Storage Allocation For Stocked and Buffer Baskets

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Abstract. The recent changes in the retailer landscape and the continuous labor shortage in Thailand and have caused many distribution centers to embrace material handling equipment capable of automatically storage and transporting products. This article presents the case study of a home improvement retailer that adopts a vertical lift module (VLM) system into one of its distribution centers. As automatic equipment dedicated for baskets, a VLM system transports two types of baskets, particularly available stock baskets preparing for picking and consolidated baskets waiting for shipping. A preliminary analysis of current operations reveals that the number of baskets allocated for each type is not suitable, resulting in low utilization of the equipment and storage space. After studying the historical data as well as nature of the business, we proposed a simulation to experiment with the effects of the following operating policies (1) the suitable number of baskets allocated for each type (2) storage policy of consolidated baskets and (3) retrieving patterns of consolidated baskets. The results suggest that the suitable level of each factor that reduces the space utilization of 6.67% and vehicles travel time of 37.5%. Nevertheless, travel times of incoming and outgoing lifters are close to similar represented by their utilization.

1. Introduction
For a few decades, the expansion of domestic infrastructure projects and the growth of their adjacent construction projects have fueled the construction material and home improvement retailers in Thailand. Nevertheless, many retailers have contemplated their distribution strategies as the recent changes in consumers’ behavior and technological developments have shifted the landscape [1,2]. Coupled with an aging society, they have embraced material handling equipment capable of automatically storage and transporting products as a means to overcome labor shortage and high wages [3,4].

The article presents the case study of a home improvement retailer that has faced with the challenges mentioned above and recently reconfigured its distribution center with a semi-automation system. This state-of-art distribution center is and equipped with different material handling, such as automatic storage and retrieval system (AS/RS), conveyor systems, as well as vertical lift module (VLM) system. The VLM consists of lifters and vehicles transporting baskets between the conveyor system and basket-size selective racks. As a dedicated system, the baskets can be classified into two types, particularly available stock baskets preparing for picking and consolidated baskets waiting for shipping.

As the first site in Thailand that adopted such equipment, the warehouse manager concerns as the previous researches suggested that the productivity of the system depends on operating policies. Furthermore, a preliminary analysis of current operations reveals that the number of baskets allocated for each type is not suitable, resulting in low utilization of the equipment and storage space. As a result, we studied the historical data and nature of business and embedded it into a discrete-event simulation.
The proposed simulation was designed to experiment with the effects of the following operating policies (1) the suitable number of baskets allocated for each type (2) storage policy of consolidated baskets and (3) retrieving patterns of consolidated baskets. After the relevant literature review in Section 2, the remaining sections of this article are organized as follows. Section 3 highlights the background of the case study distribution center and the main configuration of VLM and its related systems. Having verified input data and operational information, Section 4 focuses on the components and interactions of the VLM system as well as its represented simulation model. Before suggesting suitable operational policies in Section 6, the results of the simulation model that experiments with different scenarios are analyzed and discussed in Section 5.

2. Literature review
Related literature can be grouped into two categories: Vertical Lift Module and Warehousing policies.

2.1. Vertical lift module
As dedicated equipment designed for uniform and standardized objects, the VLM system integrates automatic transporting of objects with manual operations. Because of its potential labor reduction and independent transporting of lifters and vehicles, many researchers have elaborated and compared the VLM system with other material handling systems. Toor [5] proposed a VLM system instead of a manual picking of fast-moving products as it reduced the time required to complete an order. Meller [6] created a model to compare a VLM system with a carousel for batch picking and found that a VLM provided higher throughput, especially with fast-moving products. Later, Lenoble [7] applied a mathematical model to compare picking policies and to determine a suitable grouping that minimizes the total picking time. The study reveals that grouping orders in the same tray result in the lowest picking time. In terms of economics, Sgarbossa [8] compared a VLM system and a manual carton system and found that the installation could reduce the total annual cost. Calzavara [9] extended the study by using an industrial case study and found that using the VLM system could reduce worker costs.

2.2. Warehousing policies
As the most labor-intensive activity [10], a good picking process requires the developing of suitable storage rules and picking policies. In general, there are three storage rules, namely random storage, dedicated storage, and class-based storage. Despite the space utilization benefit of random storage, Choe and Shape [11] concluded that the selection of suitable storage rules involves many other factors. In terms of picking policies, a typical warehouse usually applies a combination of single order picking, zone picking, and batch picking to different groups based on physical products, demand patterns, size of storages, and available manpower [12, 13].

