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Storage layout optimization with Order Oriented Slotting (OOS) and Interaction Frequency Heuristic (IFH) for improved picking efficiency: a case study at Toserba Selamat Cipanas Cianjur

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ABSTRACT

At the Toserba Selamat Cipanas Cianjur warehouse, product placement is frequently determined by the availability of empty space rather than by demand levels or inter-product relationships. This unstructured warehouse layout has consequently resulted in order fulfillment delays, averaging 6.5% of total overall orders. This study aims to propose a more optimal storage layout and product arrangement to enhance picking efficiency within the warehouse. Layout optimization was carried out through the Order Oriented Slotting (OOS) and Interaction Frequency Heuristic (IFH) approaches, applied to the medium-sized (M) Non-Food Stock Keeping Unit (SKU) category, which exhibited the highest delay rate at 20%. These methods were implemented by analyzing Work Order List (WOL) data over the period of March 2024 to March 2025, based on the frequency of occurrence and inter-product interaction. The proposed layout was redesigned by prioritizing slots closest to the Inbound/Outbound (I/O) point for high-demand and highly interactive SKUs. Implementation results demonstrated a reduction in average Cycle Time from 4.03 minutes to 1.20 minutes per WOL, representing a time efficiency improvement of 70.27%. Furthermore, all WOLs in the new layout were successfully processed without any delays. These findings confirm that the OOS–IFH method is effective in enhancing picking performance and reducing travel time through demand-data-driven slot arrangement.

1. Introduction

Warehouse management plays a crucial role in the supply chain of retail business operations, contributing significantly to business continuity and product availability [1]. Effective warehouse management can reduce operational costs, accelerating the distribution process, improving customer satisfaction, and strengthening the company's competitive advantage [2]. A warehouse serves more than merely as a temporary storage facility; it functions as a logistics coordination center that handles a wide range of activities, including goods receiving, arrangement, storage, and the processes of retrieval and delivery of goods to the display area (order picking) [3][4]. Previous research [5] has demonstrated a significant correlation between the accurate placement of product storage locations and the efficiency level of the order picking process within a warehouse. The order picking process typically accounts for approximately 55% of total warehouse operational costs [6]. The time spent throughout the entire order picking process is divided into travel time, search time, extraction time, documentation time, and other ancillary activities [7][8].

Product placement is often determined solely by the availability of empty space, without considering demand levels or inter-product relationships. This condition results in warehouse personnel encountering significant difficulties during the order picking process. Such a problem is a real and observable issue at the retail business of Toserba Selamat Cipanas Cianjur (hereinafter referred to as 'Toserba'), which serves as the object of this study. This Toserba stores a diverse range of products in a single main warehouse located on the first floor, with product categories encompassing food, non-food, household appliances, office stationery, and cosmetics. The arrangement of goods in the Toserba warehouse still employs a simple grouping system, utilizing shelving units (for small-sized/S items) and pallets (for medium-sized/M items) for each respective product category.

Based on the available data, the total number of Work Order Lists (WOL) processed during the period of March 2024 to March 2025 was recorded at 77,863 requests. This figure represents an average monthly WOL volume of 6,489 requests. Figure 1 below presents a chart illustrating the percentage of WOL delivery delays across each product category.

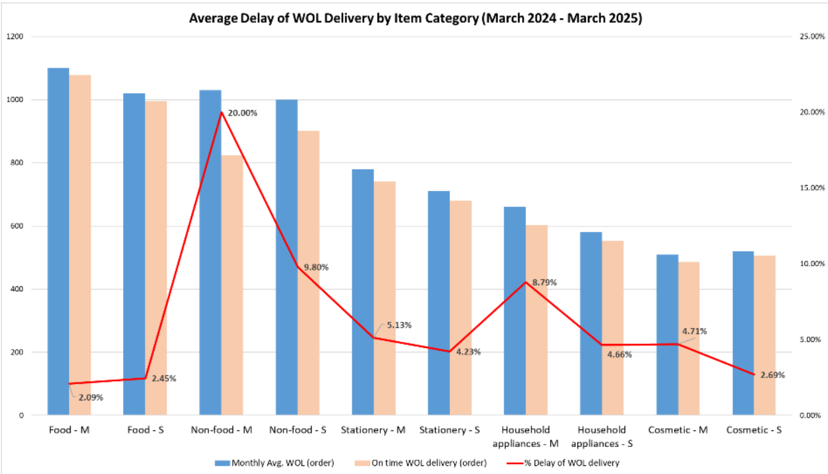

Fig. 1. Average delay of WOL per category item

Based on the data presented in Figure 1, it is evident that the Non-food M category exhibits the highest delay rate, at 20%. The Non-food M category referred to herein encompasses products such as tissues, cotton, Jolly-brand cotton buds, as well as detergent, cream, and liquid detergent products under the Attack brand. The delays observed in the Non-food M category constitute the primary problem, as this category is characterized by exceptionally high and fluctuating demand frequency. These delays occur not solely due to the high volume of requests but are also attributable to a suboptimal warehouse layout system, as evidenced by the absence of product placement based on popularity or interaction frequency, as well as numerous instances in which pickers are required to travel excessive or circuitous distances to retrieve frequently requested items. An additional contributing factor to the delays is that order picking is carried out based on urgent verbal requests or handwritten notes from the store floor, without adhering to the sequence prescribed by the WOL, thereby increasing the likelihood of errors and delays. Furthermore, based on observational data, the non-food category occupies approximately 30% of the total warehouse area during regular operational days, and may expand to as much as 40% during periods of peak demand, such as the month of Ramadan. With the highest delay rate of 20% and a considerable number of items (17 SKUs), the Non-food M category requires a more effective layout and slotting strategy than is currently implemented. This study is expected to provide stakeholders of Toserba with potential solutions to improve layout and slotting, particularly within the Non-food M category

Slotting is a design strategy employed to render SKU as accessible and reachable as possible to the areas within a warehouse where orders are consolidated based on priority [9] [10]. Previous research [11] has revealed that Order Oriented Slotting (OOS) is one of the slotting arrangement methods in which SKUs with high interaction frequency values need to be placed near one another to minimize travel distance during the order picking process. One of the methods for measuring interaction frequency within OOS is the Interaction Frequency Heuristic (IFH) approach.

Based on the problem description outlined above, this study aims to: (1) determine the proposed pallet storage layout for Non-food M category items within the warehouse; (2) determine the proposed slotting arrangement for Non-food M category items based on popularity and inter-item interaction; (3) determine the magnitude of time efficiency gains in the picking process for Non-food M category items based on the proposed layout and product arrangement.

