to quantify efficiency gains in both cost and distance metrics. This study fills that research gap by applying CBS to a temperature-controlled raw material warehouse and validating the layout through quantitative simulation.

In this study, the focus is directed towards raw material warehouse management using the Class-Based Storage method for PT. XYZ. Implementing a warehouse layout with the Class-Based Storage policy enables the calculation of material handling distances during storage and retrieval processes, allowing fast-moving items to be placed in areas closer to the warehouse entrances and exits, thus improving overall efficiency (Saidatuningtyas & Nadilla Primadhani, 2021). This study aims to implement the Class-Based Storage method in warehouse layout design to enhance storage efficiency and overall warehouse operations. The approach used in this research includes analyzing material movement data from the past year, classifying materials based on the ABC category, redesigning the warehouse layout using the Class-Based Storage method, and evaluating the effectiveness of the new layout using simulation software, AnyLogic. By simulating various scenarios, management can identify the best solutions before implementing them directly, thus reducing the risk of errors, improving efficiency, and optimizing resource utilization in the process (Mirzaei et al., 2021). The contribution of this research is the development of an optimized Class-Based Storage warehouse layout model for temperature-controlled environments.

2. Research Methods

The effectiveness of a warehouse layout for each company needs to be optimized to minimize potential losses that may arise from operational costs associated with each activity within the warehouse. The purpose of this study is to improve the efficiency of managing temperature-controlled warehouses and reduce material handling costs through layout adjustments based on the frequency of raw material movement. Given the varying activity levels of each material, the implementation of the Class-Based Storage method was chosen, as it is well-suited for designing layouts according to the activity levels of materials within the warehouse. This method also minimizes product retrieval times more effectively than both the dedicated storage and random storage methods. Compared to volume-based storage, the class-based storage method is easier to implement because it does not require a complete list of stock unit rankings based on volume, and it requires less time to manage (Rosihin et al., 2021).

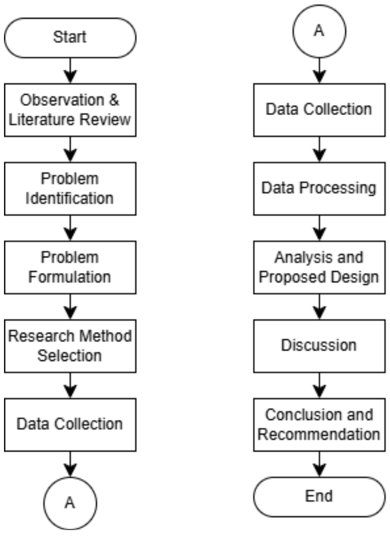

Figure 1: Research Flow

The research methodology begins with Observation & Literature Review, where the researcher observes the current conditions at PT. XYZ's temperature-controlled raw materials warehouse and conducts a review of existing literature to gather insights into similar issues and solutions. This is followed by the Problem Identification phase, in which specific challenges, such as storage limitations and inefficiencies in material handling, are recognized. Once the problems are identified, the Problem Formulation phase defines clear research questions that guide the investigation.

In the Research Method Selection phase, a quantitative approach is chosen to address the problem, involving data collection and statistical analysis. Data Collection is carried out through interviews with warehouse personnel, observations, and reviewing historical data to gain a comprehensive understanding of the warehouse's current operations. The collected data is then processed in the Data Processing phase, where raw materials are classified into categories A, B, and C based on their frequency of movement, setting the stage for more detailed analysis.

The next step, Analysis and Proposed Design, involves evaluating the existing layout and proposing a new one based on the Class-Based Storage method to optimize space usage and material handling efficiency. The Discussion phase presents the outcomes of the proposed design, analyzing its impact on operational efficiency, material handling costs, and overall performance. Finally, the research concludes with Conclusion and Recommendation, where findings are summarized and practical recommendations for improving the warehouse layout and handling procedures are provided, emphasizing the adoption of the proposed layout for better efficiency and cost reduction.

