CHAPTER III

RELATED THEORY AND LITERATURE REVIEW

3.1 Productivity

To survive in today's competition, companies have to increase their productivity. Many operations in industry have to increase their productivity such as, the production line, warehouse, transportation, and administration.

Productivity rate is defined as the ratio of output to input. There are four methods to increase productivity [Tungsub, 1995].

- Increase output and remain the same input
- Increase output but decrease the input
- Increase output and increase input but the output is increased more than the input
- The same output but the input is decreased.

Among the above methods, the fourth method of decreasing the input but retaining the same output should be used to improve productivity. The warehouse management is related to only an input, not an output, hence only the input can be varied.

3.2 Warehouse Management

Warehouse management only relates to controlling materials and internal/external transportation. There are three major materials in the warehouse; raw materials, tools, and finished products. Resources involved in a warehouse management are space, manpower and materials handling equipment. A good warehouse management can help improving the efficiency for the company [Tungsub, 1995].

3.2.1 Importance of Warehousing

Inventories have to be retained in storage for the following reasons [Stevenson, 1996].

- To accomplish the production and transportation economy.
- To achieve the quantity purchase discount.
- To absorb the affect of changing market conditions.
- To achieve the least-total cost.

3.2.2 Design of Warehouse.

The following consideration must be taking into account in designing a warehouse [Tungsub, 1995].

- Space utilisation in the warehouse
- Utilising the manpower and materials handling equipment
- Easy access of materials
- Keeping materials safely and reducing scraps
- Good management in the warehouse to reduce cost

3.2.3 The Function of Warehousing

There are two basic functions of warehousing; movement and storage. The movement function consists of receiving, transferring, order selecting, and shipping. The storage function is divided to a temporary storage and a permanent storage. However, both the movement function and storage function include all of the activities as follows [Chorafas, 1974];

Receiving Raw materials are sent into the warehouse. This step needs fast receiving and correct materials' information such as, quantity, quality, and materials. Finally, the materials are classified into type, model, and weight.

Storing The materials are moved from the receiving area to the storage area. The storage area should be run systematically.

Monitoring The materials in a warehouse are stored while the properties must be maintained. They must be prevented from disappearing from the storage area.

Checking After the stock is checked, all the information is recorded and shown to only the related personals to assist in their decision making for the right strategy to use or re-order these materials in the warehouse.

Order selection When some materials in the warehouse are ordered, they are searched and brought to the shipping area. Old materials should be picked up first to reduce any deterioration of goods.

Packing and marking The selected materials are packed and recorded. They may be classified using type, model or size so that they can be moved easily and shipped correctly.

Shipping Finally, the ordered materials must be sent to the right persons, right place and at the right time.

3.2.4 Storing Materials

Storing materials is the most important warehousing activity. Good storing management provides high efficiency and cost reduction. In addition, this helps in meeting the customer satisfaction. Therefore, the warehouse should be designed to achieve both the space utilisation and efficiency in handling. There are many activities in storing materials i.e. handling, keeping, moving, and replacement. There are four factors to be considered in storing materials.

3.2.4.1 Space Utilization

Materials must be stored as tall as possible and they must be of high density in order to minimise the storing space. Therefore, the methods in storing, packaging, and materials handling equipment should have high efficiency. Moreover, employees must be experienced and cooperative. However, a tall warehouse needs strong racks and a good warehouse structure. The materials handling equipment should be able to lift the goods up to tall racks safely.

3.2.4.2 Turn Over

All materials in the warehouse should be easily moved in/out to increase the turn over. The materials turn over depends on a warehouse plan. A good plan must consist of two parts; to support movement of the goods and to easily access to the goods. The high turn over materials should be located near to the receiving and shipping areas [Hall, 1993]. Fig. 3.1 shows the location with respect to the movement of materials.