2. Method

This research was conducted by following the rules of the scientific method, starting from preliminary studies, problem formulation, preparation of a research framework, data collection and processing, analysis of results, and drawing conclusions. The research methods are elaborated in detail in Subsections 2.1 through 2.5.

2.1 Type and Approach of Research

This study employs a quantitative method with a heuristic approach, specifically utilizing the Order Oriented Slotting – Interaction Frequency Heuristic (OOS–IFH). This approach considers the popularity value of each SKU as well as the interaction frequency between products within a single WOL, enabling the allocation of goods based on historical demand data (March 2024 – March 2025). Through this method, it is anticipated that a more optimal and efficient warehouse layout solution can be identified for the order picking process, particularly for the product category that constitutes the focus of this study.

2.2 Object and Scope of Research

The object of focus in this study is the Non-food M category items stored in the warehouse of Toserba Selamat Cipanas Cianjur. The following boundaries are established to delimit the scope of this research:

(1) This study is conducted exclusively within the warehouse located on the first floor of Toserba Selamat Cipanas Cianjur, and does not encompass the second-floor area, which serves as the storage area for fashion products.

(2) The secondary data utilized as reference consists of WOLs covering the most recent one-year period, spanning from March 2024 to March 2025, whereas the primary data in this study were collected within a one-month timeframe during April 2025.

(3) This study focuses exclusively on the non-food category of Medium (M) sized items.

(4) This study does not address the costs incurred in implementing the new warehouse layout.

2.3 Data Collection Techniques

Data collection is divided into two categories based on the type of data gathered, namely primary data (obtained through observation and interviews) and secondary data (sourced from internal warehouse records). The following data were collected in this study:

(1) Primary data: the actual conditions of the order picking process; the shelving arrangement system; the flow of goods movement from the inbound to the outbound area; the physical distances between storage locations; goods storage practices; and constraints encountered during the order picking process.

(2) Secondary data: Work Order Lists (WOLs) covering the period from March 2024 to March 2025, encompassing information regarding the volume of requests, picking frequency, as well as SKUs that frequently appear together within a single order list.

2.4 Research Procedures or Stages

The collected data will be processed through the following stages:

(1) Measurement of Storage Location Distances from the Existing Inbound/Outbound (I/O) Point, with the following sub-stages:

   a. Identification of the inbound/outbound (I/O) point and storage slot positions, yielding a list of coordinates for all product storage slots.
   b. Distance measurement using the aisle distance method, which produces the actual distance value from each slot to the I/O point.
   c. Construction of an inter-location distance matrix, resulting in a comprehensive distance matrix between storage locations, complete with the identification of critical locations (slots with the greatest distance) and strategic locations (slots with the shortest distance), which will serve as the foundational reference for composing the existing warehouse layout.
   d. Development of the existing warehouse layout, utilizing the outputs of the preceding sub-stages as reference.

(2) Pallet Relocation Strategy for Non-Food Items to Areas Near the I/O Point, with the following sub-stages:
   a. Identification of categories with low delay rates as relocation candidates. The objective of this step is to identify item categories that, when shifted to the existing Non-Food M slot positions, will not compromise the overall picking efficiency.
   b. Simulation of pallet relocation and positional rotation by re-measuring the average distance from each slot to the I/O point.

(3) Product Slotting Arrangement Based on OOS with the IFH Approach, with the following sub-stages:
   a. Measurement of the existing order picking cycle time using stopwatch
   b. Recapitulation of product popularity and interaction frequency
   c. Placement strategy for popular and frequently co-occurring SKUs
   d. Storage slot allocation and development of the proposed layout

(4) Time Efficiency Calculation, with the following sub-stages:
   a. Cycle time calculation based on the proposed layout
   b. Comparative time efficiency analysis between the existing and proposed layouts
   c. Validation of the impact of changes on the substitute categories
   d. Evaluation of the efficiency of new locations and their impact on the overall warehouse

2.5 Data Analysis Techniques

The data analysis techniques employed in this study are grounded in two principal approaches: descriptive analysis and prescriptive analysis. Descriptive analysis refers to the examination and interpretation of historical data to derive insights into what has previously occurred within a business or organization [12], whereas prescriptive analysis involves techniques for evaluating and identifying the optimal alternative for a decision-making process, considering a set of objectives, requirements, and constraints [13]. In this study, descriptive analysis is primarily applied during the stage of measuring storage location distances from the existing I/O point, resulting in the development of the existing warehouse layout. Prescriptive analysis, on the other hand, is applied through the OOS and IFH approaches to generate an optimal SKU placement solution.

3. Results and Discussion

In this section, the results of data processing and analysis of these results will be displayed, arranged based on research stages.

3.1 Presentation of Research Results

The results of this study are presented in accordance with the research stages outlined in the preceding section, namely: (1) measurement of storage location distances from the existing inbound/outbound (I/O) point; (2) pallet relocation strategy for Non-food items to areas near the I/O point; (3) product slotting arrangement based on OOS with the IFH approach; and (4) time efficiency calculation.

(1) Results of Storage Location Distance Measurement from the Existing Inbound/Outbound (I/O) Point

The storage warehouse of Toserba Selamat Cipanas covers a total area of 352 m², with dimensions of 22 meters in length and 16 meters in width. This area is divided into several storage zones based on product type and packaging size. For the Non-Food M category, the storage system employs vertically stacked pallets designed to accommodate the volume and characteristics of the products. There are three main pallet types utilized for storing Non-Food M SKUs, namely Pallet N, Pallet P, and Pallet Q, each with a differing number of slots corresponding to their respective physical dimensions and number of rack levels. Each slot within this category's pallets is designated to accommodate a single SKU (1 slot: 1 product), and is not combined with other items as is the case in other categories. Presented below is Table 1, which details the slot capacity specifications for the Non-Food M category, along with Figures 2 and 3, which illustrate the existing warehouse layout and the Non-Food M pallet layout, respectively.

