CHAPTER II

RELATED LITERATURE STUDY

2.1 Definition of warehousing

Tompkins (1988 a: 3-14) described the word 'warehousing' is used to denote both the physical processes of material handling and keeping, and the methodology underlying this process. It is the storage and retrieval of goods. The true value of warehousing lies in having the right product in the right place at the right time. Thus, warehousing provides the time-and-place utility necessary for the company's prospered.

Material handling in the production and distribution areas is a key element in current economic and industrial system, with its ever-changing requirement and technologies. The underlying factor of industrial success is efficient and economical movement of goods and materials. Warehouse management, inventory control and production control are major factors affecting profit. These can be enhanced by the proper warehousing methodology.

Warehousing methodology concerns the orderly execution of physical storage and retrieval activities and the processing of information needed about the good stored. The right methodology implies in itself the choice of efficient media, but basically it is information-oriented. It focuses on the correct evaluation, identification, classification and quantification of the goods to be stored and retrieved – and on the ways and means of handling information. Warehouse methodology must ensure that the company always has been available at the correct stock level the goods it needs; that the warehousing capacity is both economic and efficient; and that the goods are properly kept. Then, the functions performed by a warehouse are:

1. Receiving the goods from a source
2. Storing the good until they are required
3. Shipping the goods to the appropriate user

The fact is, however, that the functions performed in a finished good warehouse, receive-store-pick-ship, are identical to the function performed in a raw material storeroom. Consequently, both are warehouse. The only true distinctions between the two are the source from which the goods are received and the user to whom the goods are shipped. A raw material storeroom receives goods from an outside source, stores the goods, picks the goods, and ships the goods to an inside user. A finished goods warehouse receives goods from an inside source, stores the goods, picks the goods, and ships the goods to an outside user.

The differences among these various warehouses are restricted to the perspectives of the sources, management, and users of the warehouses. If the primary functions of an activity are receive-store-pick-ship, then the activity is a warehouse, regardless of its position in a company's logistics.

Normally, there are 3 types of stock in Warehouse:

1.Raw materials that have been purchased for use in the operation of the business

2.Semi-finished parts or partly processed raw materials waiting further processing.

3.Finished products that are in transit or awaiting distribution to customers in warehouses at the production site or at the some location a distance from it.

2.2 Objective of warehousing

Chorafas (1974 a: 3-18) described that the resources of a warehouse are space, equipment, and personnel. The cost of space not only includes the cost of building or leasing the space, but also the cost of maintaining the space. A company which is ineffectively using its available cubic space is incurring excessive operating costs.

The equipment resources of a warehouse include data processing equipment, dock equipment, unit load equipment, material handling equipment, and storage equipment, all of which combine to represent a sizable capital investment in the warehouse. To obtain an acceptable rate of return on this investment, the proper equipment must be selected and used properly.

Oftentimes, the personnel resource of the warehouse is the most neglected, even though its cost is usually the greatest. Approximately 50 percent of the costs of a typical warehouse are labor-related. Reducing the amount of labor and pursuing higher labor productivity, good labor relations, and worker satisfaction will significantly reduce warehouse operating costs.

Customer requirement are simply the demand to have the right product in good condition at the right place at the right time. Therefore, the product must be accessible and protected. If a warehouse cannot meet these requirements adequately, the warehouse does not add value to the product and, in fact, very likely subtracts value from the product.

Therefore, the following objectives must be met for a warehouse to be successful:

1. Maximize the effective use of space.
2. Maximize effective use of equipment.
3. Maximize effective use of labor.
4. Maximize accessibility of all items.
5. Maximize protection of all items.

For a warehouse to accomplish its objectives, we must consider the variable warehouse resources and mold them into an effective plan. A successful warehouse maximizes the effective use of the warehouse resources while satisfying customer requirements.

2.2.1 Major warehousing functions

Chorafas (1974 a: 12-25) described the six major elements constitute the throughput activities of the typical warehouse.

2.2.1.1 Transfer: *This includes the functions, mechanical or manual, from the reception of goods to their storage and from the retrieval of goods to their delivery at a point where the expedition process starts to their destination.*

The term ' Transfer devices' covers mechanisms for the loading, positioning and unloading of goods, as well as for their movement from one storage place to another. Mechanical transfer functions are performed by conveyors, lifts, trucks and cranes. In a warehouse, such devices contribute to the efficiency of the internal transport phase of materials handling. Mechanisation solutions must be cost-effective and not haphazard. Transfer activities are performed to and from the receiving/expediting area of the warehouse. Receiving/expediting is the interface of the warehouse with the factories, the market and the business environment in general.

2.2.1.2. Receiving: *In the receiving area, replenishment items arrive at the warehouse usually by rail or in trucks. The major functions performed in this area are the unloading of stock unpacking (unbundling), verification of the unloaded quantities against the shipping invoice, inspection of the received material for damage, and entering the receiving material into warehouse inventory.*

Receiving is one continuous process in every warehousing operation. How efficiently the job is done depends not only on the equipment of the warehouse and the training of the men performing this function, but also on the way the goods have been packaged and the bill of goods organized at the expediting point.

2.2.1.3. Storage*: Identifies the location where goods are deposited and held there for a certain period of time, until they are demanded for usage or expedition purposes. This is the main line of warehousing activities.*

The design of the storage area is a fairly complex task, since items of many different shapes and sizes are involved. Storage can be affected by the simple process of pilling up goods in boxes or pallets one on top of another or, better still through the provision of mechanized storage equipment, such as racks, and the organization of the proper identification system to aid in storage and retrieval.

Auto-storage is a modern, efficient solution to materials handling problems, including inventory management and accountability. Auto-storage represents a computer-run storage and distribution system with built-in flexibility. Its objectives are to meet changing industrial storage and retrieval requirement from raw materials to finished products and branch office sales warehouses.

2.2.1.4. Handling*: It concerns the operations directly related to the storage place and those linking one part of the storage system to another in the process of exploiting the warehouse facilities.*

Items in the warehouse which have the highest turnover should be located nearest the shipping area, thus minimizing the amount of time expended in retrieving orders. Slow moving items should definitely be kept in a unique location at a central warehouse. This is a good rule which, however, may not fit all storage systems in all situations. High-turnover items account for a large proportion of the related handling activities and the warehouse requirements for replenishment material.

The correct organization would want to minimize (a) the time required for handling high volume items; (b) the need to split stocks by locating the same item in more than one place; and (c) the risk of errors in storage and retrieval of goods. Such requirements seem to be obvious, but the solutions required in most warehouses are complex and call for a significant amount of management research. It has often proved to be true that a warehouse cannot minimize both storage and retrieval times simultaneously. In the last few years, considerable effort has been expended in developing algorithms for the purpose of optimizing the storage and retrieval times. This is one area of materials handling that promises substantially to increase the throughput capability of a warehouse in the years to come.

2.2.1.5 Expediting: *The activities involved in expediting fall into two breed categories:*

(a) Expediting, in a materials handling sense, from the warehouse to the business environment

(b) The preparation of all information documents connected with expediting.

At the expediting or shipping area, orders are received which demand item retrieval from the storage system. The handling element from storage to shopping has several functions associated with it:

The removal of the pallet (or box) from its storage location and its transfer to a depalletisation operation (unless full pallets are shipped)

The depalletisation proper (whether manual or automatic) removing the required number of items from the pallet and depositing them in the proper receiver.

The returning of the partially unloaded pallet to its proper location. The depalletised items or cases proceeds either directly to the expediting area for loading into trucks, or to an order consolidation section, where an entire order is accumulated prior to movement into the expediting (shipping) area. This is a transfer linkage, such as the one connecting the receiving area to main storage.

The functions of the shipping area include checking of quantities for each item against the shipping invoice as they are delivered from the storage system; inspecting the material to be shipped for possible damage that may have occurred *within the handling components of the warehouse; ensuring that no error in shipment occurs; and verifying that the order has been loaded into the trucks for shipment.*

2.2.1.6. Packing: *Packaging is an important element of the expediting functions. Although it is not directly connected to warehouse operations, in most warehouses it is found to be an integral part of the responsibilities assigned to warehousing.*

Literally, packaging is a way of containing merchandise that would otherwise break or spill. However, package is often used as a medium for explaining contents, application and preparation to the user. Quite often, a package is seen as a device for tempting a purchaser. However, such approaches to packaging are of no particular interest to a warehouse operation. Warehousing looks at packaging as a relatively economic away when the contents are deposited elsewhere or used up.

The importance of packing and unpacking operations in a warehouse will increase in the coming years, as the use of containers is eliminating pallet utilization outside warehouse transportation purposes. The warehouse must assume the responsibility of linking containerization, which helps improve the transportation linkages in terms of cost effectiveness, and palletisation, being necessary for internal storage purposes, in a mechanized warehouse.

2.3 Basic warehouse Activities.

Smith and Peters (1988: a 91-113) had described about the warehouse space and layout planning that in order to plan for the schedule in a warehouse, *it is necessary to identify and establish standards for the tasks to be performed and the amount of time each task should take. This includes each and every function. from receiving to shipping. As the activities grow in size, the standards of a department or activity may multiply and become more complex, but certain standards are basic in each of the warehouse activities.*

A warehouse has 10 basic activities that must be executed to move an item accurately and expeditiously from receiving to shipping, and all functions must be available on site at each warehouse. These activities are as follows:

1. Receiving

2. Inspection

3. Inventory control

4. Storage

5. Replenishment

6. Order-picking

7. Checking

8. Packing and marking

9. Staging and consolidating

10. Shipping

2.3.1 Receiving

The basic function of the receiver is to unload the incoming material: count the material: and record any overage, shortage, or damage on the receiving ticket and driver's copy of the freight bill. The receiver also records on a receiving form the name and address of the supplier, date, name of item received, part number, quantity received, purchase order shipped against, discrepancies in quantity, and/or notation of possible damage. Purchasing and Inventory Control receive documents of this receipt.

2.3.2 Inspection

The purpose of the inspection is to determine if the product meets the specifications and drawing requirements of the purchase order. Documents are prepared to notify Purchasing and Inventory Control as to the status of the material. Some businesses eliminate incoming warehouse inspection by having source inspection. However, a sample check of the inventory should still take place during order fulfillment to discover in-house damage. The degree of inspection is relative to the methods and frequency of handling in the warehouse.

2.3.3 Inventory Control

Materials are moved from the inspection area to one of two points: (1) the picking location (in the case of a picking outage) or (2) a storage location (i.e., a bin, shelf, or rack). To control the location and quantities of materials on hand, it is *important that the responsibility for routing materials to the proper locations be assigned. This is a clerical function.*

2.3.4 Storage

The physical act of moving materials from inspection and placing them in storage is generally a lift truck might be used for the horizontal move, then the product hand-transferred from the pallet to the storage shelf.

2.3.5 Replenishment

When warehouse management assigns a special area for picking stock, it is necessary to move cartons stock from general storage to the prime picking area. This is the replenishment function.

2.3.6 Order-picking

With an invoice or customer order ticket, the order picker goes about selecting the items in the quantity requested and unitizing them in a container, on a pallet, or at a station. The most critical part to this function is the document on which the order is written. The document must be legible copy: preferably a typed original, well-spaced, and of characters large enough to see under warehouse lighting conditions.

2.3.7 Checking

Each order should be checked for accuracy of items, quantity, and condition. If experience dictates, a sampling checking plan can be put into effect. The level of sampling is determined by the incidence of damage.

