CHAPTER 5

SPACE ALLOCATION AND STORAGE EQUIPMENT DESIGN

Space Allocation

All of the type 5 inventories, which are spare parts and equipment of telecommunication system, are stored in Ngamwongwan warehouse. One equipment composes of different parts which need different storing methods. Electronic parts, which normally are vulnerable in high temperature, are stored in air conditioned space. Parts which are not stand to rain and sunshine, are stored in non-air conditioned space which is not under temperature control. Other parts that do not require any special handling are stored in open air space.

In addition, There are many containers consisted in one set of equipment. The physical properties of each container are different. Some of the properties that will be useful in the space allocation and storage equipment design process are collected from Ngamwongwan warehouse. The lists of data below are shown in the following tables.

- Size of each container including width, length, and height in centimetre
- Numbers for distribution for each container
- Storage space in cubic metre calculated from the product of the volume of each container (width*length*height) and the numbers for distribution of that container.
- Total storage space required in each space (air conditioned, non-air conditioned, and open-air)
- Grand total storage space required for each set of equipment
- Weight of each container divided into 3 categories

  light weight : container with less than 5 kilograms weight

  heavy weight : container with 5-30 kilograms weight

  very heavy weight : container with more than 30 kilograms weight

TABLE 5.1 Space allocation for First Order Digital Multiplex Equipment 4w. E&M Sig

Unit NO. (A)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	30	50	40	1	0.06	✓		
2	26	30	35	2	0.0546	✓		
3	7	25	28	7	0.0343	✓		
Total					0.1489			
Non-air conditioning Space								
4	26	150	34	2	0.2652		✓	
5	23	123	52	1	0.147108		✓	
Total					0.412308			
Grand total					0.561208			

TABLE 5.2 Space allocation for UHF Digital Radio Telephone Equipment 6ch (Sub & Ex)

Unit NO. (B)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	56	64	50	2	0.3584			✓
2	42	50	10	1	0.021		✓	
Total					0.3794			
Non-air conditioning Space								
3	60	50	28	2	0.168		✓	
4	32	39	30	1	0.03744		✓	
5	56	200	27	1	0.3024		✓	
6	10	200	6	1	0.012	✓		
Total					0.51984			
Open-air Space								
7	65	65	20	1	0.0845		✓	
8	15	40	80	2	0.096			✓
Total					0.1805			
Grand total					1.07974			

TABLE 5.3 Space allocation for 2GHZ Digital Microwave Radio Equipment (8 MBPS)

Unit NO. (C)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	80	120	52	2	0.9984			✓
2	80	120	65	3	1.872			✓
3	80	115	35	1	0.322			✓
4	60	76	187	1	0.85272			✓
Total					4.04512			
Non-air conditioning Space								
5	16	222	13	2	0.092352		✓	
6	74	140	45	1	0.4662		✓	
7	30	45	25	1	0.03375		✓	
8	100	150	150	1	2.25			✓
Total					2.842302			
Open-air Space								
9	5	242	5	2	0.0121			✓
10	250	250	50	2	6.25			✓
11	30	45	25	1	0.03375		✓	
12	100	110	52	2	1.144			✓
13	20	275	20	2	0.22			✓
Total					7.65985			
Grand total					14.547272			

Table 5.4 Space allocation for Radio Set and Equipment for Microwave 13GHZ 34MB

Unit NO. (D)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	30	255	34	2	0.5202		✓	
2	38	47	30	3	0.16074	✓		
3	72	290	41	1	0.85608			✓
4	36	290	35	2	0.7308			✓
5	31	46	28	1	0.039928		✓	
6	5	100	5	2	0.005		✓	
7	42	70	47	2	0.27636		✓	
8	53	70	58	2	0.43036		✓	
9	30	46	27	1	0.03726	✓		
10	34	55	24	1	0.04488		✓	
Total					3.101608			
Non-air conditioning Space								
11	30	46	27	2	0.07452		✓	
12	30	46	27	2	0.07452			✓
13	10	15	10	1	0.0015	✓		
14	30	46	27	2	0.07452		✓	
15	40	105	35	2	0.294			✓
16	30	46	27	4	0.14904		✓	
17	60	76	187	1	0.85272			✓
18	77	110	42	1	0.35574			✓
19	45	32	5	4	0.0288			✓
Total					1.90536			
Open-air Space								
20	78	134	134	1	1.400568			✓
21	200	200	118	1	4.72			✓
Total					6.120568			
Grand total					11.127536			

TABLE 5.5 Space allocation for First Order Mux (N500 series)

Unit NO. (E)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	28	290	37	1	0.30044			✓
2	33	50	28	1	0.0462		✓	
Total					0.34664			
Non-air conditioning Space								
3	60	15	60	1	0.054		✓	
Total					0.054			
Grand total					0.40064			

TABLE 5.6 Space allocation for 2GHZ Digital Microwave Radio Equipment (34MBPS)