Table 1. Number of Non-food M SKU Slots on Each Pallet

Pallet code	Number of level (vertical)	Number of columns (horizontal)	Total Slot	Pallet length (m)	Pallet height (m)
N	4 level (1–4)	7 columns (a–g)	28	3,2	0,97
P	3 level (1–3)	8 columns (a–h)	24	3,4	0,77
Q	4 level (1–4)	8 columns (a–h)	32	3,4	1,00
TOTAL			**84 Slot**		

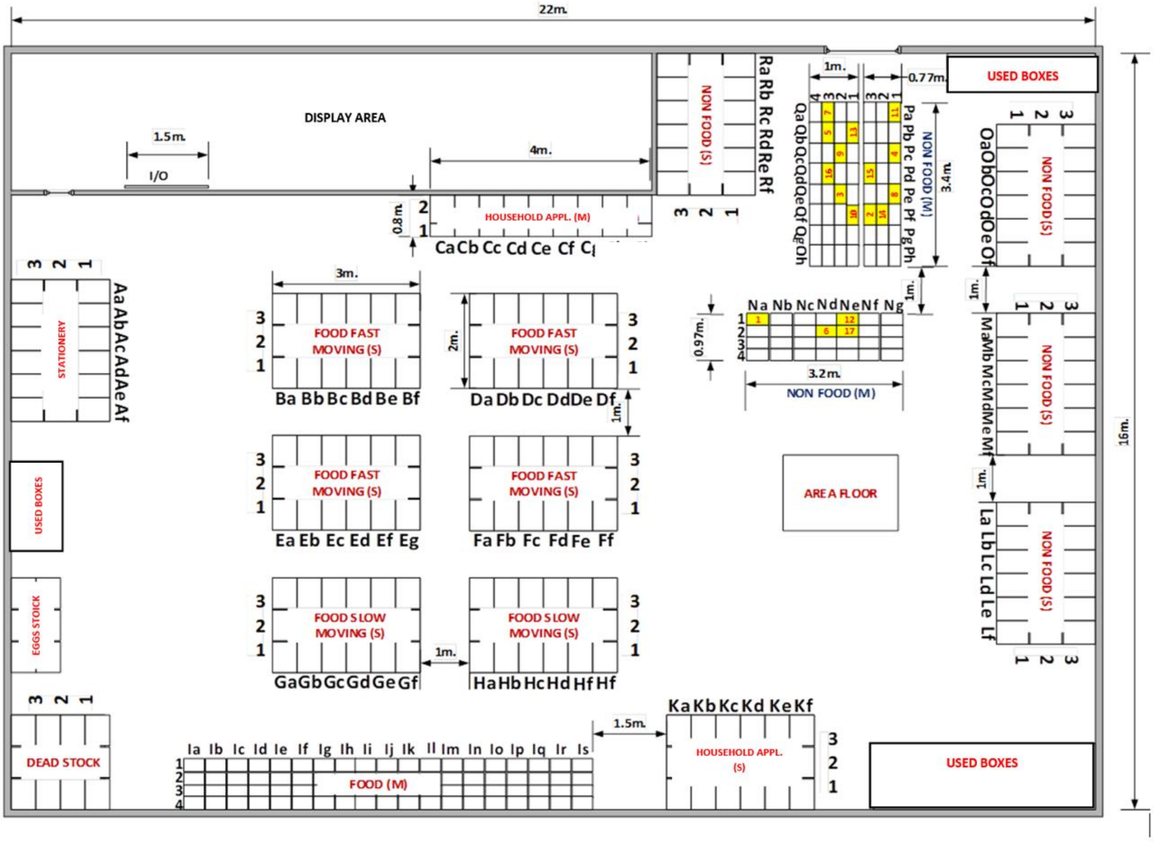

Fig. 2. Existing warehouse layout plan

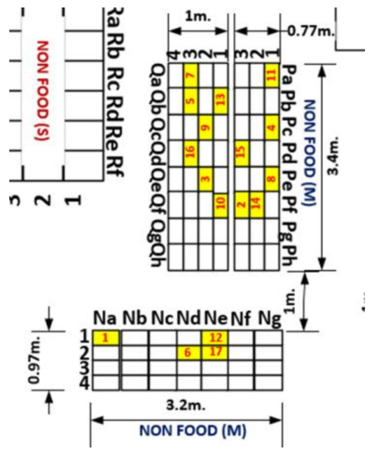

Fig. 3. Existing Layout Plan of Non-Food M Pallets

At this stage, the coordinate location (x,y) is also calculated for each of the 17 SKUs of non-food M category goods and the distance of each SKU's aisle from the I/O point as listed in Table 2. The calculation of the distance traveled for picking goods in this study uses the aisle distance method. Several previous studies

[14][15], stated that the distance strategy in warehouse layout modeling must be based on the actual aisle because the picker moves along the available path.

Table 2. Storage Slot Coordinates & Aisle Distance from I/O for Each SKU of Non-Food M

No	SKU	Slot	X (m)	Y (m)	Location	Total *Aisle Distance* from I/O (m)
1	SKU 1	Na1	11,1	–2,8	Pallet N	14.4
2	SKU 2	Pf3	13,4	–0,6	Pallet P	16,8
3	SKU 3	Qe2	12,8	0,0	Pallet Q	16,7
4	SKU 4	Pc1	13,9	0,4	Pallet P	18,6
5	SKU 5	Qb3	12,5	0,8	Pallet Q	17,8
6	SKU 6	Nd2	12,5	–3,1	Pallet N	16,3
7	SKU 7	Qa3	12,5	1,4	Pallet Q	18,2
8	SKU 8	Pe1	13,9	0,0	Pallet P	17,9
9	SKU 9	Qc2	12,8	0,4	Pallet Q	17,5
10	SKU 10	Qf1	13,0	–0,8	Pallet Q	16,6
11	SKU 11	Pa1	13,9	1,3	Pallet P	19,6
12	SKU 12	Ne1	13,1	–2,8	Pallet N	16,4
13	SKU 13	Qb1	13,1	1,0	Pallet Q	18,2
14	SKU 14	Pf2	13,6	–0,9	Pallet P	17,1
15	SKU 15	Pd3	13,3	0,1	Pallet P	17,8
16	SKU 16	Qd3	12,5	0,1	Pallet Q	16,9
17	SKU 17	Ne2	12,9	–2,9	Pallet N	16,7

(2) Pallet Relocation Strategy for Non-Food Items to Areas Near the I/O Point

The first step in the relocation strategy involves identifying all slots to be exchanged between the Non-Food M and stationery categories. The stationery category was selected as the category whose pallet locations would be swapped with those of the Non-Food M category on the basis that it exhibits the lowest delay rate (averaging 4.68%), is characterized by moderate picking frequency, and occupies pallet locations that are relatively close to the I/O point. The relocation was carried out by determining the coordinate midpoints of each pallet within the Non-Food M and stationery categories (Pallets N, P, Q, and Rack A) both before and after relocation, thereby enabling the calculation of the rectilinear distance of each pallet from the I/O point before and after the relocation process. Table 3 presents the coordinate midpoints and rectilinear distances of each pallet before and after relocation. Figure 4 illustrates the warehouse layout following the exchange of pallet positions between the Non-Food M and stationery categories.

