DESIGN OF ORDER PICKING CONDITION
FOR AUTOMATED WAREHOUSE

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ABSTRACT

Warehouse management system play a key role in logistics and supply chain management, which is the place for parking and distributing the products to the customer follow by sales order. Many company forces to improve their warehousing operation to consolidate products, reduce transportation cost and achieve economies of scale in manufacturing or in purchasing.

The order-picking operations immediately impact the warehouses and there by the supply chain's performance between the time an order is released to the warehouse and the time it takes to reach its destination. Automation for order picking processes in warehouses is deployed to limited extent large and long ranging investments are necessary, dynamic market demand requires more and more systems flexibility, and the products characteristics like size and/or weight may change significantly over time.

Then this research is like to design the condition and the operation flow diagrams for analyzing the probability to set up a picking system in the new automation warehouse. The two keys of order picking system design issue addressed in this study are the configuration of a storage system and the selection between batch and zone order picking strategies. The analytical concern in 5 area include: AS/RS

case, uni- shuttle, A rank picking area, B rank picking area and AA rank picking area, which define the different products such as fast, medium or slow moving items. To pick the products, the Unit and priority sequence for issuing Picking label is issued and picked according to; [Area], [Location], [Item code], [Lots] and [Expiry date] and Shipping label is issue by each outer box. The result from this research can decrease manual picking and picking error, improve inventory accuracy and support business growth. Moreover, the system also support time for loading by uni-shuttle make it easy to palletized process decrease waste time from manual picking.

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Nuanarwee Srisurasongkram

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LIST OF DEFINITIONS

AS/RS	Automated Storage and Retrieval Systems
CB	Counter Balanced
DC	Distribution Center
OPS	Order Picking System
SKUs	Stock Keeping Units
S/R	Storage and Retrieval
VLMs	Vertical Lift Modules

CHAPTER 1

INTRODUCTION

1.1 Introduction

Logistics had defined as a process of managing the flows of goods and services between the manufacturer and customer. The Warehouse in logistics system is possible for obtaining the products from difference suppliers and sorting them to fulfill a number of different customer's demand, since the last decade, electronic commerce; globalized economy markets have significantly changed the business environment. Many companies force to improve their warehousing operation to consolidate products reduce transportation cost and achieve economies of scale in manufacturing or in purchasing. Warehouse management system aims to control the movement and storage of products within the warehouse and process the associated transactions include receiving, put away, picking and shipping. (Tompkins, 2003)

Many companies look out to reduce cost and improve productivity within their warehouse, order picking has become one process under increasing of customer order demand, due to order picking is the most labor-intensive operation in warehouses with manual systems, and a very capital-intensive operation in warehouses with Automated systems. Order picking usually constitutes 50-70% of total operating costs for warehouse; it is also one of the most labor intensive of all warehouse process, represent as much as 60% of all labor activities in the warehouse (De Koster, 2004).

The order-picking operations immediately impacts the warehouses and thereby the supply chain's performance. Between the time an order is released to the warehouse and the time it takes to reach its destination, there is ample opportunity for errors in both accuracy and completeness, not to mention time lost. Many companies have come up with innovative solutions by using automated system in the process to solve the problem and improve the logistics system and warehouse system more accurate.

Automation for order picking processes in warehouses is only deployed to a limited extent large and long ranging investments are necessary, dynamic market demand requires more and more systems flexibility, and the products characteristics like size and/or weight may change significantly over time. For this reason, the manual operation will still represent the majority of order picking systems.

According to (Tompkins, 2003), a few reasons for increasing focus on order picking are as follows: an estimated 50% of the Distribution costs have been attributed form order picking, new operation programs such as just in time, cycle time reduction, quick response, etc. it has been introduced that require frequent delivery of small orders and inclusion of more Stock Keeping Units (SKUs) in the Order Picking System (OPS) and customers service has been improved due to renewed emphasis on minimizing product demand, transection time and picking error in the system.

1.2 Motivation

An order picking system design must consider follow warehouse management system, The design of an OPS depends on various system-design parameters; example, the configuration of the picking area and the storage system, as well as the determination of the storage policy, picking method, picking strategy, material handling system, pick-assist technology, etc. The best design depends on the objective being optimized. Some commonly used objectives include maximizing system throughput, or minimizing area, cost, response time, or picking error-rate. The decision making in the system also become the parameter to design the system as well, which helps the decision makers make decisions based on model-approximations or stochastic estimates of performance measures.

Owing to the complexity involved in designing OPS, designers who design system typically rely on simulation-based estimates of a flow model. However, simulation models are difficult to build and modify. A number of analyses are required before an "optimal" design is reached. A considerable amount of the resources required for simulation models can be minimized if analytical models are available to assist in making design decisions before build up the model of order picking system.

This research is motivated by the fact that there is a lack of management in certain areas of the OPS design in warehouse with automated system. This research intends to not only identify these critical areas, but also to model the dynamics involved in these areas through analytical, information flow and work flow as well.

1.3 Objectives of Study

This research discusses a design order picking system for Automated warehouse that consider work flow and information flow. The discussion is based on design, management and control, consequently, layout, storage location assignment and scheduling are studied in the following section.

The main goals of the research is designing the condition of order picking system to set up new warehouse, design the storage layer and order picking system process, picking area for Automated warehouse. Before design the system, designer should know which stock keeping units (SKUs) are to be stored in the picking area and their quantities. Then, involve the following problem definitions in an order picking environment follow the questions:

- What type of storage system should be used?
- Which order picking strategy (i.e., discrete, batch, zone, or bucket brigade) should be used?
- Which picking system (i.e., manual, semi-Automated, or Automated) should be used?
- Which pick-assist technology (i.e., paper-based or paper-less) should be used?

1.4 Case Study

Central Online is the Omni-channel retail leader. The group offers home entertainment and stationary shops, bookstores, and office supplies solution providers through both in-store and online formats. Office Mate is One Stop Business Solutions in central group to be the best choice for all business solutions in Thailand; Office Mate offers wide range of business equipment & supply, full range of office supply and total service solutions for all types of businesses.

This includes full-service printing capabilities, providing premium products, and offering parcel delivery service at stores. Office Mate operates various channels including more than 70 Office Mate stores nationwide, and online channels. From 2015, the company grew from the previous year, and generated 10,827 million baht or a 9.2% growth. Our net profit was 397 million baht, they increased the number of products and services to address their customers' needs and cater to various businesses. The goal of the company is to be the leader of excellence in retailing and online retailing in Asian. Office Mate is the first company has expanded to AEC countries. It will expand to Vietnam in 2016 and expected to show growth by 15% in this year.

Due to the high demand on office products and been growth dramatically in previous years, the old warehouse still using manual system for order picking, The problem for operating the warehouse in allocation the products depend on staff common senses, manual picking on Sales order, dummy picking and over stock in every quarter. So, Office mates have a plan to set up the new Automated warehouse to increase the efficiency of warehouse operation.

1.5 Scope of Study

The scope of this research will be limited to measuring, designing and managing those activities that takes place in officemate logistics limited including design condition to set up new Automated warehouse, designing master data to input in the system, design storage layer and order picking system process, picking area for Automated warehouse, by designing the structure framework of process to modify the workflow system smoothly and efficiently.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literature in the area of Distribution Center (DC), with a focus on the order picking system (OPS) within the distribution center. Section 2.1 focuses on general models for designing distribution center. Models and procedures have been proposed for the design or selection of OPS is covered in Section 2.2. Section 2.3 briefly reviews literature in specific areas of order picking, which include the forward-reserve problem, storage area configuration, and storage policy, picking strategy, simultaneous design of two or more interacting parameters, picking method, and material handling system. From literature search, this research observes that there are a large number of contributions in the areas of DC and OPS design; so This research concentrate on a few keys contributions in each of these areas.

2.1 Warehouse Management System

Warehouse can be defined as the part of firm's logistic system that stores products including raw material, parts, and goods in process and finish goods at and between the point of origin and the point of destination, and provide information to management on the status, condition and disposition of items being stored. Warehousing is an integrals part of logistics system that play the role in providing a desired level to customer service at the lowest possible total cost. The evaluation of warehousing has been constant. Driven by market competition, continuous improvements in the design and operation of distribution network have a required higher performance form warehouse.

According to Frazelle (2012), a warehouse plays the role one or more than following the role:

- **Raw material and component of warehouse**: hold the raw material at or near the point of induction in to manufacturing or assembly process
- **Work in process warehouse**: hold partially completed assemblies and products of various points along an assembly or production line
- **Finished warehouse**: hold the inventory used to balance and buffer the variation between productions schedules and demand
- **Distribution warehouses and distribution centers**: Accumulate and consolidate products from various points of manufacture within a single firm or from several firms for combined shipment to common customers
- **Fulfillment warehouses and fulfillment centers:** Receive, pick, and ship small orders for individual consumers
- **Local warehouses**: Distributed in the field in order to shorten transportation distances to permit rapid response to customer demand. (Frazelle, 2002).

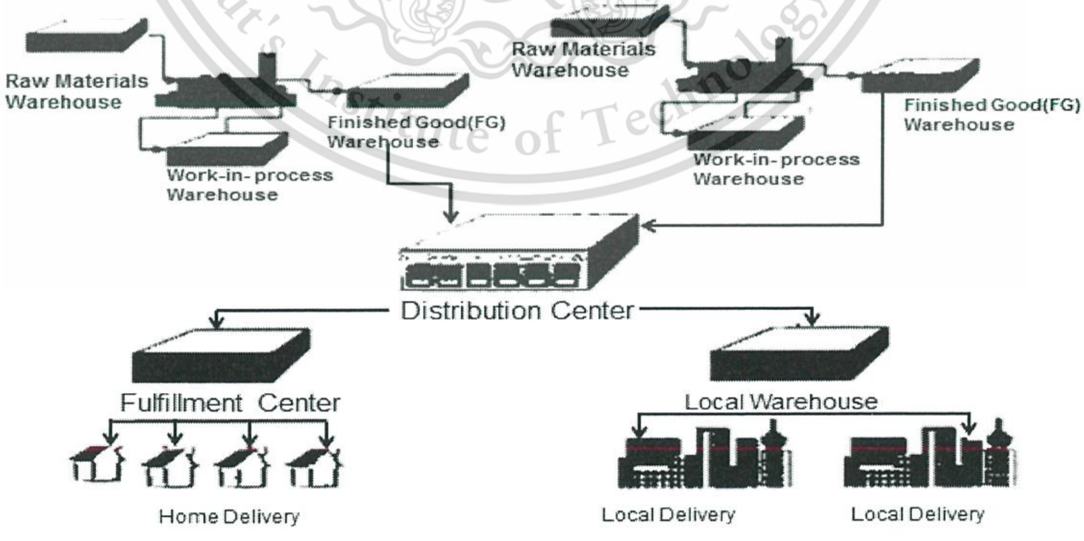


Figure 2.1 Role of Warehouse Management System in Logistics

Source: Frazelle, E. A. a. S., G.P. Correlated assignment strategy can improve order-picking operation. Industrial Engineering, 4, 33-37.

2.2 Warehouse Design and Operate

The warehouse process is complicated process. Designing the process, warehouse framework has to considers three categories: Warehouse Design, Performance Evaluation and Warehouse Operation, Warehouse Operation has to matching with the warehouse design as following figure 2, Performance evaluation provides feedback on the quality of a proposed design and/or operational policy, and more importantly, on how to improve it. Assessing the performance of a warehouse in terms of cost, throughput, space utilization, and service provides feedback about how a specific design or operational policy performs compared with the requirements, and how it can be improved. So performance evaluation is of utterly importance for both warehouse design and operation. The basic requirements in warehouse operations are to receive SKUs from suppliers, store the SKUs, receive orders from customers, retrieve SKUs and assemble them for shipment, and ship the completed orders to customers. There are many issues involved in designing and operating a warehouse to meet these requirements. Resources, such as space, labor, and equipment, need to be allocated among the different warehouse functions, and each function needs to be carefully implemented, operated, and coordinated in order to achieve system requirements in terms of capacity, throughput, and service at the minimum resource cost.

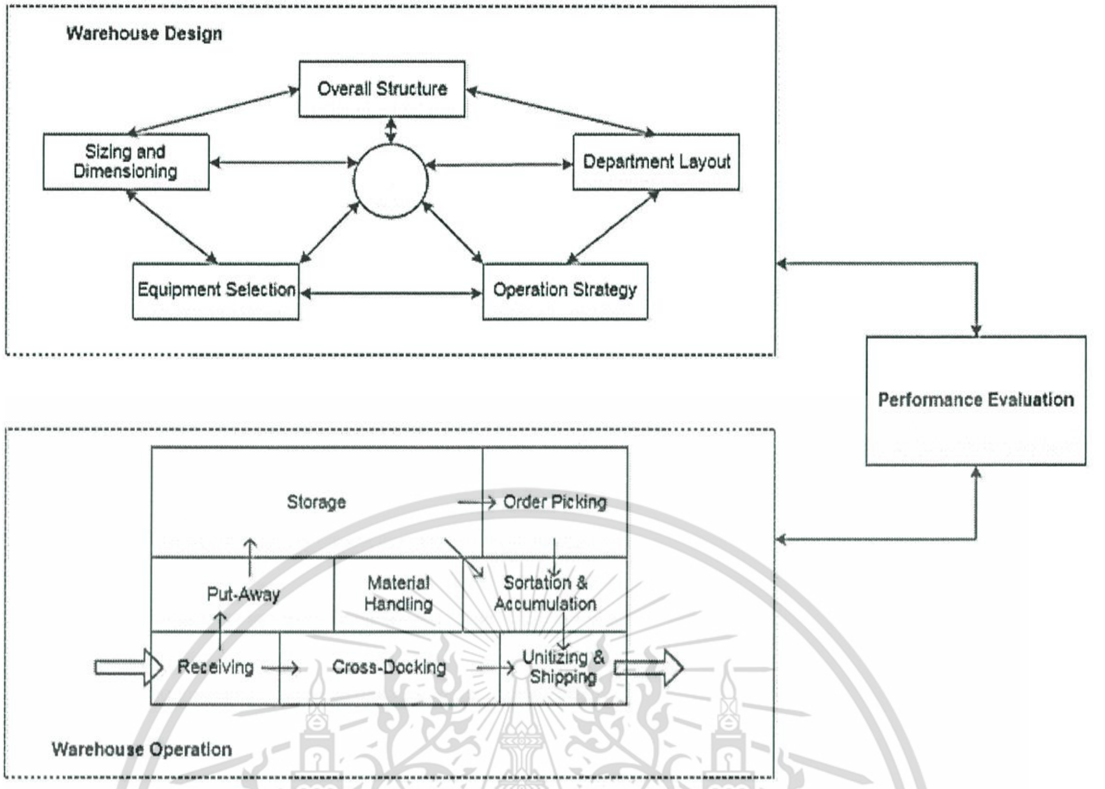


Figure 2.2 Typical Warehouse Functions and Flows

Source: Tompkins, J. A. (Tompkins). Faceiltiy Planing New york.

2.3 Warehouses and Order Picking

According to Kearney (2004), warehousing contributed to about 20% of the surveyed companies' logistics costs in 2003 (other activities distinguished are value added services, administration, inventory costs, transportation and transport packaging) (Kearney, 2004). Warehouses apparently form an important part of a firm's logistics system. They are commonly used for storing or buffering products (raw materials, goods-in-process, finished products) at and between points of origin and points of consumption. The term 'warehouse' is used if the main function is buffering and storage. If additionally distribution is a main function, the term 'warehouse' is commonly used, whereas 'transshipment', 'cross-dock', or 'platform' center are often used if storage hardly plays a role. As this research focus on order picking from inventory, it uses the term ‘warehouse’ throughout the paper.