3. Home improvement distribution center
As an essential part of the home improvement retailer, the case study distribution center provides dedicated warehousing and distributing services to its distribution network. Located in the north of Bangkok, the distribution center consists of many warehouses categorized by merchandized classes within the same area. One of which is the newly constructed warehouse using the ‘goods-to-men’ concept that stores consumer-good and home appliance categories. In addition to high-value items, this warehouse also serves as a merge-in-transit facility that combines cross-docking items received from domestic supplies with storage items purchased from international vendors. Because of the values of shipments, the semi-automated warehouse emerges as the center of warehousing operations.

3.1. Basket operation
Among different units of handling, the basket operation is viewed as one of the most critical and the focal points of the design as it connects different systems and integrates cross-docking item with storage ones. The basket system consists of three components, as follows:
- **Basket selective rack** is the storage equipment in the system that consists of two aisles and four storage banks. The rack has 18 levels and 22 bays with a storage capacity of 7,920 baskets. The initial configuration divides the storage capacity into 2,500 buffer baskets and 5,420 stock baskets.

- **Lifter** is the material handling equipment that vertically connects the basket conveyor system with vehicles. It can transfer two baskets per trip and travels at speed up to 100 meters per minute. The equipment is further classified by its function into incoming lifters and outgoing lifters. Each lifter operates independently from one other in its aisle.

- **Vehicle** is the material handling equipment that horizontally transfers baskets between lifters and baskets selective rack at speed up to 200 meters per minute. Each level has its own vehicle or 36 units in total.

### 3.2. Operating time of lifter and vehicles in VLM system

Because of its automatic transporting, the operating time of a lifter and a vehicle is consistent and consists of three components: communicating time, handling time, and traveling time. Based on operation logs, the communicating times of a lifter and a vehicle are constant at 3.01 and 3.91 seconds, respectively. Because a lifter may carry up to two baskets in the same trip, its handling times depend on a number of baskets, particularly 1.4 and 2.5 seconds for the first basket and the second basket, respectively. Conversely, the handling time of the vehicle is a constant at 8.2 seconds. In general, the traveling time directly depends on the position of an origin and a destination. Specifically, the traveling time of a lifter and a vehicle is a linear function and a piecewise linear function, as shown in Equations 1 and 2:

\[
T_{\text{lifter}}(d) = 0.6497 + 0.2807 \cdot d, \quad d \neq 0
\]

\[
T_{\text{vehicle}}(d) = \begin{cases} 
2.09 \cdot d, & \text{if } d \leq 1 \\
2.2947 + 0.2779 \cdot d, & \text{if } 2 \leq d \leq 10 \\
3.3552 + 0.1553 \cdot d, & \text{if } d > 10 
\end{cases}
\]

where \(d\) is a position of an origin and a destination and \(T_{\text{lifter}}\) and \(T_{\text{vehicle}}\) are traveling times of a lifter and a vehicle, respectively.

### 3.3. Nature of demand

Because stocked items consist of more than 3,000 articles, each of which has a different physical dimension and demand pattern. These factors affect the numbers of an item available in each basket as well as picking frequency. Therefore, we applied Pareto analysis and classified articles based on numbers available in a basket and average demand, as shown in Figure 1.

![Figure 1. Pareto analysis of articles by their physical sizes and requested demands](image)
These classifications yield the division of total articles into nine categories as shown in Table 1. Before embedded in a simulation model, the generated distribution of the categories are, as shown in Figure 2.

| Table 1. Number of articles of each category |
|---------------------------------------------|
| **Piece/basket** | **Demand** | **Fast (≥ 270)** | **Med (90-270)** | **Slow (≤ 90)** |
|                 |            |                 |                  |              |
| S (≤ 70)        |            | 234             | 132              | 541           |
| M (18 - 70)     |            | 225             | 230              | 783           |
| L (≥ 70)        |            | 269             | 301              | 1,159         |

The validation of generated categories and actual ones with two-sample Kolmogorov-Smirnov test reveals no statistical difference at the 0.95 confidence level.

4. Simulation model
Before explaining a simulation model, it is important to understand the operation, as shown in Figure 3.