Table 3. The Midpoint Coordinates and Rectilinear Distance of Each Pallet Before and After Movement

No	Pallet/rack	Midpoint coordinates before movement (x, y)	Rectilinear distance from I/O before movement (m)	Midpoint coordinates after movement (x, y)	Rectilinear distance from I/O after movement (m)	Distance difference (m)
1	Palet N	(13,0 , 2,525)	15,53 m	(–0,2 , –1,475)	1,68 m	–13,85 m
2	Palet P	(16,3 , 1,910)	18,21 m	(2,5 , –3,490)	5,99 m	–12,22 m
3	Palet Q	(14,3 , 1,810)	16,11 m	(0,4 , –3,490)	3,89 m	–12,22 m
4	Pallet/rack A (stationery)	(0,25 , –1,80)	2,05 m	(13,9 , –1,10)	15,00 m	12,95 m

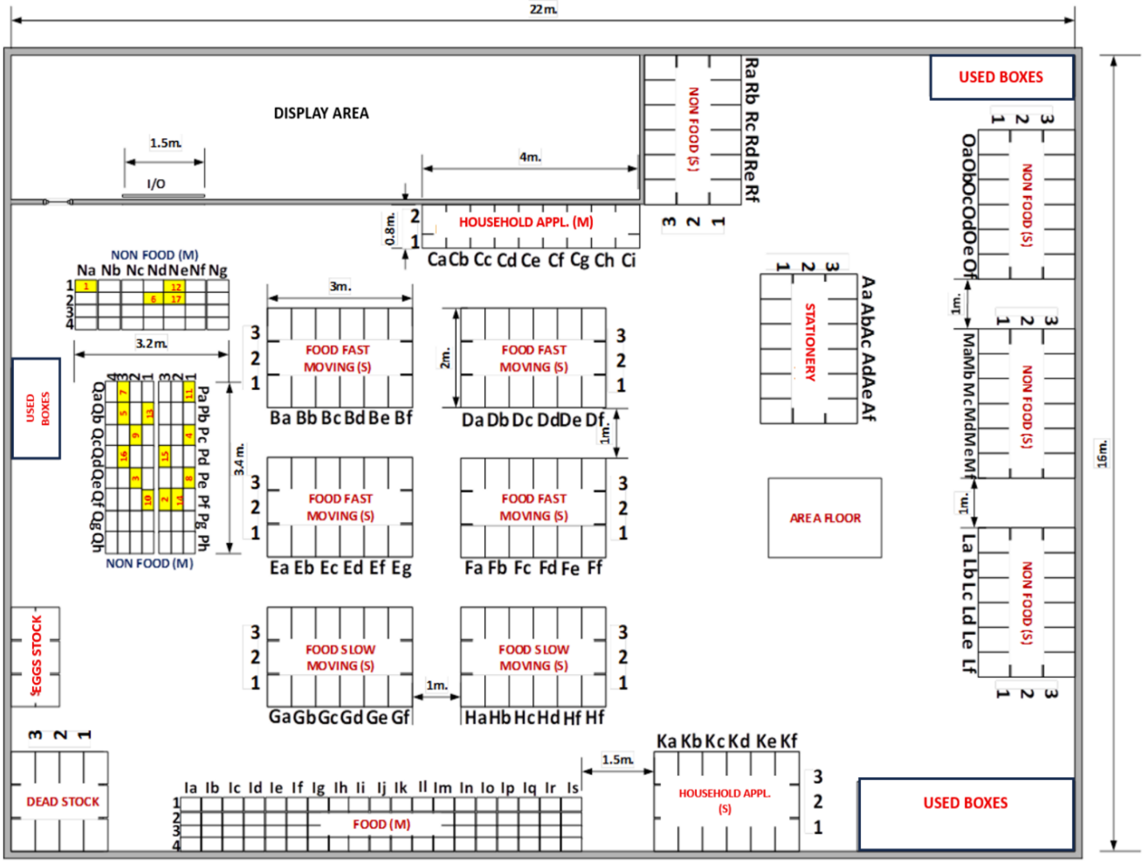

Fig. 4. Proposed warehouse layout after pallet transfer (before slotting)

(3) Product Slotting Arrangement Based on OOS with the IFH Approach

The collection of interaction data and picking frequency data for the Non-Food M category was conducted over a period of one month. Table 4 presents the picking occurrence frequency of each SKU within the Non-Food M category.

Table 4. Recap of Non-Food-M SKU Popularity for a Month

No	SKU Label	Product Name	SKU Code	Order Frequency	Total Qty	SKU Pallet
1	NFM-RNS-RFL-1800	Rinso Refill 1.8L Anti Noda	SKU1	9×	19	Na1
2	NFM-PPS-TUB-190	Pepsodent Tube 190g	SKU2	6×	9	Nd2
3	NFM-SNS-BTL-400	Sunsilk Botol 400ml – Hitam	SKU3	6×	9	Qe2
4	NFM-MLT-RFL-800	Molto Refill 800ml Pink	SKU4	7×	11	Pf3
5	NFM-LFB-BTL-900	Lifebuoy Botol 900ml	SKU5	6×	9	Qa3
6	NFM-SKL-BTL-950	So Klin Botol 950ml	SKU6	5×	7	Qb3
7	NFM-BGN-RFL-1000	Baygon Refill 1L	SKU7	4×	5	Pc1
8	NFM-ZIP-BTL-1000	Zip Pembersih Botol 1L	SKU8	4×	4	Pa1
9	NFM-RNS-RFL-1600	Rinso Refill 1.6L	SKU9	3×	4	Qc2
10	NFM-BLY-BTL-600	Bayclin Botol 600ml	SKU10	3×	3	Pd3
11	NFM-KPK-BTL-800	Kapur Ajaib Botol 800ml	SKU11	1×	1	Pf2
12	NFM-VIX-REF-900	Vixal Refill 900ml	SKU12	1×	1	Ne1
13	NFM-DNY-BTL-1000	Downy Botol 1L	SKU13	1×	1	Qf1
14	NFM-HRP-BTL-400	Harpic Botol 400ml	SKU14	1×	1	Ne2
15	NFM-BRK-GLS-1000	Bayfresh Gelas 1000ml	SKU15	1×	1	Qb1
16	NFM-SAJ-BTL-1000	So Soft Botol 1L	SKU16	1×	1	Qd3
17	NFM-LUX-BTL-1000	Sabun Lux Botol 1L	SKU17	1×	1	Pe1

The inter-SKU interaction matrix is calculated by recording the number of times two SKUs appear together within a single WOL. The more frequently two SKUs co-occur, the greater their interaction value, indicating that the two products should ideally be placed near one another to minimize picker travel distance. The interaction matrix is subsequently summarized to enable the identification of interactive SKU pairs, two SKUs that frequently appear together within a single order request (WOL) as displayed in Table 5. These pairs constitute the primary candidates positioned adjacently in the proposed layout based on the Interaction Frequency Heuristic (IFH) method, particularly for Case 1 (direct-interaction SKU grouping).