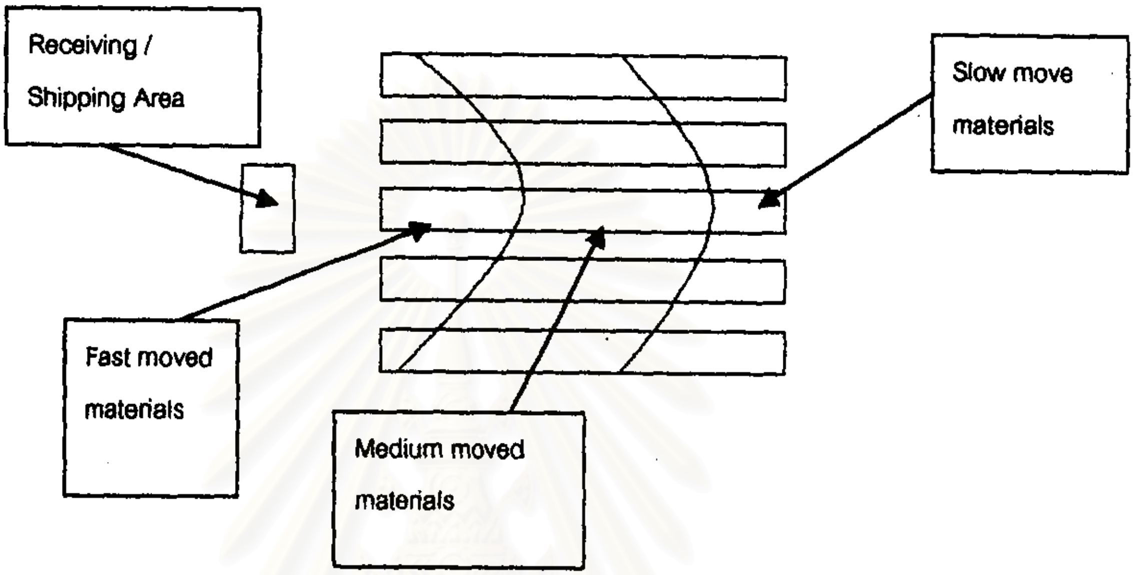

Fig. 3.1 : Location inside the warehouse with respect to the movement of materials.

The aisle must have enough space for the materials handling machine to pick/store items. The aisle should be as straight as possible.

The high turn over goods must be piled at the location where it is easy to pick/store. On the other hand, the low turn over goods must be stored in a secured structure to be kept in the warehouse for a long time.

3.2.4.3 Systematic

Same materials should be stored in the same place so that warehouse staffs can check, pick up, or store easily. In addition, the standard package or pallets should be used to increase the stability and accessibility. Each compartment must be fully filled before starting the new compartment. The goods must be picked from the same compartment until it is empty. After that, the other compartment is then emptied.

3.2.4.4 Type of Materials

Some materials must be in better care than normal materials e.g. high value materials, toxic substances, combustible or explosive materials, fragile materials, and easily deteriorated materials.

3.3 Routing

Routing problems are closely related to many factors. For example, each customer's location is different and different goods are ordered. The trucks cannot deliver all of the goods due to the insufficient capability to carry and time to deliver. All the routes must be the shortest. Clarke et al. proposed a methodology to find the suitable routing. There are numbers of routes if there are many locations to go to. They developed an iterative procedure to select the optimum or near-optimum route.

There are two solutions for the routing problems [Bodin et al., 1983].

1 Optimal Solution

2 Near Optimal Solution

The optimal solution requires a high performance computer to do the calculation. It takes a long time to achieve the optimal solution. Therefore, the near optimal solution is more widely used to solve the routing problems. Heuristic Algorithm is one of many techniques which provides a near optimal solution.

3.3.1 Classes In Heuristic Algorithm

There are three classes in heuristic algorithm [Bodin et al., 1983].

3.3.1.1 Tour Construction Procedures

In this process, an approximate tour from the warehouse to several customers must be decided. Information about the distance is recorded in the distance matrix. These matrices are of two types; symmetric and asymmetric.

Nearest Neighbour Heuristic [Cook et al., 1993]

This technique provides routing which is a near optimal solution. There are three steps involved in this technique. The Tour construction by Nearest Neighbour Heuristic is shown in Fig. 3.2.

1 Set the original point

2 Find new nearest point from the latest point in routing

3 Construct routing to that point

4 Repeat step 2 until returning to the original point

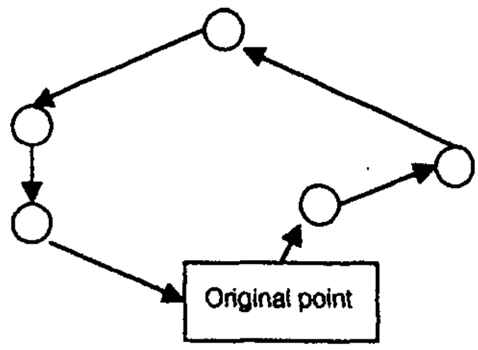

Fig. 3.2 : Tour construction by Nearest Neighbour Heuristic.