3.1. Data Processing

After data collection, data processing is carried out using the Class-Based Storage method. This subsection focuses on transforming raw operational data into structured inputs required for the CBS method, the results of the ABC classification are used for the proposed layout design. The following are the steps taken in the data processing process:

- Calculate the frequency of raw material movement in the temperature-controlled raw material warehouse by summing the average input and output activities within one month.
- Determine product classes based on the percentage of movement frequency, using the ABC classification. Class A (fast moving) represents 20% of the inventory but accounts for 80% of the value. Class B (medium moving) represents 30% of the inventory and accounts for 15% of the value. Class C (slow moving) represents 50% of the inventory but only accounts for 5% of the value. This classification is based on the company's demand and supported by previous research conducted by (Alfatiyah et al., 2021). The percentage of movement is calculated based on equation (1) adopted from (Kharisma et al., 2024) as follows:

$$\%Transfer = \frac{Monthly\ average\ transfer\ frequency}{Quantity\ per\ transfer\ operation} \quad (1)$$

- The required data includes the average input and output frequency per month for each raw material. The results obtained are sorted in order from the highest to the lowest frequency. Then, cumulative frequency calculations are performed to determine the raw material categories.
- Calculate the estimated pallet requirements for each raw material based on the maximum stock and the maximum weight of raw material per pallet.

3.2. Data Analysis

This subsection focuses on analyzing the processed data to evaluate warehouse layout performance, including distance calculation, material handling cost estimation, and comparison of layout alternatives.

a. Analysis of the Initial Temperature-Controlled Warehouse Layout

The initial layout analysis involves calculating the material handling cost (MHC) based on equation (2), (3), and (4) adopted from (Alfatiyah et al., 2021) as follows:

$$\text{Material Handling Cost} = \text{Equipment Cost} + \text{Operator Cost} \quad (2)$$

Supported by the equation:

$$\text{Equipment Cost} = \text{Depreciation Cost} + \text{Maintenance Cost} + \text{Fuel Cost} \quad (3)$$

$$Depreciation = \frac{Initial\ Cost - Salvage\ Value}{Economic\ Life\ (Years)} \quad (4)$$

This calculation includes measuring the rectilinear I/O distance for each rack using the initial warehouse size data with equation (5), which was adopted from (Heragu, 2018):

$$dij = |Xi - Xj| + |Yi - Yj| \quad (5)$$

After the distance is determined, the total travel distance is calculated by summing the I/O distance for each raw material with each material handling equipment. This travel distance calculation uses the raw material input and output frequency data. Then, an evaluation is carried out by creating a simulation using AnyLogic software with the average frequency data for each rack and the average MHC for each rack. The simulation is generalized for each rack as they share similar classifications.

b. Proposed Layout Design Analysis

The design is based on data processing to minimize material handling distance. Two layout design proposals for raw materials using the CBS method were created. Both layouts apply the nearest location (NL) principle by prioritizing the placement of high-movement-frequency (Class A) raw materials near the input/output (I/O) area and allocating hazardous materials. The layout was developed using Microsoft Excel. The analysis is being conducted to select the design that meets the following criteria: minimizing raw material movement distance, minimizing material handling costs, ensuring safety by placing heavy raw materials on the first floor, placing hazardous materials in Rack E (in accordance with the company's internal safety policy), and placing raw materials that have similarities placed close together. Proposed Layout

1 emphasizes a fixed and structured allocation of storage slots based on maximum stock requirements. Each raw material is assigned a predetermined number of pallet slots, ensuring that storage capacity is sufficient and rack usage is optimized. In contrast, proposed Layout 2 introduces slot flexibility based on packaging similarity. In addition to movement frequency and safety considerations, this layout allows temporary reallocation of empty slots among raw materials with similar packaging characteristics. The analysis layout is performed by comparing the total travel distance and the total MHC for each proposal. The calculations are done using equation (2), supported by equations (3) and (4). Then, the results are validated using simulations with AnyLogic software.

c. Simulation Using AnyLogic Software

To validate the analytical results obtained from the material handling cost calculations, a simulation was conducted using AnyLogic Professional version 8.7.7. The simulation was designed to replicate real warehouse operations by modeling the inflow and outflow of raw materials. An exponential distribution was applied to represent the inter-arrival times between events, effectively capturing the randomness and variability of material movement in the warehouse environment. This simulation validates the performance of each layout design. The simulation modeled the movement of raw materials using an event-driven approach with exponential distribution to reflect the variability in inter-arrival times during warehouse operations.

3. Results and Discussion

This section presents an integrated discussion of calculations, classification, layout design, simulation, and interpretation of the main results obtained.

3.1. Classification of Raw Materials Based on Movement Frequency

The initial step in implementing the Class-Based Storage method is to group raw materials based on their movement frequency. Historical data on raw material inflows and outflows from January to December 2024 was used as the basis for analysis. Using the ABC classification method, raw materials were categorized into three classes: Class A (fast-moving), Class B (medium-moving), and Class C (slow-moving). The classification was determined based on the Pareto principle, where:

- Class A: 20% of the raw material types account for 80% of total movement activity.
- Class B: 30% account for 15% of total activity.
- Class C: 50% account for only 5% of total activity.

