

CHAPTER 2

LITERATURE REVIEW AND BASIC THEORY

2.1. Literature Review

The problem in the shipping process is one of the main challenges in warehouse management, especially for the manufacturing industry, which relies on the punctuality of product distribution. Delays in the shipment can bring a significant impact towards customer satisfaction, logistic costs, and the overall supply chain. In this context, delayed shipment is mostly caused by internal warehouse issues. Previous research explains how several issues in the warehouse could both directly and indirectly affect the delay in the shipping process. Therefore, it is important to do further analysis about these issues occurring in the warehouse.

2.1.1. Internal Warehouse Problems Causing Product Picking Up Delay

Delay in product picking up in the warehouse might be caused by several factors. Man (People), Material, Method, and Machine could affect warehouse performance in terms of the product picking process, according to Oo & Sukhotu (2023). Man (people) issues refer to incompetent staff who are in charge of the picking up activity that does not apply the efficient way to retrieve stored product. The staff is only focusing on picking items according to lists provided. Most staff travel around the warehouse, leading to unnecessary motion during orders. Repetitive picking frequently happens from the same location. In the Material factor, the staff is not provided with proper material handling equipment. This allows the warehouse staff to use more time and energy to retrieve the product. Moreover, the staff start to work on every order announcement, resulting in extra processing time with many order adjustments. This is possibly caused by the lack of workflow and cutoff time. Additionally, there is no proper guidance for each staff, when a new staff is in charge, they will take more time to find and pick the listed products, which often end up finish not on time. Even though the company implemented software to facilitate real-time inventory data and order status check, sometimes it was unavailable which allows staff to manually check and input the shelf locations. This process takes hours during which pickers were left idle.

2.1.2. Common Problem of Picking Activity in Warehouse

In recent years, to meet the increasingly diverse needs of customers, companies must deliver a wide variety of products to customers within short delivery times.

Logistics warehouses, which comprise the core of the supply chain, have attracted attention as solutions to this problem. The operations in a typical logistics warehouse are storing, storage, order picking, and packing. According to Tompkins et al. (2010), most of time consumed in the product picking operation is travel time. There are five factors that need to be optimized in order to reduce pickers' journey times: batching, routing techniques, storage assignment, layout design, and order zoning. Picker behavior is limited by order batching, routing, and zoning optimization, which may put the picker under stress. The layout design and storage assignment are the main topics of this study. Both factors have a major impact on warehouse operation efficiency; therefore, optimizing them will enhance a facility's operation management. In order to determine the best warehouse design and the impact of design modifications on all warehouse attributes, this study aims to build a model. The final objective is to use this to develop a system that aids businesses in their choice to redesign their warehouses. Therefore, it is important to deeply acknowledge the impact of each element of the layout and storage assignment on the efficiency of the order picking operations.

2.1.3. Warehouse Operations Disruptions by Order Changes and Blocked Aisle

In warehouse operations, several factors are involved, such as proper allocation of manpower, the optimal layout design, and the usage of material handling tools. Issues such as sudden changes or adjustments in the picking order and aisle blockages can arise during warehouse product picking activities, according to Ueno et al. (2024). When there is a new update of products to be shipped or picked, or a change in staffing, a picking order change will occur. Aisle blocking caused by a transporter, such as forklift, is parked in the aisle; carts or pallets filled with stored products are sitting on the aisle; or there is staff doing the picking in the area. These kinds of disruptions usually lead to changes in picking routes, which affect the warehouse's performance.

Order picking refers to the retrieval activity in units of placed orders. According to Merkurjev et al. (2009), picking activity is a critical and costly activity in the warehouse, up to 55% accounted of all warehouse operating costs. This means that picking activity is very crucial and one of a huge indicator of the overall warehouse performance.