Unit NO. (F)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	80	120	80	2	1.536			✓
2	50	76	187	1	0.7106			✓
3	70	230	65	2	2.093			✓
Total					4.3396			
Non-air conditioning Space								
4	80	115	35	1	0.322			✓
5	44	47	37	1	0.076516	✓		
6	27	150	30	4	0.486		✓	
Total					0.884516			
Open-air Space								
1	80	50	50	1	0.2			✓
2	180	180	50	2	3.24			✓
3	10	250	10	2	0.05			✓
4	70	80	30	1	0.168			✓
5	100	150	150	1	2.25			✓
Total					5.908			
Grand total					11.132116			

TABLE 5.7 Space allocation for 140MBPS Digital Mux Equipment (Full System)

Unit NO. (G)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	40	290	40	1	0.464			✓
2	40	290	35	1	0.406			✓
3	37	290	35	1	0.37555			✓
4	37	290	35	1	0.37555			✓
5	47	290	36	2	0.98136			✓
Total					2.60246			
Grand total					2.60246			

TABLE 5.8 Space allocation for Digital Line Concentrator DCS-20 for 2MBPS PCM Transmission

Unit NO. (H)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	77	88	63	4	1.707552			✓
2	35	48	20	1	0.0336		✓	
Total					1.741152			
Grand total					1.741152			

TABLE 5.9 Space allocation for Microwave Minilink Equipment 13GHZ 34MB

Unit NO. (I)	Size (cm)			Number for distribution	Storage Space (cubic m.)	Weight		
	Width	Length	Height			light	heavy	very heavy
Air conditioned Space								
1	40	50	40	1	0.08		✓	
2	70	230	65	2	2.093			✓
Total					2.173			
Open-air Space								
3	80	200	200	2	6.4			✓
4	10	170	170	1	0.289			✓
Total					6.689			
Grand total					8.862			

The stock kept in the warehouse for a period of time is normally to serve the demand in that period and to be the safety stocks. Tables 5.1 - 5.9 illustrate the space required per only one set of each equipment. The whole space, to store the maximum stock level per a period of time and the safety stocks, for the mentioned inventory is calculated by the sum of the space required for each equipment.

Whole Space for storing the Mentioned Inventory

- First Order Digital Multiplex Equipment 4W.E&M Sig requires 0.56 m^3 for one set
  maximum stock level / a period of time = 13 sets
  safety stocks = 4.05
  total storage numbers = 13 + 4.05 = 17.05 = 17 sets
  whole space required for this equipment = 17 * 0.56 = 9.52 m^3

- UHF Digital Radio Telephone Equipment 6 Ch (Sub&Ex)
  maximum stock level / a period of time = 3 sets
  safety stocks = 1.47
  total storage numbers = 3 + 1.47 = 4.47 = 5 sets
  whole space required for this equipment = 4 * 1.08 = 4.32 m^3

- 2GHz Digital Microwave Radio Equipment (8 MBPS)
  maximum stock level / a period of time = 1 set
  safety stocks = 0.45
  total storage numbers = 1 + 0.45 = 1.45 = 2 sets
  whole space required for this equipment = 2 * 14.55 = 29.10 m^3

- Radio Set and Equipment for Microwave 13GHz 34MB
  maximum stock level / a period of time = 1 set
  safety stocks = 1.14
  total storage numbers = 1 + 1.14 = 2.14 = 3 sets
  whole space required for this equipment = 3 * 11.13 = 33.39 m^3

- First Order Mux (N 500series)
  maximum stock level / a period of time = 2 sets
  safety stocks = 0.93

total storage numbers = 2 + 0.93 = 2.93 = 3 sets

whole space required for this equipment = 3 * 0.40 = 1.20 m^3

- 2GHz Digital Microwave Radio Equipment (34 MBPS)

maximum stock level / a period of time = 1 set

safety stocks = 0.39

total storage numbers = 1 + 0.39 = 1.39 = 2 sets

whole space required for this equipment = 2 * 11.13 = 22.26 m^3

- 140 MBPS Digital Mux Equipment (Full System)

maximum stock level / a period of time = 1 set

safety stocks = 0.32

total storage numbers = 1 + 0.32 = 1.32 = 2 sets

whole space required for this equipment = 2 * 2.60 = 5.20 m^3

- Digital Line Concentrator DCS-20 for 2MBPS PCM Transmission

maximum stock level / a period of time = 1 set

safety stocks = 0.45

total storage numbers = 1 + 0.45 = 1.45 = 2 sets

whole space required for this equipment = 2 * 1.74 = 3.48 m^3

- Microwave Minilink Equipment 13GHz 34MB

maximum stock level / a period of time = 1 set

safety stocks = 0.41

total storage numbers = 1 + 0.41 = 1.41 = 2 sets

whole space required for this equipment = 2 * 8.86 = 17.72 m^3

Therefore, total space for storing the mentioned inventory per one period of time, equal to the sum of the space required for each equipment = 9.52+4.32+29.10+33.39+1.20+22.26+5.20+3.48+17.72 = 126.19 m^3

Recommended Storage System

Telecommunication system is always developing. The system currently used will not be efficient in the near future and the equipment installed in that system will be replaced by the new one. Consequently, there will be new equipment in the warehouse either for substitution or increase the Stock Keeping Unit. Flexibility to change the physical layout of the warehouse is important.