Table 5. Order of Interactive SKU Pairs Based on Interaction Frequency

No	Interactive SKU Pairs	Interaction Frequency
1	SKU1 × SKU2 (Rinso 1.8 × Pepsodent)	4×
2	SKU1 × SKU3 (Rinso 1.8 × Sunsilk)	3×
3	SKU1 × SKU4 (Rinso 1.8 1 × Molto)	3×
4	SKU2 × SKU3 (Pepsodent × Sunsilk)	2×
5	SKU2 × SKU4 (Pepsodent × Molto)	2×
6	SKU2 × SKU5 (Pepsodent × Lifebuoy)	2×
7	SKU3 × SKU4 (Sunsilk × Molto)	2×
8	SKU1 × SKU5 (Rinso 1.8 × Lifebuoy)	2×
9	SKU1× SKU6 (Rinso 1.8 × So Klin)	2×
10	SKU3 × SKU5 (Sunsilk × Lifebuoy)	1×
11	SKU3 × SKU6 (Sunsilk × So Klin)	1×
12	SKU4 × SKU5 (Molto × Lifebuoy)	1×
13	SKU4× SKU10 (Molto × Bayclin)	1×
14	SKU5 × SKU6 (Lifebuoy × So Klin)	1×
15	SKU7 × SKU8 (Baygon × Zip)	1×
16	SKU1 × SKU7 (Rinso 1.8 × Baygon)	1×
17	SKU1× SKU8 (Rinso 1.8 × Zip)	1×
18	SKU1 × SKU9 (Rinso 1.8 × Rinso 1.6)	1×
19	SKU1 × SKU 10 (Rinso 1.8 × Bayclin)	1×
20	SKU2 × SKU8 (Pepsodent × Zip)	1×
21	SKU2 × SKU6 (Pepsodent × So Klin)	1×
22	SKU2 × SKU11 (Pepsodent × Kapur Ajaib)	1×
23	SKU2 × SKU10 (Pepsodent × Bayclin)	1×

Based on the compiled results of SKU popularity and interaction data gathered over one month of observation, all 17 SKUs were classified into four main groups. This classification refers to the IFH theoretical framework, which differentiates the types of inter-SKU relationships based on co-occurrence frequency, as well as the OOS principle, which prioritizes the placement of popular SKUs near the warehouse entrance/exit point.

Following the SKU classification process based on interaction category and popularity, the next stage involves formulating a slot placement strategy for each SKU within the proposed warehouse layout. This strategy is designed to reduce picker travel time, minimize the occurrence of delays, and optimize picking efficiency, while simultaneously considering the physical conditions and spatial structure of the Non-Food M storage area. The Non-Food M storage area is proposed to adopt a vertical pallet system consisting of 6 levels and 7 primary columns on Pallet A (Aa–Ag), along with 3 additional columns on Pallet B (Ba–Bc). It should be noted that the pallet designations for the Non-Food M category, previously labeled as Pallets N, P, and Q, have been replaced with the rack nomenclature from the stationery category, resulting in the pallets being renamed as Pallet A and Pallet B. The SKU priority classification by case is presented in Table 6.

Table 6. SKU priority classification based on case

Category	Priority	Placement	Explanation
***Case* 1**	Highest	Column Aa–Ad, level 6 (top level)	Popular and interactive SKUs, must be side by side
***Case* 2**	High	Column Ae–Af, level 6 & 5 (top & second level)	Popular SKUs without strong partners, placed in the main block
***Case* 3**	Medium	Column Aa5–Ad5, bottom	SKU is not popular but has limited pairs
***Case* 4**	Low	Column Ba–Bc	Unpopular and non-interactive SKUs are separated so as not to disrupt the main channel.

Based on the classification results, all 17 non-food SKUs in category M were rearranged in the proposed layout, considering popularity factors, interactions between SKUs, and the physical location of the warehouse. Table 7 below presents a comparison between the initial slots and the proposed slots designed using the IFH and OOS methods. Figure 5 shows the proposed warehouse layout after OOS and IFH.

Table 7. Proposed non-food SKU M slots based on IFH and OOS

No	SKU Code	Product Name	Initial pallet slot	Proposed pallet slot	Priority Category	Placement Explanation
1	SKU1	Rinso Refill 1.8L	Na1	Aa6	*Case* 1	Popular & highly interactive, main block center
2	SKU2	Pepsodent 190g	Nd2	Ab6	*Case* 1	The strong pairs for Rinso, Sunsilk
3	SKU4	Molto Refill 800ml	Pf3	Ac6	*Case* 1	Interactive with Rinso, Sunsilk
4	SKU3	Sunsilk Botol 400ml	Qe2	Ad6	*Case* 1	Interactive with 3 other SKUs
5	SKU6	So Klin Botol 950ml	Qb3	Ae6	*Case* 2	Secondary interactions, still in the main block
6	SKU5	Lifebuoy Botol 900ml	Qa3	Af6	*Case* 2	Popular, minor interactions
7	SKU7	Baygon Refill 1L	Pc1	Aa5	*Case* 3	One time pairing with Zip
8	SKU8	Zip Pembersih Botol 1L	Pa1	Ab5	*Case* 3	Baygon pair, placed side by side
9	SKU9	Rinso Refill 1.6L	Qc2	Ac5	*Case* 2	Another version of Rinso 1.8L (the most popular SKU)
10	SKU10	Bayclin Botol 600ml	Pd3	Ad5	*Case* 4	Not interactive, bottom slot
11	SKU11	Kapur Ajaib	Pf2	Ae5	*Case* 4	Not interactive, bottom slot
12	SKU12	Vixal Refill 900ml	Ne1	Af5	*Case* 4	Not interactive, bottom slot
13	SKU13	Downy Botol 1L	Qf1	Ag5	*Case* 4	Non-interactive, last slot of pallet A
14	SKU14	Harpic Botol 400ml	Ne2	Ag6	*Case* 4	Non-interactive, last slot of pallet A
15	SKU15	Bayfresh Gelas 1000ml	Qb1	Ba6	*Case* 4	SKU is very rare to appear, Pallet Slot B
16	SKU16	So Soft Botol 1L	Qd3	Ba5	*Case* 4	SKU is very rare to appear, Pallet Slot B
17	SKU17	Sabun Lux Botol 1L	Pe1	Ba4	*Case* 4	SKU is very rare to appear, Pallet Slot B