2.1.4. Picking Process Delay Due to Inefficient Storage Assignment

Another significant issue in warehouse operations that contributes to delays in the picking process is inefficient storage assignment, which often leads to excessive travel distances and picker congestion. When high-demand items are placed far from dispatch areas or grouped without considering picking frequency, pickers are forced to travel longer distances and frequently cross paths with others, leading to traffic bottlenecks, especially during peak hours. Based on Alherimi et al. (2024), unoptimized storage zones not only increase picking times but also contribute to higher operational costs due to the additional labor and equipment usage required to fulfill orders. Their study implemented a hybrid optimization approach using genetic algorithms and simulation modeling to analyze and redesign the warehouse layout, resulting in a significant improvement in overall picking performance and a notable reduction in congestion within high-traffic aisles.

In a similar vein, Roodbergen et al. (2009) emphasized that congestion in narrow aisles, particularly in picker-to-parts systems, is a primary cause of delay when multiple pickers or forklifts operate simultaneously within limited space. Their research highlighted that while optimizing travel distance is crucial, it must be complemented by strategic zoning and space allocation to reduce conflicts between pickers. Additionally, Erdoğan et al. (2012) argued that traditional storage assignment strategies fail to account for order correlation where certain SKUs are frequently picked together, thus leading to inefficient routes and unnecessary backtracking.

To address these issues, modern warehouses are increasingly adopting ABC-based zoning, dynamic slotting, and traffic flow simulations to ensure that storage assignment aligns with both product demand and operational flow. These methods not only reduce the average picking time but also minimize aisle blockages and improve safety within the warehouse. Therefore, it is evident that improving picking efficiency requires a holistic approach that incorporates both layout optimization and intelligent storage planning strategies. The summary of the literature review is in Table 2.1.

Table 2.1. Summary of Literature Review

Nr.	Author	Object	Problem	Solution
1	Oo & Sukhotu (2023)	Internal warehouse operations.	Picking delays due to human error, lack of guidance, and system unavailability.	Staff training, process structuring, and reliable system support.
2	Tompkins et al. (2010)	General warehouse picking system.	High picking time due to inefficient travel routes.	Optimization of batching, routing, zoning, storage, and layout design.
3	Ueno & Hirata (2024)	Picking a disruption scenario.	Aisle blockage and order changes causing route deviation.	Flexible routing and better aisle management.
4	Merkuryev et al. (2009)	Warehouse cost structure.	High cost from picking operations (up to 55%).	Efficiency improvements in picking activity.
5	Alherimi et al. (2021)	Warehouse layout design.	Inefficient storage leading to congestion and travel delay.	Hybrid optimization approach for layout redesign.
6	Roodbergen & Vis (2009)	Picker-tp-parts systems.	Congestion in narrow aisle.	Strategic zoning and aisle management.
7	Erdoğan & Miller-Hooks (2012)	Storage assignment policy	Storage policies ignoring SKU correlation lead to inefficiency.	ABC zoning, order correlation analysis, and dynamic slotting.

2.2. Theoretical Background

Basic theory is a conceptual framework that can help in conducting research. This theoretical basis has been adjusted to the problems and solutions being addressed.

2.2.1. Systematic Layout Planning (SLP)

Based on Kumar et al. (2022), Systematic Layout Planning (SLP) is a structured methodology used to design or optimize facility layouts, focusing on material flow and activity relationships. It involves analyzing the relationships between warehouse activities, such as receiving, storage, picking, and shipping, to create an efficient and logical arrangement of resources. The process starts by gathering detailed data about the warehouse's operations, including flow volumes and activity relationships. Next, a relationship diagram is created to visualize the connections and dependencies between activities. Based on these insights, alternative layouts are developed and evaluated against key criteria, such as space constraints, operational efficiency, and safety considerations. SLP ensures that the final layout minimizes unnecessary movement, reduces handling time, and aligns with the warehouse's operational goals. For the company, this method helps ensure that products are organized logically, improving retrieval times and reducing the risk of damage during handling.