4.1. Operations process in the VLM system
Stocked items are replenished into the VLM system by cartons from another storage area and arranged into baskets before stored at the stocking zone of the basket selective racks. At the beginning of each picking wave, specific baskets of requested items are retrieved and transferred to primary sorted stations. At the stations, items are assorted into several transport baskets destined for eight different secondary assorted stations based on requested quantities. At the destination, transport baskets are merged with cross-docking baskets and picked into different buffer baskets presenting the same stores by a worker. Once accumulated items in a buffer basket reach a certain height, the conveyor belt transfers the basket into the buffer zone of the selective rack waiting for the accumulation of 25 baskets or the end of picking wave. These outgoing baskets are sequentially requested by a store at buffer palletizing stations before stacking on a pallet and transporting to its own docking area.
4.2. Simulation model
As the most suitable tool to model and analyze a complex system, a discrete-event time simulation is selected to provide insights and compare the combination of policies without disrupting the ongoing operation. The simulation is organized similar to the current operation discussed in Section 4.1 that schedules into three six-hour slots.

4.3. Operational policy
With the exception of urgent picking and replenishment, the retailer currently considers a scenario that consists of the combination of storage policy and retrieval policy as follows:

Storage policy represents the selection of storage locations in a selective rack by a different type of baskets. This policy can be further divided into two alternatives, particularly

- **Two storage zones** (S0): This is the initial configuration that reserves continuous buffer baskets near lifters, called buffer zone, at the maximum requirement or 25 baskets per store, thereby ensuring no blocking. The remaining and further storage capacity is referred to as the stocking zone and allocated to stock baskets.

- **Three storage zones** (S1): Since some retail branches are more active in a particular wave, the alternative proposed mixing zone where stock baskets and buffer basket can occupy if their zones are full. Based on the physical configuration of rack, buffer, stocking, and mixing zones, sequentially consist of 20, 80, and 10 bays, respectively.

Retrieval policy reflects a logical setting in which stock baskets of a particular product are retrieval. The policy can be further categorized into three alternatives.

- **First-In-First-Out** (R0): As the initial configuration, the alternative sequences stock baskets based on the time stamp in the system.

- **Pick-to-Clear** (R1): The alternative selects the stock basket with the smallest quantities first as it aimed to generate more storage locations.

- **Pick-at-Most** (R2): A popular alternative that sequences stock baskets based on their quantities and selects a basket whose product quantity is more than and/or close to requested quantities first.

5. Results and discussion
To compare these scenarios, we embedded related parameters and operations into a simulation using R/RStudio [14]. Each combination and repeated 30 replications to obtain 10% relative precision [15] with seven days time horizon. The key results of the simulation include space utilization, lifter travel time, and vehicle travel time, as shown in Table 2.

| Scenario | Policy | Space Allocation | Retrieval Sequencing | Space Utilization | Average Travel time (minute/day) |
|----------|--------|------------------|----------------------|-------------------|---------------------------------|
| 0        | S0     | R0               |                      | 41.99%            | 410.17 ± 38.57, 432.34 ± 53.66, 1,090.26 ± 89.19 |
| 1        | S0     | R1               |                      | 39.20%            | 410.30 ± 38.44, 433.90 ± 52.94, 1,090.34 ± 99.45 |
| 2        | S0     | R2               |                      | 42.44%            | 397.71 ± 38.28, 422.48 ± 52.81, 1,042.70 ± 100.68 |
| 3        | S1     | R0               |                      | 42.00%            | 416.07 ± 39.21, 444.06 ± 54.23, 804.16 ± 58.32 |
| 4        | S1     | R1               |                      | 39.20%            | 416.12 ± 39.12, 445.34 ± 53.72, 792.76 ± 63.04 |
| 5        | S1     | R2               |                      | 42.41%            | 403.69 ± 38.99, 434.48 ± 53.76, 755.05 ± 60.71 |

In Table 2, Scenario 1-5 are used to probe different policies, whereas Scenario 0 serves as a base case to compare. In terms of space allocation policy, the result reveals that three-storage-zones alternative dominates the two-storage-zones alternative as baskets are stored closer to the P/U station, resulting in a reduction of vehicles travel time. The effects of the retrieval sequencing policy can be
6. Conclusion
This study reported an ongoing effort to adopt automated material handling equipment in Thailand and the adaptation of the VLM system in a distribution center of home improvement retailers. After analyzing and simplifying the related products and processes, we embedded empirical parameters into a simulation model and experimented with retrieving policy and storage policy. The combinations of these policies can be grouped into six different scenarios in which the percentage of space utilization, lifter traveling time, and vehicle travel time are computed and compared. The result reveals that the most suitable combination of operational policies is the scenario in which selects three zones and pick-to-clear as storage and retrieval policies, respectively. With a moderate utilization of the system, the scenario provides relatively low traveling time of vehicles while minimizes the number of baskets requested. However, the further system may require if the retailer decides to expand its branches or engage in the online market. The suggestion of utilizing three zones storage policy also raises questions on the sizes of each storage zone and the possibility of overlapped zones.

7. References
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