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# Improving Warehouse Layout Design of a Chicken Slaughterhouse using Combined ABC Class Based and Optimized Allocation Techniques

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***Abstract*—This paper was about analyzing and designing appropriate warehouse operation of a representative meat product factory. A chicken slaughterhouse was chosen as a case study. ABC class-based storage policy and optimized product allocation using linear programming were combined and used to design an improved warehouse layout. The product circulation ratio was considered. Results indicated that the combined technique offers significant improvement to the existing layout. Reductions of the overall travel distance during operation by almost 45% or over 6,000 m a day and the picking time by 42% can be achieved. Projected increases in the space utilization performance and the inventory service level are 45 and 28%, respectively. When proposed layout and picking system are implemented, attractive return on investment can be realized with discounted payback period of less than one and half year.**

***Index Terms*—ABC class based storage, Linear programming, Food industry, Warehouse management**

## I. Introduction

Manufacturers are facing several competitions and challenges on various fronts. These include price war, emerge of new technology leap, fluctuating demand, and emerge of new competitors. Change in technology is becoming faster and affecting the product life cycle. To sustain and survive in this rapidly changed environment, the manufacturers have to increase their competitiveness by either improving their performances or reducing their costs. Logistics management is viewed as one of the ways to achieve this. It directly affects process effectiveness which consists of quality, cost and delivery. Using the logistics management properly will permanently improve the organization performance. Warehouse management is one of the most important techniques in logistic management due to the fact that inventory directly influences production cost and customer service [1]. Improving inventory management could decrease the production cost, leading to increase in market share, profit and customer service for the company.

In this research, a chicken slaughterhouse company was studied. Their main product is fresh chicken that are distributed domestically and for export. Due to the expansion of market, the demand is increasing every year. However, the uncertainty of raw materials (live chicken) that come in can be found daily. To prevent the loss in opportunity in business, the company has to process all live chicken coming in day-by-day. The over production is to be stored as the inventory waiting for future purchasing. Due to the company's make-to-order and make-to-stock policy, this forces the company to have more than a hundred types of finished products stored in its warehouses. High number of product varieties is the main problem that happens in storage areas. The employees trend to have difficulty finding the right products in warehouses quickly. New warehouse layout design may alleviate this problem.

ABC class-based storage and optimization technique are well established that they have been successfully implemented in a number of industries. However, they are rarely adopted in the Thai food industry. In this work, attempt was made to combine both techniques to improve warehouse operations of the chicken slaughterhouse. The current operation was evaluated and analyzed. Previous twelve-month order of four main customers was collected, and classified by ABC class-based system. Optimization using linear programming technique was then employed to determine new product locations that were considered to have the lowest overall traveling time and distance. New layout was designed accordingly.

## II. Literature Reviews

Warehouse management is one of logistics activities that currently occupy the highest cost. It has direct effect on profit of organization and customer demand fulfillment [2]. This factor could boost ability of market competition [3]. Warehouse operation problem relates to the four major functions; receiving, storage, picking and shipping [4]. Warehouse management involves location selection, sizing, layout design, administration system design, location control, delivery and data record [5]. From previous literature reviews, it was found that there are two types of warehouse management; internal operation system management and layout management. Recently, most researchers focus on operation system management. Order picking is a key operation in managing a warehouse

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efficiently. It presents 65% of the total operating costs of a warehouse [6, 7]. Management of order picking should be precedence development. Many researches develop support system for order picking. Majority of papers focused on storage department layout in order to maximize performance of order picking, such as the utilization of Pareto rule for product grading and reducing average travel time. It was also suggested that class-based storage is an efficient strategy for eliminating search time [8].

The strategy used to allocate the products influences almost all the warehouse performance and depends strongly on its layout. Storage location assignment problem consists of allocating the product to the different slots in a warehouse, minimizing the handling costs, and maximizing the space utilization. Bozarth and Vilarinho [9] found that there are several obstacles for supreme space employment. For example: space assignments were not reevaluated as the needs of the business had changed, resulting in large, empty storage areas. The basic principle is that the high-demand products have to be allocated in the slot closer to the input and output (I/O) doors for reducing the total time in handling.