The Sweep Approach [Bodin et al., 1983]

This routing generation method relies on the capacity of the truck to generate the distance and number of customers in each tour. Firstly, the warehouse is specified and then given C equals the maximum capacity of the truck, and T is the maximum time per tour. The processes are as follows;

1. Specify the starting point.
2. Turn AB in the counterclockwise direction until the capacity is greater than C.
3. Finding the routing for each truck.
4. Calculate the time consuming. If the time is greater than T, turn AB in the clockwise direction until the time consuming is less than T.
5. Return to step 2 at the next point until return to the starting point.
6. Try to repeat the procedures in the opposite direction to construct another set of result.
7. Compare the results and choose the better one.

A sketch of this sweep approach is displayed below in Fig. 3.3.

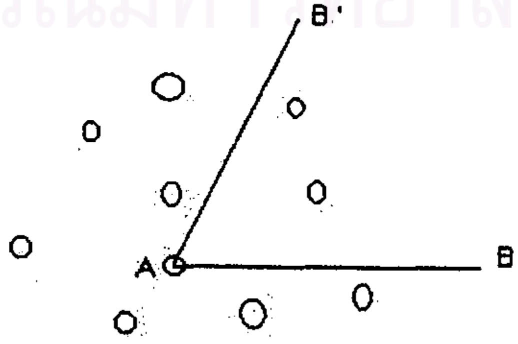

Fig. 3.3 : Sketch of the sweep approach in a tour construction.

3.3.1.2 Tour Improvement Procedures [Bodin et al., 1983]

This process is used to find a better tour using Branch Exchange Heuristics. There are several steps in these procedures as follows;

Step 1. Generate an initial tour by random.

Step 2. Improve the tour by Branch Exchange Heuristics.

Step 3. Return to step 2 until no further improvement.

3.3.1.3 Composite Procedures [Bodin et al., 1983]

This class of heuristic algorithm yields a good solution by following the three steps.

Step 1. Generate an initial tour from the tour construction procedures.

Step 2. Improve the initial tour by applying 2-opt procedure.

Step 3. Improve the tour in step 2 by applying 3-opt procedure.

3.4 Cost Model

In transportation, there are many ways to calculate the cost. The Rate-Distance model is another mean to calculate the cost. From this model, all of the cost of transportation cost (T) multiplied by distance (D) are summed up as in equation 3.1.

$$C = T_1D_1 + T_2D_2 + T_3D_3 + T_4D_4 + ... + T_nD_n = \sum_{i=1}^{n} T_iD_i \qquad \text{-----} \qquad \text{equation 3.1}$$

where T = cost of transportation in baht per distance (Baht/Km.),

D = distance,

C = total cost, and

i = 1,2,3,….,n

3.5 Literature Survey

3.5.1 Warehouse

Ratliff and Rosenthal (1983) presented the problem of order picking in a simple warehouse. The objective of their study was to minimize the picking time or the distance traveled by the vehicle. Their algorithm required only a small memory. As a result, this algorithm could be implemented on a personal computer. They first built an unlimited number of parallel arcs. Next, they found the shortest route in picking all the ordered items. The limitation of this algorithm is that the crossovers must be located at the either end of an aisle.

Elsayed and Stern (1983) developed the new algorithms in processing a set of orders in a warehouse. They grouped some orders that had the same criterion together. They then used the travelling salesman problem to determine an optimal travel distance. However, the result depends very much on the capacity of the vehicle.

Jarvis and Mcdowell (1991) presented a basis in locating a product in an order picking warehouse. The objective was to minimize an average order picking time. Therefore, all the related items should be located near to each other to assist the picker to collect all the items at a single place. They found that if the number of picking per order was constant, the number of items in a warehouse did not affect much in picking time. In addition, congestion might occur if an aisle had many high turnover items or the aisle was too narrow.

Kim (1993) studied the problem of clustering inventory items to assign the storage locations. He determined the storage locations and space requirements simultaneously. Kim also gave a numerical example. He suggested a heuristic algorithm that changed the location assignments of the items until the total cost could not reduced any further.

Hall (1993) concentrated on evaluating and comparing strategies for manual material handling routing in a rectangular warehouse. He has proposed three major strategies; the traversal strategy, the mid-point return strategy, and the largest gap return strategy. The equations related to total distance and the shape of warehouse were derived. These equations were based on normal distribution of order items. He also suggested that high turnover materials should be assigned to stock near the loading dock. Thus the traversal and the largest gap strategies were favoured.