According to the rapidly change of telecommunication system, several new product's parts and technologies are required to be changed and improved which creates more stocks and also affects the current storage system. To organize all the changes in terms of handling system and space utilization, shelf-life becomes a significant issue to be concerned in order to minimize dead-stock products' parts regarding technology change. The equipment that firstly deposited in the warehouse should be the first one retrieving. The First In First Out (FIFO) storage system is a suitable and most effective method to eliminate this problems.

Whole set of the inventory under my study, telecommunication equipment, consists of many items which are separated packed in many containers. Some delicate parts require the storage system with the equipment protection characteristic. Steel shelving and floor storage are currently employed in Ngamwongwan warehouse. The lightweight containers can be stored on the shelf while the heavy weight containers can only stored on the lower shelf. Unlike those two types; very heavy weight containers are not capable for shelf storing, they must be stored on the floor.

Unorganized stock inventory, allocated in different areas, of TOT 's current storage system creates gigantic problems for searching any required parts regarding my research experience with TOT such as

- Communication equipment is separately located in different containers.
- Location of each container type-size and weight
- Different locations of steel shelving and floor storage in Ngamwongwan warehouse.

All these complicated issues lead to the inconvenience working and unvalued to the organization. To make thing easier and be more efficient, a new effective storage-distribution system is truly needed.

From my study with TOT's storage systems, flexibility, FIFO,equipment protection, and whole-set distribution are the significant tools in order to implement a useful and effective storage system. Nowadays, there are various types of storage equipment being used. The equipment suited for storing the inventory under my study must perform those characteristics.

Steel shelving and floor storage, currently used in this warehouse, carries out the flexibility when FIFO is the distinct characteristic of flow rack. Pallet rack is one of the storage system that all types of the containers, large parts and small parts, can be stored together. The characteristics of each storage system, the advantages, and the disadvantages for using them are discussed in the following section.

Steel shelving

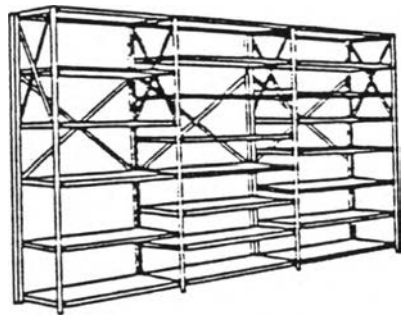

FIGURE 5.1 Steel Shelving

Characteristics of Shelving

One of the eldest methods of product storage which have not been much improved over the times is shelving. Shelving consists of four vertical posts that support one or more horizontal shelves. Versatility in the type and quantity of the stored goods are the major advantages of this fundamental storage method. Shelving, however, is not an inherently space-efficient storage technique since its cubic space utilization is usually lower than 50%. This poor space utilization is caused by two major reasons, poor use of the vertical space available and the potential for poor utilization of space in a given shelf space.

Poor use of the vertical space available in the warehouse usually exists in shelving installation. Common significant wasted-over-head space, for example, results from installations of 84-inch high shelving in warehouse with 20 feet of clear stacking height available.

Poor utilization of space in a given shelf opening results from the air space requirements. Air rather than product occupies more space in many shelves caused the requirements of reach-in accessibility to the stored items and improperly specifying the shelving for the product to be stored.

These space utilization problems directly result in high costs related to the amount of shelving required and the amount of warehouse space required for the shelving. Additionally, they indirectly lead to employee productivity losses in the warehouse, operator must travel greater distances to access shelf location.

Advantages

- Flexibility to stored the different size containers is allowed

Disadvantages

-Steel shelving is not suitable for a FIFO storage system because it is hard to ensure that the first container stored in the shelf will be the one pulled out first.
- Steel Shelving is most suitable for only storing packaged items,
-There are many aisles between each shelf for picking the containers.