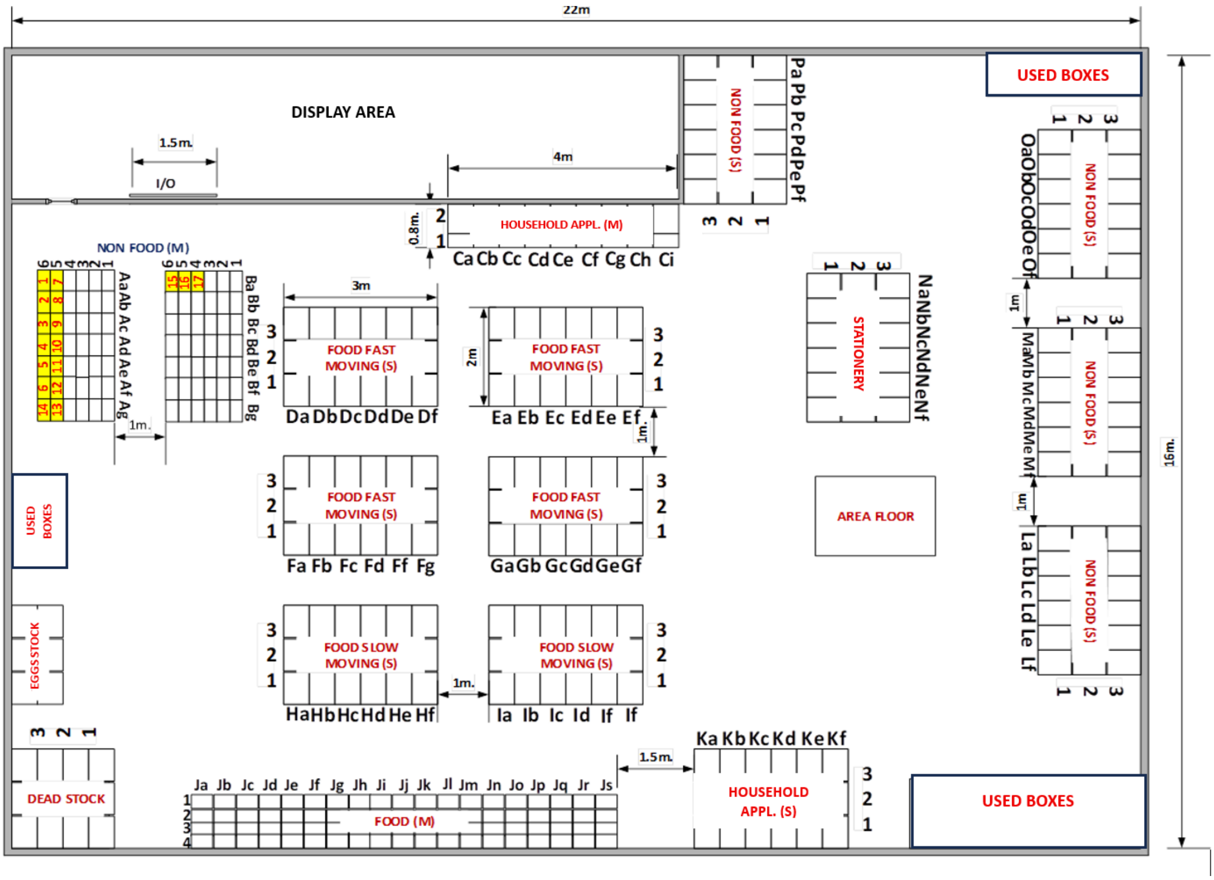

Fig. 5. Overall proposed warehouse layout after OOS and IFH

(4) Time efficiency calculation

The calculation of time efficiency for the proposed layout requires the prior calculation of the cycle time for each WOL under the existing warehouse layout. Cycle time calculation is performed to determine the actual time required by a picker to complete the order picking process within the existing warehouse layout. Previous studies have employed cycle time calculation as an indicator for evaluating the optimality of order picking routes. All cycle time data were calculated using a direct measurement method with a stopwatch over a one-month period for each WOL. Each picking route was recorded from the I/O point to the first slot, continuing sequentially to subsequent slots, and returning to the I/O point upon completion. Based on the cycle time calculations for each WOL, the average cycle time for the Non-Food M category order picking process was determined to be 4.03 minutes.

The determination of standard time was conducted to establish the ideal working time used as a benchmark in evaluating the efficiency of the order picking process within the existing warehouse layout. This process consists of two stages, namely the calculation of Normal Time (NT) through correction for work adjustment factors, and the correction of Standard Time (ST) through the addition of allowance factors. The average Cycle Time (CT) of 4.03 minutes, derived from one month of observational data, serves as the initial basis for the calculation. Based on the researcher's observation and analysis, an adjustment factor of 0.03 minutes and an allowance factor of 0.07 minutes were obtained, yielding the following results:

$$NT = CT \text{ x } (1+\text{Adjustment}) = 4{,}03 \text{ x } (1+0{,}03) = 4{,}15 \text{ minutes}$$

$$ST = \frac{NT \text{ x } 100}{100 - (\text{Allowance x } 100)} = \frac{4{,}15 \text{ x } 100}{93} = 4{,}46 \text{ minutes}$$

The comparison between cycle time per WOL and standard time in the existing warehouse layout is explained in Figure 6.

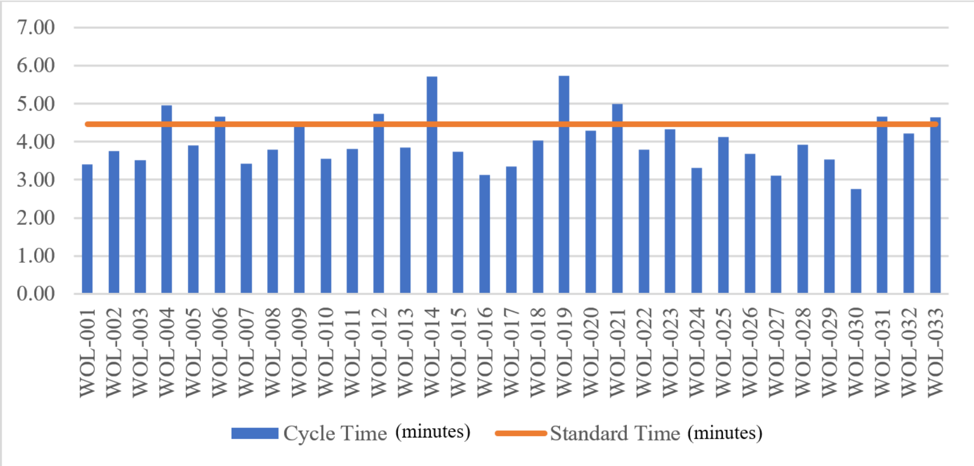

Fig. 6. Comparison chart of cycle time per WOL non-food M with standard time in existing warehouse layout

The calculation of cycle time per WOL for the proposed layout was carried out using the same method as that applied in the cycle time calculation for the existing layout. Further evaluation was conducted by comparing the cycle time measurement results per WOL in the proposed layout against the previously calculated standard time of 4.47 minutes, yielding a comparative graph as illustrated in Figure 7.