2.3.8 Packing and Marking

Less than full-carton quantities of product have to be packaged and packed for shipment. In some warehouse operations, split-case handling is avoided by shipping the next full case if the order for a broken case lot is 50% or more of a carton or by shipping short if the order for a broken case lot is less than 50% of a carton. This technique is generally practiced within the same firm, as when a central warehouse ships stock to a regional warehouse. The marking or labeling of a *container must contain the consignor, consignee, invoice number, purchase order, account number, quantity, and description. There are variations of this data, such as bar code labeling, industry marking practices, governmental marking requirements, and international zymology.*

2.3.9 Staging and Consolidation

This function is necessary for gathering together the various orders for a single customer. The orders may have entered the cycle at different times; or, if entered into the cycle as a group, may have been held up within the cycle for several legitimate reasons. Orders are also staged by carriers that service different regions of the distribution area that the warehouse serves.

2.3.10 Shipping

The actual loading of the carrier is generally accomplished by one of four methods or a combination thereof: hand-pallet truck; forklift truck; mobile containers.

With the 10 basic warehouse functions described, the next step in establishing standards is to determine the tasks performed within a given function. Some are performed with a degree of frequency during any given work period or shift. Other tasks are performed only a few times per day or week. When established work standards for a given function, the frequently performed tasks should have a time value assigned, express as an amount of time per unit or cycle, or a number of units per hour. The infrequently performed duties can be summarized as a total amount of time per day or week. Such non-routine tasks found in a warehouse could include:

1. *Obtaining supplies, such as carton tape*
2. *Totalizing receiving reports*
3. *Writing inspection summaries.*
4. *Replacing missing or damaged merchandise on order*

2.4 Warehouse operation system

Chorafas (1974 a: 37-52) had described about a basic systems model for an overall warehousing planning and control system. *The requirements of a warehouse operating system vary. What constitutes the optimum system depends on the special* *circumstances within each organization. Factors such as organization style, economic needs, and materials characteristics are also influenced by environmental considerations. The above and other factors are in a state of continuing change.*

A warehousing operating system must satisfy the operating objectives established by management, of which three are generally accepted for a typical marketing system.

1. Minimize the time required from sales order to its final execution: expediting to customer.

2. Utilize men effectively, as well as mechanism, storage capacity and time resources.

3.Provide warehousing management with the information needed to guarantee a timely, orderly and continuous flow of incoming and outgoing goods.

The decision regarding which functions are included in warehouse operations is an organizational one. There is a tendency to include functions within the warehousing management scope over and above that of just storekeeping. This is consistent with the total materials cycle concept.

From Pongpat Phetrungrueng (1996), there are 10 sequential steps involved in effective warehouse operation system. Not all are needed in every situation, but all of them should be considered. Warehouse operations include the following:

1.Receiving

2.Identifying and Sorting

3.Dispatching to Storage : Put away

4. Storage

5.Order picking

6.Packing

7.Staging

8.Loading and Shipping

9.Physical inventory

10. Reporting

2.4.1. Receiving System

Apple (1988: a 561-579) described that receiving can be defined as that activity concerned with the orderly receipt of all materials coming into the warehouse, the necessary activities to ensure that the disbursement of the materials to the organizational functions required them. *The primary objectives of a receiving system are:*

- *Safe and efficient unloading carriers*
- *Prompt and accurate processing of receipts*
- *Maintaining accurate records of activities*
- *Disbursing receipts to appropriate locations for subsequent use*

Accomplishing the objectives of a receiving system required concentration on an efficient procedure to complete each of the following basic functions:

1. *Analysis of documents for planning purpose.*
2. *Unloading carriers and clearing bills of lading or carrier responsibility*
3. *Unpacking goods as necessary*
4. *Identifying and sorting goods*
5. *Checking receipts against packing slips and other documentation*
6. *Marking records to call attention to unusual actions to be taken*
7. *Recording receipts on receiving slip or equivalent*
8. *Noting overages, shortages, and damaged goods*
9. *Disbursing goods received to appropriate location for subsequent use*
10. *Maintaining adequate and accurate records of all receiving activities*

2.4.1.1. Receiving system design principles

To provide effective designs for both the physical layout and equipment for receiving and the information control system, the following basic principles should be observed:

1. *Utilize carrier driver for unloading function.*
2. *Concentrate as many functions as possible at one work station*
3. *Balance carrier load at dock.*
4. *Arrange activities to permit straight-through flow.*
5. *Minimize or eliminate walking.*
6. *Schedule manpower for peaks to keep material moving.*
7. *Provide efficient flow for exceptions.*
8. *Consider returnable container staging.*
9. *Provide easy access to receiving data.*

10. Plan for small vehicles and small receipts.

11. Except when using the carrier's vehicle as an operating storage location, turn trucks around quickly.

12. Redistribute (cross docking) whenever possible to eliminate unnecessary materials handling and storage between receiving and shipping.

The collection of important data on the receiving operation is essential to a design that will meet the objectives most efficiently. In order to segregate the most important data required, several factors must be considered. The following list provides a starting point for factors to be considered in a receiving system design process.

A. Material received: Category, Characteristics, and Receipts.

B. Space: External, Internal

C. Building Characteristics

D. Space Layout

E. Equipment

F. Operations

2.4.2. Identifying and sorting system

The purpose of identifying and sorting is to quickly and easily identify and group a product, in order to identify the assigned warehouse keeping location. This ease of recognition reduces errors and time required for either stock selection of put-away.

Before the implementation of the product identification system, the information that appears on the tag or label must be selected. Typically this includes the following: storage position, quantity received, pick position, product description and weight of the product are needed.

Ackerman (1997: a 51-61) described that identifying method can be done in several ways

1.No identification method that relies on the suppliers markings on the exterior

2.Manual handwritten label method, where a receiving operators handwrites the product number on a self-adhesive label method that is placed onto the product exterior.

3. Machine-printed human- and machine-readable label method, in which a computer-controlled machine-printed label is place on the product exterior.

4. Machine-printed human- and machine-readable label method, in which alphanumeric characters and a bar code appear on the surface. The label is placed onto the product exterior.

2.4.3. Dispatching to storage: put away

The physical act of moving items from inspection and placing them in storage is generally a lift truck might be used for the horizontal move. The purpose of this operation is to move a product from receiving area to its storage area. Moving a product to its storage area could be done in both manpower and machine to handle it to the storage area but selection depends on product and width of aisle to storage area. The physical attributes of a product or stock-keeping-unit influence the selection of appropriate material handling method.

2.4.4. Storage

The physical act of hand-transferred the product from the pallet to the storage shelf. The purpose of storage system is to:

- Flexible in quantity for storage
- Maximize use of storage space
- Accessibility to all product being store
- Protection from damage
- Easy to count and check
- Ability to locate an item

Storage operation requires many support systems to achieve its objective. Following this are the systems that need to be considered in storage operation

2.4.4.1 Stock Locator system

The stock location system is the system that allows us to track product movement throughout the facility. The locator system that suit to each warehouse, depend on consideration such as space available, dimension of product, weight of items, storage methods, equipment and labor availability.

Mulcahy (1994: a 12.1-12.38) explained several types of locator systems and evaluate the strengths and weaknesses of each type.

(A) Memory systems

Basic Concept – Memory systems are solely dependent on human recall. Often they are little more than someone saying, " I think it's over there."

The foundations of this locator system are simplicity, relative freedom from paperwork or data entry, and maximum utilization of all available space. Memory systems depend directly on people and only work if several or all of the conditions in following this exist at the same time.

- *Storage locations are limited in number.*
- *Storage locations are limited in size.*
- *The variety of items stored in a location is limited.*
- *The size, shape, or unitization of items allows for easy visual identification work within the storage areas.*
- *Operators within the storage area do not have duties that require them to be away from those locations.*
- *The basic types of items making up the inventory do not radically change within short time periods.*
- *There is not a lot of stock movement.*

Impact on Physical space

Because no item has a dedicated location that would prevent other Stock-keeping-units from occupying that same stock location position if it were empty.

Advantage of Memory systems

- *Simple to understand*
- *Little or no ongoing paper-based or computer-based tracking required*
- *Full utilization of space*
- *No requirement for tying a particular stocking location. identifier, to a specific Stock-keeping-unit.*
- *Requirements of single item facilities can be met.*

Disadvantage of Memory systems

- *The organization's ability to function must strongly rely on the memory, health, availability, and attitude of a single individual.*
- *Significant and immediate decreases in accuracy result from changes in the warehouse conditions.*
- *Once an item is lost to call, it is lost to the system.*

(B) Fixed Location Systems

Basic Concept- In pure fixed location systems, every item has a home and nothing else can live there. Some fixed systems allow two or more items to be assigned to the same location, with only those items being stored there.

Impact on Physical space

If quantities of any given Stock-keeping-unit are large, then its "home" may consist of two or more storage positions. However, collectively all of these positions are the only places where this item may exist within the facility, and no other item may reside there. Basically, everything has a home and nothing else can live there.

Fixed location systems require large amounts of space. There are two reasons for this:

- *Honeycombing*
- *Planning around the largest quantity of an item that will be in the facility at one time.*

Honeycombing is the warehousing situation where there is storage space available but not being fully utilized due to product shape, product put away, location system rules and poor housekeeping.

Honeycombing is unavoidable given location system tradeoffs, product shape, and so on. The goal of a careful layout is to minimize how often and to what extent this happens.

Honeycombing occurs both horizontally (side-to-side) and vertically (up-and-down), robbing us of both square feet and cubic space.

There are two simple methods of determining the level of honeycombing within our own facility. One deals with a simple ratio analysis, the other with cubic space.

The other thing that causes the fixed system to require significant space is the necessity of planning around the largest quantity of an item that will be in the facility at one time. Each item will have an assigned location. Their storage location must be large enough to contain the total cubic space the item will fill-up at the time the largest quantity of that item will be in the facility at one time. Therefore, the total space required for all items in a fixed system will be the total cubic space of one hundred percent of all Stock-keeping-units as though the maximum quantity of each of them was in the facility at one time.

Advantage of Fixed location systems

- *Immediate knowledge of where all items are located. This system feature dramatically reduces confusion as to where " to put it, " "where to find it, " which increases efficiency and productivity, while reducing errors in both stocking and order fulfillment.*
- *Training time for new hires and temporary workers reduced.*
- *Simplifies and expedites both receiving and stock replenishment because predetermined put-away instructions can be generated.*
- *Allows for controlled routing of order fillers. It can assist an organization in fulfilling an order quickly.*
- *Allow product to be aligned sequentially*
- *Allow for strong control of individual lots, facilitating first in first out ("FIFO") control, if that is desired. Lot control can also be accomplished under a random location system. However simpler, more definitive control is possible using the dedicated location concept.*
- *Allows product to be positioned close to its ultimate point-of-use.*
- *Allows product to be placed in a location most suitable to an item's size, weight, toxic nature, flammability, or other similar characteristics.*

Disadvantage of Fixed location systems

- *Contributes to honeycombing within storage areas.*
- *Space planning must allow for the total cubic volume of all products likely to be in a facility within a defined period of time.*

- *Dedicated systems are somewhat inflexible. If you have aligned product by sequential numbering and then add a subpart or delete a numbered item, then you must move all products to allow for add-in or collapse out location to fill-in the gap.*

Basically, fixed or dedicated location system allow for strong control over items without the need to constantly update location records. That control must be counterbalanced by the amount of physical space required by this system.

(C) Zoning Systems

Basic Concept – Zoning is centered on an item's characteristics. Like a fixed system, only items with certain characteristics can live in a particular area. Items with different attributes can't live there.