Floor Storage

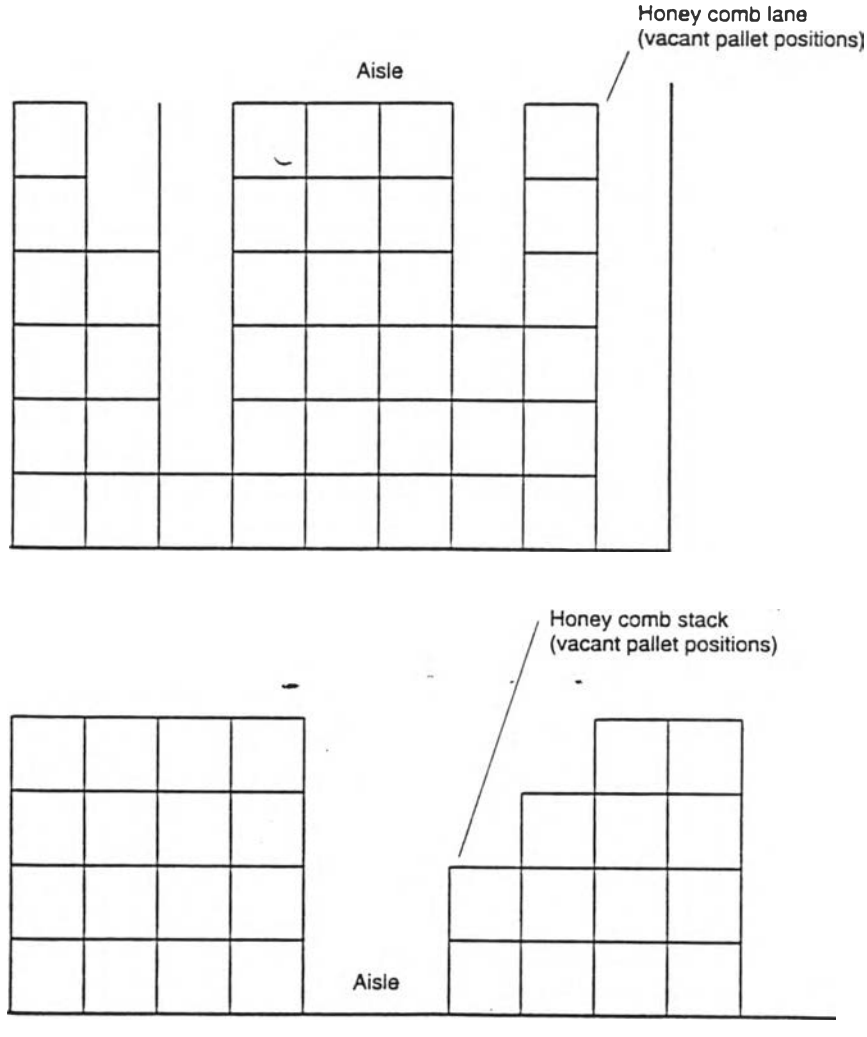

FIGURE 5.2 Floor Storage

Characteristics of Floor storage.

Containers are placed on the floor in the floor stack storage. A maximum of 6 to 10 containers deep per storage lane is allowed in this system. A storage lane is a single lane or back-to-back lanes. One pitfall of floor storage is that lift truck operator deposit and withdrawal productivity is usually reduced because of the leaning of unit loads and the variance of the unit load placement.

To utilize the space, additional unit loads are stacked onto the floor-unit loads. The unit load or product container on the floor must be capable to support the stacking weight. Floor stack storage when full, offer the highest storage density with the lowest investment cost but poor unit load accessibility.

A 60 percent utilization factor occurs from honeycombing (vacant unit-load positions in the vertical stack) and vacant unit-load positions in the storage lane. These cause by normal lift truck pallet load transactions (withdrawals) from the lane. To perform a transaction, a lift truck uses only an aisle to enter and back out from the loading position of the storage lane.

The number of unit loads deep per storage lane is varied to bury building columns in or between the storage lanes. The floor storage system has a last in first out (LIFO) product rotation, handles a high throughput volume, and interfaces with wide-aisle and narrow aisle lift trucks.

Advantages

- Good space utilization in a very low ceiling warehouse is allowed
- The narrow aisles is required with hand stacking
- According to no shelf investment, floor storage performs the lowest cost system.
- Floor stack storage, when full, offers the highest storage density
- Floor storage has flexibility if there is a change in the physical layout
- The inventory, both of which are able and unable to load on the shelf, can be stored closely for distribution in whole set.

Disadvantages

- With hand stacking there are increased staff injuries and fatigue and staff productivity is low.
- Overhead storage space utilization of floor storage system is low.
- Space usage is not maximized due to honey combing

Flow Rack

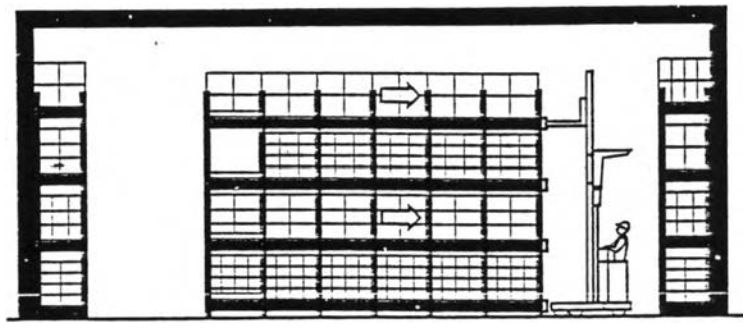

FIGURE 5.3 Gravity Flow Rack

Characteristics of Gravity Flow Rack

Gravity flow rack is a single rack that has one aisle for unit-load deposit and a second aisle for unit-load withdrawal. Usually, it is designed to include 3 to 20 unit load per storage flow lane. The unit load is placed onto a captive or slave pallet board to ensure a smooth flow through the flow lane. However some systems employs the conveyor rollers instead.