Bartholdi and Hankman [10] indicated that travel time is wasted since it costs labor hours but does not add value. Warehouses have to improve their order fulfillment operations through better storage, batching and routing strategies [11]. Petersen *et al.* [12] classified storage assignment policies into three broad categories: randomized, volume-base, and class-based. The class-based storage approach is the most effective method, dividing the items into classes and assigning to each class a set of areas in which the products are located in whatever way. Guerriero *et al.* [13] developed a linear mathematical model and a heuristics for the multi-levels product allocation problem of a warehouse with the aim of minimizing the delivery times; the inventories; the logistics costs. Simulation results showed that the purposed heuristic could find good quality solutions with a computational effort lower than that required to solve the proposed mathematical model. Chan and Chan [14] presented a simulation study of a real case regarding storage assignment problem of a manual-pick and multi-level rack warehouse. They indicated that the key to effective implementation of a storage assignment system is to match the types of warehouse storage system and the variety of items in the customer order. Chuang *et al.* [15] indicated that clustering-assignment problem model is suitable for orders with multiple items and smaller quantities in the modern retailing sector. It can effectively shorten the picking distance, compared with popular frequency-based and random assignment storage methods.

It is clear that the class-based technique can enhance a typical storage and warehouse management. It has been proven to be successful in a number of industries. It is therefore expected that this technique can improve meat products' warehouse management significantly since it can speed up overall warehousing process. This aspect is especially crucial for perishable and short shelf-life goods like meat products.

## III. Methodology

### *3.1 Background of the Case Study*

The case study chosen in this work was a chicken slaughterhouse factory. It is situated in Lopburi province of central Thailand. It started doing business since 1990. The operation processes are composed of (i) live birds receiving, (ii) carving, (iii) trimming, (iv) packaging, and (v) storage. The maximum capacity is estimated at 260,000 chickens per day. Working time is divided into two shifts, 24 h a day, six days a week. In this work, only chilled chicken products were investigated. The products are normally stored in a chilled room at temperature below 4$^{o}$C. Typical dimension of the stored room was 18 x 29 x 7 m in width, length, and height, respectively.

The company has four main customers and each has different individual order. At present, the products are made and arranged randomly, a last-in-first-out (LIFO) concept. Searching for particular products could be very difficult at times. Since there was no shelf set up in the stored room, the products were placed on the floor. The maximum capacity of existing layout was 200 pallets. Six forklifts and one extra worker per shift were available for this storage. Presently, the factory can deliver merely 178,000 kg at maximum capacity, while 68,000 kg of finished goods remain undeliverable.

### *3.2 Data Collection and Analysis*

Methodology of this research can be summarized in Fig. 1. Initially, the operation of case study was thoroughly investigated to observe as-is approach, especially warehouse operation. As the first step, the current operations were evaluated and data collection was carried out from actual processes in warehouse department. The products were classified using class based storage policy. A linear mathematic model was developed to determine each product location. The analysis was performed, considering previous 12 months historical picking list of customer order. The company has four main customers while each customer has individual order. Collected data was analyzed in 4 stages;

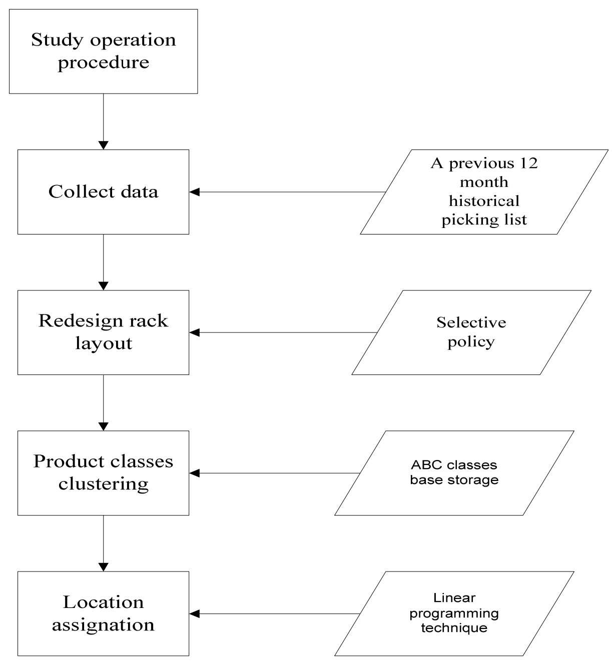


Fig.1. Flow chart of methodology for improved layout design


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*(a) New rack layout design*

Current rack layout of warehouse was redesigned. The selective policy was adopted for new layout system. Multi-level rack design was utilized in order to maximize storage contents.