Lambert (1998) state that more than 750,000 warehouse facilities exist worldwide, including state-of-art, professionally managed warehouses, as well as company stockrooms and self-store facilities. Warehouses often involve large investments and operating costs (e.g. cost of land, facility equipment, labor, etc.) (Lambert, 1998). So, why do warehouses exist? According to Lambert, they contribute to a multitude of the company’s missions, like

- Achieving transportation economies (e.g. combine shipment, full-container load).
- Achieving production economies (e.g. make-to-stock production policy).
- Taking advantage of quality purchase discounts and forward buys.
- Supporting the firm’s customer service policies.
- Meeting changing market conditions and uncertainties (e.g. seasonality, demand fluctuations, competition).
- Overcoming the time and space differences that exist between producers and customers.
- Accomplishing least total cost logistics commensurate with a desired level of customer service.
- Supporting the just-in-time programs of suppliers and customers.
- Providing customers with a mix of products instead of a single product on each order (i.e. consolidation).
- Providing temporary storage of material to be disposed or recycled (i.e. reverse logistics).

- Providing a buffer location for trans-shipments (i.e. direct delivery, cross-docking).

In some special situations, storage functions in a supply chain can be reduced. But, in almost all supply chains, raw materials, parts, and product inventories still need to be stored or buffered, implying that warehouses are needed and play a critical role in the companies' logistics success.

Warehouse flows

Figure 2.3 shows the typical functional areas and flows within warehouses. The main warehouse activities include: receiving, transfer and put away, order picking/selection, accumulation/sortation, cross-docking, and shipping.

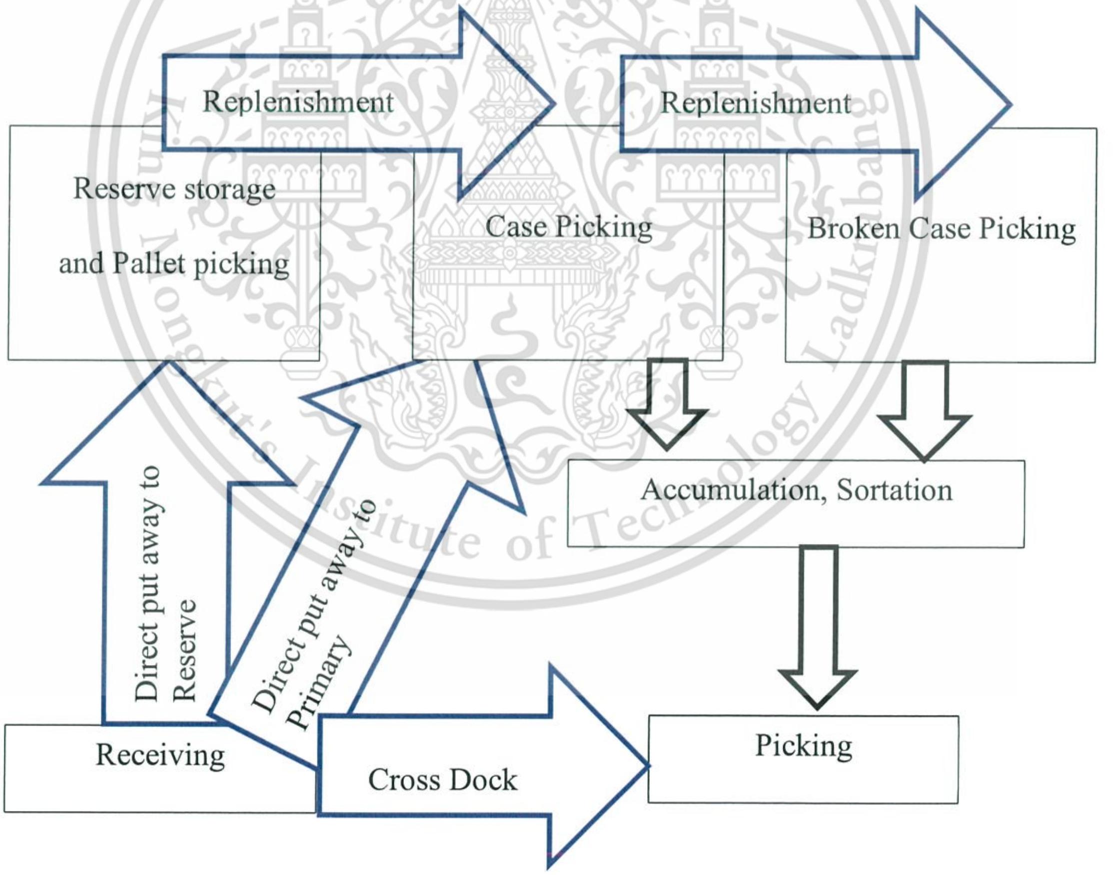


Figure 2.3 Typical warehouse functions and flows

Source: Tompkins, J. A.. Faceiltiy Planing New york.

The receiving activity includes the unloading of products from the transport carrier, updating the inventory record, inspection to find if there is any quantity or quality inconsistency. Transfer and put away involves the transfer of incoming products to storage locations. It may also include repackaging (e.g. full pallets to cases, or standardized bins), and physical movements (from the receiving docks to different functional areas, between these areas, from these areas to the shipping docks).

The order picking or selection is the major activity in most warehouses. It involves the process of obtaining a right amount of the right products for a set of customer orders. The accumulation or sortation of picked orders into individual (customer) orders is a necessary activity if the orders have been picked in batches. In such a case the picked units have to be grouped by customer order, upon completion of the pick process. After picking, orders often have to be packed and stacked on the right unit load (e.g. a pallet). Cross-docking is performed when the received products are transferred directly to the shipping docks (short stays or services may be required but little or no order picking is needed).

Order picking

Order picking involves the process of clustering and scheduling the customer orders, assigning stock on locations to order lines, releasing orders to the floor, picking the articles from storage locations and the disposal of the picked articles. Customer orders consist of order lines, each line for a unique product or stock keeping unit (SKU), in a certain quantity. In **Figure 2.3**, order lines are split, based on quantity and product carrier of the SKU, in pallet picks, case picks and broken case (unit) picks. Many different order- picking system types can be found in warehouses. Often multiple order-picking systems are employed within one warehouse

The majority of warehouses employ humans for order picking. Among these, the picker-to-parts systems, where the order picker walks or drives along the aisles to pick items, are most common (De Koster, 2004). This research can distinguish two types of picker-to-parts systems: low-level picking and high-level picking. In low-level order-picking systems, the order picker picks requested items from storage racks or bins (bin-shelving storage), while travelling along the storage aisles. Other order-picking systems employ high storage racks; order pickers travel to the pick locations on board of a lifting order-pick truck or crane. The crane automatically stops in front of the appropriate pick location and waits for the order picker to perform the pick. This type of system is called a high-level or a man-aboard order-picking system.

Parts-to-picker systems include Automated storage and retrieval systems (AS/RS), using mostly aisle-bound cranes that retrieve one or more unit loads (pallets or bins; in the latter case the system is often called a mini-load) and bring them to a pick position (i.e. a depot). At this position, the order picker takes the required number of pieces, after which the remaining load is stored again. This type of system is also called a unit-load or end-of-aisle order-picking system. The Automated crane (also: storage and retrieval (S/R) machine) can work under different operating modes: single, dual and multiple command cycles. The single-command cycle means that either a load is moved from the depot to a rack location or from a rack location to the depot. In the dual-command mode, first a load is moved from the depot to the rack location and next another load is retrieved from the rack. In multiple command cycles, the S/R machines have more than one shuttle and can pick up and drop off several loads in one cycle.

2.4 Order Picking

Order picking is one of the main activities in a Warehouse (Order picking refers to an operation through which the items are retrieved from their storage locations to fulfill customer orders.) Customer orders are generally received by a DC throughout the day. These orders are recorded and converted into a format that can be used by the Oder Picking System (OPS) to pick items from the storage area. Some of the order picking work elements includes traveling to the item, searching for the item, reaching and extracting the item from storage, documenting the pick, sorting items, etc. Depending on the type of OPS employed, one or more of the above activities may be unnecessary (e.g., sorting items while picking is not relevant when employing a zone picking strategy). An order picking system is a complex mix of the aforementioned design parameters to ensure that a specific objective (e.g., throughput, space, cost, etc.) is optimized. Below is a list of some of the major strategies and policies that a designer can choose from while designing an OPS.

Storage System Configuration in the Picking Area: For a given volume of SKUs to store in a picking area, the key decisions required in configuring a storage system include:

- Number of storage levels; i.e., number of storage locations at a pick-face, where a pick-face is defined as a two-dimensional section of the storage area from where the pickers extract items to be picked. A pick-face may represent a column of pallet rack, a bay of flow rack, or a section of bin shelving;
- Lane-depth; i.e., depth of the pick-face in terms of the number of unit-loads stored; and

- Number and width of aisles; in terms of width, aisles can be considered wide (10-12 ft.) or narrow (5-10 ft.), and this determines which picking method can be used and if the pickers may pass one another in the aisle.

An order picking strategy defines the manner, which the pickers navigate the order picking aisles of a storage area to pick the required items. There are three basic order picking strategies:

- Discrete picking, in which a picker is responsible for picking all the items in a single order during a pick-tour.
- Batch picking, in which several orders are batched together and a picker picks all the items in a given batch.
- Zone picking, in which each picker is assigned to a specific region of the storage area and is responsible for picking the items (for single or batch of orders) in that region only.

For OPSs configured in a manner similar to a flow-line in a production system, bucket brigade picking a control policy for discrete picking may be employed.

Picking Method: Depending on whether or not humans are involved in the system, there are three methods in which order picking can be accomplished; namely, manual, semi-Automated, and Automated. A manual (or picker-to-product) OPS is one in which the order pickers travel to the point where the item to be picked is located (e.g., pick-to-tote/cart/truck). A semi-Automated (or product-to-picker) OPS is one in which the items to be picked are brought to a stationary picker through mechanical means (e.g., carousel, vertical lift module, etc.). An Automated OPS has the potential of picking orders without any human intervention (e.g., A-frame).

Material Handling Equipment: In an OPS, material handling equipment can be used either to assist in manual, semi-Automated, or Automated picking of items. A variety of materials handling equipment are employed in a modern DC to increase the productivity of OPS. These include totes, carts, conveyors, trucks (counter-balanced (CB) lift, order-picker, reach, etc.), horizontal and vertical carousels, vertical lift modules (VLMs), and A-frame dispenser, end-of-aisle mini-load Automated storage and retrieval systems (AS/RS)(MHIA, 2006), etc. Some of this equipment is illustrated in **Figure 2.4**:

Figure 2.4 Material Handling Equipment Employed within OPS in a DC

Source: MHIA. (2006). Material Handling Taxonomy - Order Picker.

Furthermore, some OPSs may require that the items, which were picked from the storage area, be sorted (or consolidated) according to customer orders. For this purpose, a manual or an automated sorting system (e.g., tilt-tray, sliding-shoe, cross-belt, etc.) may be employed.

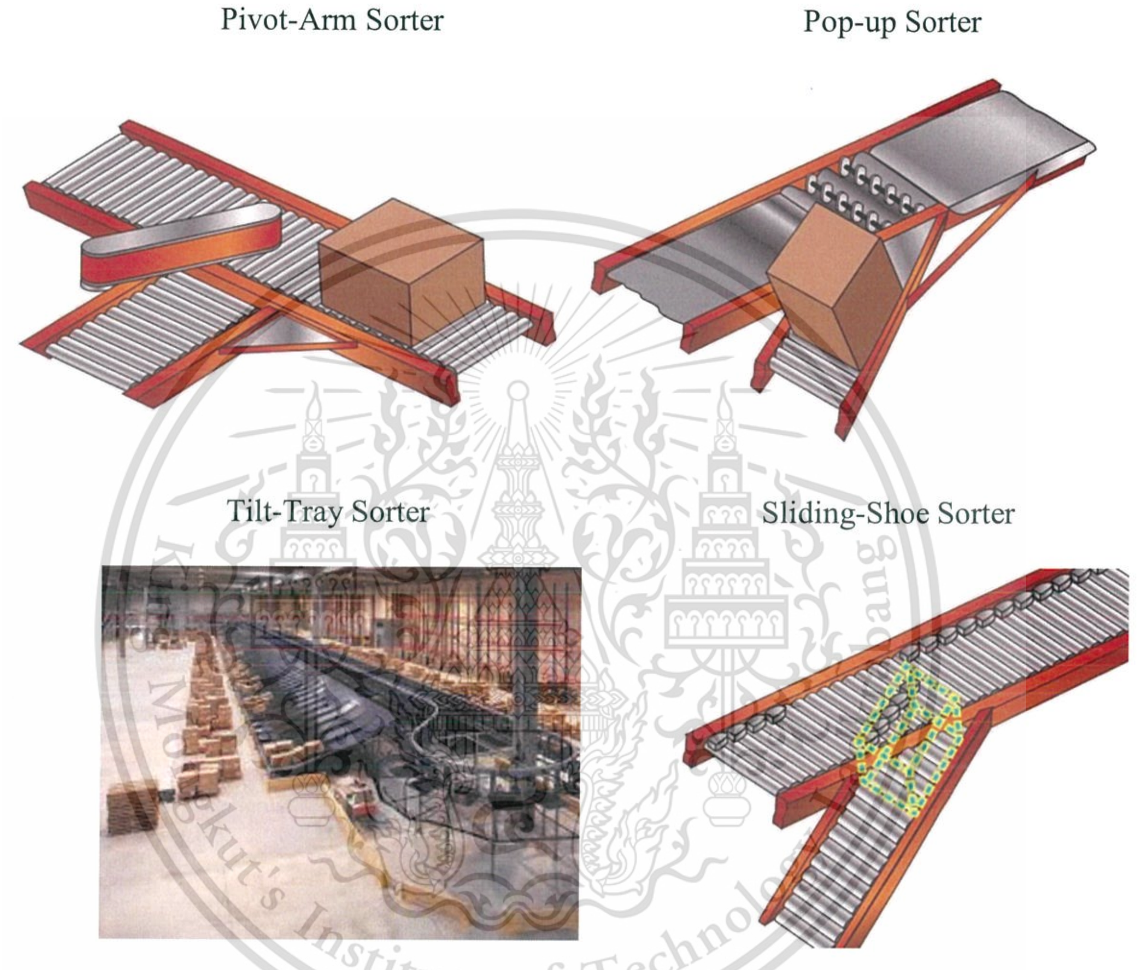


Figure 2.5 Automated Sortation Systems Typically Used in A DC.

Source: MHIA. (2006). Material Handling Taxonomy - Order Picker.

2.5 Design Models for a Warehouse

As mentioned in Chapter 1, designing a DC (or a warehouse) is a complex task involving a number of design parameters. A designer is face with the challenge of how best to address all the design issues without committing too large an amount of resources (Gu, 2005). To this end, several models have been presented in the literature to design a DC. Below this research presents a brief review of some of these models; details on several other models are presented in the four survey papers (van den Berg, 1999).

Gu (2005) reviews various analytical- and simulation-based approaches proposed for warehouse design problems. They conclude that, in general, neither a pure analytical approach nor a pure simulation approach will lead to a practical design method. As a potential solution, they suggest a two-step procedure for warehouse design. As a first step of this procedure, analytical models could be used to quickly compare different design alternatives and to select only a few feasible alternatives, thus, reducing the search space. As a second step, an elaborate simulation model can be built to include dynamics that could not be modeled using analytical approaches. This research also advocate such a two-step procedure and concentrate our efforts on the first step; i.e., the development of analytical models to aid in the design of a DC.