A lift truck in deposit aisle places a unit load onto the conveyor at the deposit (entry) end of the storage flow lane. The unit load flows through the storage flow lane to the withdrawal (exit) end of the storage flow lane by the effect of gravity and it weight. The unit load is then stored in the lane for later removing by a lift truck from the exit end of the storage flow lane which allow the next unit load in the flow lane to move (index) forward to the withdrawal position.

The unit-load gravity flow system indexing movement of the unit loads from the deposit (entry) position to the withdrawal position allows each storage flow lane to accommodate one SKU per storage lane. This feature permits unit flow racks to have a utilization factor of 85 percent and to handle a high volume. Gravity flow storage with two aisles has high storage density and fair unit-load accessibility.

Advantages

- Flow rack system is a first in first out storage system. Containers are constantly being indexed forward, with the first container stored in the lane always being the first one withdrawn from that lane
- Flow rack is a high density storage system, good space utilization is provided.
- Truck travel distance is minimal because flow rack has one load and one discharge point for each time.

Disadvantages

- The extremely high cost is required for flow rack storage system
- Flow rack is very inflexible when it is necessary to change the physical layout of the warehouse.
- It is very expensive to rearrange the land depths, flow rack is not suitable for the telecommunication equipment which always be replace by others.
- Due to the moving parts having in flow rack, the mechanical failure can be occurred.

Pallet Rack

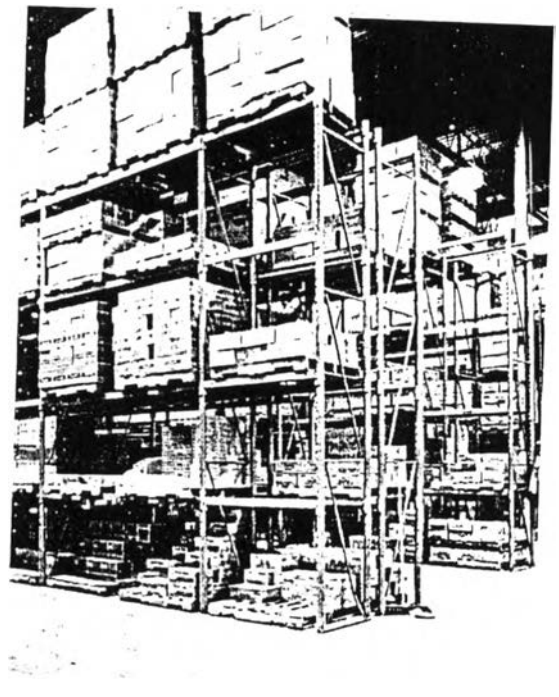

FIGURE 5.4 Pallet Rack

Characteristics of Pallet Rack

Steel pallet rack has been designed to maximize the storage space for the palletized products. The pallet rack with the drive-through aisle can provide First-In-First-Out (FIFO) storage operations, whereas drive-in racks only function with First-In-Last-Out (FILO) storage systems.

Selective pallet storage racks consist of upright frames and a pair of load beams for each shelf elevation. The rack design depends on the pallet and the unit load, including weight and overall dimensions. The overall height of the storage rack must be compatible with that of the maximum lift height of any lift truck equipment.

Advantages

- Good space utilization is provided for the products stored on pallet.
- Every kinds, including size and weight, of containers can be placed together on the pallet for whole-set distribution.
- The palletized products are easy to move.

Disadvantages

- The pallet racks require additional investment for the lift truck.
- There is a chance for the light-weight products to falling down from the pallets.

To design the storage equipment, the equipment containers should be categorized in 2 types, small-size containers (delicate parts) and big-size containers, for the effective storage system. There are many characteristics to consider, equipment protection, whole-set distribution, flexibility, and FIFO are the important characteristics in this case. Space utilization in the warehouse is the one that must be considered in order to make the profit from the area that has a great value. Other characteristics which should be considered are shown in table 5.10 and 5.11.

Comparison by weighing method of the four storage systems as mentioned in the previous section is done by questionnaire filling by the warehouse staff. The results are shown in the tables 5.10 and 5.11.

Score 4 means very good

Score 3 means good

Score 2 means acceptable

Score 1 means poor

Characteristics	Weight	Shelving		Floor Storage		Flow Rack		Pallet Rack	
Equipment protection	10	4	40	1	10	2	20	1	10
Space utilization	10	4	40	1	10	3	30	2	20
Whole-set distribution capability	8	2	16	4	32	3	24	4	32
Flexibility	8	3	24	4	32	1	8	3	24
FIFO	8	2	16	1	8	4	32	3	24
Cost saving	5	2	10	4	20	1	5	3	15
Ease to move	5	4	20	1	5	3	15	3	15
Ease to store	5	3	15	2	10	4	20	3	15
High density storage	3	3	9	4	12	3	9	3	9
Minimize truck travel distance	3	3	9	2	6	4	12	3	9
No mechanical failure	3	3	9	4	12	1	3	3	9
Total			208		157		178		182

TABLE 5.10 Characteristics-Comparison of Shelving, Floor Storage, Flow Rack, and Pallet Rack for small-size containers