Rosenwein (1994) focused on an application of cluster analysis to locate items in a warehouse. The important function in a warehouse is to pick items from the storage area to complete each order. This function has high cost. As a result, he presented a cluster analysis technique. This technique has combined the frequently ordered items together. Therefore, all the clustered items were located together. Hence, the picking tour became more efficient. Rosenwein also generated random items to compare with the clustered items. He found that the distance of his cluster analysis application, was 14% lower than that from the random items.

Rosenwein (1995) compared Order Batching Heuristic with Gibson and Sharp Heuristic. Rosenwein combined a group of orders as a batch. The picker then made a picking tour to collect all the items. He used traverses strategy in order to generate a picking tour. The result of traverse strategy is such that the pickers must exit an aisle at the opposite end. The travel distance of the Order Batching Heuristic is approximately 12% less than the distance of the Gibson and Sharp Heuristic. Furthermore, the number of aisles traversed is about 33% less than the other one. However, the processing time is sometimes twice of the Gibson and Sharp Heuristic.

Tungsub (1995) improved the utilization of the warehouse area and the storage system of stock in an air-conditioning factory. He adjusted the demand of storage area for each part in the stock. It was calculated from the demand frequency. The result was used to limit the suitable stock (on-hand quantities) for each part. He set the placement and used a shelf for each item to develop the utilization of the warehouse to be efficient. He planned the place to store each material.

Tompkins and Schaffer (1996) mentioned the developing of materials handling and its future. In the future, the materials handling systems will be reliable, totally integrated, flexible, upgradable, automatic, simpler to use, and maintainable. In the next millennium, the materials handling systems may be similar to today's but their technology is more advanced. They will also be faster but of lower cost.

Allred (1996) concentrated on the factory logistics and materials handling. He mentioned about an inefficiency caused by the factory logistics. For example, if the workstations do not receive any raw materials, the entire process stops. He advised the company to reengineer the logistics so that the waste will be eliminated. The company should change their strategy from 'make-to-inventory' to 'make-to-order'.

Thuy (1996) focused on an order picking in both planning level and operation level. This thesis is concerned with redesigning the layout, and selection of picking rules. He used systematic planning to find the solution. He then proposed four picking policies which are; single command, multi command and optimal bottom return, multi command and optimal traversal, and multi command and heuristic traversal. He measured each solution from the travel distance using Monte-Carlo simulation to evaluate picking policies. The single command picking policy should not be used in small ordered items and quantities warehouse.

Petrongreung (1996) concentrated on an improvement of warehousing operations in an air conditioning warehouse factory. The problem of this warehouse was that there were many processes of receiving, storing and picking up goods. Therefore, this thesis suggests an improvement of the utilization of warehouse to be systematic. He specified the place to store each model. In addition, the use of materials handling is improved by increasing the quantities of goods per pallet and grouping in a unit load. This technique provided an easy method in checking the quantity. He reduced the operating cost of this warehouse by 6.05%. Moreover, storing, receiving, and picking processes had higher accuracy.

Beiping (1997) studied a spare parts warehouse of EPSON in China. He tried to improve the performance of the existed operating system. He designed the warehouse to achieve less travel distance in a picking process. The dedicated storage policy for this warehouse was recommended. However, the shared storage policy was recommended if the supplier changed the replenishment pattern. He also developed a computer program to calculate the solutions.

Kieawsrikul (1998) studied the decision support system for a warehouse space management. He wrote a software called 'SpaceMan' to maximize the space utilization. He also used heuristic algorithms for the Two-dimensional packing problem to calculate the best performing system. The database was designed to improve the productivity and efficiency in a warehouse.

3.5.2 Transportation

Chetbundhit (1990) studied the problem in routing and scheduling of gasoline delivery trucks. This thesis involved three developed procedures; the shortest part construction and travel time estimation, matching, and truck scheduling. Dijkstra's algorithm was used to solve the shortest part problems and 0-1 linear programming and greedy approach are used to solve the matching of customers problems.

Klibbua (1990) considered the vehicle routing and warehouse designing. He used heuristic methodology to solve the vehicle routing. The case study warehouse was in Chiangmai. This warehouse had to distribute dairy products such as milk, ice-cream, yogurt, and UHT-milk to neighbouring provinces. He combined the customers in the upcountry into four groups that four trucks were used to deliver the short life products. He also planned an average demand growth rate in the next five years. The 2-opt heuristic to find the solution of routing was used. Moreover, he designed a new warehouse for the demand in the next five years.