Bartholdi (2006) proposes a multi-stage hierarchical decision approach to model the composite design and operating problems for a typical order-consolidation warehouse. As an objective function, they consider minimization of annualized incremental initial costs plus the warehouse operating costs. The various decisions to be made include warehouse layout, equipment and technology selection, item location, zoning, picker routing, pick list generation, and order batching. Their hierarchical approach utilizes a sequence of coordinated mathematical models to evaluate the major economic tradeoffs and to prune the decision space to a few superior alternatives) (J. J. Bartholdi, Eisenstein, D. D., & Foley, R. D., 2006). These alternatives can then be evaluated and compared using detailed simulation models. The main elements of this hierarchical approach include facility design and technology selection, item allocation, and operating policy (in the form of order batch size and number of zones in the forward area). They also illustrate the application of their method via an automation spare-parts warehouse example.

Van (1999) presents a literature survey on methods and techniques for the planning and control of warehousing systems. Planning-related decisions include inventory management and storage location assignment, while control-related decisions include picker routing, sequencing, scheduling, and order batching. Based on the survey, he makes two summarizing remarks related to: (1) a need for completely different approaches to solve most of the planning and control-related problems, instead of using dedicated heuristic approaches; and (2) a need for approaches that consider trade-offs between productivity (in terms of throughput) and urgency (in terms of order completion deadlines) (van den Berg, 1999).

Rouwenhorst (2000) sent a reference framework and a classification of warehouse design and control problems. They define a warehouse design as a structured approach of decision making at a strategic, tactical, and operational level in an attempt to meet a number of well-defined performance criteria." The strategic level includes decisions concerning the design of process flow and level of automation. Decisions at the tactical level include resource requirements (e.g., storage system, number of employees, etc.), determination of a layout, and organizational issues. The main decisions at the operational level are concerned with assignment and control problems of people and equipment. Through a comprehensive literature review, the authors identify a strong need for design-oriented approaches as opposed to analysis-oriented approaches for warehouse design problems (Rouwenhorst, 2000).

2.6 Automated Storage and Retrieval Systems

Automated Storage and Retrieval Systems (commonly referred to as ASRS) are most commonly used in manufacturing and distribution facilities. They typically replace large areas of shelving to save floor space, improve safety and increase productivity. With varying technologies and applications

Automated Storage and Retrieval Systems are automated systems that efficiently and securely store items in a compact footprint. It allows users to easily and quickly retrieve items when needed. Several companies manufacture a wide variety of self-contained, goods-to-person, Automated storage and retrieval systems (ASRS). The technologies handle different volumes, types and velocities of non-palletized inventory at variable speeds to accommodate varying throughput demands. When considering the options, keep in mind both the storage density your facility needs as well as your throughput goals.

AS/RS is available for various shapes and weights of buckets and carton cases. This is widely used for picking and shipping work precisely and speedily supplies desired amounts of goods at times. Automated goods-to-person picking technologies can be broken down into three categories:

1. **Shelf based picking**: an entire shelf or tray of product is delivered to an operator
2. **Bin based picking**: an individual bin or tote is delivered to the operator
3. **Robotic picking**: delivery robots are operating within some type of enclosed shelving system to deliver goods to an operator

AS/RS is used for picking. System integration using Digital picking, handy terminals, and/or picking carts facilitate accurate and efficient picking and packing of loose parts.

2.7 Order Picking System Design Models

Order picking has been identified as a major activity in a DC and the prime contributor to overall DC operating expenses. Although there have apparently been several research contributions that propose models for the design and selection of an appropriate OPS for a given application, most of these articles are not a part of the published OPS literature. This researcher view two contributions that are a part of the published literature; the other unpublished contributions are reviewed in survey papers by (Rouwenhorst, 2000) and (van den Berg, 1999).

(Brynzer, 1994) present a zero-based analysis methodology for the evaluation of OPS as a basis for system design and managerial decisions. The basic idea of a zero based analysis is to divide the resource consumption in an OPS into three parts. The first part is the necessary work, which refers to the time consumed in reaching, grabbing, and transferring an item to an appropriate position. The second part refers to time losses incurred due to reading and identification, traveling, and waiting. The third part refers to the cost involved with picking preparation and finishing, quality assurance, and other administrative activities. By measuring all three parts of resource consumption in appropriate units, various OPS designs can be compared and the best design can be selected. This approach is limited by the fact that it is not clear as to what constitutes necessary work. That is, is necessary work considered in reference to the current number of items being picked per unit time or the maximum number of items that can be picked in that time? Also, this approach is limited to a picker-to-product OPS; other OPSs, such as product-to-picker and Automated systems may exhibit different resource consumption schemes, for which the zero-based analysis is not applicable.

Yoon and Sharp (1996) present a structured procedure for the analysis and design of order picking systems that considers interdependent relationships between different functional areas (e.g., receiving, picking, sorting, etc.) of an OPS.

2.8 Picking Strategy

A picking strategy defines the manner in which pickers navigate the order picking area to pick items from storage locations. The primary objective of a picking strategy is to maximize throughput or minimize cost or response time. There are three basic picking strategies: discrete, batch, and zone. Another picking strategy, called bucket brigade picking, was proposed by (J. J. Bartholdi, Eisenstein, D. D., and Foley, R. D., 2006). Bucket brigade, a concept that originated in assembly lines, was developed as a way of coordinating workers who progressively assemble a product along a line. The authors apply the bucket brigade concept to an order picking system in a DC. According to this strategy, each picker follows the rule (J. J. a. H. Bartholdi, S., 2001) Pick forward until someone takes over your work.

Characterizing bucket brigade picking as a self-balancing strategy, the authors develop stochastic models to analyze the performance of this strategy in high-volume OPSs. Through simulation experiments comparing bucket brigade picking to sequential zone picking, they suggest that the production rate efficiency (which is a ratio of realized production rate and maximum possible rate) of a simulated bucket brigade is similar to that of zone picking for the case when the OPS had identical pickers in terms of their walk and pick times. With an increasing difference in the walk and pick times of individual pickers, bucket brigade picking is more productive. Through a real-world study, the authors mention that bucket brigade picking improved pick-rates by 34% as compared to a sequential zone picking strategy. The only limitation this strategy faces is that it can be effective only in cases when the picking aisle is structured as a flow line, and when the time to hand-off an order is low.

The choice of a picking strategy can have a tremendous effect on the efficiency and cost of OPS in mail order companies. To this end, he evaluates five order picking strategies discrete (or strict), batch, sequential (or pick and pass) zone, simultaneous zone (which he calls batch zone), and simultaneous zone-wave use a simulation model developed in C (a common computer language). The author considers labor requirements, total processing time, and customer service (in terms of mean percentage of orders not fulfilled in an 8-hr. shift) as performance measures across which these strategies are compared. Using an experimental design approach, the author considers three key factors that include picking strategy, daily order volume, and demand with several levels for each factor. Based on the results, simultaneous zone-wave picking and batch picking are superior and that their performance is not adversely affected by changes in demand patterns or daily order volume. On the other hand, the performance of sequential zone and batch zone picking deteriorates as order volume increases.

CHAPTER 3

METHODOLOGY

In this section, the methodology used in the study is explained. An order picking system is described with basic assumptions and explanations according to process flow. Then, the system model, storage assignment method, and scheduling method, are presented and explained separately. The design of OPS is a complex task. The complexity arises due to the numerous combinations of design parameters (e.g., storage configuration, storage policy, picking method, picking strategy, material handling system, pick-assist technology, etc.). The design decisions related to these design flow are highlighted.

3.1 Design the Condition for Oder Picking System

As mention above order picking system is complex and have many components have to concern before design and build up the process, there is some problem that have not yet been addressed completely in the OPS literature.

During the design process, a designer aims at optimizing one or more objectives, which include (but are not limited to):

- Throughput: how to maximize the average number of orders fulfilled per hour considering current and future customer order patterns?
- Cost: how to minimize the system cost (which includes the costs related to the storage area, equipment, labor, etc.)?
- Space: how to minimize the space required storing the SKUs?
- Response time: how to minimize the time required fulfilling an order once received?

- Picking error-rate: how to minimize the proportion of customer orders not fulfilled correctly?

The objects above are conflicting in nature. Moreover, the research also need to concern to Picking strategy, picking method and material handling equipment, picking assist technology and storage process as well such as storage policy, storage configuration. All of this is the condition that this research has to concern. To designing the conditions are completely correcting data and data process designs have to correct. To confirm all data input to design are correct, this research collects the data form the staffs and task from the old office mate warehouse to build up the new condition and process in the new automated warehouse.

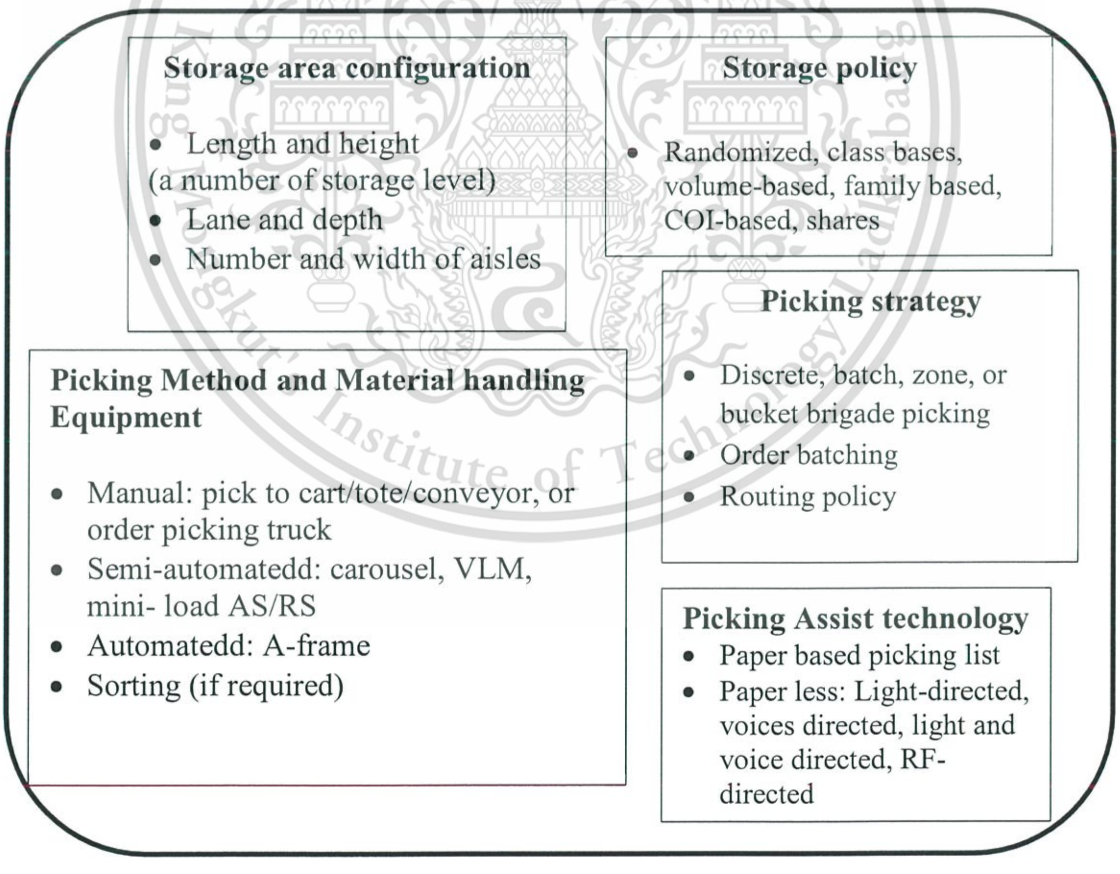


Figure 3.1 Design The Condition and Decision In a DC.

3.2 Design the Method of the Order Picking System

The process of order picking system is quite complicated, designing the process has to consider many components, order picking can be a wild process, starting with the reception and scheduling of customer orders and proceeding with the assigning of stock on locations to order lines, the release of the orders to the pickers and finally the retrieval of the articles from storage locations, the actual picking.

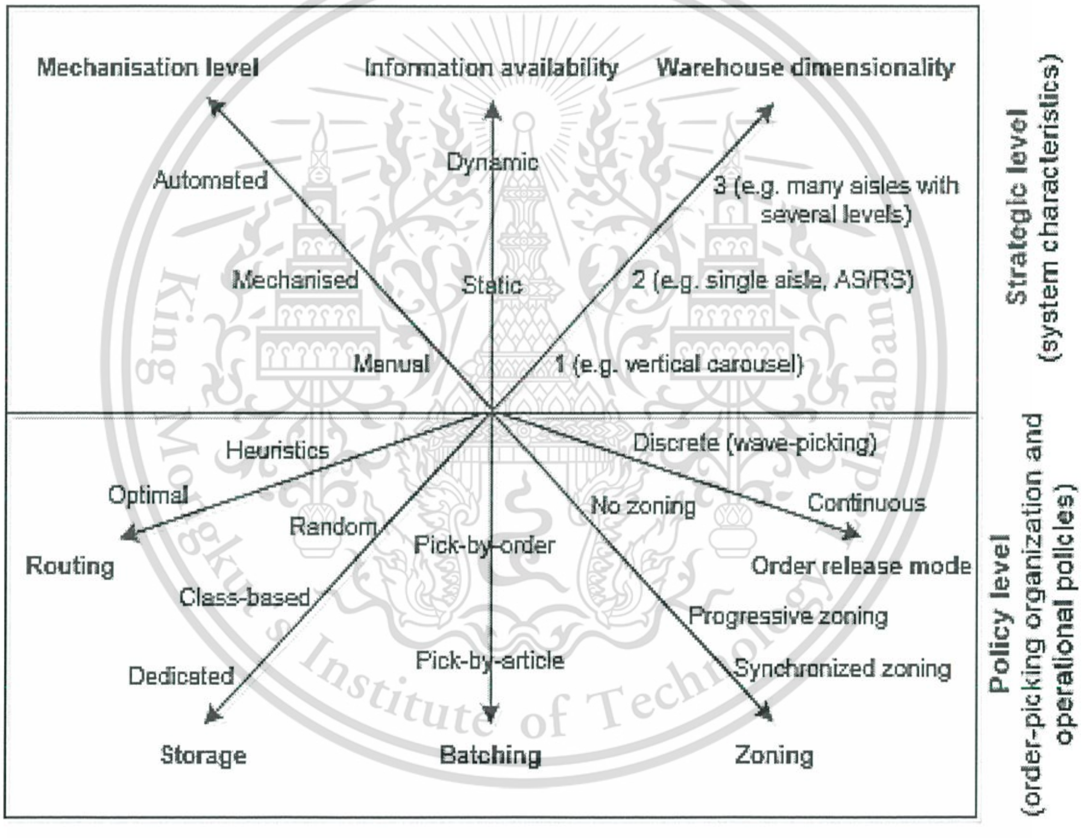


Figure 3.2 Design Character of Order Picking Process in a DC.

The organization and operational policies, they include mainly in five factors of the process: routing, storage, batching, zoning and order release mode. The order-picking organization and operational policies can be changed and adjusted more effortlessly (being tactical and operational decisions). However, these policies are always limited by the strategic decisions in effect to the order picking system. Mostly, order picking method had defined in two employing include human and machine. Employing human is picking method by manually system or human picking includes of three methods such as Picker to parts, put system and part to pickers. In Other hand, employing machine is picking by automated system or robots depend on items and picking condition.