Characteristics	Weight	Shelving		Floor Storage		Flow Rack		Pallet Rack	
Equipment protection	10	4	40	2	20	2	20	2	20
Space utilization	10	2	20	1	10	2	20	4	40
Whole-set distribution capability	8	2	16	4	16	2	16	4	32
Flexibility	8	3	24	4	8	1	8	3	24
FIFO	8	2	16	1	32	4	32	3	24
Cost saving	5	2	10	4	5	1	5	3	15
Ease to move	5	4	5	2	15	3	15	4	20
Ease to store	5	3	5	2	5	1	5	4	20
High density storage	3	3	6	4	9	3	9	3	9
Minimize truck travel distance	3	3	6	2	12	4	12	3	9
No mechanical failure	3	3	9	4	3	1	3	3	9
Total			157		145		145		222

TABLE 5.11 Characteristics-Comparison of Shelving, Floor Storage, Flow Rack, and Pallet Rack for big-size containers

Table 5.10 illustrates that shelving gets more scores when compare with floor storage, flow rack, and pallet rack. Hence, shelving is the suitable equipment for storing the small-size containers.

Table 5.11 illustrates that pallet rack gets more score when compare with shelving, floor storage, and flow rack. Therefore, pallet rack is the suitable equipment for storing big-size containers.

The recommended storage system is the mixed system between shelving and pallet rack, the delicate parts have to be stored on the shelve when the big-size parts are stored on the pallet rack. To perform the whole-set-distribution characteristic, each set of the telecommunication equipment, consists of many containers, must be stacked together on the pallet. The very heavy containers must be placed on the pallet, the heavy and the light packs are placed on them. Pallet rack is employed to maximize the horizontal space utilization. The stacking of each set should be arrange in order to maximize the space utilization on the pallet.

Shelving is employed to store the equipment that need good protection, delicate electronic parts, for instance. It is possible for drive-through rack to provide First-In-First-Out storage system. Therefore, the path for retrieving pallet and the equipment on the shelve must be the one-way path as indicated by the arrow in the figure 5.5.