An item's characteristics would cause the item to be placed within a certain area of the stockroom or at a particular level within a section of shelving or rack section. For example, irregular shaped items might be placed in lower levels to ease handling, or all items requiring the use of a forklift for put away or retrieval might be located in a specific area and on pallets.

Impact on Physical Space

As with fixed location system, the more it is tightly controlled where a particular item will be stored, the more it is contributed to honeycombing or to the need to plan around maximum quantities.

Advantage of Zoning systems

- *Allow for the isolation of items according to such characteristics as size, variety, flammability, toxicity, weight, lot control, private labeling, and so on.*
- *Allows for flexibility moving items from one zone to another quickly or in creating different zones efficiently.*
- *Allows for the additions of items within a zone without having to move significant amount of product to create room within an assigned location or within a sequentially numbered group of items. It also does not require the collapsing of space if an item is deleted.*

- *Allows for flexibility in planning: Although items are assigned to a general zone, because they do not have a specific position they must reside in, there is no need to plan around one hundred percent of any given item's cubic requirements.*

Disadvantage of Zoning systems

- *Zoning is not always required for efficient product handling. You may be adding needless administrative complexity by utilizing zoning.*
- *Zoning may contribute to honeycombing.*
- *Zoning requires updating of stock movement information.*

Basically zoning allows for control of item placement based on whatever characteristics the stock-keeper feels are important.

(D)Random Location systems

Basic Concept- In a random system nothing has a home, but it knows where everything is. Pure random location systems allow for the maximization of space since no item has a fixed home and may be placed wherever there is space. This allows items to be placed above or in front of one another and for multiple items to occupy a single bin/slot/position/rack. The primary characteristic of a random locator system that makes it different from a memory system is that each item identifier is tied to whatever location address it is in while it is there. In other words, memory systems tie nothing together, except in the mind of the stock-keeper. Random systems have the flexibility of a memory system coupled with the control of a fixed or zone system. Essentially an item can be placed anywhere so long as its location is accurately noted in a computer database or a manually maintained paper-based card file system. When the item moves, it is deleted from that location. Therefore, an item's address id the location it is in while it is there.

Impact on Physical Space

Because items may be placed wherever there is space for them, random locator systems provide us with the best use of space and maximum flexibility while still allowing control over where an item can be found.

Planning space around a random locator system is generally based on the cubic system space required for the average numbers of items on-hand at any one *time. Therefore, in planning space requirements around a random locator system, it needs to discern from inventory records what average inventory levels are and what products are generally present within that average. By multiplying the cubic footage of each of those items by the quantity of each usually on hand, a space required can be determined.*

Advantage of Random Location systems

- *Maximization of space*
- *Control of where all items are at any given time.*

Disadvantage of Random Location systems

- *Constant updating of information is necessary to track where each item is at any given time. Updating must be accomplished through manual paper-based recording, bar code scanning, or data entry intensive updating.*
- *May be unnecessarily complicated if organization has a small number of items.*

Basically, random location systems force a tradeoff between maximization of administration.

(E) Combination Systems

Basic Concept – Combination systems enable us to assign specific locations to those items requiring special consideration, while the bulk of the product mix will be randomly located. Very few systems are purely fixed or purely random.

Conceptually the best features of the fixed and random systems can be combined at the same time. It can be achieved by assigning only selected items to fixed home but not all items. Therefore, it needs to plan around the maximum space required by the selected items instead of that required by all items. For the items not in fixed homes, it can be planned around the average quantities on a daily, ongoing basis. So, the fixed system is used for the selected items and the random system for everything else.

A common application of the combination system approach is where certain items are an organization's primary product or raw materials line and must be placed as close as possible to a packing/shipping area. Those items are assigned a *fixed position, while the remainder of the product line is randomly positioned elsewhere.*

2.4.4.2 Item placement system

Stock location systems provide a broad overview of where items will be found within a facility. Item placement system is the system that manages where a particular item should be physically positioned. Most approaches fall into one of three concepts: inventory stratification, family grouping, and special considerations. Mulcahy (1994: a 12.50-12.55) explained the item placement system as following this:

*(A) **Inventory Stratification:** Inventory Stratification consists of two parts:*

A-B-C categorization of Stock-keeping-units: This item placement approach is based on "Pareto's Law". The concept stands for the proposition that within any given population of things, approximately 20 percent of them 80 percent of the "value" of all of the items concentrated within them, and that the other 80 percent only have 20 percent of the value concentrated within them. If the criterion is usage rate, then 20 percent of all items represent the 80 percent of the items most often used/sold.

Accordingly, for efficient physical inventory control, using popularity (speed of movement into and through the facility) as the criterion, the most productive overall location for an item is a storage position closet to that item's point-of-use. Items are separated into A-B-C categories, with "A" representing the most popular, fastest moving items, "B" representing the next most active, and "C" the show-movers.

In order to separate an inventory into A-B-C categories, it is necessary to create a sorted matrix that presents all items in descending order of importance and allows for the calculation of those items representing the greatest concentration of value.

Utilizing a Stock-keeping-unit's unloading/loading ratio: Even more efficiency in physical inventory control can be achieved through placing items within the A-B-C zones according to that item's unloading to loading ratio. The unloading/loading ratio reflects the number of trip necessary to bring an item to a *storage location compared with the number of trips required to transport it from a storage point to a point-of-use. If one trip was required to bring in and store a case of product. but 10 trips were required to actually take it content to a point-of-use, the unloading/loading ratio would be 1 to 10 (1:10). Substantial reductions in handling times can be achieved through application of this principle. The closer the unloading/loading ratio is to 1:1, the less it matters where an item is stored within an A-B-C zone because the travel time is the same on either side of the storage location. The more critical it is to place an item closer to its point-of-use.*

(B) Family Grouping: *An alternative to the A-B-C approach is the family grouping/like product approach. This approach to item placement positions items with similar characteristics together. Theoretically, similar characteristics will lead to a natural grouping of items, which will be received/stored/picked/shipped together.*

Grouping can be based on:

- *Like characteristics*
- *Items that are regularly sold together-parts needed to tune-up a car.*
- *Items that are regularly used together.*

Advantage of Family Grouping

- *Ease of storage and retrieval using similar techniques and equipment.*
- *Ease of recognition of product groupings.*
- *Ease of using zoning location systems.*

Disadvantage of Family Grouping

- *Some items are so similar they become substituted one for the other such as electronics parts.*
- *Danger of properly positioning an active item close to its point-of-use but consuming valuable space close to that area by housing far less active "family member" items with their popular relative.*
- *Danger of housing an active product with its inactive relatives far from the popular item's point-of-use, all for the sake of keeping like items together.*

▪ *An item can be used in more than one family.*

Effective item placement can often be achieved through tying both the inventory stratification and family grouping approaches together. The end result is a more efficient overall layout.

A product's characteristics may force warehouse to receive/store/pick/ship it in a particular manner. The product may be extremely heavy or light, toxic or flammable, frozen, odd in shape, and so on. Even with items requiring special handling or storage such as frozen food stored in a freezer, the inventory stratification and family grouping concept can and should be employed to ensure efficient inventory layout.

2.4.4.3 Location addresses and item identifiers system

This system is very important because it is not possible to control what it can't be found. Apple (1988 a: 561-579) described that in order to keep track of where items are at any given time, it is necessary to:

(A) Clearly mark items with an items identifier. Clearly mark items with a unit of measure such as pack size. *The item identifier is generally an organization's internal identifying code for the item rather than a manufacturer's or customer's number for that items. Although the item number itself is often adequate for identification purposes, in manufacturing it may be necessary to also include lot and serial numbers to aid in quality control. Lot and serial numbers make it possible to track manufacturing batch, date, location, and inspector. Markings related to unit of measure (such as each/pair/dozen/barrel/ounce/pound/cylinder/ barrel/case)*

(B) Clearly mark location addresses on bins/slots/shelves/racks/floor locations/drawers/and so on. *The addressing or location system that is selected should have an underlying logic that is easy to understand. Addresses should be as short as possible, yet they should convey all needed information.*

The first consideration is whether the system will be all numeric, all alphabetic (alpha), or alpha-numeric. In deciding which system to adopt, consider the following:

▪ ***All numeric systems require sufficient*** *digit positions to allow for future growth. Because each numeric position only allows for 10 variations(0-9),* *numeric systems sometimes become too lengthy. In other words, since a single a single numeric position only allows for 10 variations, if it required 100 different variations, you would need 2 digit positions, representing 00 through 99 (10x10). One thousand variations would require three numeric positions, 000 through 999, and so on.*

- *Systems that is completely alphabetic for 26 variations per position, A through Z (assuming only capital letters). Two alphas together, AA through ZZ (26x26), allow for 676 variations. Three alphas, AAA through ZZZ, allow for 17,576 variations. Although alphas provide numerous variations in a short address, systems that are completely alphabetic are visually confusing.*
- *Alpha-numeric systems often provide for visual differentiation while allowing sufficient variations in a short address.*
- *While alpha systems require fewer characters to hold the same number of variations, they are more error prone.*

(C) Tie item numbers and location addresses together either in a manual card file system or within a computerized database: *The placement of identifiers on both product and physical locations creates an infrastructure by which product and it move can be tracked. The next step is bonding together an item number and the location(s) where that item is located. This can be easily accomplished by using a simple card file system.*

(D) Update product moves: *A final step in managing inventory is tracking it as it is added to, deleted, or moved. This challenge exists for any organization whether or not the company uses manual tracking, computerized approaches, or bar coding.*

The best generally available approach for real-time tracking of items as they move is using bar coding mobile scanners with radio frequency capability. If radio frequency bar coding is not available, then updating can be accomplished as follows:

- *Portable bar code scanners that capture the information within the scanner mechanism or on a disk in the scanner. The information is then uploaded* *into the computerized database either through the communications ports on the scanner and computer, or by loading the scanner disk into the computer.*

- *Manually captured, paper-based information is entered into the database through keying by human.*
- *Manually captured, paper-based information is manually written onto file cards.*

No matter what method is used, it is imperative that information relative to inventory additions, deletions, or movement be inputted into the system as soon as possible. To the greatest extent possible, the shelf count should match the record count. The longer the time lag between inventory movement and information capture and updating of the record count, the greater the chance for the error, lost product, and increased costs.

2.4.5. Order picking

Huffman (1988: a 595-617) described that the accurate order-picking is typically the most important warehouse operating responsibility. In many warehouses, order-picking is the largest single expense category in the operations. *Good order-picking demands high levels of management in planning, the order-picking system consists of picking locations where the item is available for selection in the quantity called for on the picking document. The picking location depends on the system, but they must always provide the necessary picking identification and be physically conductive to low fatigue and error-free picking. In other words, put the most popular items between waist and eye level.*

Order-picking is rarely done by only one method. Variances in packages size and configuration, picking quantities, stocking quantities, and inventory requirements often necessitate more than one system. Most order-picking operations are hybrids of three order-picking methods, listed here in order of system complexity:

1. Unit-load picking is done when a pallet load of product is pulled from stock. An example of unit-load picking is a major appliance warehouse.

2. Case-lot picking is the selection of full cases of a product. However, the order is less than a full-pallet unit-load. Case-lot picking is best done by staging a unit load in a pick line and pulling case quantities until the unit load is depleted.

3.Broken-case picking is done when less than full cases are called for by the customer's order. This kind of picking may be done from shelving or flow rack, depending on the size and volume of orders.

An order-picking system consists of:

1.A physical subsystem comprised of order-picking personnel or mechanical picking equipment and the related material handling equipment required to pick, check, pack and ship an order.