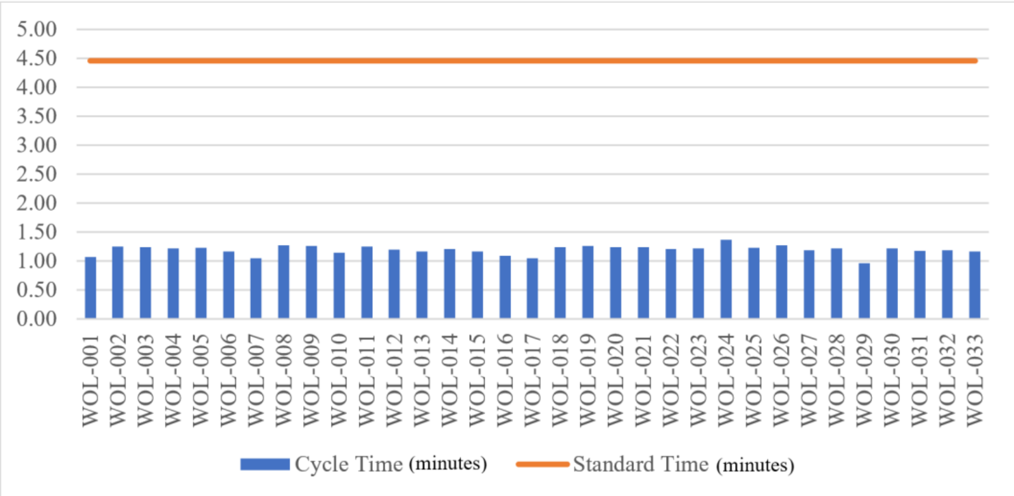

Fig. 7. Comparison chart of cycle time per WOL non-food M with standard time in proposed warehouse layout

Based on the graph in Figure 7, it can be observed that all 33 WOLs of the Non-Food M category consistently exhibit Cycle Time values lower than the standard time. No WOL reached or exceeded the threshold of 4.46 minutes. This demonstrates that the layout produced through the IFH and OOS slotting methods successfully delivers an efficient distribution of picking time, while simultaneously creating shorter, less overlapping, and logically structured picking routes based on SKU pairings.

A comparison between the cycle time per WOL and the standard time under the proposed layout was also conducted for the stationery category, to assess the impact of relocating the stationery rack positions. Figure 8 presents the comparative graph of cycle time per WOL for the stationery category against the standard time of 4.46 minutes.

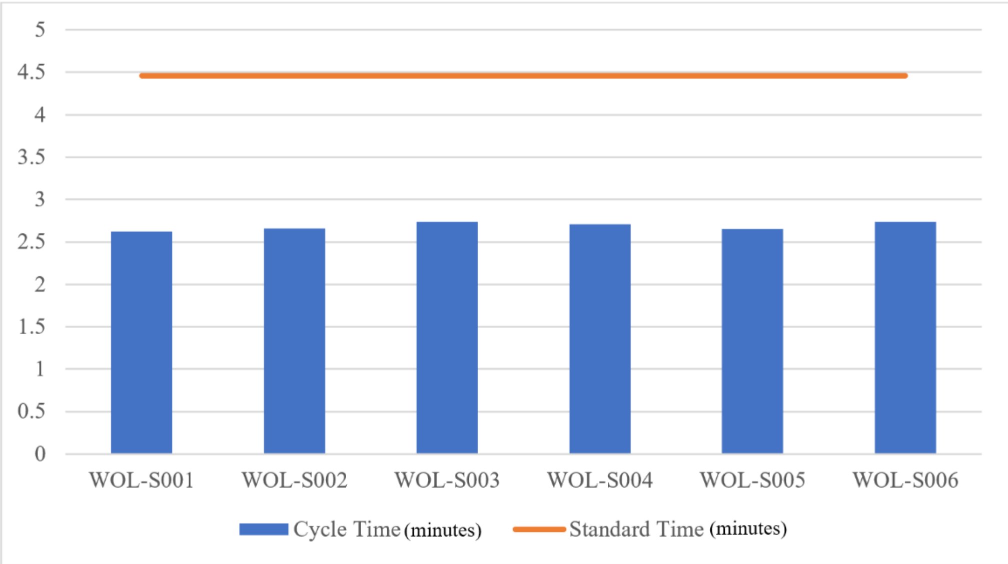

Fig. 8. Comparison chart of cycle time per WOL stationery with standard time in proposed warehouse layout

Based on the graph in Figure 8, all six WOLs of the stationery category exhibit cycle times ranging from 2.62 to 2.74 minutes, indicating that they fall below the standard time of 4.46 minutes. Despite the stationery SKU slots being more dispersed and positioned at considerably greater distances from one another, pickers were still able to complete the retrieval process within an efficient timeframe. This may be attributed to the substantially smaller number of SKUs per WOL in the stationery category compared to that of the Non-Food M category.

3.2 Analysis of Findings

The analysis was conducted across several research points, namely: (1) analysis of the existing warehouse layout conditions; (2) warehouse layout improvement strategy; (3) analysis of the application of the OOS and IFH methods; and (4) performance analysis of the proposed layout.

(1) Analysis of the Existing Warehouse Layout Conditions

Based on the description of the existing warehouse layout conditions presented in the results section, several key points form the foundation of this study:

a. An inefficiency in the initial slotting was identified, whereby the placement of Non-Food M category SKUs was distributed across three pallets (N, P, Q) without consideration of order frequency or product popularity, resulting in an unstructured picking route. Pickers were required to traverse convoluted routes, and search time increased considerably, rendering the picking process inefficient.
b. An average Cycle Time of 4.03 minutes against a Standard Time of 4.46 minutes indicates a discrepancy between the ideal and actual processing times. Of the 33 WOLs observed, 9 WOLs experienced delays, confirming that time efficiency in the existing layout remains suboptimal.
c. Order picking delays were influenced by the following factors: (1) pallet locations situated at a considerable distance from the I/O point; (2) a non-strategic and mutually obstructive layout configuration; (3) increased SKU search time due to insufficient picker proficiency; and (4) SKU placement that does not account for interaction patterns or order frequency.