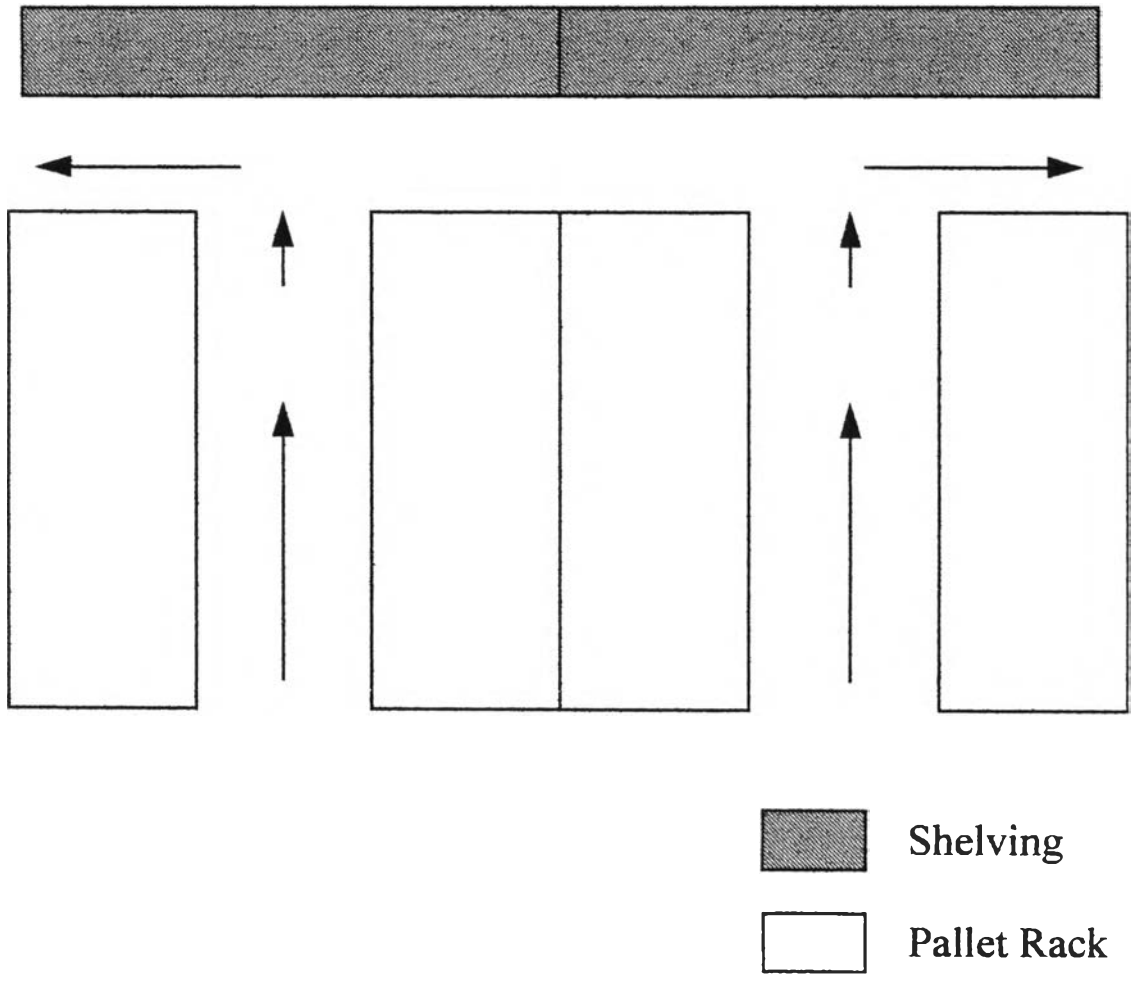

FIGURE 5.5 The Path for Retrieving the Products

Pallet rack and shelving for each equipment must install closely, as shown in figure 5.6, to minimize the truck travel distance in withdrawal process.

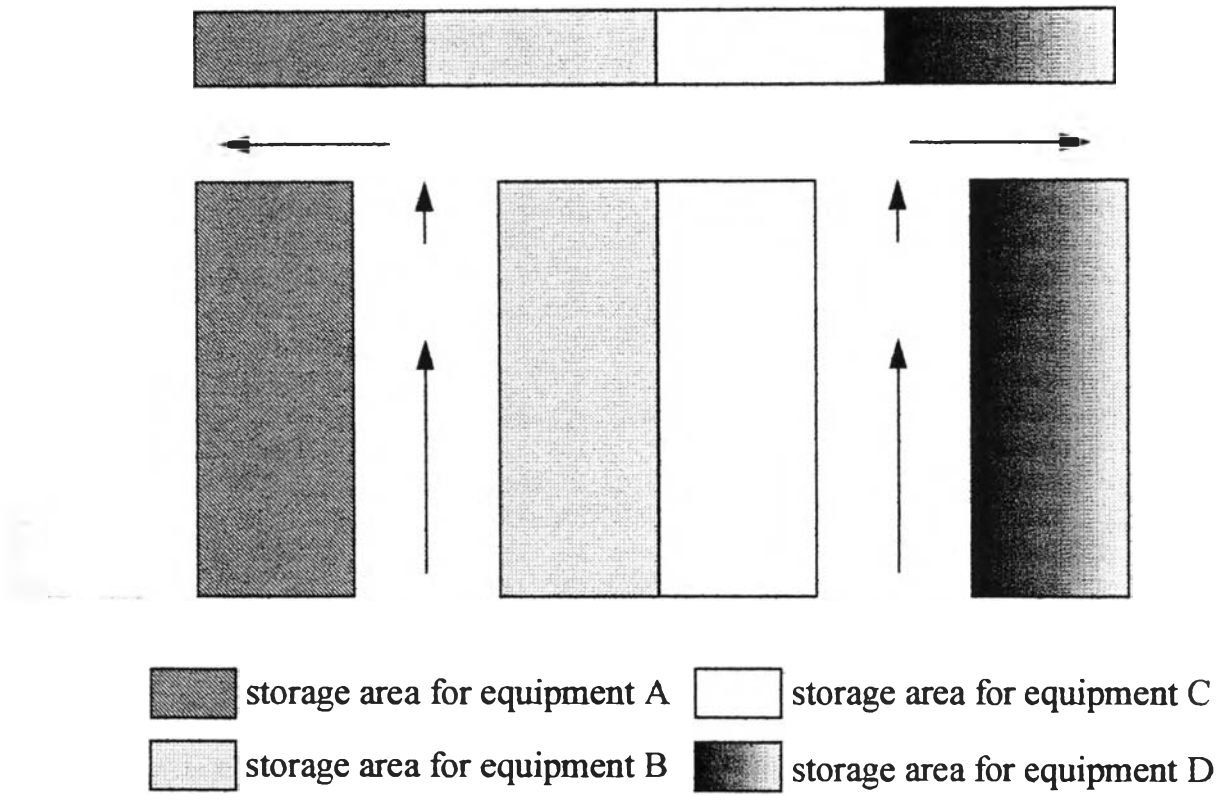

FIGURE 5.6 Storage Area for each Equipment

There is not much loading and retrieving process in this warehouse, which can see from chapter 4 that the monthly demand of each equipment is not much. Therefore, the manually controlled lift, as shown in figure 5.7, must be employed for retrieving the pallets of equipment containers from pallet rack. This kind of lift truck does not move fast so the warehouse operators can easily control the direction of it. According to the slow moving when compare with the power lift truck, the chance to hit the rack and cause damage to the products is low. For the shelve, loading and retrieving process are done by hand.