2. Data processing subsystems that provide the information required to operate the physical system

In many warehouses, there are additional data processing subsystems that assist warehouse supervision to plan and control operations.

2.4.5.1 Physical Subsystems

Warehouses in which the picking operation is performed by an order, filler are called "manual warehouses". Picking personnel walk or ride a vehicle; picking instructions are provided to them by documents or visual displays.

Mechanical systems release merchandise from each picking position in the quantity and at the times specified by a computer executing stored picking instructions. The balance of the order-picking system, in either case, consists of the workstations, methods and procedures, and material and information handling equipment required to check, pack, and ship an order.

2.4.5.2 Data Processing Subsystems

(A)The primary data processing subsystem

The primary data processing subsystem processes orders against the customer and item files. Its outputs are:

1. *Instructions to order fillers or mechanical order-filling equipment, checkers, packers, and shipping dock personnel.*
2. *Information to the customer about items ordered, but not picked, or partially picked.*
3. *Information for invoicing*
4. *Cost and/ or selling price information to the customer, when necessary*

5. *A separate packing list, when necessary*
6. *Shipping labels, when necessary*

Since order processing updates item inventories, it also provides information for purchasing and inventory control.

(B)Picking Position Replenishment subsystems

When orders are picked mechanically or picking positions are confined to flow rack, shelving, or pallet-rack positions reachable by a walking picker, the order-picking system includes an informal or formal subsystem for replenishing picking position inventories from reserve stock. The output of a formal replenishment subsystem is usually one or more picking documents, but may include displays; it may also include random picking position assignments.

(C) Operations Planning and Control subsystems

The information required to prepare the outputs of the primary data processing subsystem can be used by other data processing subsystems which:

1. *Determine the mode of shipment: common carrier or captive truck*
2. *Plan deliveries by captive trucks*
3. *Estimate picking, packing, checking, shipping, and replenishment staffing requirements by shift*
4. *Prepare a daily, short-interval schedule for these operations and estimate the staffing required by each one during each schedule period*

The outputs of these subsystems are documents not required to pick orders; the subsystems are usually interactive.

2.4.5.1 Order-picking system design

The design of an order-picking system depends primarily upon the manner in which order integrity is treated during picking and subsequent operations. Order integrity may be:

1. Maintained during the picking, checking, packing, and staging of an order for shipment

2. Destroyed during picking, but restored during order assembly on the shipping dock

When order integrity is maintained, there is one order-picking system. It usually consists of mobile equipment, such as picking cart, and a location-sequenced picking list. As the order is picked, it is assembled for packing, checking, and shipping. The computer maintains one inventory and one picking position per item. It frequently does not distinguish between repack and full-case picks of the same item.

When order integrity is destroyed and restored, the warehouse layout includes several order-picking systems that occupy separate areas. An order is picked simultaneously in each area by the order fillers assigned to it. Typically, one group of order fillers picks repack with a picking list, another picks conveyable cases with labels, and a third uses mobile equipment and labels to pick non-conveyable merchandise. Mechanical order-filling equipment may replace the repack picker, the conveyable cases to the shipping dock, where they are sorted and merged with any non-conveyable to order integrity.

When order integrity is destroyed and restored, the computer distinguishes broken-case picks from full-case picks of the same item. It maintains separate picking positions and picking inventories and provides different documents for picking from them. The physical and data processing subsystems and the operating methods and procedures of the order-picking system must be designed simultaneously to provide the desired warehouse throughput and level of customer service.

2.4.5.2 Four methods of order-picking

The job of selecting orders can be divided into at least four categories: single-order-picking, batch picking, zone picking, and wave picking.

Single-order-picking is the most common mean of selecting an order. One order picker takes a single order and fills it from start to finish.

In batch picking, the order picker takes a group of orders, perhaps a dozen. A batch list is prepared that contains the total quantity of each stock-keeping unit found in the whole group. The order picker then collects the batch and takes it to a staging area where it is separated into single orders.

Zone picking is the assignment of each order selector to a given zone of the warehouse. Under a zone picking plan, one order picker select all parts of the order that are found, for example, in aisle 12, and the order is then passed to another picker who select all of the item in aisle 13. Under this system, the order is always handled by more than one individual.

Wave picking is the division of shipments by a given characteristic, such as common carrier.

2.4.5.3 Quality in order-picking

Quality means performance to standards and nothing more. Warehouse management must design, implement, and then insist upon standards of order-picking that are error-free. Any order-picking error could be a customer lost, never to be regained.

2.4.5.4 Order-picking forms

A good order-picking form is one that has only essential information on it, that is, customer identification, order number or date, location of items to be picked.

The use of color coding in the order-picking operation will reduce errors. Color coding should be used in any operation where it can be applied.

To reduce errors, be sure that the same terminology is used for the same items throughout the system in the warehouse.

2.4.6. Packing

The purpose of packing operation is to protect and contain product by package while it is delivered. The suit package to the product should provide protection against the common hazards of warehousing and distribution. These include stacking compression; shock and vibration in transit and handling; and protection against temperature extremes and changes, moisture, and infestion.

Sometime packing operation is required because some products have the same destination and if they are packed at the same container or package, it will be easier and cheaper for shipping operation.

There are several ways to pack item but the popular methods are using container and using box or carton to contain the product while they are shipped to destination. But beware of using the wrong size and strength of the package can cause damages to the products.

2.4.7 Stacking

One of the critical activities in the receiving and shipping area is the inbound-outbound product stacking activity. To have productive employees with minimal product damage and accurate inventory control, space of stacking area must be sufficient directly behind the dock doors to accommodate the inbound and outbound capacity for a full delivery truck. The stacking area requires vehicular traffic aisles that connect the dock area to the storage area.

2.4.8. Loading and shipping

Footik (1988: a 638-647) described that the ideal shipping routine is roughly the opposite of that just described for receiving. If an order destined for shipping is pulled from inventory by one employee and checked and loaded by another, the likelihood of discovering errors is greatly increased. Insisting on a shipping schedule will do a great deal to prevent unexpected peaks in workload or unpleasant surprises. A specified count of shipping labels or tags is a good way to create a double check of quantities in shipping. The shipping dock is also the last chance to discover mistakes made by order pickers.

The first step is the determination of the common carriers or private carriage means by which goods will be shipped. There is a vast menu of available shipping methods. From this vast menu, a selection must be made based on the physical characteristics of the products, the quantities to be shipped, the quatity of service desired and, of course, the costs. An examination of service must include such factors as the speed of delivery, scheduling flexibility, consistency of service, reliability, and cooperation,

After the shipping method has been selected, the next area to look at is how these products will be loaded. In part this will be dictates by quantity, physical characteristics, and distance the product will be moved. Materials that are delivered from one side of town to the other, every single day, and always between point A and point B should be palletized, unitized, or on some type of transfer vehicle. One-way shipments for long distances, however, may require an entirely different method of vehicle loading. Therefore, these determinations are made on a case-by-case basis with a large measure of common sense.

2.4.9 Physical inventory

The purpose of this operation is to count the real quantity of stock-keeping-units and compare it to the number in the report. The other benefit of this operation is to check the quality of stock-keeping-units then, both quantity and quality of stock-keeping-units in storage area are supposed to be checked at this operation.

There are 2 methods to operate physical inventory:

1.Periodic Physical Inventory. Usually, this method has been done once a year and its main purpose is to check quantity of stock-keeping-units. To do this operation, most of other functions in warehouse should be stopped until it is finished. Many errors in warehouse operation that have been overlooked for a whole year will be unveiled by this operation. It means that it is difficult to identify the causes of these errors.

2.Cycle counting. This method can overcome disadvantages of periodic physical inventory. It needs operators who have to do this operation regularly as their routine job. It can find errors immediately so it is easy to track back to the root cause of the errors.

2.4.10 Reporting

The last activity of storage function is a paper work or record keeping of all activities in warehouse. In the modern day, most warehouses operate this activity through computer system and warehouse software.

2.5 Warehouse space and layout planning

Smith and Peters (1994: a 91-113) described that space is a primary, finite resource common to all warehouses. *The amount of space available, the physical nature of the space, and the arrangement, or layout, of the space is critical to the operating efficiency and effectiveness of the warehouse. Consequently, proper planning of warehouse space and layout requirements is needed to ensure that all the objectives of the warehouse are adequately met. This chapter addresses proper space planning and layout planning for the warehouse.*

2.5.1 Warehouse space planning

Space planning is the part of the science of warehousing concerned with making a quantitative assessment of warehouse space requirements. As is true of any science, space planning possesses a very specific methodology, and it consists of the following general steps:

1. *Determine what is to be accomplished.*
2. *Determine how to accomplish it.*
3. *Determine space allowances for each element required to accomplish the activity.*
4. *Calculate the total space requirements.*

The first two steps of the space planning process define the activity and the techniques, equipment, information, and so on, to be used in performing that activity. Step three involves determining the space requirements of each element that goes into performing the activity. In warehousing, these elements might include personnel and personnel services, and utilities. Finally, step four combines the space requirements of the individual elements to obtain total space requirements.

Two major activities in a warehouse require space planning: receiving and shipping activities. The following sections of this chapter transform the general space planning methodology outlined above into very specific methodologies for the receiving and shipping activities, and for the storage activities.

2.5.1.2 Space planning for receiving and shipping

The most important functions of a warehouse occur on the receiving and shipping docks. Unfortunately, these are also the most neglected areas of a warehouse. The transfer of control of merchandise from the source or carrier of the merchandise to the warehouse usually takes place on the receiving dock. On the shipping dock, the transfer of control of merchandise from the warehouse to the user or carrier of the merchandise usually takes place. If these transfers of control are not accomplished efficiently, safe, and accurate receiving and shipping activities is enough space in which to perform them. The following methodology should be followed to determine the space requirements of receiving and shipping activities.

(A) Define the materials received and shipped: *The first step in space planning for receiving and shipping operations is to define what is to be accomplished, that is to define the materials to be received or shipped. An excellent tool for this is the receiving and shipping analysis chart ((RSAC). A completed RSAC appears in **figure 2.1.** The first five columns of the RSAC define what is to be received or shipped and column 7 shows when the receipts and shipments will occur. For an existing warehouse, the information for the first seven columns of the RSAC can be obtained by reading old receiving reports or shipping release to determine what has actually been received or shipped in the past. This historical data can be tempered, based on projections of future business activity. For a new facility, historical data is not available; consequently, base the information requirements of the first seven columns of the RSAC on forecasts of the types and volumes of materials that will be received or shipped.*

It is seldom practical to have a separate entry on the RSAC for each individual stock-keeping unit, and, in fact, it is usually undesirable to do so. It is impractical because most warehouses store thousands of different stock-keeping units and completing the RSAC for each would be an extremely time-consuming job. It is undesirable because the forecasts from which the information is obtained are inevitably wrong. Consequently, planning a warehouse based on specific item requirements will result in an inaccurate warehouse plan.

A much better strategy for completing the RSAC is to establish generic categories of items and then to complete the RSAC for each generic category. The items in a given generic category should have similar characteristics with respect to type of item and unit load received, stored, or shipped. Developing generic categories reduces the number of entries on the RSAC to a manageable level. Another advantage is that fluctuations in requirements for individual stock-keeping units will have less impact because they will affect a generic category, not just one unit.