*(b) ABC class-based storage*

In this step, products were grouped into three classes; namely A, B, and C. Class A represents the fastest movable product class which contributes to about 60% of the turnover, while the slowest movable products which account for about 10% of the turnover is represented by class C. The products were categorized based on quantity of order for each item. Only 24 items of the chilled products were subjected to ABC classification. From previous data, the highest number of orders amounted to 252 pallets required per day.

*(c) Layout design and location assignment*

The new layout was proposed, taking into consideration the maximum space utilization and convenience in picking product. The location was specified using class based storage and linear programming. Rollers are to be employed. Product items of similar types for each customer were located near each other. The rapidly movable items were designated to storage areas closer to the I/O door. This way, the overall travel distance can be reduced.

*(d) Development of mathematical model*

Once requirements of all products were known, the mathematical model was developed to determine commodities location. Mathematical model developed here was a special case of the general multi-commodity problem. Based on linear programming, the mathematical model of the problem can be formulated as follows;

***Minimize***

$$\sum_{i=1}^{I}\sum_{j=1}^{J} f_i e_{ij} \times x_{ij} \qquad (1)$$

***Subject to***

$$\sum_{j=1}^{J} x_{ij} = q_i \qquad \forall j, J \qquad (2)$$

$$\sum_{i=1}^{I} x_{ij} \leq c_j \qquad \forall i, I \qquad (3)$$

$$x_{ij} = 0,1 \qquad (4)$$

where $i$ is the number of commodities ($i = 1, 2, \ldots, I$), $j$ is the number of destinations ($j = 1, 2, \ldots, J$), $R_i$ is the amount of required space for commodity $i$, $q_i$ is the demand of commodity $i$, and $f_i$ is the frequency transfer of commodity $i$. It can be found from

$$f_i = \frac{R_i}{q_i} \qquad (5)$$

where $e_{ij}$ is the transfer distance of commodity $i$ to destination $j$, $c_j$ is the maximum capacity of destination $j$, and $x_{ij}$ is the available product $i$ in destination $j$, respectively

Clearly, the model aimed to minimize travel distance of products from the origins (door) to destinations (location), formulated in eq. (1). Constraint (2) represented that total amount of a commodity $i$ at destination $j$ should be equal to demand of the commodity. Constraint (3) stated that total amount of a commodity $i$ should not exceed maximum capacity of destination $j$. Constraint (4) addressed that if the product $i$ was assigned to destination $j$, the value of this variable was either 1 or 0. The formulated mathematical model was employed to evaluate the warehouse arrangement efficiency by considering total traveling time of all products, before and after layout improving process. Lingo software program version 10.0 was used.

## IV. Results and Discussion

### *4.1 Layout Design*

Existing products' arrangement (shown in Fig. 2a) was random and of LIFO type. Searching for particular product items were time consuming and moving these products covered large distances. The maximum capacity was merely 200 pallets. Analysis of demand data revealed that total space requirement was 252 pallets per day. To get ready for even higher demand that may arise in the future, the warehouse layout was re-designed.

The proposed layout is equipped with 5-storey, selective shelves to support first-in-first-out (FIFO) policy, and motor-driven conveyor rollers installed at side walls to facilitate picking activities. The new layout is able to store 260 pallets in a 16 x 19 x 7 $m^3$ area. The size of new rack is 1.5 x 1.35 x 1.25 $m^3$ per pallet. The new rack is allotted to be 14 zones; namely AL, AR, BL, BR, CL, CR, DL, DR, EL, ER, FL, FR, R and L. Each rack has 5 levels and 4 bays, except racks L and R which have only 5 levels and 2 bays. The width of middle aisle is 4.4 m. Separation between shelves is 3 m. Moving products by the forklifts can be in much shorter distances. Rather than moving a product all the way to the door, the proposed layout requires only to move the product to the rollers. Configuration of the new warehouse is illustrated in Fig. 2b, and Fig. 3.