(2) Warehouse Layout Improvement Strategy

Based on the description of the warehouse layout improvement strategy through the relocation of Non-Food M pallets presented in the results section, several analytical points are identified:

a. The relocation of all Non-Food M category slots to Rack A, situated near the I/O point, was demonstrated to enhance picker movement efficiency. This measure did not affect the stationery category, given its low picking frequency. The comprehensive rack-level relocation constitutes an essential foundation for the consistent application of the OOS–IFH method.

b. Rectilinear distance calculations revealed a significant reduction in picker travel distance to Pallets N, P, and Q, amounting to -13.85 m, -12.22 m, and -12.22 m, respectively. This confirms that the new layout is more efficient. Although Rack A (stationery) was relocated to a farther position (+12.95 m), the impact is minimal due to the low picking frequency of stationery SKUs.

(3) Analysis of the Application of the OOS and IFH Methods
Based on the application of the OOS and IFH methods to the proposed warehouse layout, several analytical points are identified:

a. The analysis of SKU popularity and inter-SKU interaction yielded a placement priority scheme derived from the interaction matrix. Popular SKUs were positioned near the I/O point, while SKU pairs with high interaction values were placed adjacently. This strategy reduces back-and-forth picker movement and aligns the layout with actual order patterns.
b. The new slotting strategy positions popular SKUs in priority slots that are easily accessible (lower racks, left columns), while interactive SKUs are placed in adjacent positions even when not necessarily occupying priority slots. This creates a more systematic slotting system that is oriented toward consumer order patterns and effectively addresses the shortcomings of the previously randomized layout.
c. The proposed layout, comprising Pallet A and Pallet B (for the Non-Food M category), contains a total of 84 slots arranged in 6 vertical levels with a 1-meter inter-pallet spacing. SKU placement must also consider item weight (heavier SKUs on lower levels, lighter ones on upper levels) as well as picker accessibility. The stationery rack, which has exchanged locations with the Non-Food M pallet positions, does not impede picker operations given the relatively small number of SKUs in the stationery category. The visualization of the proposed layout demonstrates a more efficient and structured slot distribution that supports a straight picking flow from the I/O point.

(4) Performance Analysis of the Proposed Layout
The performance of the proposed layout can be assessed through the achievable time efficiency gains. The key analytical points regarding the proposed layout's performance are as follows:

a. The application of the IFH and OOS methods successfully reduced the average cycle time for the Non-Food M category to 1.20 minutes per WOL, well below the standard time of 4.46 minutes. The strategic placement of popular SKUs and interactive pairs at prioritized locations resulted in shorter picker routes and faster SKU retrieval. For the stationery category, despite being relocated farther from the I/O point, Cycle Time remained below the standard due to its low picking frequency.
b. In the existing layout, 27.27% of WOLs experienced delays. However, in the proposed layout, all 33 Non-Food M WOLs were completed without any delay. This demonstrates the effectiveness of the empirical data-driven slotting method based on SKU popularity and interaction. The performance of the stationery category also remained stable following relocation, confirming that the slot redistribution did not produce any adverse impact.
c. The cycle time comparison graph reflects a positive trend, with cycle times in the proposed layout consistently lower, ranging from 0.97 to 1.37 minutes for Non-Food M and 2.62 to 2.74 minutes for stationery. This visualization reinforces the evidence that the new layout is more adaptive to the actual demands of the picking process and is capable of significantly reducing delays.

3.3 Implications of the Results

Based on the results and analysis presented in this study, the following implications can be formulated:

(1) The improvement of goods arrangement in warehouses with many item types and product categories can be accomplished through an approach based on interaction patterns and demand frequency.

(2) The goods arrangement strategy and warehouse layout determination can be rendered more precise by considering demand patterns, as this facilitates the identification of popular items and easily accessible priority slots.

(3) Warehouse stakeholders may undertake partial — rather than comprehensive — layout improvements and goods rearrangement in accordance with item popularity levels and priority slot designations.

(4) Future research is recommended to employ the Association Rule algorithm in processing interaction frequency data. This approach can assist in identifying inter-SKU relationship patterns more profoundly, thereby enabling slot determination based on product interaction proximity to be conducted with greater accuracy and grounded in actual historical data.

3.4 Limitations of the Study

Several limitations were encountered during this study, including:

(1) The adequacy test and uniformity test for cycle time data were not conducted, owing to the severely limited time and restricted data collection access. Consequently, the cycle time data obtained represent sample-based picking time measurements for each WOL rather than the complete dataset.

(2) This study employs a heuristic method, which generally does not guarantee a truly optimal solution, as it tends to rely on simplified rules in problem-solving. The adoption of alternative approaches, such as the Association Rule algorithm, would enable the identification of more accurate interaction patterns.

4. Conclusion

This study successfully addressed three research objectives related to warehouse layout optimization for the Non-Food M category at Toserba Selamat Cipanas Cianjur. First, the relocation of Non-Food M pallets (N, P, Q) to Rack A yielded a more strategic pallet storage layout, reducing the rectilinear distance of each pallet from the I/O point by 12.22 to 13.85 meters. Second, the slotting arrangement based on the OOS–IFH method successfully classified all 17 SKUs into four priority cases, positioning popular and highly interactive SKUs (Case 1–2) in the most accessible slots nearest to the I/O point, while low-demand SKUs (Case 3–4) were assigned to secondary positions without disrupting the overall picking flow. Third, the proposed layout demonstrated a time efficiency improvement of 70.27%, with average cycle time reduced from 4.03 minutes to 1.20 minutes per WOL, and all 33 WOLs processed without delay. This study addresses a gap in the existing literature regarding the practical application of OOS–IFH in small-to-medium retail warehouse settings, where product placement has traditionally relied on available space rather than demand-driven data. The findings demonstrate that even a partial, category-focused layout intervention can yield substantial efficiency gains. For future research, it is recommended to: (1) apply the Association Rule algorithm to capture more nuanced inter-SKU interaction patterns; (2) extend the scope to include additional product categories to assess cross-category layout optimization; and (3) incorporate implementation cost analysis to evaluate the economic feasibility of the proposed layout changes.

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