2.2.2. Facility Layout Design by Process Layout

According to Gu et al. (2010), facility layout refers to the physical arrangement of various resources and operational elements within a workspace, including machines, equipment, storage areas, and material handling systems, with the primary goal of enhancing overall workflow efficiency and space utilization. A well-designed layout minimizes material handling time, reduces travel distances, prevents congestion, and ensures smooth and safe movement of goods and personnel.

A process layout or functional layout, is a layout design where similar processes or functions are grouped together in certain designated areas. Process layout is commonly applied in environments where a wide variety of products are handled and where every product may require different processing activity steps. The process layout is suitable for operations with low product volume and high variability, as it brings flexibility in the goods and workers movement. In the context of a warehouse, process layout allows different functional areas, such as receiving, inspection, sorting, packing, and dispatch, to be separated and optimized independently. This setup supports efficient resource utilization, especially when the warehouse handles various product types or custom orders. However, one of the challenges of process layout is the potential increase in travel distance

between departments, which might impact efficiency if not well-managed. Despite this, process layout remains an effective method in facilities where customization, product diversity, and process specialization occur.

2.2.3. Warehouse Storage Policy

The effectiveness of a warehouse's operation is related to and affected by the implemented storage policy. A storage policy that is properly adopted determines how products are assigned in the warehouse, directly affects the space utilization, picking efficiency, and overall operational costs. The selection of a storage policy must be align with the inventory characteristics, demand patterns, and the level of automation available. According to Tompkins et al. (2010), commonly, warehouses use storage policies such as;

a. Dedicated Storage

In this policy, each product or SKU is assigned a specific, fixed location in the warehouse, regardless of inventory level. The characteristics of this policy are easy to locate and pick items, but have inefficient use of space, creating empty locations when stock is low. This policy is often used for high-demand or high-turnover items.

b. Randomized Storage

Also called “shared storage”, items are stored in any available location. The location will be tracked using a warehouse management system (WMS). The characteristics of this policy are maximizing warehouse space utilization but it requires accurate real-time tracking, moreover, it needs longer search time and retrieval time if WMS is inefficient.

c. Class-Based Storage

In class-based storage, products are grouped into several classes, for example like A, B, C, based on metrics like frequency of use or turnover, and each class is assigned a specific storage zone.

d. Other Policies

Other policies such as Zone storage (items stored based on department or category) or Cube-per-order Index that minimizes picking travel by storing items often picked together nearby.

Dedicated storage, randomized storage, and class-based storage, each offering unique trade-offs between accessibility and space efficiency. In addition, in modern warehouses, other strategies such as dynamic slotting or zone-based storage are

increasingly used as part of adaptation to fluctuating demand and product variety. Understanding these approaches is essential for improving warehouse performance and ensuring timely demand fulfillment.

2.2.4. ABC Classification Theory

ABC classification is a widely used inventory and warehouse management method that categorizes products based on their significance, typically measured through movement frequency, value contribution, or demand volume. According to Tompkins et al. (2010), this technique is grounded in the Pareto principle, which suggests that a small percentage of items with a ratio for A class 20%, B class 30%, and C class 50%. The graphical representation of the ABC classification can be seen in Figure 2.1.

Graphical representation:

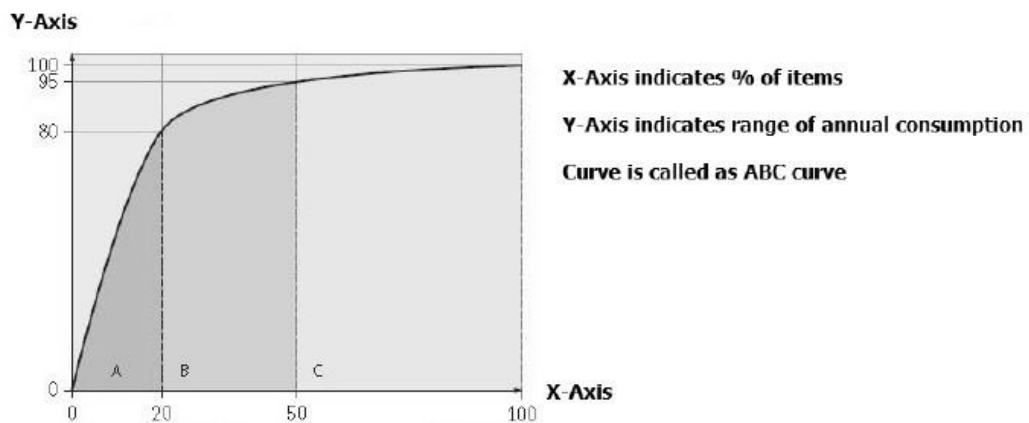


Figure 2.1. ABC Classification Graphical Representation

In this classification, Class A items are high-priority products with the highest picking frequency or inventory turnover, and therefore should be placed in locations closest to high-access areas, such as packing or shipping zones. A class having the highest amount, which is 70-80% of the company's annual consumption value, which only determines 10-20% of the total inventory items. Meanwhile, Class B items have moderate movement and can be stored in mid-range accessibility areas. B items are 15-25% of the company's annual consumption value and only account for 30% of the total inventory items. Last, Class C items are low-frequency or low-value products that can be stored in more remote or less accessible zones. C items is below 5% of the company's annual consumption value and account for 50% from the total inventory items. According to Gopalakrishnan et al. (1977), the application of ABC classification in layout planning can significantly reduce material

handling costs and improve operational efficiency by ensuring that the most frequently accessed items are the easiest to retrieve. In warehouse environments, especially those with a wide variety of SKUs and storage demands, ABC-based zoning enables optimal space allocation, improves picking speed, and supports inventory control strategies by aligning product placement with real usage data.

2.2.5. Storage Area Calculation

To determine the area needed for storage activity, several calculations can be done. The calculation of Length (L_x) and Width (L_y) can be calculated by the formulation below, according to Askin and Standridge (1993).

a. Storage Length

$$L_x = \left(\alpha_x + \frac{1}{2} w_x \right) \cdot n_x \quad (2.1)$$

b. Storage Width

$$L_y = \alpha_y \cdot n_y + w_y \quad (2.2)$$

c. Number of storage locations along the X-axis (n'_x)

$$n'_x = \sqrt{\frac{m \cdot \alpha_y}{2n_z \left(\alpha_x + \frac{1}{2} w_x \right)}} \quad (2.3)$$

d. Number of storage locations along the Y-axis (n'_y)

$$n'_y = \sqrt{\frac{2m \left(\alpha_x + \frac{1}{2} w_x \right)}{\alpha_y + n_z}} \quad (2.4)$$

Notation:

α_x = The unit load used side along the x-axis direction

α_y = The unit load used side along the y-axis direction

w_x = Aisle side width along the x-axis

w_y = Aisle side width along the y-axis

n_x = Number of storage locations along the x-axis

n_y = Number of storage locations along the y-axis

n_z = Number of storage locations along the z-axis (stack level)

m = Number of storage locations according to storage policy (dedicated or random policy)

2.2.6. Lead Time

According to Tompkins et al (2010), Lead time refers to the total amount of time it takes for a process to be completed, starting from the initiation of a request or order to its final delivery or completion. In the context of supply chain and warehouse management, lead time is crucial as it directly impacts customer satisfaction, inventory levels, and overall operational efficiency. There are several types of lead times depending on the context. First is order lead time, which is the time taken from when a customer places an order until it is delivered. Manufacturing lead time is the time required to produce a product from the moment raw materials are available until it becomes a finished product. Procurement lead time: The duration from when a purchase order is placed with a supplier until the materials or products are received.

Lead time consists of multiple components, such as processing time, waiting or idle time, and transportation time. Reducing lead time is often a priority for businesses to ensure faster deliveries, lower costs, and a competitive edge in the market. Strategies to minimize lead time include streamlining workflows, optimizing inventory management, using automation, and improving supplier relationships.