Space usage level per one pallet is calculated from total area divided by amount of pallet. The existing space usage level was 2.61 $m^2$ and the new one is 1.17 $m^2$, respectively. It is clear that the new warehouse layout can increase space utilization by almost 45%.

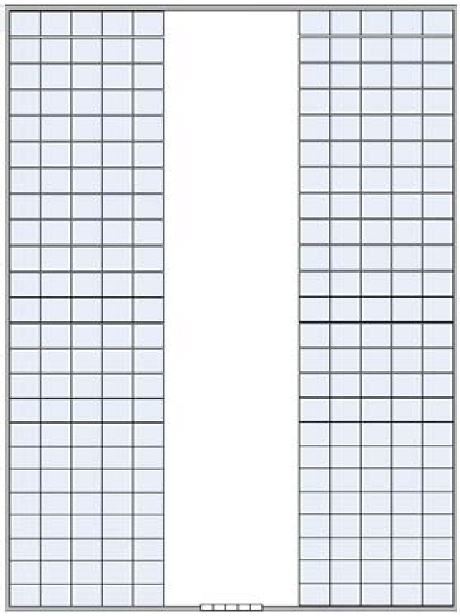

Fig. 2a. Existing Layout designs of case study's warehouse

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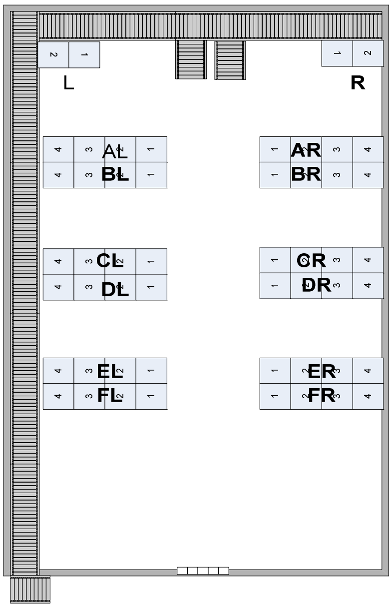