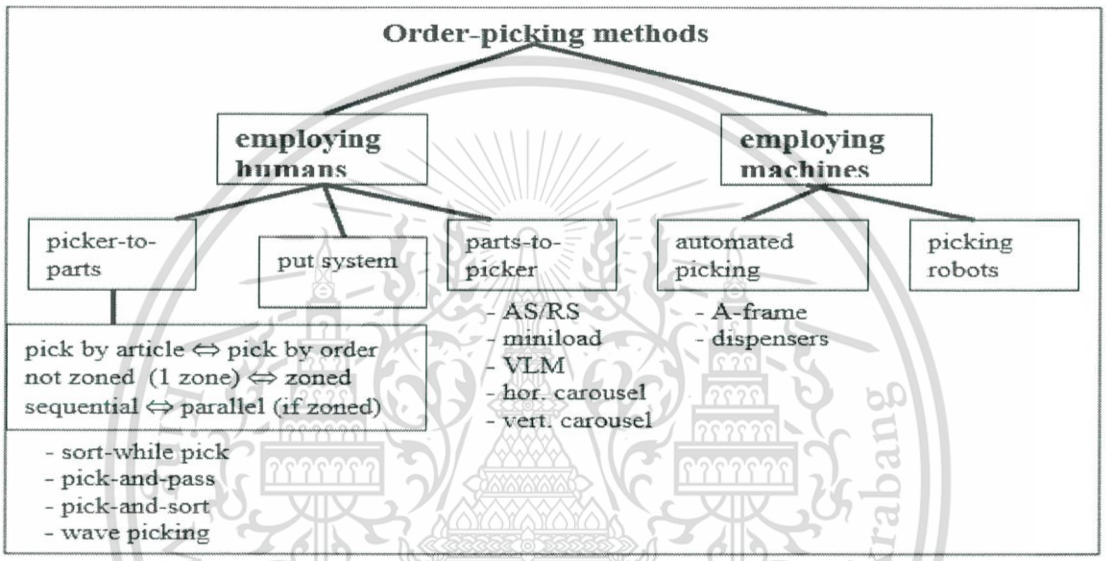


Figure 3.3 Method of Order Picking Process in a DC.

In this research focus on design the order picking in Automated warehouse, the process designs used both human and automated method include AS/RS case, Automated piking and robots as well, for this section design will present in chapter 4.

3.3 Data Collection

Data gathering for design the condition and operation process in this research was conducted via a meeting and interview with relevant with stakeholders of the warehouse. This research concern data include of two parts: the qualitative method collect by questionnaire and depth information via interview with supervisor and manager of warehouse. Especially, the worker who work in picking zone to find out the task, problem case of picking in each area, in other hand, quantitative method are collect by numerical outcomes via the annual reports, etc.

3.4 Rules for design condition

To identify the condition for order picking system in new warehouse system, there are some rules that had set for the condition before. The rules divided in three categories include Product dimension check by count per piece concern about width, length, height, weight, and barcode. Product 2 levels dimension checks by count per piece but piece and outer are equal (Piece: Outer(1:1)), Product 3 levels dimension checks per piece but Piece, outer and pallet are difference (Piece: Outer(1:N:N)). Freshness Management of canteen product requires days for shipping / effective days (Shelf life not less than 30 days.) All products have different barcode and SKU for setting volume per pallet in case of 2 levels and 3 levels. Products receive follow the receive pattern (FIFO) and all products have sale unit.

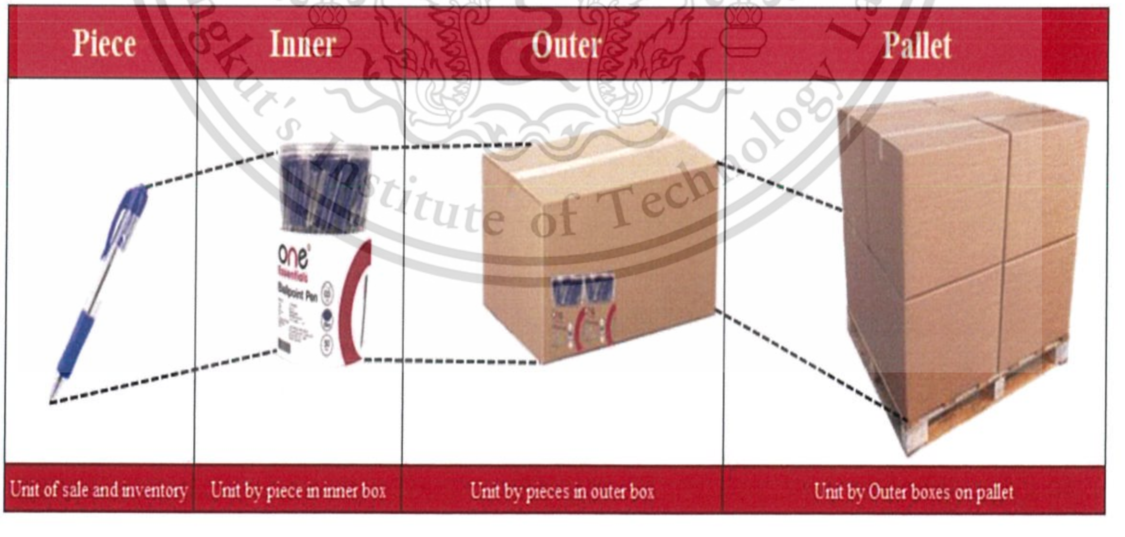


Figure 3.4 Dimension Measurement

CHAPTER 4

DESIGN AND RESULTS

This section consists of two parts. The first part describes the condition to set up the new automation warehouse system including designing the storage layout and picking condition to add in to master data and AS/RS system for picking products by using machine and the second part describes designing a new workflows order Picking system in both manual and automation case.

4.1 Overview of the Automation Warehouse Management System

To set the new automation warehouse system, designer needs to consider the culture of the operation and management of warehouse, as system models are difficult to build and modify. Designers have to understand deeply in processes of warehouse and understand why have to set up the new warehouse system.

Table 4.1 Picking Area and Dimension Measurement

Zone	Machine	Transection				Size	Packaging			Status
		Super Fast	Fast	Medium	Slow		I-packable	Manual Pack	Supplier	
AA	Pick To Light + Handheld	Y	N	N	N	Y	Y	Y	N	Relay picking
A	Pick To Light + Handheld	N	Y	N	N	Y	Y	N	N	Relay picking
B	Handheld	N	N	Y	N	Y	Y	N	N	Relay picking
C	ASRS	N	N	N	Y	Y	Y	N	N	Relay picking

AA Very fast 16 pallets

A Fast 1,920 locations

B Middle 3,160 locations

C Slow 5,460 locations (~6,000 SKUs)

Picking zone divide in four areas include A rank, B rank, C rank and AA rack are used for different type of products transaction which use different kind of machines as table 4.1. AA zone use for very fast move items which has 16 pallets locations, A zone use for fast move items which has 1,920 locations, B zone use for middle move items which has 3,160 locations and C use for slow move item which has 5,460 locations and can store more than 6,000 SKUs.

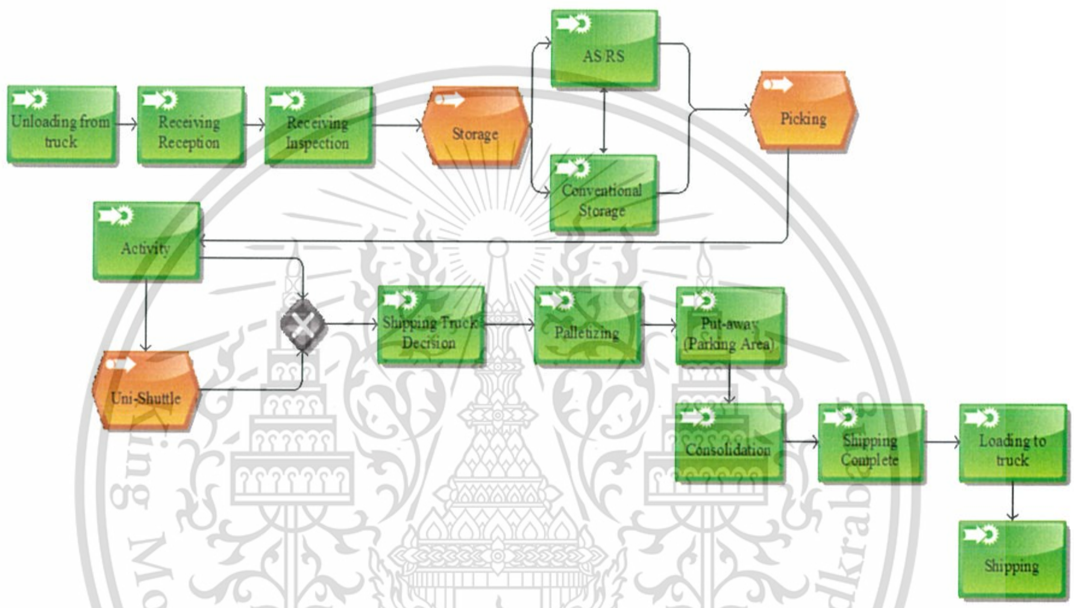


Figure 4.1 Warehouse Operation Flow

As the **Figure 4.1**: the flow of warehouse operation start from unloading products from truck, receiving product and put in to storage both AS/RS and case conventional storage. Then, pick up the products per order transfer to park in uni-shuttle wait for shipping to customers.

The research focus on modeling the order picking system (OPS), the process flow start form receiving order form customers, the system will run the process to pick the products from storage and delivery to customer. Before this research designing the order picking operation flow, modeler has to identify the picking management areas to set up the condition, layout and storage location and picking role as well.

4.2 Design Condition of Order Picking System.

The space for set up and design the order picking system in this research focus on 5 areas include: AS/RS case, uni- shuttle, A rank picking area, B rank picking area and AA rank picking area as **Figure 4.2.**

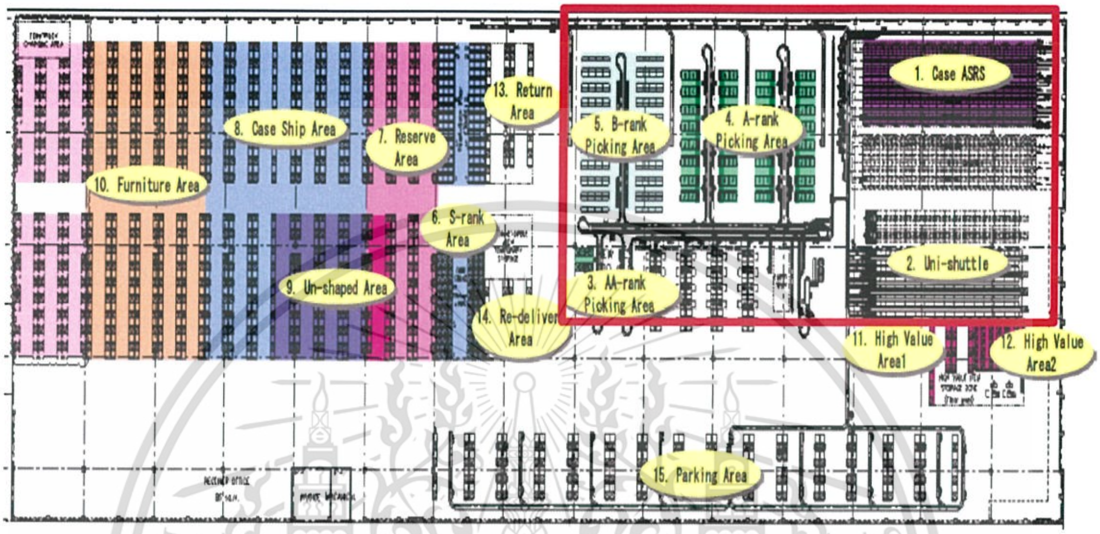


Figure 4.2 Order Picking Area Management

Table 4.2 describes the definition of parking area, in each area to be used for different type of products such as fast move items, slow move items or medium move items. Moreover, in different area also use different equipment for picking products f such as crane, shuttle, DPS.

Table 4.2 Description of Picking Area

Picking Area	Equipment	Description	Products type
AS/RS	Crane	Storage for C-rank Item	Slow move items
Uni-shuttle	shuttle	Sequencing Buffer for Shipping Boxes	Shipping Boxes
A Rank	DPS	Piece Picking Area for A-rank Item	Fast move items
B rank	DPS	Piece Picking Area for B-rank Item	Medium move items
AA Rank		Piece Picking Area for AA-rank Item	Fast move items (High value)

4.2.1 Design Layout of AS/RS

In case of AS/RS is use for storage of slow moving products, to design the condition for order picking in this case, modeler designing the condition include: specification of AS/RS, the total level of rank consist 10 lows, 21 bays, 26 levels and 5,460 locations for storage as **Figure 4.3**, for picking condition in this case it picking follow the location format as [row], [bay], [detail bay] and [level] from AS/RS machine by using crane.

Low height Crane #1-5: 10(rows) * 21(bays) * 7(levels) = 1,470(locations)

Middle height Crane #1-5: 10(rows) * 21(bays) * 11(levels) = 2,310(locations)

High height Crane #1-5: 10(rows) * 21(bays) * 8(levels) = 1,680(locations)

Total: 10 lows 21 bays 26 levels 5,460 locations

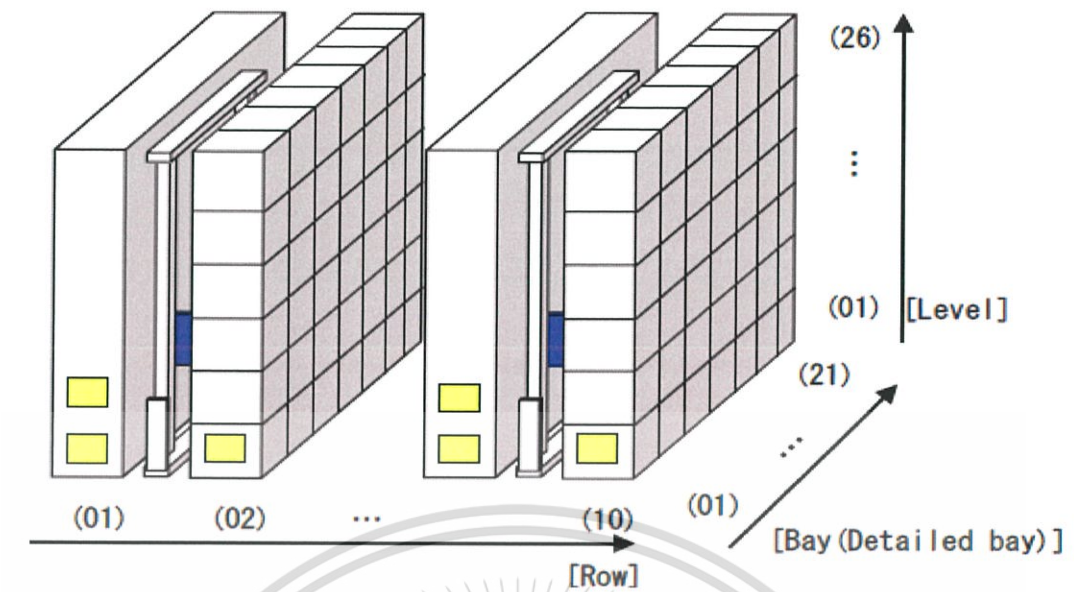


Figure 4.3 Location format of AS/RS management

Moreover, the condition for item location also define follow the size of the box of products which design in three sizes include S out Box size 225-280 mm, M size 281-380 mm and L size 381-450 mm and storage follow the Low, middle, and high level zone according the size L, M and S in the top.