Table 1: ABC Classification Summary of Raw Materials

Class	Number of Items	Percentage of Items	Percentage of Movement
A	110	26.89%	79.81%
B	117	28.60%	15.14%
C	182	44.49%	5.05%

The total cumulative movement frequency of raw materials is 12.980. The raw material with the highest movement frequency is RM 001 (refers to a company-defined raw material identification code), with a monthly cumulative frequency of 497, representing 3.86% of the total. The visualization of the ABC distribution on the initial warehouse layout reveals a misalignment between item activity and storage location. Many Class A items are placed far from the I/O point, resulting in longer travel distances and increased operational inefficiency.

3.2. Redesign of Warehouse Layout

The initial warehouse layout at PT. XYZ utilized the Dedicated Storage method, where each raw material was assigned a fixed storage location. While this approach offers ease in tracking, it does not take into account the frequency of use, leading to inefficiencies in terms of travel distance and material retrieval time. Based on the ABC classification, two alternative layout designs were developed, taking into consideration the nearest location principle, safety, and ease of access. High-frequency materials (Class A) are positioned closest to the I/O gate to minimize handling time and distance. Heavily packaged raw materials are placed on the ground floor to reduce the risk of workplace accidents. The initial layout is illustrated in Figure 2, while proposed layout 1 is illustrated in, and proposed layout 3 is illustrated in Figure 4.

3.3. Evaluation of Travel Distance and Material Handling Cost for the Initial Layout

The travel distance was calculated using the rectilinear distance method, based on the coordinates of each rack and the I/O point (assumed to be at coordinate (0,0)). The total monthly travel distance for all raw materials in the initial layout reached 507,142.4 meters. Subsequently, the Material Handling Cost was calculated using Equation (2). Two types of material handling equipment were considered: stackers and order pickers. Equipment cost, depreciation, and operational expenses were used to determine the material handling cost per meter:

- Stacker: Rp32.19/m
- Order Picker: Rp26.46/m

Based on these calculations, the total monthly Material Handling Cost amounted to Rp14,733,407.43, and the daily Material Handling Cost (assuming 22 working days) was Rp669,700.34. Table 2 provides a summary of the MHC evaluation for the initial layout.

Table 2: Summary of MHC Evaluation for Initial Layout

Component	Value
Total Travel Distance (meters/month)	507,142.4
MHC per Meter – Stacker (Rp/m)	32.19
MHC per Meter – Order Picker (Rp/m)	26.46
Total Monthly MHC Cost (Rp)	14,733,407.43
Daily MHC Cost (22 working days) (Rp)	669,700.34

The analysis of the initial layout was conducted by calculating the MHC. This calculation began with determining the rectilinear distance from the I/O area to each storage coordinate using AutoCAD software. Then, the travel distance for material handling for each raw material was calculated using input and output frequency data. The temperature-controlled raw material warehouse has 291 storage racks. The material handling equipment costs per meter were Rp32.19 for the stacker and Rp26.46 for the order picker. After calculating the MHC, the total MHC for the initial layout was Rp14,733,407.43 per month and Rp669,700.34 per day, with a total travel distance of 507,142.4 meters per month.

3.4. Evaluation of Proposed Layout 1

Proposed Layout 1 was designed to balance space utilization while minimizing material handling distances. The layout applies the nearest location (NL) principle by placing raw materials with high movement frequency closer to the I/O area. Following the nearest location principle, Class A materials are positioned on racks closest to the I/O area. The layout also considers packaging safety by grouping materials with similar or large packaging, and placing flammable materials (with hazard labels) specifically in Rack E to minimize risk. The rectilinear distance method used in the initial layout was retained for this evaluation, as the rack locations remained unchanged. Table 3 presents a summary of the MHC evaluation for Proposed Layout 1.

Table 3: Summary of MHC Evaluation for Proposed Layout 1

Component	Value
Total Travel Distance (meters/month)	367,406.9
MHC Cost per Meter – Stacker (Rp/m)	32.19
MHC Cost per Meter – Order Picker (Rp/m)	26.46
Total Monthly MHC Cost (Rp)	10,492,432.65
Daily MHC Cost (22 working days) (Rp)	476,928.76

Proposed Layout 1 strategically places Class A raw materials on the front racks (A and B), followed by Class B and Class C materials in sequential order. This arrangement successfully reduced the total travel distance to 367,406.9 meters per month, a 27.55% decrease compared to the initial layout. The MHC calculation for this layout also shows a significant reduction monthly MHC decreased to Rp10,492,432.65 and daily MHC dropped to Rp476,928.76, representing a 28.67% reduction from the initial layout.