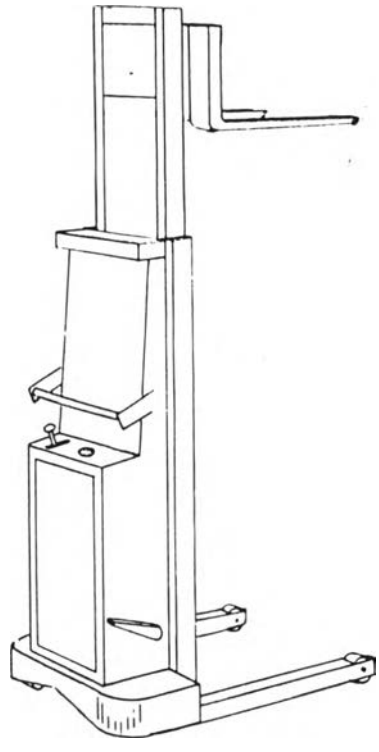

FIGURE 5. 7 Manually controlled Lift

The other characteristics that should also be considered are the ease for handling all containers in one set and transporting to another place, the exchange for instance. Because of the three-different-space storing which are located far apart, the truck travel distance for retrieving a set of equipment from all space are usually long. The huge size and very heavy containers, especially in the open air space, is hard to carry for a long way. Designing the drive in area, as shown in the figure 5.8 in the warehouse can minimize the truck travel distance.

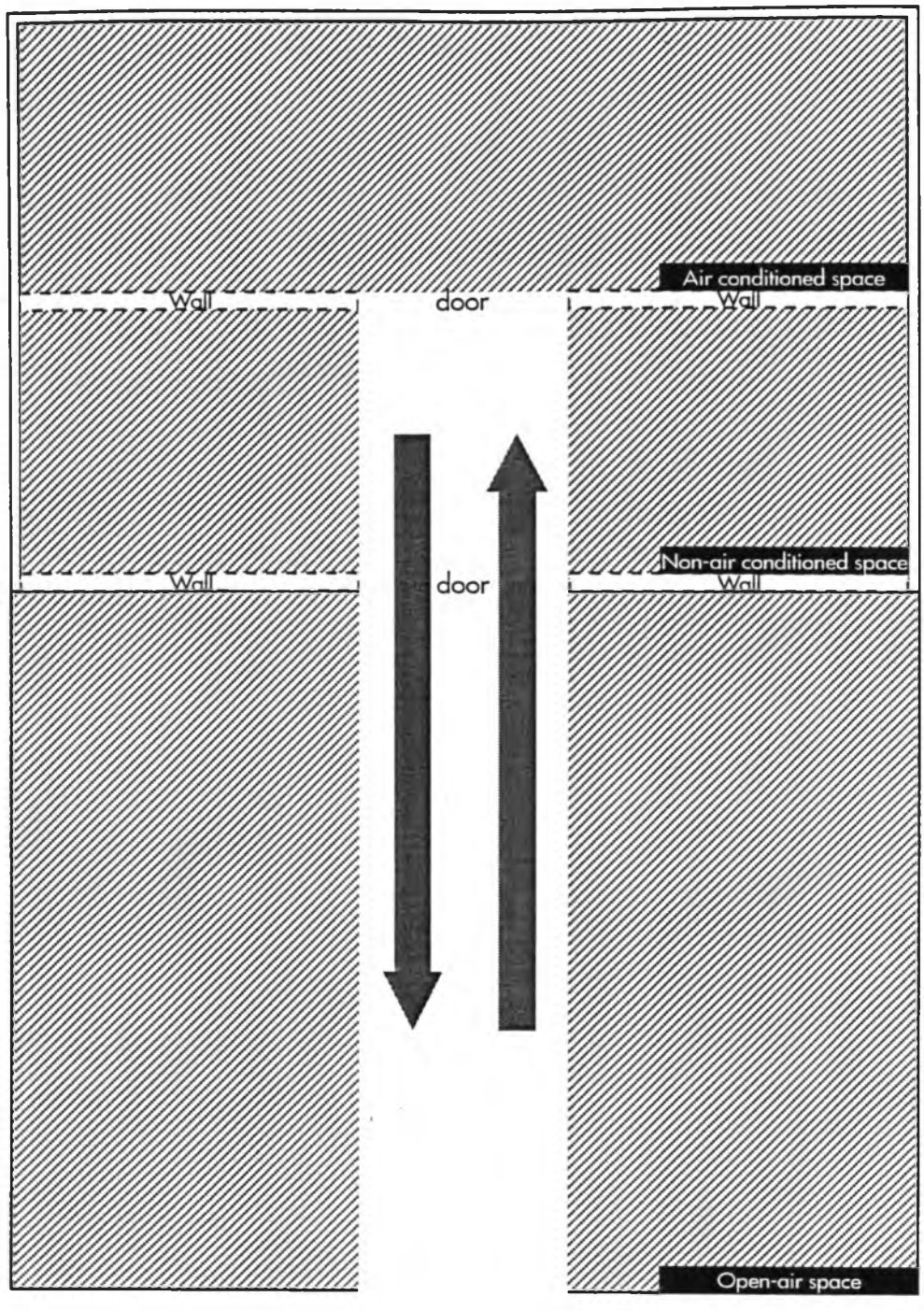

FIGURE 5.8 Warehouse with the Drive-In Area