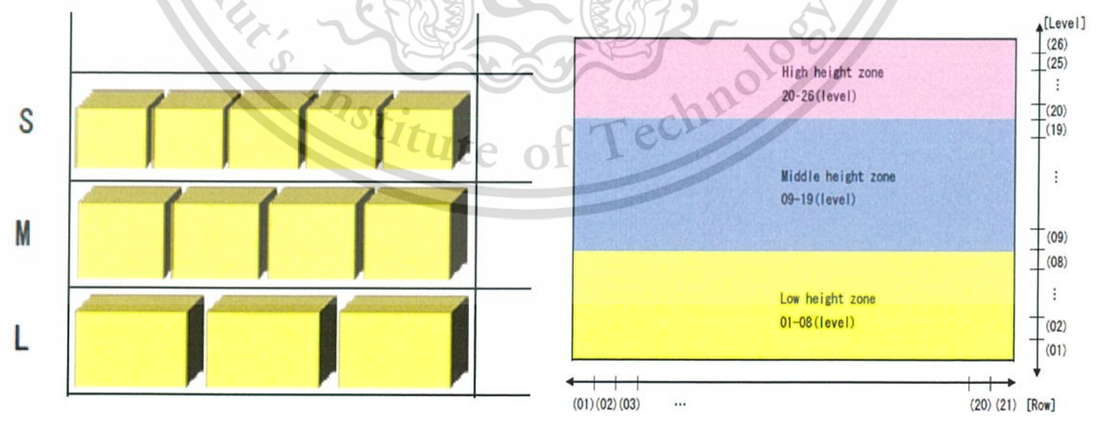


Figure 4.4 AS/RS Location View

Table 4.3 AS/RS Location Attributes

Location attribute	Outer box size	Storable outer Box quantity in one location
S	225-280 mm	5(c/s)
M	281-380 mm	4(c/s)
L	381-450mm	3(c/s)

4.2.2 Design Layout of Uni-Shuttle

In case of Uni-shuttle is use for Shipping Boxes, to design the condition for order picking in this case, modeler designing the condition includes: specification of Uni-shuttle, the total level of rank consist 10 lows, 21 bays, 26 levels and 5,460 locations for storage as **Figure 4.5**, for picking condition in this case it picking follow the location format as [row], [bay], [detail bay] and [level] by using a shuttle.

Low height Crane #1-4: 8(rows) * 14(bays) * 6(levels) = 672(locations)

Middle height Crane #1-4: 8(rows) * 14(bays) * 8(levels) = 896(locations)

High height Crane #1-4: 8(rows) * 14(bays) * 1(levels) = 112(locations)

Total: 8 lows 14 bays 15 levels 1,680 locations

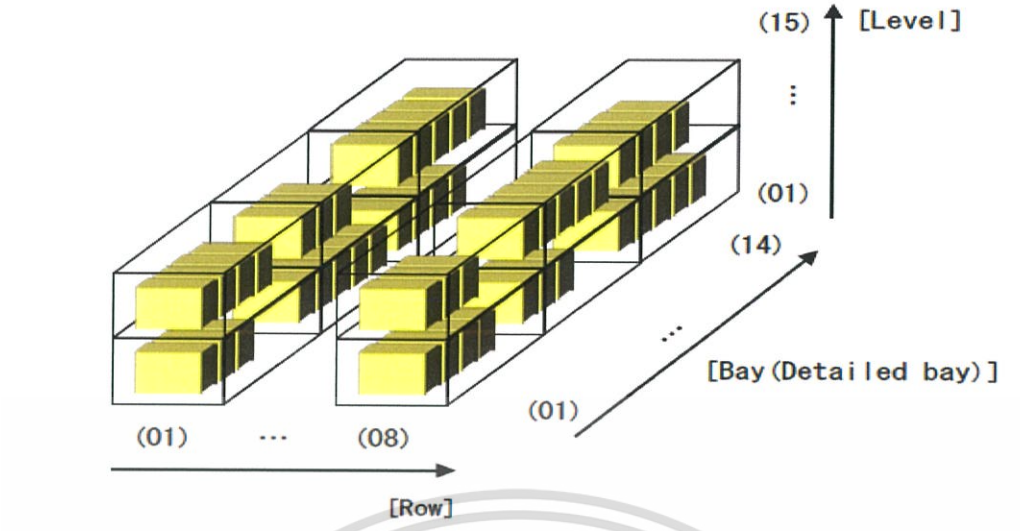


Figure 4.5 Location Format of Uni-Shuttle Management

The condition for item location also define follow the size of the box of products which design in four sizes include S out Box size 225-280 mm, M size 281-380 mm and L size 381-450 mm and storage follow the Low, middle, and high level zone according the size LL, L, M and S in the top.

Table 4.4 Uni-shuttle location attributes

Location attribute	Outer box size	Storable outer Box quantity in one location
S	225-235 mm	7(c/s)
M	236-295 mm	6(c/s)
L	296-375mm	5(c/s)
LL	375-450mm	4(c/s)

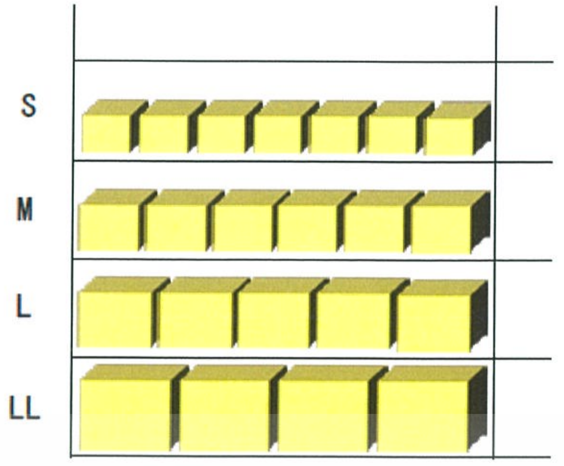


Figure 4.6 Uni-shuttle Location View

4.2.3 Design Layout of A-Rank Picking Area

In the Storage, A rank picking area manages for the flow rank and shelf rank for small item as a fast moving item consist of 32 rows, 15 bays and 4 levels, 1920 locations, picking format by row, bay and level.

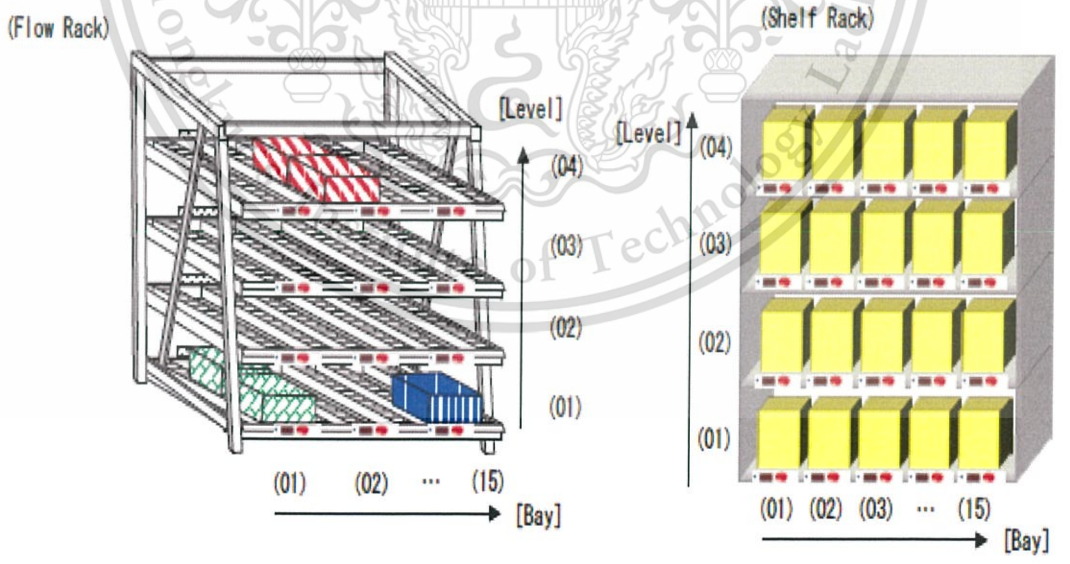


Figure 4.7 A Rank Picking Location View

4.2.4 Design Layout of B-Rank Area

In the Storage, A rank picking area manages shelf rank for small item as a medium moving item consist of 40 rows, 20 bays and 4 levels, 3,160 locations, picking format by [row], [bay] and [level].

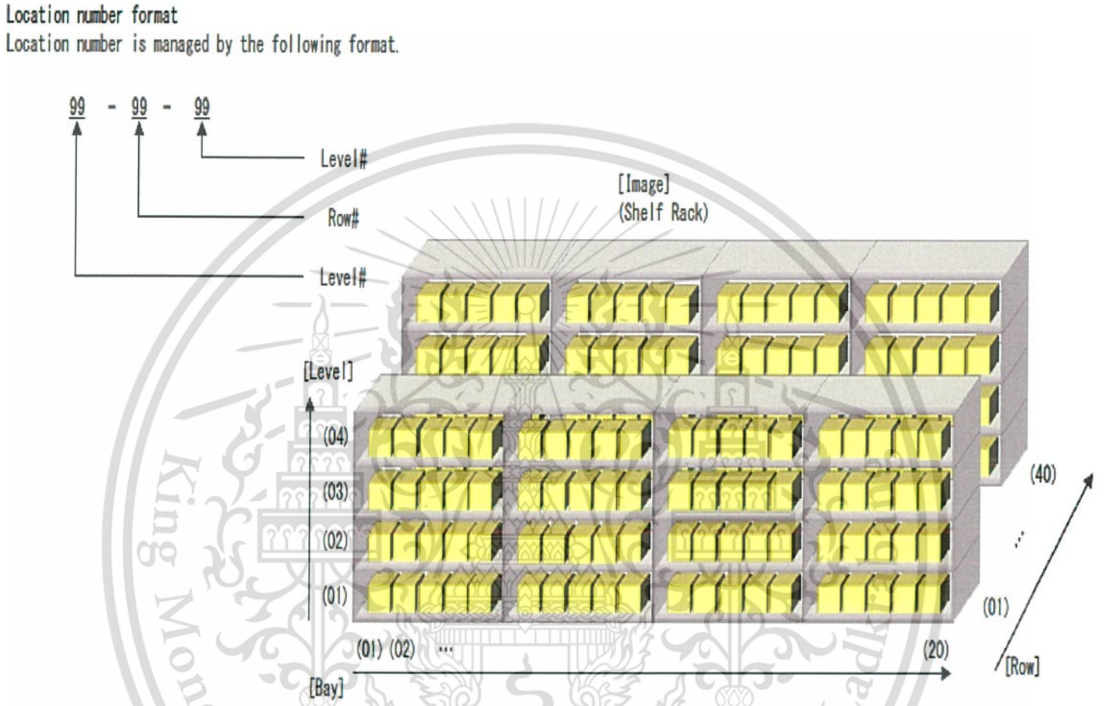


Figure 4.8 B Rank Picking Location View

4.2.1 Design Layout of AA-Rank Area

In the Storage doesn't have only small item, it also serve for products build up in pallet as well, AA-rank picking area manages the floor storage in 4 rows, 4 bays and 1 levels (Pallet Storage), identifying the picking condition follow the location format by [row], [bay] and [level], AA-rank picking area manages support supper fast moving items 16 SKUs/ time.

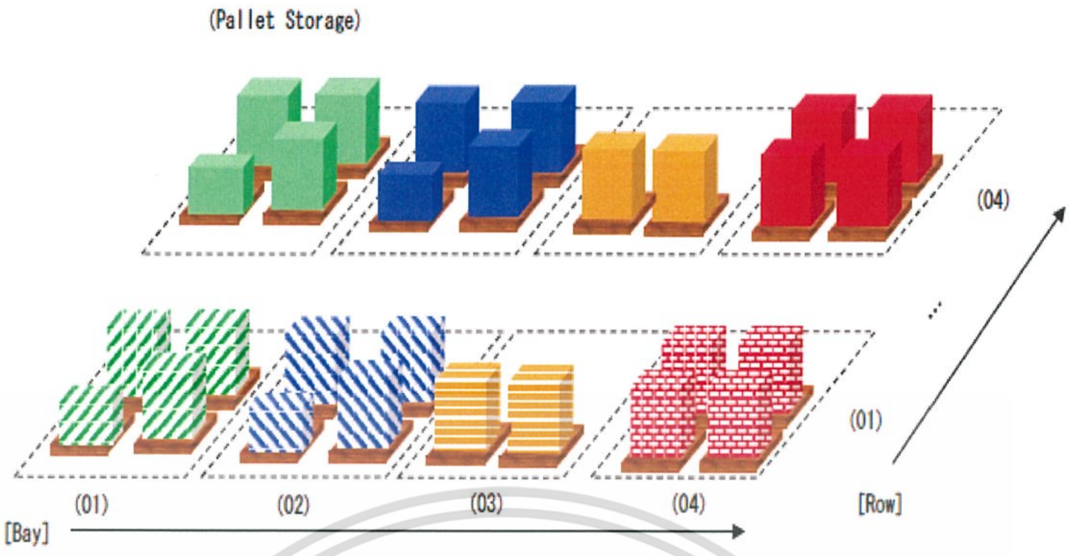


Figure 4.9 AA Rank Picking Location View

4.2.5 The Condition of Order Picking System

All of the layout that been designed above, have to follow the condition in the order picking system as the unit for picking products start with two units include relay picking and AS/RS which consist of products in AA rank picking area, A rank, B rank and C rank picking area, in case of picking unit form AA rank and A rank picked by (PTL), B rank picked by handheld terminal (HHT) and C rank picked by PC at picking station in AS/RS and storage in Uni-shuttle for waiting picking item to deliver to customers. Other case of AS/RS picking unit in outer it use to pick by PC at the reject station and store in a Uni-shuttle for waiting picking item in **Table 4.5**.

Table 4.5 Picking Procedure

Unit for Picking Start	Storage Area		Picking unit	Picked by	Queuing Storage (Picking item)
Relay picking	Picking Area	AA rank	Inner or Piece	PTL	Uni-shuttle
		A rank			
		B rank		HHT	
	Case AS/RS	C rank		PC (at Picking station)	
Case AS/RS	Case AS/RS		Outer	PC (at reject station)	Uni-shuttle

In case multiple SKU are assigned in Case ASRS for one sales order, they are grouped and retrieved to the same picking station. Moreover, In case one SKU is assigned in Case ASRS for one sales order and this SKUs are assigned for multiple sales orders, multiple picking operations are ordered in one assigned tray or outer box. To picked the products, the Unit and priority sequence for issuing Picking label is issued by each [Area], [Location], [Item code], [Lot] and [Expiry date] and Shipping label is issued by each outer box. Priority sequence is as follows.

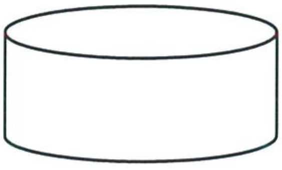
4.3 Design the Order Picking Operation

After, setting up the condition for order picking system, this research is designing the operation of order picking processes in all areas that had mention before include AS/RS case, AA rank, A rank, B rank and uni-shuttle, in the process of order picking system has many participate the organize the processes and the characters of symbols use to identify the processes that show in table 5, The operation flow consists of 4 participates are host system describes the part related to warehouse management system, warehouse management system functions, operations and other to manage the warehouse process flow.