3.5. Evaluation of Proposed Layout 2

Proposed Layout 2 applies the nearest location (NL) principle by placing Class A raw materials on racks located closest to the I/O area. The layout also considers slot flexibility based on packaging similarity. When two raw materials have similar packaging but different quantities (and one lacks sufficient rack slots) temporary adjustments are made. In such cases, empty slots can be temporarily allocated to the material with similar packaging to optimize space usage and avoid underutilization. Table 4 presents a summary of the MHC evaluation for Proposed Layout 2.

Figure 1: The Initial Layout

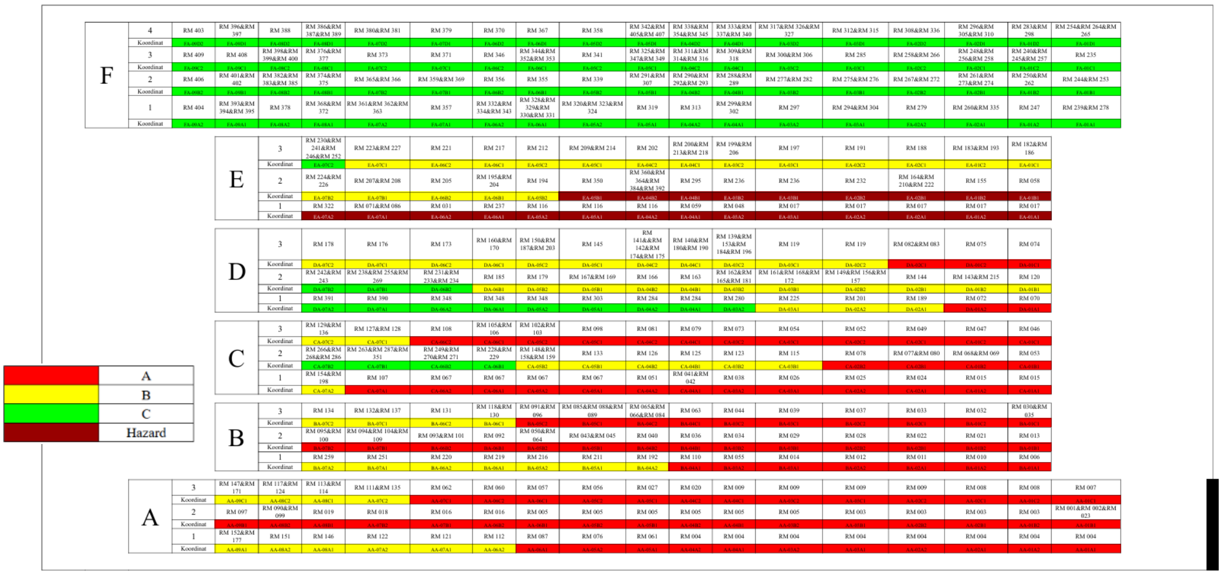

Figure 2: Proposed Layout 1

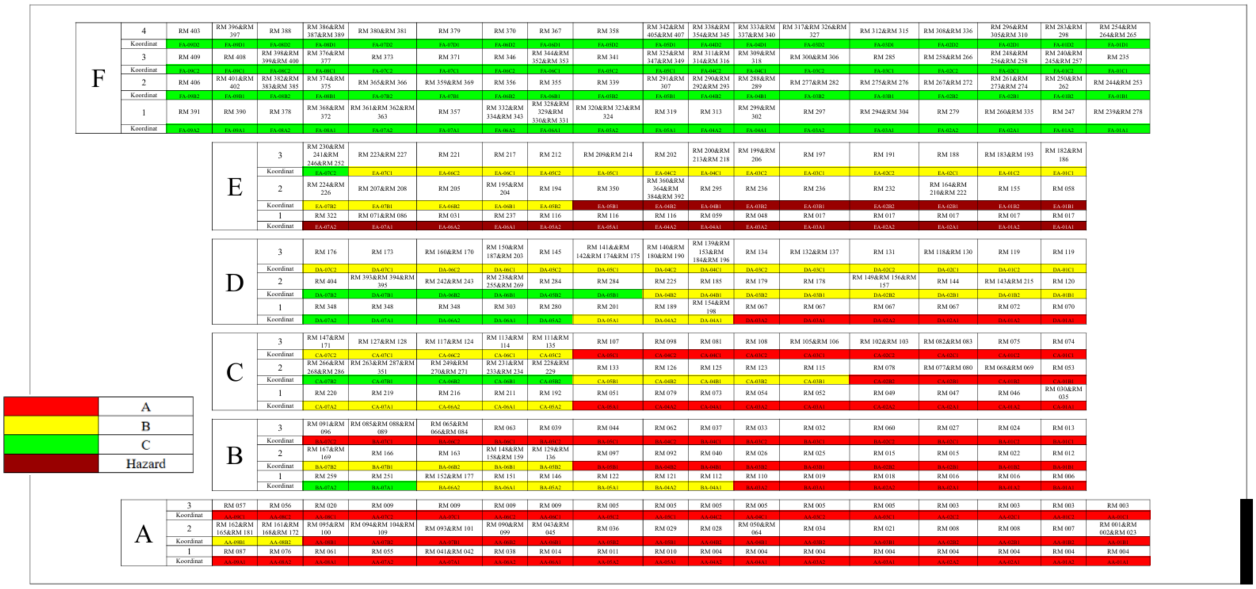

Figure 3: Proposed Layout 2

Table 4. Summary of MHC Evaluation for Proposed Layout 2

Component	Value
Total Travel Distance (meters/month)	367,461.3
MHC Cost per Meter – Stacker (Rp/m)	32.19
MHC Cost per Meter – Order Picker (Rp/m)	26.46
Total Monthly MHC Cost (Rp)	10,545,483.18
Daily MHC Cost (22 working days) (Rp)	479,340.14

Proposed Layout 2 incorporates considerations of packaging similarity between raw materials and places hazardous materials specifically in Rack E to enhance safety. This layout results in a total material handling travel distance of 367,461.3 meters per month (slightly higher than Proposed Layout 1), yet still substantially lower compared to the initial layout. The monthly MHC for this layout is Rp10,545,483.18, with a daily cost of Rp479,340.14 based on 22 working days. Although the travel distance and MHC are marginally higher than those in Proposed Layout 1, the added flexibility in rack slot usage (through grouping similar packaging types) provides operational advantages that may support more dynamic warehouse conditions.

3.6. Validate Layout

This validation uses simulation to provide a dynamic visualization of warehouse activities under each layout scenario. Figure 5 illustrates the simulation results for the initial layout, while Figure 6 and Figure 7 present the simulations for Proposed Layout 1 and Proposed Layout 2, respectively. These visual simulations serve as an essential tool for assessing layout performance and validating the effectiveness of the proposed improvements.

Following the calculations, the initial layout simulation revealed a daily MHC of Rp663,661.00, confirming the inefficiencies predicted by the analytical results (particularly due to the suboptimal placement of high-frequency items far from the I/O area).

In the simulation of Proposed Layout 1, where Class A items were positioned near the I/O point and layout planning considered both frequency and packaging constraints, the resulting daily MHC was significantly reduced to Rp473,534.00. This represents a substantial improvement in operational efficiency. Similarly, the simulation of Proposed Layout 2, which also applied the nearest location principle while adding considerations for packaging similarity and flammable material placement, showed a daily MHC of Rp479,727.00. Although slightly higher than Layout 1, this configuration still demonstrated a major cost reduction compared to the initial layout and offered greater flexibility for dynamic warehouse operations. These simulation results further validate the effectiveness of the proposed layouts in reducing operational costs and improving material handling efficiency.