Fig. 2b. Proposed Layout designs of case study's warehouse

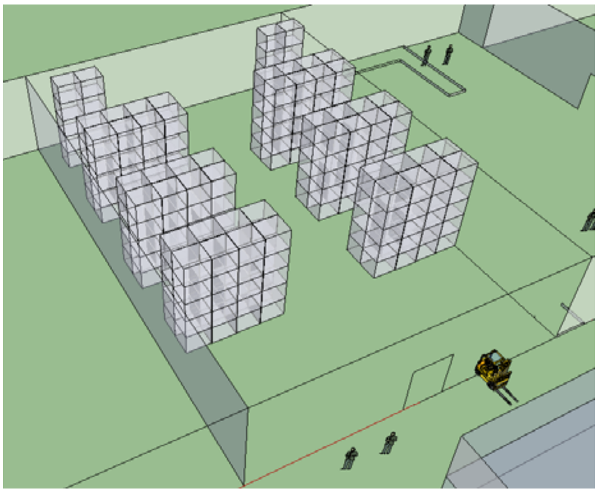

Fig. 3. Proposed layout design with shelf rack

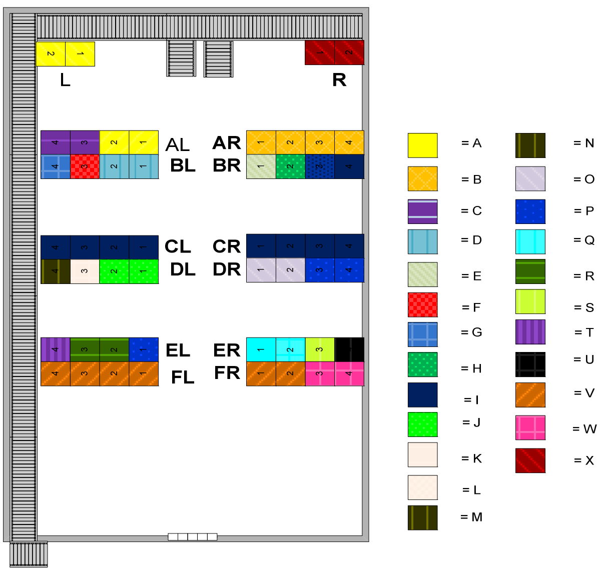


Fig. 4. Rack design of class based storage

### 4.2 *Class-based Storage*

The considered products were chilled fresh chicken stored at temperature below 4$^{o}$C. According to the Good Manufacturing Practice, the products are needed to be delivered within 48 h. Therefore, these chilled products have to be moved in and out of the storage all the time. For the four main customers, Customer 1 has the highest order volume, averaging at 53%, while Customers 2, 3 and 4 have order volumes equal to 28, 11 and 8%, respectively. Total number of product items was 24. The classification revealed that class A contains products of Customers 1 and 2. There are 15 items, labeling A to I. Class B holds 7 items which are Customer 3's product items P to V, while class C makes up of 2 items of Customer 4.

### 4.3 *Proposed Product Allocation and Picking Activity*

Lingo software program version 10.0 was used to analyze optimal solution. Proposed allocation of products is shown in Table 1, and illustrated in Figure 4. Significant reduction in travelling distance of products (from 13.7 to 7.6 km a day) can be achieved after improvement. As a direct consequence, average picking time per pallet can be cut down by 42%. The proposed layout and improved picking system can enhance finished goods delivery capacity, hence, the previously undeliverable finished goods is no longer a problem. Inventory service level can be increased from 72 to 92%.

Initial cost in implementing the proposed warehouse layout is estimated at around 2.5 million THB or 83,000 USD. Cost saving in terms of less labor requirement, reduced forklift rental fee, and lower maintenance is about 7,000 USD a month. Discounted payback period at 8% MARR is calculated to be within 17 months.

## V. CONCLUSIONS

A multi-commodity warehouse has been taken as a case study. ABC class based storage concept combined with product allocation using linear programming have been employed to determine a new layout and picking system. The proposed layout design offers two advantages; it is easier to search and pick products, and it can increase space utilization to support the growth demand that may occur in the future. The results showed that performance of warehouse management based on minimized total travel distance and time can be improved. Reductions in the travel distance by 45% and the picking time by 42% can be realized. Space utilization is also expected to increase around 45%. Return on investment to implement the new layout is economically attractive.

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**TABLE I**
LOCATION ANALYSIS RESULT OF COMMODITY A TO X

| Product | Rack no. | | | | | | | | | | | | | | Demand slot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **AL** | **AR** | **BL** | **BR** | **CL** | **CR** | **DL** | **DR** | **EL** | **ER** | **FL** | **FR** | **L** | **R** | |
| A | 11 | | | | | | | | | | | | 1 | 10 | 22 |
| B | | | 19 | | | | | | | | | | | | 19 |
| C | 9 | 3 | 1 | | | | | | | | | | | | 13 |
| D | | 7 | | | | | | | | | | | | | 7 |
| E | | | | 5 | | | | | | | | | | | 5 |
| F | | 5 | | | | | | | | | | | | | 5 |
| G | | 5 | | | | | | | | | | | | | 5 |
| H | | | | 5 | | | | | | | | | | | 5 |
| I | | | | 10 | 20 | 3 | 20 | | | | | | | | 53 |
| J | | | | | | 8 | | | | | | | | | 8 |
| K | | | | | | 2 | | | | | | | | | 2 |
| L | | | | | | 2 | | | | | | | | | 2 |
| M | | | | | | 2 | | | | | | | | | 2 |
| N | | | | | | 2 | | | | | | | | | 2 |
| O | | | | | | | | 12 | | | | | | | 12 |
| P | | | | | | 1 | | 8 | 4 | | | | | | 13 |
| Q | | | | | | | | | | | 10 | | | | 10 |
| R | | | | | | | | | 7 | | | | | | 7 |
| S | | | | | | | | | | | 5 | | | | 5 |
| T | | | | | | | | | 4 | | | | | | 4 |
| U | | | | | | | | | | | 4 | | | | 4 |
| V | | | | | | | | | 5 | 13 | 1 | 10 | | | 29 |
| W | | | | | | | | | | | | 10 | 5 | | 15 |
| X | | | | | | | | | | | | | 4 | | 4 |
| Available slot | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 10 | 10 | |
| Utilized slot | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 13 | 20 | 20 | 10 | 10 | |
| Remaining slot | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | |

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