Table 4.6 Description of Operation flow

Operation Flow	Description
Host system	This describes the part related to WMS functions in the Host System. This describes each system name in case several systems exist.
WMS	This is WMS functions, processing content, and files related to each operation. But, this is only to show some ideas about WMS and the data to be used (Real data) are going to be different. A horizontal line is to show the passage of time.
Other	This shows the process functions of sub systems used with WMS. (e.g. Transport by conveyor)
Operation	This shows an operator and operation content.

To describe the order picking operation flow, this research use the symbol as below

Symbol	Description
	Files or data base

	Ledger label
	Online Process
	Process flow Information flow
	operators
	Group of process
	Duty description

Figure 4.10 Description of Operation Symbols

4.3.1 Master Data Flow in Order Picking Process

Mater Data flow is used to collect and analyze data. Then, input the condition and data into the system as the flow below, the process of master flow start from input data in host system, warehouse management system received the data from the host system then check the case of data include data of new item or data for no goods, in case item master data is no goods, the system check data receiving error then confirm and deal the error with operators. Other hand, for new item need has to register for new item first and input to the master data include the information such as [area], [zone], [location],[item code], at the replenishment point located face the master data by operators.

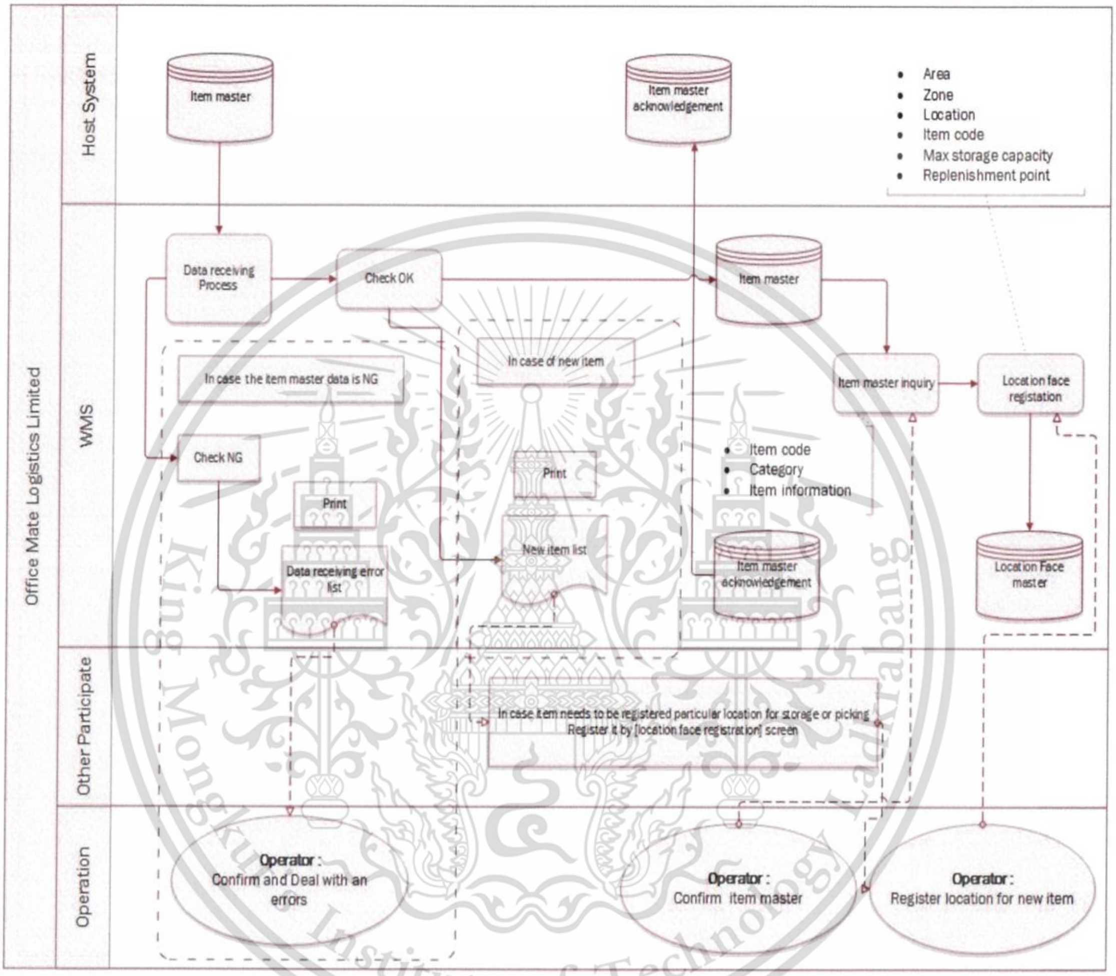


Figure 4.11 Master Data Flow

4.3.2 Relay Picking Flow in Order Picking Process

Relay picking process is a process using Automated functions and conveyors to pick the item form case ASRS and transfer to uni-shuttle, Relay picking use to pick the small item form AS/RS or Small item using picking tray and transfer to next picking zone. The first zone, start by retrieval operator create the retrieval schedule in the system, in case of AS/RS C rank item, the retrieval process and using the command to transfer case at retrieval point for scanning the receiving label and arrive at the picking station. The process will be complete when the item has put in the picking tray or I-PACK. And transfer to next station as **Figure 4.12**.

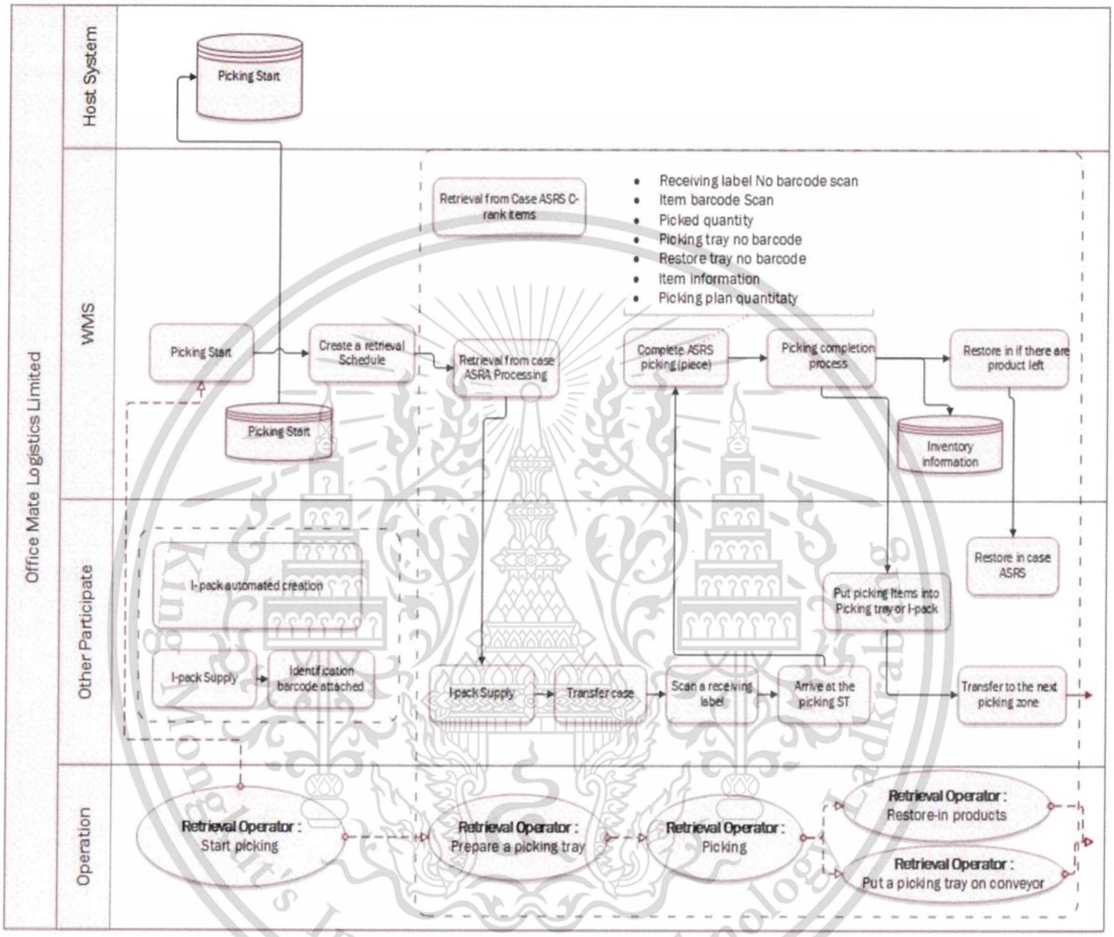


Figure 4.12 Relay Picking Flows

After receive items form last section **Figure 4.13**, item have to scan an identification barcode at digital picking point, In case of Digital piking system in A rank items, when items arrive the picking point, the operator will remove from the picking tray buy using handheld terminal and transfer to next picking zone. Then, items will remove from a picking tray when arrive at picking point after scan and identify barcode to complete the picking process in the system and transfer to next picking zone as shown in figure below.

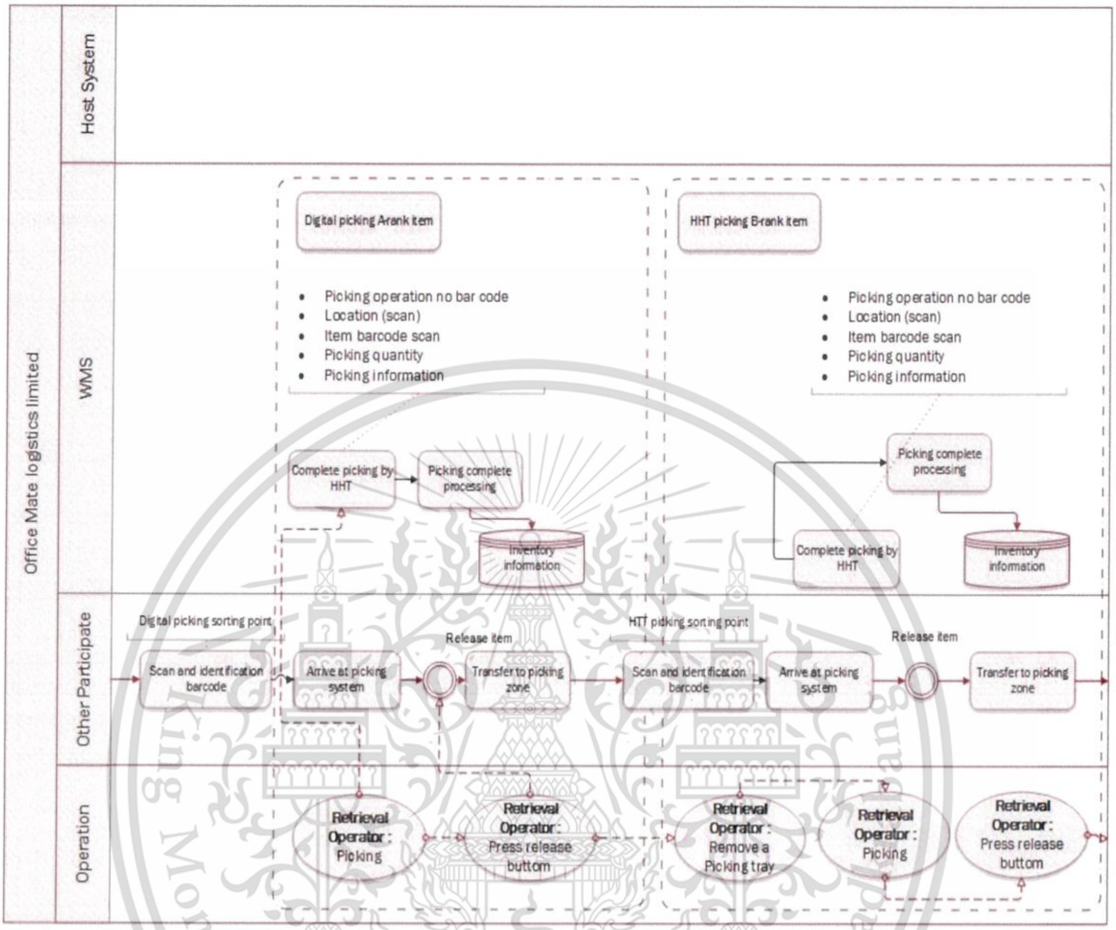


Figure 4.13 Relay Picking Flows

In case of AA rank pick by digital picking system, the picking start from scanning and identifying the barcode, after that picking by handheld terminal to the picking tray and transfer to next picking zone

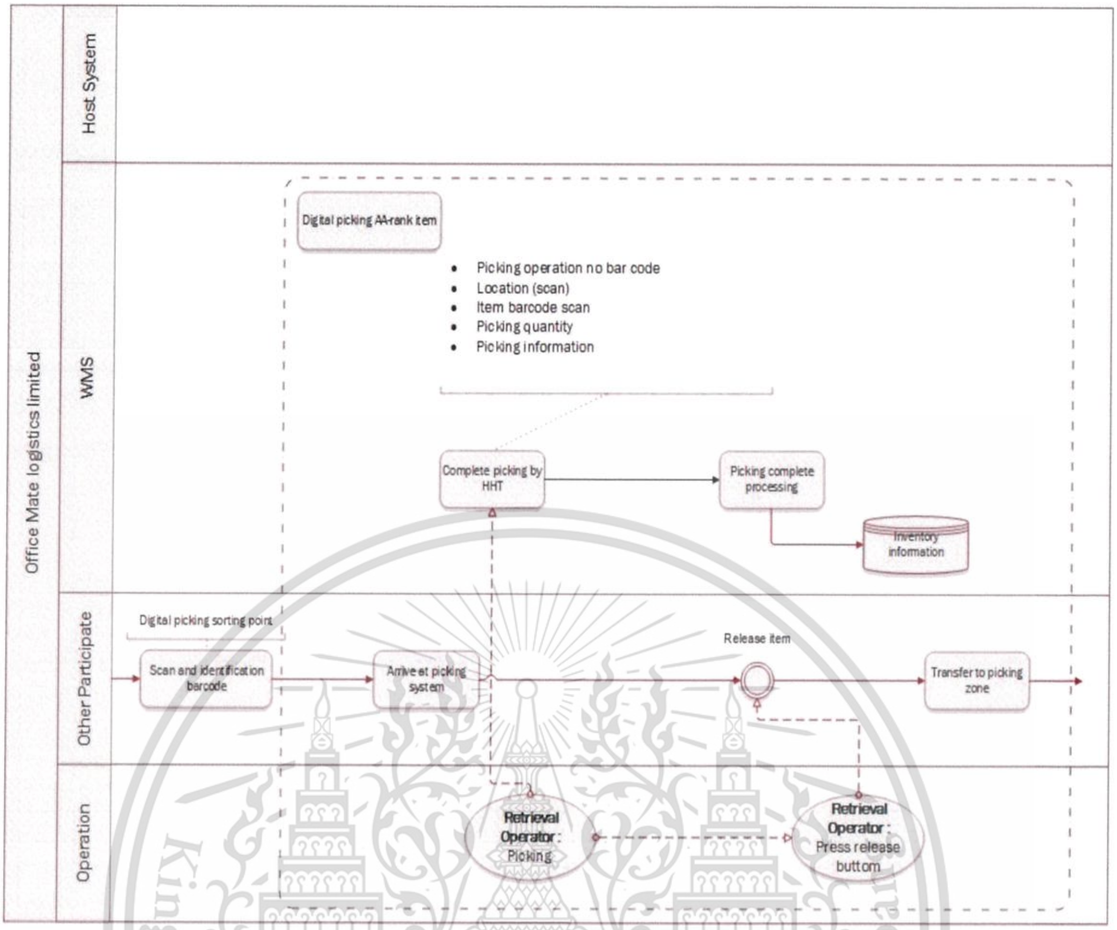


Figure 4.14 Relay Picking Flows

Figure 4.5 and **Figure 4.16** had shown an automated packing flow. The item has to be scan and identify the barcode on digital picking system point first, and then a shipping label is attached on I-PACK after weight check, dimension check and closing box. Then I-PACK will be transferred to the Uni-Shuttle.