Column 8 and 9 of the RSAC list the types of carriers that might handle each generic category of material. The important characteristics include the length, width, height of the carrier bed off the road-way, and the clearance height of the top of the carrier. This information can be readily obtained for an existing warehouse contacting the freight carriers used in the past or, for a new warehouse, by contacting the carriers projected for use in the future. The freight carriers should *be able to predict the types and characteristics of carriers that will be used over the next 5 to 10 years, for the types and quantities of materials that will be warehoused.*

The last two columns of the RSAC deal with the methods and time required to unload the carrier on the receiving dock or to load the carrier on the shipping dock. This information will prove valuable in determining labor and material handling equipment requirements to perform the receiving and shipping activities.

***(B) Determine dock requirements**: After the materials to be received or shipped have been defined, the next step is to determine the requirements for the receiving or shipping dock bays. Two questions must be addressed: (1) How many dock bays are required? And (2) How should the dock bays be configured.?*

The number if dock bays required is a function of the time intervals between carrier arrivals at the dock and the time required to service the carriers upon arrival, and simulation is the proper tool for determining this requirement. (Refer to Chapter 9 for more information on the use of simulation in the warehouse.)

Two basic dock configurations exist: 90^O docks and finger docks. With a 90^O docks, the truck is positioned at the dock so that the angle between the truck and the dock is 90^O. At a finger dock, the angle between the truck and the dock less than 90^O. For example, for a 45^O finger docks, the angle between the truck and the dock is 45^O. The difference between 90^O docks and finger docks lie in the amount of space required for dock operations inside and outside the warehouse. A 90^O docks requires less width (the distance parallel to the building) than a finger dock. Therefore, a 90^O docks requires less inside warehouse space and more outside space than does a finger dock. The amount of inside space required by finger dock decreases as the angle of the finger dock increases, but it is always greater than the space required by a 90^O docks. As the angle of the finger dock increases, the outside space required also increases, but it always less than the space required by a 90^O docks.

Company A.R.C., Inc.	Date March 8,1986						Raw Materials _____		In-Process Goods	Finished Goods
Prepared by J. Smith	Sheet 1 of 1						Plant Supplies _____		_____	_____

Description (1)	Unit Loads				Size of shipment (Unit Loads) (6)	Frequency of Shipment (7)	Transportation		Material Handling	
	Type (2)	Capacity (3)	Size (4)	Weight (5)			Mode (8)	Specs (9)	Method (10)	Time, hr (11)
Steel pipe plug, 1.00 in diameter x 0.50 in.	Wooden crate	3200 pcs.	2 ft x 2 ft x 4 ft	825 lb	12 crates	Quarterly	Truck	34 ft x 8 ft x 7 ft	Food truck	0.75
Aluminium bar 2.75 in, x 250 in x 16 ft	Bundles	25 bars	12.5 in x 14 in x 6 ft	1625 lb	25 bundles	Quarterly	Open-bed truck	34 ft x 8 ft	Crane	5.00
Stainless Steel bar 0.875 in, x 12 ft	Bundles	36 bars	6 in x 6 in x 12 ft	900 lb	7 bundles	Semiannual	Open-bed truck	34 ft x 8 ft	Crane	1.00
Rubber O ring 0.75 in diameter	Cartons	40,000 O rings	12 in x 18 in x 3 ft	125 lb	2 cartons	Semiannual	Truck	20 ft x 8 ft x 7 ft	Hand truck	0.25
Brass bar, 0.75 in diameter x 12 ft	Bundles	36 bars	6 in x 6 in x 12 ft	720 lb	14 bundles	Semiannual	Open-bed truck	34 ft x 8 ft	Crane	2.00

Figure 2.1-Receiving and shipping analysis chart

Typically, space inside a warehouse is more expensive than space outside a warehouse; 90^{O} docks are more popular than finger docks because they require less inside space. When outside space is at a premium, however, because of the shape of the warehouse site or need to expand, finger docks are a much more attractive dock configuration.

(C)Determine maneuvering allowances inside the warehouse: *The maneuvering space required on a receiving or shipping dock consists of the space needed to enter and exit the carrier and to travel between the carrier and the buffer area, into which incoming material is deposited, or the staging area, from which outgoing material is retrieved. The first component of the receiving or shipping dock* *maneuvering space is the area occupied by the dock leveling device used. Generally, temporary inside dock leveling devices will occupy 3 to 7 feet, measured from the dock face, while permanent inside dock leveling devices will require 4 to 10 feet of inside warehouse space. Other types of dock leveling devices are installed outside the warehouse or on the truck itself and require no inside warehouse space allowances.*

The second component of the receiving or shipping dock maneuvering space is an aisle located between the back edge of the inside dock leveling device and the receiving buffer area or shipping staging area. This aisle allows unloading/loading personnel and equipment to enter and exit the carrier and to travel to the appropriate buffer or staging area. The dock maneuvering aisle should not be a main warehouse aisle; travel in this aisle should be restricted to dock personnel and equipment actively servicing carriers. The existence of other traffic within the dock maneuvering aisle will inevitably result in injuries to both dock personnel and the other traffic. The required width of the dock maneuvering aisle depends on the type of material handling equipment used to service the carriers. Generally, 6 to 8 feet are recommended for manual handling and non-powered material handling equipment, whereas 8 to 12 feet are sufficient for powered material handling equipment.

***(D) Determine buffer and staging area requirements:** A buffer area for a shipping dock should be located behind the dock maneuvering aisle. The receiving buffer area serves as a depository for the materials unloaded from the carriers. The receiving buffer area allows the dock personnel to concentrate on unloading the carrier for fast receiving "throughput". Fast receiving throughput is essential for companies with large investments in their own trucking fleets. For companies without their own trucking fleets, it avoids demurrage, or detention, charges. Once their carrier is unloaded and released, a more through check-in and inspection of the merchandise can be performed within the receiving buffer area.*

The shipping staging area serves as an accumulation point for the merchandise that comprises a shipment. Various levels of accumulation may be established within the shipping buffer area. For example, individual line items that make up a customer order, the customer orders that comprise a shipment, or the shipments for a particular region can be accumulated. Activities performed within the *staging area might include packing. Unitizing, or verifying that the entire customer order or shipment is ready for loading onto the carrier.*

Specifying accurately the optimum amount of receiving buffer space or shipping staging space is very difficult task. Unfortunately, an incorrect amount of space will reduce greatly the efficiency and effectiveness of the receiving or shipping operation. The impact will be particularly severe if too little buffer space or staging space is provided. Too little buffer or staging space will lead to clock congestion that will inevitably cost lost material, damaged material, split shipments, and erroneous shipments. Determining the amount of buffer or staging space required is largely a matter of the degree of control which exists over the work load is throughout the day, the more flexible the receiving buffer area or the shipping staging area must be. For example, if a warehouse has the ability to schedule carrier arrivals, and if that schedule is adhered to, then chances are good that the receiving buffer area or shipping staging area can be limited to one truckload of material per dock bay. However, if carrier arrivals are not controlled, and if they are extremely heavy during certain parts of the day and extremely light during other parts of the day, the amount of buffer or staging area must be based on how much area is required during the surge periods of the day. Requirements for buffer area or staging are in existing warehouses should be determined by analyzing historical shipping patterns to identify the surge periods and volumes. For new facilities, the anticipated suppliers and users of the warehouse should be asked for estimates of when and in what quantities their materials will be received or shipped; then, the buffet and staging area allocations can be based on the anticipated surge in activity.

Aisle space must be provided within the buffet or staging area. This aisle space is not intended for use in placing materials in or taking them out of the buffer or staging area. Instead, it provides access to and egress from the dock area to other parts of the warehouse. Materials should be placed in the buffer and staging areas from one end and taken out from the other end; therefore, intra buffer-area and intra staging-are aisles should be kept at a minimum. The width of a buffer or staging area aisle depends on the type of traffic that will use the aisle. Powered equipment traffic will require a wider aisle than predominantly pedestrian traffic. Likewise, aisles with bidirectional travel need to be wider than for single-direction travel.

(E) Determine dock-related space requirements

Several dock-related space requirements exists which support the receiving and shipping functions. These include;

1. *Office space*
2. *Receiving hold area*
3. *Trash disposal*
4. *Empty pallet storage*
5. *Trucker's lounge*

Office space must be provided for receiving and shipping supervision and for clerical activities. Approximately 125 square feet of office space should be provided for each dock employee who will regularly work in the office. Oftentimes, the supervisor's office space will be located within the dock area, and many of the receiving and shipping clerical and data processing activities will be combined with similar activities in the remainder of the warehouse.

A receiving hold area is essential for accumulating received material that has been rejected during a receiving or quality-control inspection and that is awaiting either return to the vendor or some other form of disposition. Rejected material should never be allowed to accumulate in the receiving buffer area. To do so will surely cause unsatisfactory merchandise to be accepted by the warehouse. A separate and distinct receiving hold area must be allocated. The amount of space required for the receiving hold area depends on the type of material likely to be rejected, the specific inspection process followed, and the timeliness of disposition of the rejected merchandise.

Dock operations, particularly receiving functions, generate a tremendous amount of trash, including corrugated boxes, binding materials, broken and disposable pallets, bracing, and packing materials. Space must be allocated within the receiving and shipping areas for disposal of these items. Failure to do so will result in poor housekeeping, congestion, unsafe working conditions, and a loss of productivity. Oftentimes, receiving and shipping functions are planned without concern for trash disposal and so must sacrifice space allocated for some other function to hold the trash. Dock operations generate trash; therefore, be prepared.

In most warehouses, loads often arrive unpalletized or on pallets with odd dimensions and require palletizing or repalletizing. Store of empty pallets must be readily available to the dock area so that this activity can be accomplished.

A truckers' lounge is an area to which truck drivers are confined when not servicing their trucks. The trucker' lounge should include seating, magazines, and, ideally, refreshment facilities, telephones, and private toilet facilities to provide everything the trucker needs while waiting fir his or her truck to be serviced. General space requirements for a basic trucker's lounge are approximately 125 square feet for the first trucker, and an additional 25 square feet for each additional trucker expected in the lounge at the same time. Consequently, a trucker's lounge designed for an average of three truckers would require approximately 175 square feet.

The purpose of the truckers' lounge is to effectively control the movements of the trucker while on site. Doing so will eliminate many potential problems related to trucker safety, theft and pilferage, labor-union campaigning, and warehouse employee productivity.

2.5.1.2 Space planning for storage activities

The second major area in a warehouse that requires space planning is the storage activity. Storage space planning is particularly critical because the storage activity accounts for the bulk of the space requirements of a warehouse. Inadequate storage space planning can easily result in a warehouse that is significantly larger or smaller than required. Too little storage space will result in a world of operational problems, including lost stock, inaccessible material, poor housekeeping, damaged material, safety problem, and low productivity. Too much storage space will breed poor use of space so that it appears that all the available space is really needed. The result will be high space costs in the form of land construction, equipment, and energy.

To avoid these problems, storage space planning must be approached from a quantitative viewpoint as opposed to a quantitative assessment of requirements. The following sections present the scientific methodology of storage space planning, that, when followed, will generate a quantitative and defensible assessment of storage space requirements.

(A) ***Define the materials to be stored:*** *The first step in storage space planning, as in receiving and shipping planning, is to define what is to be accomplished, that is, to define the materials to be stored. A useful tool in defining the materials to be stored is the storage analysis chart (SAC) given in figure 2.2. The first five columns of the SAC define what materials are to be stored, columns 6 through 8 specify how much is to be stored, and columns 9 through 12 define how the materials are to be stored.*

If a receiving and shipping analysis chart (Figure 2.1) has been completed, the information in the first five columns can likely be used in the first five columns of the SAC. Changes might be necessary only if the unit load to be stored is different from the unit load received or shipped. However, the generic categories of materials that are on the RSAC should also be recorded on the SAC. If an RSAC has not been completed (which might be true if one is analyzing the storage space requirements is an existing facility where the dock requirements are not under investigation), the information requirements for columns 1 through 5 of the SAC can be obtain by physically surveying the existing storage areas. The survey would proceed by identifying. Generically classifying, measuring, and weighing the unit loads presently in the storage areas.