Sripetchdamon (1993) focused on the use of Clarke-Wright Heuristic to choose the best way to ship products to customers. He later performed a vehicle routing model on a microcomputer. There was only one warehouse in his case and its goods were distributed to many customers by many trucks. He prepared the vehicle routing, and goods shipping.

Thanh (1997) studied the vehicle routing and scheduling problem. The matching is performed to maximise the travel distance. LINDO and SAS/OR packages are used to solve the problems and generate schedules. The 0-1 linear programming is used to solve the matching model. The result indicated that greater number of jobs could be combined so that the company can reduce the cost.

3.5.3 Related Books

Warman (1971) focused on the determination of the type of goods which should be stored in a warehouse and how they should be kept. The book also emphasized on the optimum method in operating a warehouse and the number of each good which should be kept. Moreover, it provided information about stock holding which is necessary. Nevertheless, it is a nonproductive activity in a business.

Chorafas (1974) mentioned an importance of inventory control. This book focused on the types of goods which should be kept and how to check an account of the inventory. This book also explained how to evaluate the performance and report the materials in a warehouse to the management team.

Fair and Williams (1981) discussed that logistics was not a new methodology because it concerned with movement of man and materials. This book wanted to emphasize the logistics in the total system design and development process. In addition, it suggested that logistics would help to consider the systems needed to accomplish the mission. There are 3 main parts in this book. First, this book explained some topics that is related to logistics such as cost effectiveness, system effectiveness, reliability, maintainability and statistic techniques. Then it advised how to apply these principles. Finally, it focused on integration of these principles.

Ballou (1992) showed the importance of logistics in a factory. Logistics was used to manage all or a part of the following; inventory, order processing, warehousing, materials handling, packaging and more. This book focused on the planning, organizing and controlling of these activities.

Waters (1992) mentioned about logistics, which consist of facility location, transportation, inventory control, warehousing and associated communications. An inventory control is a management function concerning the level of stock. On the other hand, warehousing is an operation function of the stock. Warehousing functions are as follows.

- Setting the warehouse objectives
- Warehouse design and layout
- Receiving goods
- Storing goods
- Shipping of materials
- Monitoring and control
- Managing warehouse personnel

Cook and Russell (1993) focused on the Operations esearch/Management Science (OR/MS). It contains the Nearest Neighbor Heuristic Methodology. This methodology was used to determine the route for a travel salesman problem. They also show transportation problems which was solved using the operation research method.

3.6 Summary of Literature

For the warehouse operations in the 70's, Warman focused on the general operation in a warehouse while Chorafas focused on the types of goods which should be stored in a warehouse. In 1991, Fair and Williams proposed an idea that logistics should be managed in the overall system. Ballou in 1992 presented the activities such as inventory, order processing, warehousing, materials handling, and packaging that should be managed by logistics. In addition, Allred also mentioned about an importance of logistics in 1996. To improve the efficiency in a warehouse, Thuy and Beiping redesigned the warehouse to reduce the travel distance. Furthermore, Petrongreung specified the storing locations and he introduced the use of pallets to increase the materials handling capacity. Jarvis and Mcdowell , Rosenwein (1994) and Kim developed a cluster technique to group items of the same ordering pattern together. Orders which had the same criteria were grouped to reduce the picking tour distance was suggested by Elsayed and Stern. This technique was also used by Rosenwien (1996). He combined a group of order into a batch. Hall proposed three major strategies for materials handling routing; the traversal strategy, the mid-point return strategy, and the largest gap return strategy. He suggested the use of the traversal and the largest gap strategies. However, Ratliff and Rosenthal presented the technique to determine the optimal route in picking item in a rectangular warehouse. Space utilization was improved by Tungsub in 1995 and Kieawsrikul in 1998 who wrote a software called 'SpaceMan' to maximise the space utilization.

For transportation operations, Clark and Wright introduced the technique to improve vehicle routing and scheduling as early as in 1964. This technique was used by Sripetchdamon in 1993 to generate the vehicle routing for delivery to many customers by various vehicles. Bodin et al. published a review paper in routing and scheduling techniques which were later applied by Klibbua. Klibbua applied the heuristic methodology to solve the vehicle routing. The Dijkstra's algorithm was selected to solve the shortest part problems by Chetbundhit. He also used 0-1 linear programming to solve the problem of customers matching. LINDO and SAS/OR packages were used to solve problems in vehicle routing and scheduling by Thanh. The Nearest Neighbor Heuristic methodology was used by Cook and Russell to determine the route for "Travel Salesman Problem" (TSP).