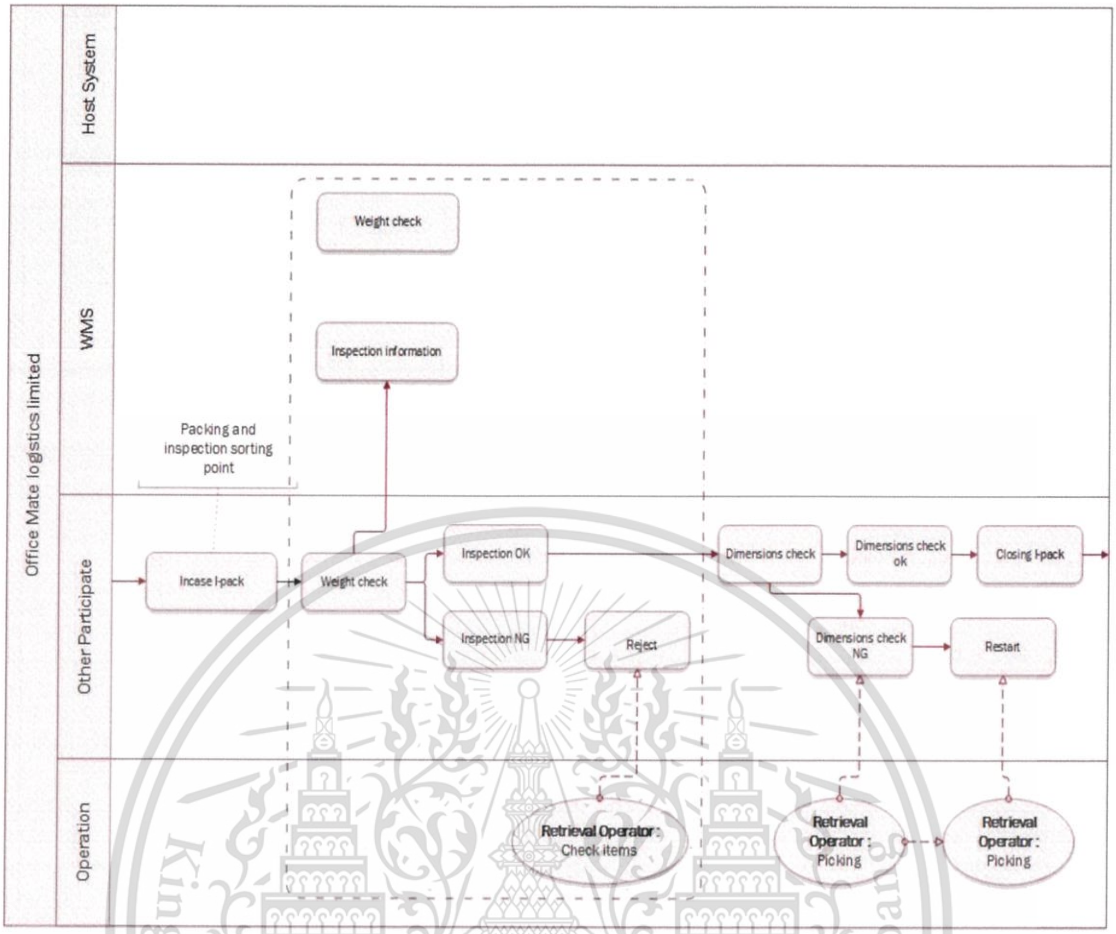


Figure 4.15 Relay Picking Flows

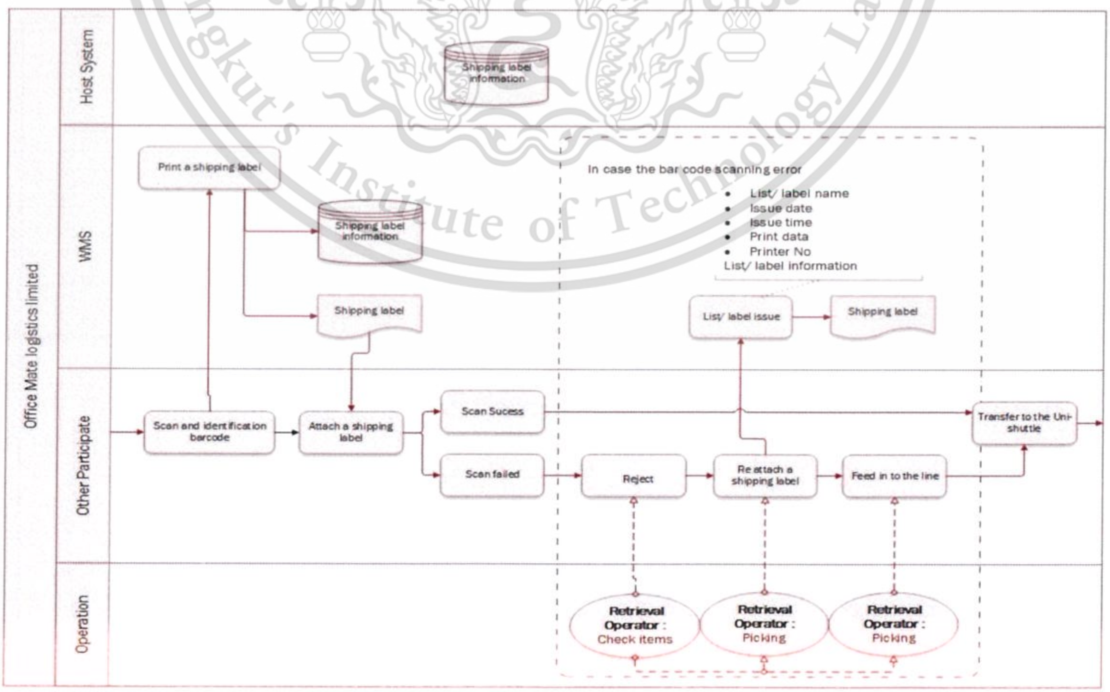


Figure 4.16 Relay Picking Flows

In case of manual picking, the shipping label on the shipping boxes after the inspection and packing process, the item will feed in a shipping line and transfer to uni-shuttle, this case use for pallet area or large item.

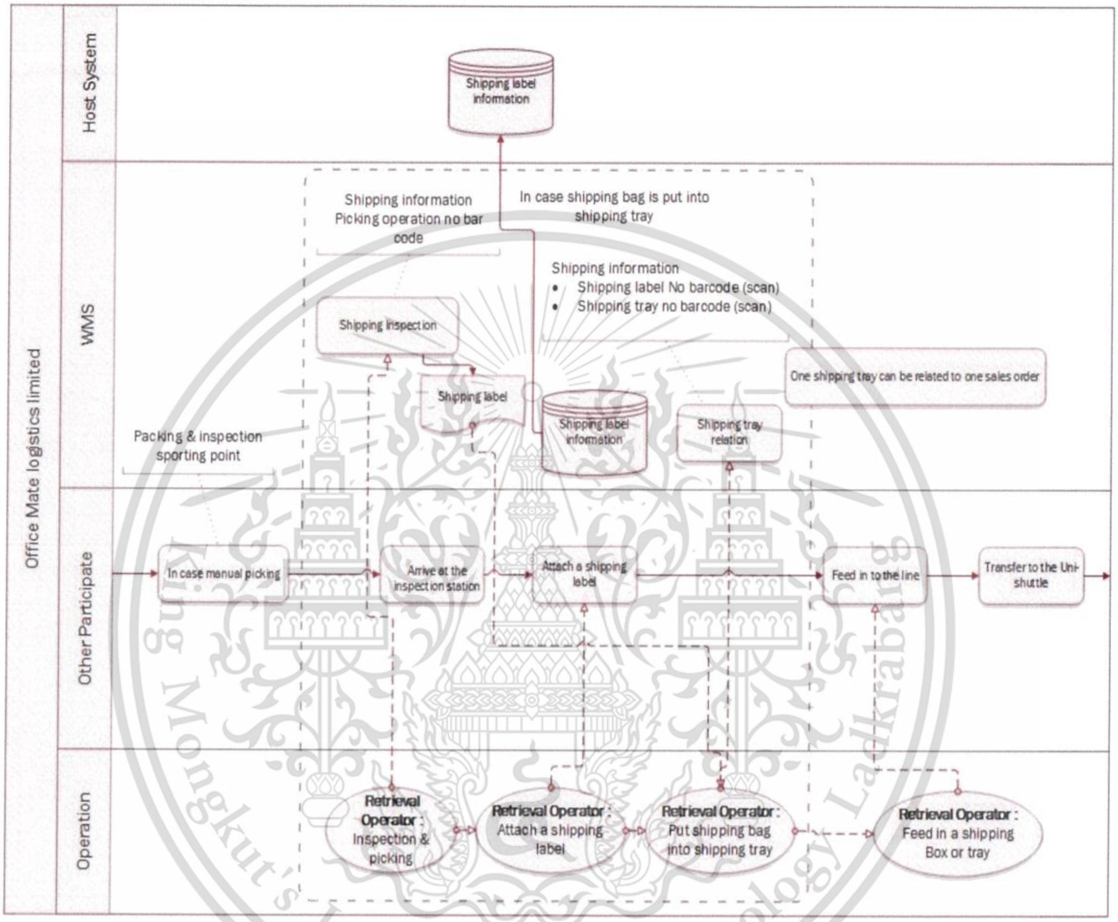


Figure 4.17 Relay Picking Flows

Before transferring to the shipping box to the uni-shuttle for waiting to shipping out of warehouse, items have to detect load dimensions then scan the shipping label or tray ID to store in uni-shuttle by conveyor line.

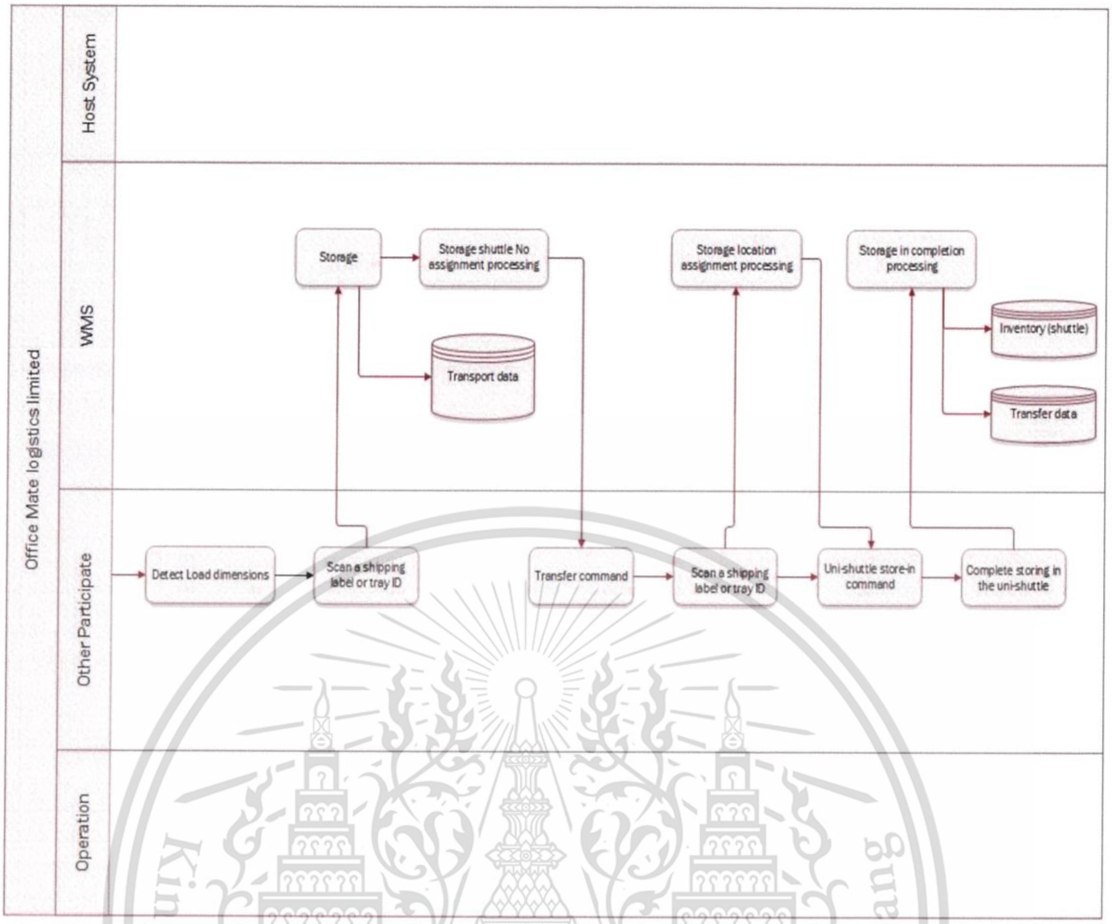


Figure 4.18 Relay Picking Flows

4.3.3 A Rank and B Rank Flow in Order Picking Process

A rank items and B ranks design are the same process because the item in A rank and B bank area are the small item and storage in the flow rank and shelf rank, the picking in this case start from the operator use the command for pickings by create the retrieval schedule in the system, In case of A- rank and B-rank items, the retrieval process and use the command use to transfer case at retrieval point for scanning the receive label and arrive at the picking station. The process will be complete when the item has put in the picking tray or I-PACK. And transfer to next station

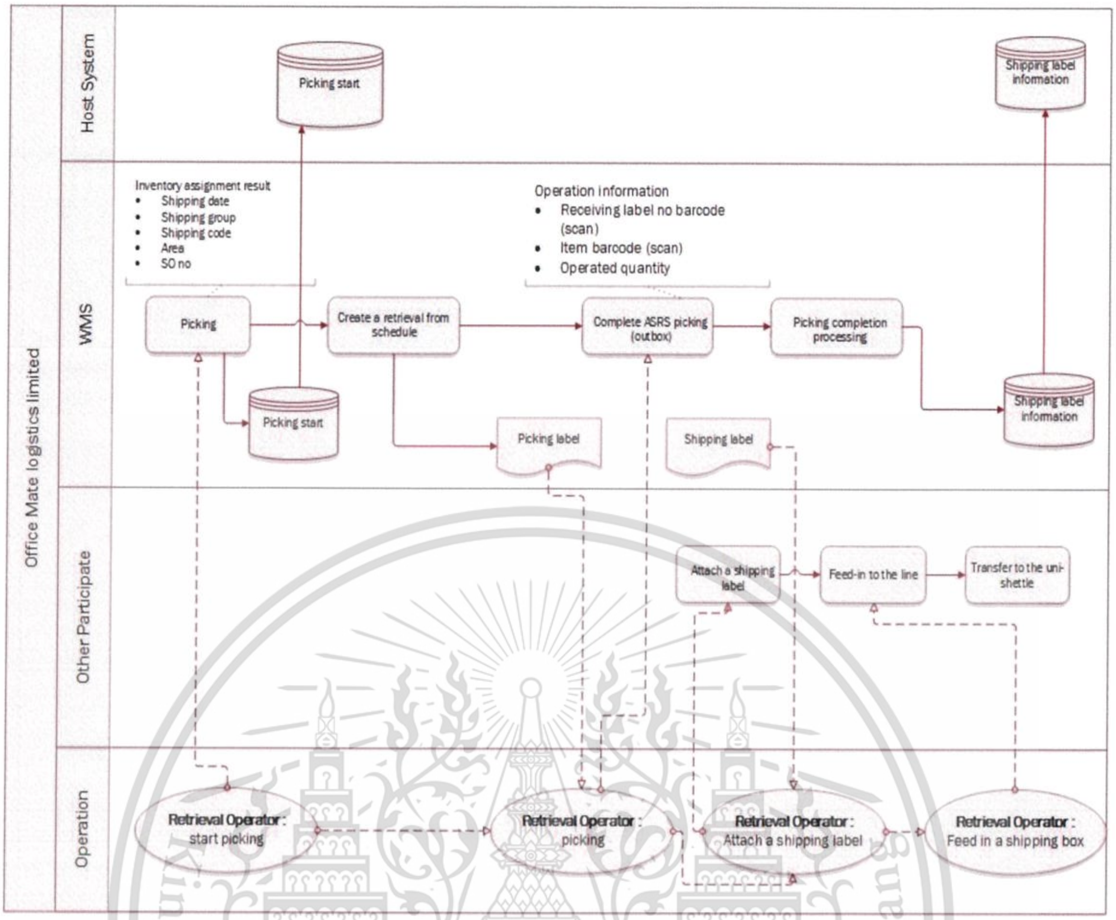


Figure 4.19 A Rank and B Rank Picking Flows

Then transfer the shipping box to the uni-shuttle for waiting to shipping out of warehouse, items have to detect load dimensions then scan the shipping label or tray ID to store in uni-shuttle by conveyor line.