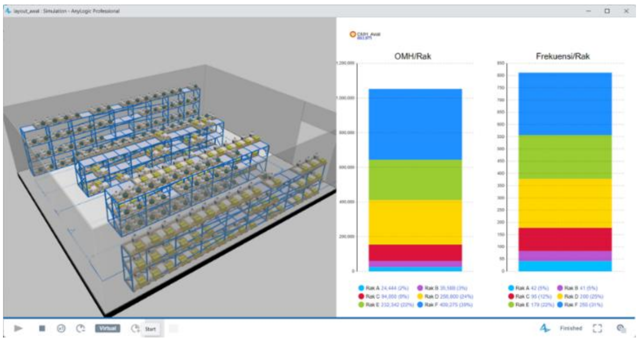

Figure 4: Simulation Results for the Initial Layout

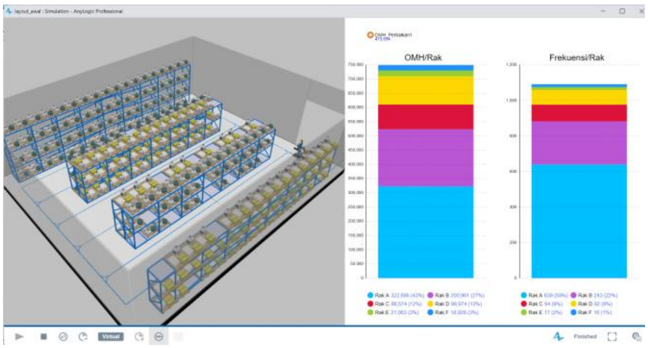

Figure 5: Simulations for Proposed Layout 1

Figure 6: Simulations for Proposed Layout 2

3.7. Selection of The Final Layout Design

The redesign of the temperature-controlled raw material warehouse layout using the CBS method resulted in two proposed layout alternatives, both demonstrating higher efficiency compared to the initial layout. The improved efficiency is primarily attributed to the reduction in material transportation distances and operator movements, as the total travel distance decreased significantly. Additionally, space utilization was optimized by calculating the required number of pallet slots for each raw material based on its maximum stock level, ensuring that storage space was allocated more effectively.

Both proposed layouts applied the nearest location principle, prioritizing the placement of fast-moving items closer to the I/O area and considering important factors such as packaging type, quantity, and hazard classifications. These improvements not only reduced operational costs but also enhanced safety and accessibility within the warehouse. Table 5 presents a comprehensive comparison between the initial layout and the two proposed layouts, highlighting key performance metrics such as total travel distance, MHC, and daily cost savings to support the selection of the most suitable layout design.

Table 5: Comparison Table

Description (Unit)	Initial Layout	Proposed Layout 1	Proposed Layout 2
Total Travel Distance (m)	23,051.93	16,700.31	16,702.79
Percentage Reduction in Total Travel Distance	-	27.55%	27.54%
Material Handling Cost (MHC) (Rp)	Rp669,700.34	Rp476,928.76	Rp479,340.14
Percentage Reduction in Material Handling Cost	-	28.78%	28.42%
Simulated Material Handling Cost (Rp)	Rp663,661.00	Rp473,534.00	Rp479,727.00
Percentage Reduction in Simulated Material Handling Cost	-	28.65%	27.72%

The total travel distance for the initial layout per month was 507,142.4 meters. In contrast, the total travel distance for Proposed Layout 1 is 367,406.85 meters, and for Proposed Layout 2, it is 367,461.35 meters. The reduction in total travel distance for Proposed Layout 1 compared to the initial layout is 27.55%, while for Proposed Layout 2, it is 27.54%. In this consideration, Proposed Layout 1 offers the largest percentage reduction.

Based on the calculations for travel distance and MHC, the largest reductions in both travel distance and MHC are seen in Proposed Layout 1 compared to Proposed Layout 2. However, Proposed Layout 1 does not fully meet one of the company's criteria: placing raw materials with similar packaging close together. Both proposed layouts have very small differences in percentage reductions and nearly identical results. Therefore, the layout selected for implementation by the company is Proposed Layout 2. This consideration is expected to reduce the number of empty rack slots, as they can be temporarily used for raw materials with similar packaging.

4. Conclusion

This study aimed to enhance the efficiency of a temperature-controlled raw material warehouse at PT. XYZ through the implementation of the CBS method. The temperature-controlled condition was treated as an operational constraint that defines the storage environment and layout boundaries. The study successfully addressed all objectives by classifying raw materials based on movement frequency, designing optimized layouts using CBS, and evaluating their performance through cost analysis and simulation. The main findings indicate that applying the CBS method significantly improves warehouse efficiency. The selected layout (Proposed Layout 2) demonstrated the best compromise between material handling cost reduction and practical flexibility. Although Proposed Layout 1 yielded slightly better numerical results in reducing travel distance and operational cost, Layout 2 was ultimately chosen for implementation due to its consideration of packaging similarities and space utilization flexibility, which aligns better with the company's operational needs.

The implementation of CBS not only reduced total material travel distance and handling costs but also enhanced layout accessibility, improved safety for hazardous materials, and allowed more efficient space utilization based on maximum stock levels. These improvements have direct implications for reducing daily operational costs and improving inventory control accuracy in FMCG supply chains.

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