Columns 6 and 7 of the SAC list the maximum and average number of unit loads of each category of material that should be on hand. In most firms, determination of inventory policy falls outside the control of warehouse management and into the realm of production and inventory control. Consequently, the inventory control department should be queried for the maximum and average inventory levels for each category of material listed in column 1 of the SAC.

Column 8 of the SAC cites the planned inventory level of each type of material for which storage area will be planned. Determining the proper inventory level is directly related to the storage philosophy that will be used for each category of materials. The different storage philosophies and the decision process one should use to determine the proper planned inventory level will be discussed in the next section as this chapter.

The last four columns of the SAC define the physical characteristics of the storage area being planned. These physical characteristics include the method of storage and the space requirements of that method.

(B) Determine Storage Philosophy: *Once the maximum and average inventory levels have been recorded, the inventory level that will be used as a basis for planning required storage space must be determined. The planned inventory levels depend on the philosophy followed in assigning material to storage space. There are two major material-storage philosophies, fixed, or assigned, location storage; and random, or floating, location storage. In fixed-location storage, each individual stock-keeping unit is always stored in a specific location, and no other stock-keeping unit may be stored in that location, even though that location may be empty.*

With random-location storage, any stock-keeping unit may be assigned to any available storage location. A stock-keeping unit in location A one month might be stored in location B the following month, and a different stock-keeping unit stored in location A.

The amount of space planned for a stock-keeping unit is directly related to the method of assigning space. If fixed-location storage is used, a given stock-keeping unit must be assigned sufficient space to store the maximum amount of the stock-keeping unit that will ever be on hand at any one time. For random-location storage, the quantity of items on hand at any time will be the average amount of each stock-keeping unit. In other words, when the inventory level of one item is above average, another item will likely have an inventory level that is below average; the sum of the two will be close to the average.

Oftentimes, the storage philosophy chosen for a specific stock-keeping unit will not be strictly fixed-location storage or random-location storage. Instead, it will be combination of the two. A grocery store is an excellent example combination, or hybrid, location storage. Fixed location storage is used in the sales area of a grocery store where the consumers shop. Pickles are assigned a fixed location, and only pickles are stored in that location. Pickles will not be found in any other location in the sales area of the grocery store. In the back room, store room, of the grocery store, however, the excess, or overstock, merchandise is usually stored randomly. Pickles may be found in one location one week and in a different location the next week. Because combination location storage is based on a mixture of fixed-location storage and random-location storage, its planned inventory level falls between the fixed-location quantity and random-location quantity. At what point between the *fixed-location and random-location quantity the planned inventory level falls is dependent upon the percentage of inventory to be assigned to fixed location.*

Company A.R.C.. Inc.	Date March 18.1986							Raw Materials / Plant Supplies	In-Process Goods		Finished Goods
Prepared by J. Smith	Sheet 1 of 1										
	Unit Loads				Quantity of Unit Loads Stored			Storage Space			
Description (1)	Type (2)	Capacity (3)	Size (4)	Weight (5)	Maximum (6)	Average (7)	Planned (8)	Method (9)	Specs (10)	Area ft² (11)	Ceiling Height Required, ft (12)
Steel pipe plug, 1.00 in diameter x 0.50 in.	Wooden crate	3200 pcs.	2 ft x 2 ft x 4 ft	825 lb	14	8	12	Pallet Rack	25 ft x 10 ft x 3 ft	66	9
Aluminium bar 2.75 in, x 250 in x 16 ft	Bundles	25 bars	12.5 in x 14 in x 6 ft	1625 lb	30	17	30	Two cantilever racks	Four-arm dual rack, 5 ft x 16 in x 8 ft	160	8
Stainless Steel bar 0.875 in, x 12 ft	Bundles	36 bars	6 in x 6 in x 12 ft	900 lb	7	4	7	cantilever racks	Four-arm dual rack, 4 ft x 12 in x 10 ft	48	10
Rubber O ring 0.75 in diameter	Cartons	40,000 O rings	12 in x 18 in x 3 ft	125 lb	2	1	2	Storage shelf	Metal frame, 12 ft x 2 ft x 8 ft	24	8
Brass bar, 0.75 in diameter x 12 ft	Bundles	36 bars	6 in x 6 in x 12 ft	720 lb	15	8	14	cantilever racks	Four-arm dual rack, 4 ft x 12 in x 6 ft	48	6

Figure 2.2-Storage Analysis Chart (SAC)

To summarize, the planned inventory level recorded in column 8 of the storage analysis chart in Figure 2.2 should be equal to the maximum inventory level (column 6) for fixed-location storage, the average inventory level (column 7) for random-location storage, or a value between the maximum and average quantities for combination-location storage.

(C) Determine Alternative Storage Method Space Requirements: *The space requirements of a storage alternative are directly related to the volume of* *material to be stored and to the use-of-space characteristics of the alternative. The two most important use-of-space characteristics are aisle allowances and honeycombing allowances. Aisle allowance is the percentage of space occupied by aisles within storage area. Aisles are necessary within a storage area to allow accessibility to the material being stored. The amount of aisle allowance depends on the storage method, which dictates the number of aisles required, and on the material-handling method, which dictates the size of the aisles. Expected aisle allowance must be calculated for each storage alternative under consideration.*

Honeycombing allowances are the percentage of storage space lost because of ineffective use of the capacity of a storage area. The unoccupied area within the storage location is honeycombed space. Honeycombing occurs whenever a storage location is only partially filled with material and may occur horizontally and vertically. For example, Figure 2.3a present a plan view of a bulk storage area in which material can be placed four units deep. Because the bulk storage area is full, no honeycombing occurs. In Figure 2.3b, however, two units of product A and one unit of product B have been removed, leaving three empty slots. No other items can be placed in these slots until the remaining units of A and B have been removed (otherwise, blocked stock will result), so these slots are horizontal honeycombing losses. Figure 2.3c is an elevation view of a bulk storage area in which material can be stacked three units high. Here again, the storage area is full and no honeycombing occurs. In figure 2.3d, however, two units of product A and one unit of product B have been removed, leaving three empty slots. To avoid blocked stock or poor stock rotation, no other units can be placed in these slots until the remaining unit of A and B have been removed. Consequently, the empty slots are vertical honeycombing losses will occur. Efforts to totally eliminate honeycombing may improve apace utilization but will assuredly result in increased material handling costs related to double handling loads, material damage, and lost productivity. Honeycombing, while it should be minimized, must be considered a natural and allowed for phenomenon of the storage process. For each storage alternative under consideration, the expected honeycombing allowance must be estimated.

Once the aisle and honeycombing allowances for a storage method alternative have been determined, a space standard can be calculated for that storage method. A space standard is a benchmark which defines the amount of space required *per unit of product stored. Given the space standard and the total inventory of a class of items to be stored, the total space required for that class of items can then be calculated.*

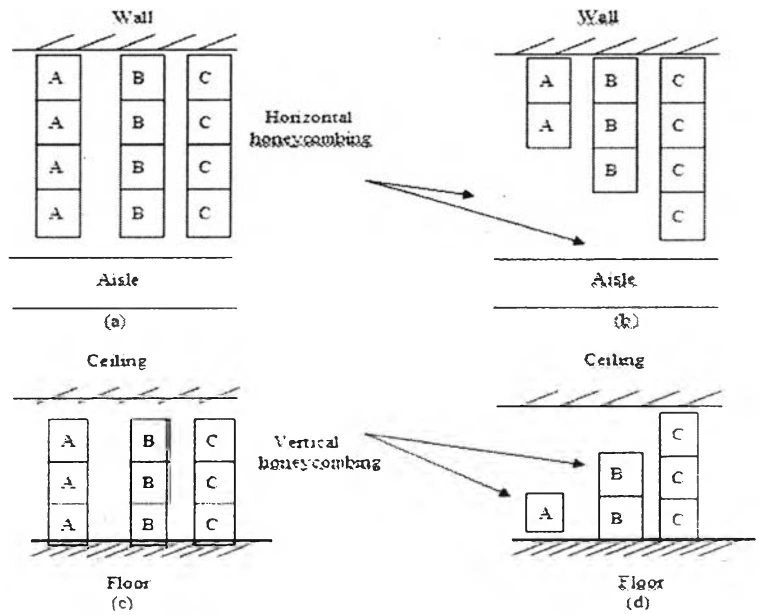

Figure 2.3- Horizontal and vertical honeycombing. (a) Plan view of bulk storage area – no honeycombing. (b) Plan view of bulk storage area showing horizontal honeycombing. (c) El-evation view of bulk storage area – no honeycombing. (d) El-evation view of bulk storage area showing horizontal honeycombing.

2.5.2 Warehouse layout planning

Smith and Peters (1994: a 91-100) described that before layout planning can begin, the specific objectives of a warehouse layout must be determined. In general, the objectives of a warehouse layout are:

1. To use space efficiently
2. To allow the most efficient material handling
3. To provide the most economical storage in relation to costs of equipment, use of space, damage to material, and handling labor
4. To provide maximum flexibility in order to meet changing storage and handling requirements
5. To make the warehouse a model of good housekeeping

The objectives of a warehouse are:

1. To maximize effective use of space
2. To maximize effective use of equipment

3. To maximize effective use of labor
4. To maximize accessibility of all items
5. To maximize protection of all items

It is true that the objectives of both a warehouse itself and of the warehouse layout are almost redundant. This shows the importance of layout planning to warehouse planning. Without a good warehouse layout, it is impossible to have a good warehouse. The objective of layout planning is to arrange and coordinate the space, equipment and labor resources of the warehouse. Poor layout planning can undermine superior space, equipment, and personnel planning. Put another way, accomplishing the objective of warehousing depends on having a good layout. If the warehouse layout is bad, the warehouse as a whole will be bad; and if the warehouse as a whole is bad, chances are the warehouse layout is bad.

The fourth objective of a warehouse layout recognizes the fact that warehousing exists not within a static, unchanging environment. If the mission of a warehouse changes, the warehouse layout should very likely change, too, to adapt to the new mission. However, a good warehouse layout possesses the flexibility to absorb minor variances in expected storage volumes and product mixes with few or no alterations required. This flexibility allows the warehouse to function even if the forecasts on which it was planned prove to be wrong, as they inevitably do.

The last objective of warehousing follows the principle that there is efficiency on order. Good housekeeping is essential to good warehousing: a good warehouse cannot exist without good housekeeping. Yet good housekeeping by itself will not ensure a good warehouse. If the space equipment, personnel, and layout are not properly planned, all the housekeepers in the world could not get a warehouse to function. But poor housekeeping will surely undermine good space, equipment, personnel, and layout planning.

2.5.2.1 Layout planning methodology

Smith and Peters (1994: a 91-100) described that the warehouse layout planning methodology consists of two steps:

1. Generate a series of warehouse layout alternatives.
2. Evaluate each alternative against specific criteria to identify the best warehouse layout.

These two steps are discussed in the following sections.