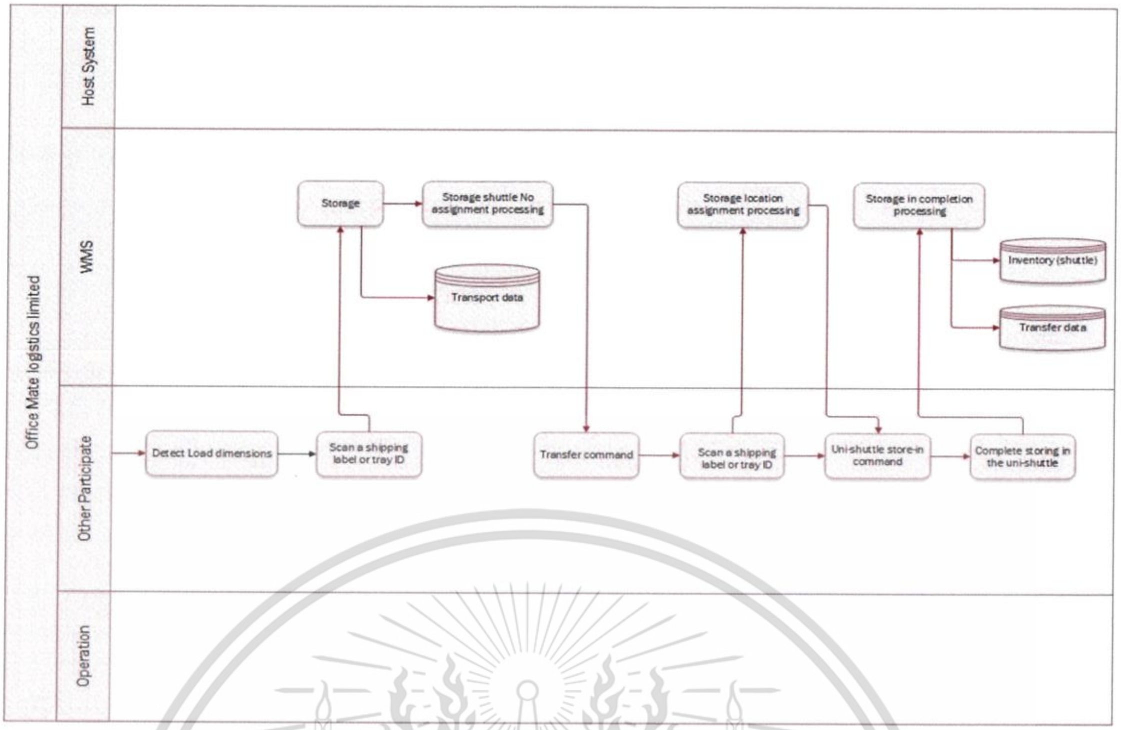


Figure 4.20 A Rank and B Rank Picking Flows

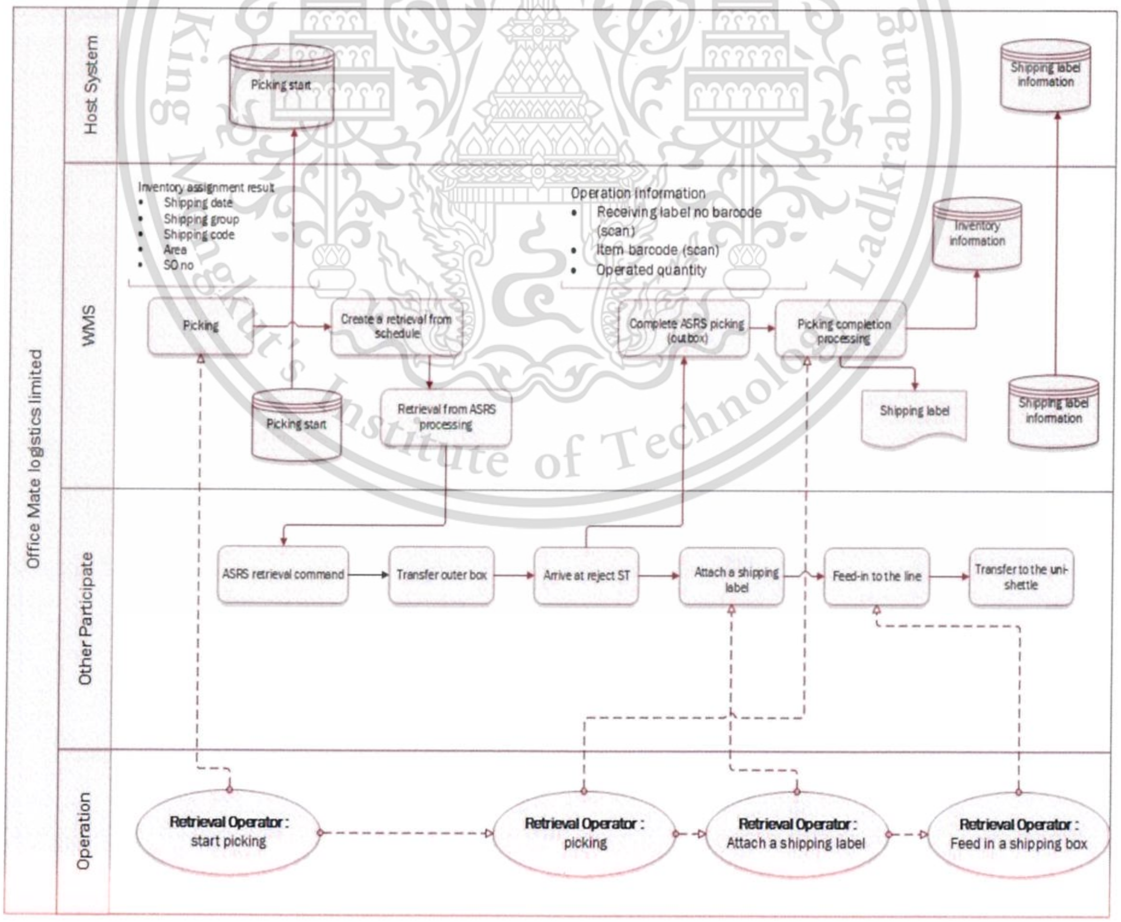


Figure 4.21 AS/RS Picking Flows

The picking in this case start from the operators use the command for pickings by create the retrieval schedule in the system, in case of AS/RS items, The retrieval process and use the command to transfer case at retrieval point transfer outer boxes to reject station attached the shipping label and feed in the line transfer to uni- shuttle.

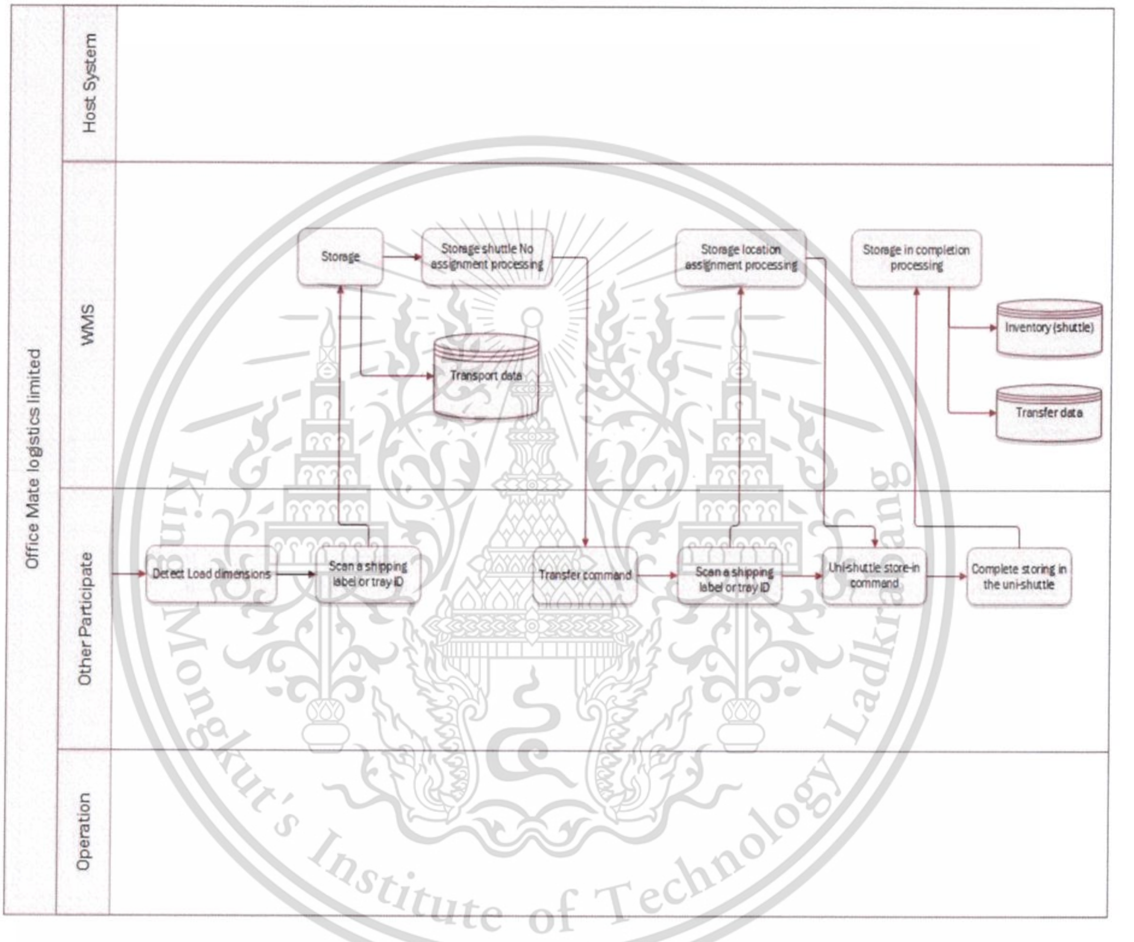


Figure 4.22 AS/RS Picking Flows

CHAPTER 5

CONCLUSIONS

Logistics had defined as a process of managing the flows of goods and services between the manufacturing and customer. The warehouse is in logistics system is possible for obtaining the products from difference suppliers and sorting them to fulfill a number of different customer's demand. Various activities in a DC include order receipt, material receipt, labeling, put-away, replenishment, inventory control, order picking, sorting and packing, staging, shipping, and returns processing.

Many companies look out for reduce cost and improve productivity within their warehouse, order picking is the most labor-intensive operation in warehouses with manual systems, and a very capital-intensive operation in warehouses with Automated systems. The order-picking operations immediately impact the warehouses and thereby the supply chain's performance, many companies have come up with innovative solutions by using automated system in the process to solve the problem and improve the logistics system and warehouse system more accurate.

Automation for order picking processes in warehouses is only deployed to a limited extent large and long ranging investments are necessary, dynamic market demand requires more and more systems flexibility, and the products characteristics like size and/or weight may change significantly over time.

In this research focuses on designing the condition of order picking system to set up new warehouse and designing the storage layer and order picking system process, and picking area for automated warehouse. The design of an order picking system depends on various components which include conditions, decision and parameter in processes; e.g., identification of the piking area layout, confiscation of storage system and determination of the storage policy, picking method, picking strategy, material handling system and picking assist technology, etc. the best design would depend on the objective to be optimized.

The two keys order picking system design issues addressed in the dissertation are the configuration of a storage system and the selection between batch and zone order picking strategies. This research has identified several factors that affect both decisions. First, the study models the condition and decision making in the process. Second, the study designs the process of order picking system for automated warehouse as the result below:

Design the condition and decision of order picking warehouse: the order picking system in this research focus on 5 areas include: AS/RS case, uni- shuttle, A rank picking area, B rank picking area and AA rank picking area, which define the different products such as fast, medium or slow moving items. To defined the condition of order picking system, designer has to understand the nature of the order picking process in each area have different conditions. So, this research sets the condition according to the items include size of boxes, level of rank, storage area, picking assist technology. Boxes size device in 3 or 4 sizes consists of S, M, L and LL, level of rank consists low level for L size and LL size items, medium level for M size and high level for S size. Moreover, In case multiple SKU are assigned in Case ASRS for one sales order, they are grouped and retrieved to the same picking station. Moreover, In case one SKU is assigned in Case ASRS for one sales order and this SKU are assigned for multiple sales orders, multiple picking operations are ordered in one assigned tray or outer box. To picked the products, the Unit and priority sequence for issuing Picking label is issued by each [Area], [Location], [Item code], [Lot] and [Expiry date] and Shipping label is issued by each outer box.

To design the operation process of order picking warehouse: First, set up the condition for order picking system. Next, this research focus in designing the operation of order picking processes in all areas that had mention before include AS/RS case, AA rank, A rank, B rank and uni-shuttle. In the process of order picking system, 4 participates are host system describes the part related to warehouse management system, warehouse management system functions, operations and other to manage the warehouse process flow. Each area has different of process and depend on items and conditions, which every picking processes start form receiving order picking. The process starts form input the data master to items information include [Area], [zone], [location],[item code], users will use the command to picking the items follow master data, the process of system in each area are different depend on picking technology as well.

After design the condition and operation processes, this research has use to set up for new Automated warehouse of office mate Logistics Company and the as result get from this research one decrease manual picking and picking error, improve inventory accuracy and support business growth. Moreover, the system also supports time for loading by uni-shuttle to make it easy to palletized process, decreasing waste time from manual picking as well.

Due to the process in warehouse still need to be improved all the time. Studying and developing warehouse management system is complicated that every process should be the unique task and relationship among them. After designing the automated warehouse, the result is only a model and condition but it doesn't get the result of using it. For future study, the effectiveness of using Automated warehouse compared with the general warehouse should be studied more to evaluate optimize performance in warehouse management.

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