(A) Generate Alternative Layouts: *Generating alternative warehouse layout is as much art as it is science. The quality of the layout alternatives will largely depend on the skill and ingenuity of the layout planner. This fact is crucial to the most common approach to generating layout alternatives: template juggling. The word juggle means to skillfully manipulate a group of objects to obtain a desired effect. Consequently, template juggling is the skilful manipulation of a group of templates, models, or other representations of warehouse space, equipment, and personnel in order to obtain a warehouse layout that meets objectives. In other words, template juggling is a trial-and-error approach to finding the proper arrangement and coordination of the physical resources of the warehouse.*

The quality of the alternatives created from template juggling depends on the creativity of the layout planner. Unfortunately, layout planners often either lack creativity or do not attempt to express their creativity. Many layout planners approach the problem with a preconceived idea about what the solution should be. They trend to bias the layout planning process toward that preconceived solution. As a result, creativity is stifled. Oftentimes, the layout chosen for a new warehouse looks exactly like the layout used in the old warehouse. The generation of layout alternatives thrives on the creativity of the layout planner, yet many layout planners withhold his basic and essential ingredient.

The generation of warehouse layout alternatives should be accomplished by the following procedure:

1. Define the location of fixed obstacles. Some objectives in a warehouse can be located only in certain places, and they can have only certain configurations. These objects should be identified and placed in the layout alternative first before objects with more flexibility are located. Some fixed obstacles are building support columns, sprinkler system controls, heating and air conditioning equipment, and, in some cases, offices. Failure to consider the location of these types of items first will prove disastrous. The warehousing corollary to Murphy's law states, "If a column can be in the wrong position, it will be". Don't be the layout planner who designs a warehouse and buys the storage and material handling equipment only to find that, when the equipment is installed, the location of the building columns makes an aisle too narrow for the handling equipment.

2. Define the location of the receiving and shipping functions. Oftentimes, the configuration of the warehouse site will dictate the location of the receiving and shipping functions. When this is not true, however, the receiving and shipping location decision becomes an important one. Receiving and shipping are high-activity areas and should be located so as to maximize productivity, improve material flow, and properly utilize the warehouse site. The location of access roads and railroad tracks, if rail service is required, are important considerations in locating receiving and shipping should be located together or in different areas of the warehouse must be addressed. Common receiving and shipping docks can often result in economies of scale related to sharing space, equipment, and personnel. Separate receiving and shipping areas may, on the other hand, be best to ensure better material control and reduce congestion. Energy considerations are important. Where a choice exists, receiving and shipping docks should not be located on the side of the building that faces north. Avoiding this location reduces the amount of heat loss in the winter from northerly winds entering the warehouse through open dock doors. The preferred location of the receiving and shipping docks is the south side of the warehouse, with east and west as second and third choices. The particular weather patterns around each warehouse site should be examined, however, to identify the prevailing wind direction at that particular site, and the docks should be located away from the prevailing wind.

3. Locate the storage areas and equipment, including required aisles. The types of storage areas and equipment to be used will dictate to some extent the configuration of the storage layout and the aisle requirements. Be sure to make allowances for the fixed obstacles in the facility. Main warehouse aisles should connect the various parts of the warehouse. The cross aisle at the end of the storage area may need to be wider than the aisle within the storage area, depending on the type of material handling equipment used. For example, a side-loading fork truck that can operate with a 7-foot-wide storage aisle may require 12-foot-wide cross aisles at the ends of the storage aisles to allow maneuvering into and out of the storage aisle.

4. Assign the material to be stored to the storage locations. This step in the generation of layout alternatives ensures that storage allowances have been made for all the items to be stored. In addition, it allows the performance of a mental simulation of the activities expected within the warehouse.

5. Repeat the process to generate other alternatives. Once a warehouse layout alternative has been established following the four steps just outlined, the process must be repeated many times to generate additional layout alternatives. Different layout configurations, building shapes, and equipment alternatives should be used. The creativity of the layout planner should be taxed to ensure that each succeeding layout alternative is not essentially identical to the first.

(B) Evaluate the Alternative Layouts: *A number of warehouse layout philosophies exist to serve as guidelines for the development of an effective warehouse layout. Each warehouse layout alternative should be evaluated against the specific critical established for each of these warehouse layout philosophies.*

1. Popularity philosophy. An Italian economist named Pareto once stated that 85 percent of the wealth of the world is held by 15 percent of the people. On closer examination, Pareto's law actually pertains to many areas other than wealth; one of these areas is warehousing. In a typical warehouse, it is not unusual to find that 85 percent of the product throughput is attributed 15 percent of the items, that another 10 percent of the product throughput is attributable to 30 percent of the items, and that the remaining 5 percent of the product throughput is attributable to 55 percent of the items. Consequently, the warehouse contains a very small number of highly active items (often called A items). A slightly larger number of moderately active items (often called B items), and a very large number of infrequently active items (often called C items). The warehouse layout philosophy on popularity suggests that the warehouse should be planned around the small number of highly active items that constitute the great majority of the activity in the warehouse. The popularity philosophy maintains that the materials having the greatest throughput should be located in an area that allows the most efficient material handling. Consequently, high-turnover items should be located as close as possible to the point of use.

The popularity philosophy also suggests that the popularity of the items help determine the storage method used. Items with the greatest throughput should be stored by methods that maximize the use of space. For example, if bulk storage is used, high-turnover items should be stored in as deep a space block as possible. Because the items are moving into and out of storage at a relatively high rate, the danger of excessive honeycombing losses is reduced, and excellent use of *space will result from the high-density storage. Low-throughput items in deep bulk storage blocks will cause severe honeycombing losses because no other items can be stored in that location until the low-throughput items is removed.*

2. Similarity philosophy. Items that are commonly received and/or shipped together should be store together should be stored together. For example, consider a retail auto parts distributor. Chances are that a customer who requires a spark plug wrench will not buy, at the same time, an exhaust system tailpipe. Chances are good, however, that a customer who buys the spark plug wrench might also require a condenser, points, and spark plugs. Because these items are typically sold (shipped) together, they should be stored in the same area. The exhaust system tailpipe should be stored in the same area that the mufflers, brackets, and gaskets are stored. Sometimes, certain items are commonly received together, possibly from the same vendor: they should be stored together. Similar types of items handling methods, so their consolidation in the same area results in more efficient use of space and more efficient material handling.

An exception to the similarity philosophy arises whenever items are so similar that storing them close together might result in order picking and shipping errors. Examples of items that are too similar are two way, three-way, and four-way electrical switches; they look identical but function quite differently.

3. Size philosophy. The size philosophy suggests that heavy, bulky, hard-to-handle goods should be close to their point of use. The cost of handling these items is usually must greater than that of handling other items. That is an incentive to minimize the distance over which they are handled. In addition, if the ceiling height in the warehouse varies from one area to another, the heavy items should be stored in the areas with a low ceiling, and the lightweight, easy-to-handles items should be stored in the areas with a high ceiling. Available cubic space in the warehouse should be used in the most effective way while meeting restrictions on floor loading capacity. Lightweight material can be stored at greater heights within typical floor loading capacities than heavy materials can.

The size philosophy also asserts that the size of the storage location should fit the size of the material to be stored. Do not store a unit load of 10 cubic feet in a storage location capable of accommodating a unit load of 30 cubic feet. A variety of storage location sizes must be provided so that different items can be stored *differently. In addition to looking at the physical size of an individual item, one must consider the total quantity of the item to be stored. Different storage methods and layouts will be used for storing two pallet loads of an item than will be used for storing 200 pallet loads of the same material.*

4. Product characteristic philosophy. Some materials have certain attributes or traits that restrict or dictate the storage methods and layout used. Perishable material is quite different from non-perishable material, from a warehousing point of view. The warehouse layout must encourage good stock rotation so that limitations on shelf life are met. Oddly shaped and crushable items, subject to stocking limitations, will dictate special storage methods and layout configurations to effectively use available cubic space. Hazardous material such as explosives, corrosives, and highly flammable chemicals must be stored in accordance with government regulations. Items of high value or items commonly subject to pilferage may require increased security measures, such as isolated storage with restricted access. The warehouse layout must be adapted to provide the needed protection. The compatibility of items stored close together must also be examined. Contact between certain individual harmless materials can result in extremely hazardous reactions and/or significant produce damage. Specific steps must be taken to separate incompatible materials. Oftentimes, the easiest way to accomplish this objective is through the warehouse layout.

5. Space utilization philosophy. This Philosophy can be separated into four areas:

a. Conservation of space

b. Limitations on use of space

c. Accessibility of material

d. Orderliness

The conservation-of-space principle asserts that the maximum amount of material should be concentrated within a storage area, the total cubic space available should be effectively used, and the potential honeycombing within the storage area should be minimized. Unfortunately, these objectives often conflict. Increased concentration of material with usually causes increased honeycombing allowances. Therefore, determining the proper level of space conservation is a matter of making trade-offs among the objectives that maximize use of space.

Limitations on use of space must be identified early in the layout planning process. Space requirements for building support columns, trusses, sprinkler system components, heating-system components, fire extinguishers and hoses, and emergency exits will affect the suitability of certain storage and handling methods and layout configurations. Floor loading capacities will restrict storage height and densities.

The warehouse layout should meet specified objectives for material accessibility. Min travel aisles should be straight and should lead to doors in order to improve maneuverability and reduce travel times. Aisles should be wide enough to permit efficient operation, but they should not waste space. Aisle widths should be tailored to the type of handling equipment using the aisle and the amount of traffic expected.

The orderliness principles emphasize the fact that good warehouse housekeeping begins with housekeeping in mind. Aisles should be well marked with aisle tape or paint, otherwise, materials will begin to infringe on the aisle space and accessibility to material will be reduced.

2.6 Warehouse Equipment

Generally, warehouse equipment can be divided into 2 categories. The first category is Handling Equipment and another is Storage Equipment.

2.6.1 Handling Equipment

The various product handling equipment types for use inside or outside a distribution facility are similar but not identical. They all move product and the differences lie in their power source, aisle width, capacity, storage height and controls. Ackerman (1997 a: 473) described that prior to the purchase and implementation of product-handling equipment, the operational parameters must be clearly defined:

- Unit –load dimensions with overhang (length, width, height, plus weigh)
- Average and peak inbound and outbound transactions per hour
- Unit-load storage position type and clearance
- Unit-load bottom support method (pallet, board type, skid, slip sheet, or container)

- Stacking height and storage area's environmental conditions
- Condition of storage area floor and surface
- Aisle width and length

There are 4 main types of handling equipment and they will be discussed following this:

2.6.1.1. Industrial trucks

Industrial truck is a vehicle capable of picking up a unit load, with the unit load traveling through a warehouse aisle and performing the unit-load deposit or withdrawal transaction. It is used in a warehouse operation to handle a unit load that includes product. It is the flexible and able to move anywhere with require no other tool. Different unit-load storage vehicles that are used in a warehouse operation have a wide range of capabilities. There are three basic truck classifications are wide-aisle, narrow-aisle and very narrow-aisle.

2.6.1.2. Conveyor

Conveyor can transfer products from one certain point to another one certain point in both vertical and horizontal. There are various types of conveyor such as Gravity conveyor, Powered Roller conveyor and Recirculation conveyor. Conveyor fits to a continuous transfer operation and need to be installed in specific area.

2.6.1.3. Hand-operated Pallet trucks

It is a vehicle that required hand-operated pallet truck. It is designed to use with small and light weight products.

2.6.1.4. Automatic Guided Vehicle system (AGVS)

Ackerman (1997 a: 473) described that *AGVS are battery-powered, driverless vehicles that are equipped to follow either wire guide paths or a reflective tape placed on the floor while either towing or carrying a load. It can be designed to carry a variety of sizes and weight capacities. However, consideration must be given to traveling speed in relation to the force required to start and stop the load. The AGVS may be programmed to load, unload, accelerate, deliver, stop, start, block, and select travel paths, all without human intervention.*

2.6.1.5 Automated Storage and Retrieval Systems (AS/RS)

This system consists of storage racks and mobile equipment. It automatically move product in and out its storage area. AS/RS provide a wide variety of unit-load, miniload and deep-lane system in warehouse operation today. It can be controlled by both an operator and a program.

2.6.2 Storage Equipment

A warehouse is more than a storage building. To handle cargo, it needs equipment. And it is the selection and use of that equipment that may spell the difference profit and loss. The equipment choice is usually governed by the following criteria:

- Degree of flexibility desired for different uses
- Nature of the warehouse building
- Nature of the handling job-bulk, unit load, individual package, or broken package distribution
- Volume to be handled by the warehouse
- Reliability
- Total system cost

Ackerman (1997 a:461-471) described that *the warehouse has several storage modes. Products may be floor-stored, solid-stacked, or in racks. Storage equipments are various types such as Pallet, Rack, Shelf and Bin. Detail of some storage equipments will be discussed following this:*

Pallet: Pallet is the storage equipment which is most widely used in general warehouse. It is a portable platform on which goods can be moved, stacked, and stored, especially with the aid of a forklift truck. It may be made of wood or plastic. It is used for storing a product that is difficult to stack or pile properly. Pallet can carry many cartons at one time. There are sizes of pallet but the most widely use is the standard size 40in x 48in. And the models of pallet that are used widely in warehouses, is two-way pallet, four-way pallet and box pallet. The consideration of pallet storage method selection includes:

- *Ease of storage*
- *Ease of retrieval*

- *Ease of location*
- *Low risk of damage*
- *Good use of cubic space*
- *Cost of handling equipment*
- *Cost of operations*

2.6.2.1Rack

Rack is a framework, typically with rails, bars, hooks, or pegs, for holding or storing things a cogged or toothed bar or rail. Rack storage is advantageous for ease of storage and retrieval. They are also preferable when the volume per item is too. Because the storage rack is relatively simple, it is easy to overlook way in which storage capacity can be greatly increased by using a rack. The most common storage rack found in warehouses is the three-high static rack system. But there are many types of rack such as:

(A) Drive-in rack can provide greater storage density. With drive-in rack, each load is supported by a flange that grips the edge of the pallet. While the drive-in rack achieves maximum density, it may do so at a sacrifice in handling efficiency as the driver guides his lift truck through the narrow alley between rows.

(B) Tier rack is a self-supporting framework that covers the unit load and permits freestanding high stacks supported by the rack structure rather than the merchandise. Tier rack is frequently used for stacking auto tires or other products having no packaging or structural strength.

(C) Flow rack is a series of vertical columns, horizontal load supports, and conveyors that rest on load supports. A flow-rack system is quite simply a conveyor within a rack structure. Two factors govern the size of a flow-rack system: lane depth and the number of levels in the rack. There are essentially no restrictions to lane depth. There are, however, two problems with a very deep lane: acceleration and travel distance.

(D) Shelving: Shelving represents one of the earliest forms of product storage and has changed very little over the years. In its simplest form, shelving consists of four vertical pots that support one or more horizontal shelves. Shelving is a very basic storage method that affords the user significant flexibility in

the type and quantity of goods that can be stored, and at a relatively low capital investment.

2.7 Performance Measurement

Ackerman (1997 a: 91-98) described that many warehouse performance measurement systems have not been successful. Those that have succeeded generally follow certain principles which are listed below:

- Keep it simple. The best systems are those every warehouse employee can understand. They not only know how the system works, but also what the system is and why it is there. Systems designed with participation from warehouse employees have an excellent chance of success.
- Avoid making frequent changes in standards. With warehouse standards, accuracy may be less important than consistency. Warehouse work changes frequently and constant changes in standards may make measurements meaningless. Furthermore, frequent standard changes may be the source of employee distrust.
- Create measurement systems to cope with predictable changes in the product line. Every warehouse inventory has certain predetermined variations in product mix that can be anticipated when establishing a standard.
- Never use performance measurement systems for worker discipline. Maintenance of such systems depends on worker cooperation. If they are seen as a way for management to spy on the workers for disciplinary purposes, the entire reporting system will break down.

There are 6 main methods that are widely used in most warehouses:

1. Space Utilization
2. Order fulfillment
3. Inventory accuracy
4. Total Throughput
5. Transportation
6. Loss and Damage from warehouse operation

2.8 Literature Survey

2.8.1 Related Thesis Study

Numpon Tungsub. (1995). An utilization improvement of a warehouse for air-conditioning Industry. Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University

The objective of this thesis is to improve a warehouse of the air-conditioning factory by focusing on the utilization of warehouse area and the storage system of stock in this factory. There are 2 essential problems in factory. The first is a problem in area utilization and storage area designing. The second is a problem in the placement of each part. However, these problems can be solved by the following proposal : The area utilization and storage area designing : Adjust the demand of storage area for each part in stock calculated from the frequency of using and limit the suitable stock on-hand quantities for each part. The placement of each part: Set the placement and use the shelves for each part. The results from these adjustments can reduce the storage area and the time to store and retrieve each part.

Pongpat Phetrungrueng. (1996). An efficiency improvement of warehousing operations: a case study of air conditioner warehouse. Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University

The purpose of this thesis is to study and suggest an efficiency improvement of a case study of air conditioner warehousing operations. The general feature of this air conditioner warehouse is the receiving place of air conditioners from the suppliers and to store that air conditioners waiting for delivery to the customer. The problems of warehousing operations before the improvement are the area usage for warehouse activity and storage activity; the diversity of air conditioner types; and the warehousing operation. These problems cause the delay and error in warehousing operations. The efficiency improvement of warehousing operations to obtain the highest productivity can operate by means of planning the efficient usage of warehouse area by allocating air conditioner storage area and confining the area of warehousing operations corresponding to the specific air conditioner attribution and air conditioner quantity. The improvement of air conditioner storage by storing air conditioners in unit load and defining the firm location of each air conditioner type including reducing repeated and unnecessary warehousing operations is a method to improve this warehouse efficiency.

Teerapoj Charojrochkul. (1999). Improvement of material handling routing in warehouses and transportation operations in an automotive parts industry. Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University

The objectives of this study are to improve the material handing routing in a warehouse of an automotive parts industry and to improve transportation operations in that company. The warehouse department and delivery department are in focus in the case study factory. The methodology in this thesis can be adapted to other factories or industries of the same feature. The warehouse stores more than 500 items. The items are stored based on items' models. However, the frequency in ordering each item is not considered. Therefore, the locations for some items are not appropriate. In addition, the routing for material handling are not considered. The routes are planned only by the experience of the warehouse workers. In the transportation operations, some routes to customers are not optimal because there are many new routes to some customers. In addition, the existing delivery schedule is out of date. However, these problems can be solved by the following proposals. Warehouse 'items are reallocated based on the frequency of use or ordering. A new warehouse layout using the Nearest Neighbour Heuristic technique is proposed in this thesis to plan the material handling routes. Transportation: New routes to customers are investigated and the time to each customer is measured, and then the new delivery schedule and the routes have been proposed.

Panika Chaitamart. (2000) An efficiency improvement of warehousing management. Master's Thesis Department of Industrial Engineering, Graduate School, Chulalongkorn University

Problems found due to the study of the warehouse operations were 1. The finished goods warehouse did not have an optimized method of physical storage and arrangement and 2. Order-picking takes longtime and has errors. Thus the objective of this thesis is to improve the efficiency of warehouse management focusing on the storage and order-picking system by designing storage layout, location assignment system and work procedure according to the system which details are (1) Design storage layout: Determine the space planning and storage layout in order to utilize the space and handling equipment with maximum efficiency. ; Set a storage code system, stock locator, in order to reference storage location. (2) Assign storage location: Determine the pattern of movement which is the storage and retrieval system, product factors and space factors in order to assign the appropriate storage location. (3) Design and develop a program which helps to design the storage location in order to arrange the goods in orderly convenient for order-picking and inventory checking. (4) Set up work procedure: Prepare working procedure that suite with the location assignment system.

Sirang Klankamsorn.(1997) Development of a software for warehouse management system. Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University

The objective of this study is to develop software for warehouse management system. The thesis studies activities and relationships among departments in a warehouse to use as a reference in developing software for warehouse management. The system comprises of 6 modules, namely 1) Inventory module for registration of basic item data and for reporting inventory status, 2) Receiving module for recording receipts, 3) Location module for processing information concerning storage locations, 4) Order processing module for sequential routing of operators, 5) Shipping module for recording the issues of inventory items and for issuing moving tickets, and 6) Performance Evaluation module for reporting performances of the warehouse

2.8.2 Related Book Study

Tompkins, J. A. and Smith, J. D., eds. 1988. The Warehouse Management Handbook., USA: McGraw-Hill

This is the second edition of The Warehouse Management Handbook. The second edition offers 39 crucial, leading-edge chapters, each written by a different noted warehouse management expert. The Warehouse Management Handbook, Second Edition is literally brimming with information that will improve warehouse performance and the bottom line. Chapter topics include: Third Party Warehousing, Warehouse Space and Layout Planning, Simulation, Hazardous Materials

Management, Environmental Concerns in Warehousing, Automated Guided Vehicle Systems, RF Communication, Warehouse Management Systems, Electronic Data Interchange, and Loss Control. The Warehouse Management Handbook, Second Edition is the standard warehouse management reference.

In The Warehouse Management Handbook, it contains practical, hands-on information and advice on key topics such as:

- Developing a process and selecting the right warehouse management system
- Planning both space and layout requirements for the warehouse
- Grasping the issues involved in third party logistics decisions
- Utilizing information systems for maximum effectiveness
- Choosing the best warehouse site
- Designing the most efficient truck and rail dock facilities, and establishing yard requirements
- Establishing effective stock location and inventory control systems
- Understanding the importance of maintenance in your warehouse operation
- Controlling losses due to theft, damage, fire, and obsolescence
- Taking full advantage of storage and retrieval systems, conveyor systems, and shipping systems among others
- Evaluating capital investments

Chorafas, D. N. 1974. Warehousing Planning, Organising and Controlling the storage and distribution of goods., USA: Macmillan Press Ltd

This book presents advice from direct personal experience and from research into this field which is suit to management level. This book endeavours to explain the method of how to arrive at warehousing decisions, including the necessary studied and evaluations. It has been developed in response to a need for obtaining approximate cost figures on the basis of a fairy broad understanding of the technical job to be done.

Mulcahy, D. E. 1994. Warehouse Distribution and Operations Handbook., USA: McGraw-Hill

This book is a guide to creating a totally integrated warehouse system, presenting tested methods for reducing operating costs, enhancing inventory control, increasing profits, improving customer satisfaction, and protecting assets. Organized to follow the sequence of activities for moving a product through a distribution facility, the Handbook examines the latest practices, equipment applications, and current technology that contribute to the effective operation of any type of warehouse, including industrial, mail-order, and retail facilities.

Ackerman, K. B. 1997. Practical Handbook of Warehousing. 4th Edition., USA: Chapman & Hall

This text book describes four crucial elements of warehousing and how they are audited, including communications and electronic data interchange, packaging and identification, transportation, and accountability, and discusses other aspects such as contract warehousing, real estate aspects, security, the use of computers in the industry, and employee performance.