PC COMPUTER BASED ALGORITHM FOR THE SELECTION OF
MATERIAL HANDLING EQUIPMENT FOR A DISTRIBUTION WAREHOUSE
BASED ON LEAST ANNUAL COST AND OPERATING PARAMETERS

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This thesis is dedicated to my mother, Aminah Hidajat K., my wife Reni Kusriani and my daughter Nadiya Amalina for their continuous love and support.
ABSTRACT

Warehousing does not add value to a product. On the contrary, warehousing is strictly an additional cost activity. It is a portion of the business system which affects the relationship of materials and packaging to the product, the facility, and the customer without adding usable worth or changing the nature of the product. The functions of a warehouse are receiving, storing, picking and shipping. Although these activities do not change the nature of the product, they are an essential part of the business.

Since warehousing is a necessary and additional cost activity, it is important to maximize the effective use of warehouse resources (space, equipment and labor) while satisfying customer requirements.

This thesis discusses the selection of several alternatives of material-handling equipment configurations for pallet handling and order picking in the distribution warehouse. The selection criteria is least annual cost subject to the ability of the equipment to satisfy the warehouse's operating parameters (load capacities and building limitations). The material handling equipment selection considers the materials to be handled, the activity pattern, and the building conditions. The materials to be handled are in unit common denominators, such as a pallet, tote-box, box, etc., and the load rate. The building conditions are building clearance height and column spacing.

The process begins with the evaluation of the equipment as to whether or not it can accommodate the load rate of the material and whether it is appropriate within the building limitations. All equipment options which meet these criteria are evaluated on the basis of annual cost. The annual cost consists of two major costs: Inventory-related costs and transaction-related costs. The inventory-related costs include building cost and inventory cost, while the transaction costs include labor cost and vehicle cost.

After the equipment has been ranked according to least annual cost in each storage, the compatibility of the equipment is evaluated. The equipment which has the least annual cost and is compatible with other equipment in the warehouse is selected. Once equipment configurations is established, the storage area needed to support the inventory is determined. The number of equipment units, the number of laborers, and the number of docks required to support the warehouse operations are also determined.
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1.1 History of Warehousing

Warehousing systems have been in existence since the early civilizations, where they were used to store food for later use. The primary function of earlier warehouses was to store agricultural products. As civilization developed, the role of the warehouse became broader and more complex. Warehouses were used not only for storing food, but also for stock piling, product mixing, and distributing merchandise.

A major influence in the development of warehousing concepts was the growth of manufacturing, trading, and new methods of transportation. Today, warehousing plays an important role in business and is one of the activities to be considered due to its functions in business.

1.2 Warehouse Definition

A warehouse can be defined according to the functions it performs. These functions include:
1. Receiving goods from a source.
2. Storing goods until they are required.
3. Picking or selecting goods when they are needed.
4. Shipping goods to the appropriate user.

While all warehouses share some common functions, there exists some distinctions among warehouses. These distinctions
include the source of materials, the management, and the user of the warehouse. Raw material warehouses, finished goods warehouses, and distribution warehouses are all different in terms of the source and user. A raw material warehouse receives materials from outside sources. The materials are stored, picked when needed, and then shipped to inside users. A finished goods warehouse receives materials from an inside source, stores, picks when needed, and ships to outside users. A distribution warehouse receives goods from outside sources such as suppliers and manufacturers, stores the materials, picks orders, and ships to outside users. This research is limited to distribution warehouses.

Practical Order Picking (12) describes the characteristics of a distribution warehouse as:

1. Highly diverse packages.
2. Varying order rates.
3. Fluctuating inventory levels.
4. A wide range of merchandise values.
5. Varying product mix.
6. A large variety of outbound transportation.

1.3 The Value Of Warehousing

There are a number of important benefits of warehousing. These benefits include:

1. Timeliness, i.e. the availability of the goods or materials when needed at the right time, at the
right place, and at the right amount.

2. As a mixing point, i.e. a warehouse draws production together from different plants and mixes products for filling customer orders.

3. As a buffer between production and distribution.

4. As a sales branch and customer service facility.

1.4 Operating Decisions in a Warehouse

A warehouse exists for the purpose of storing inventory. The success of managing a warehouse basically depends on how one makes decisions and sets policies concerning inventory control in the warehouse. Many of these decisions are made without consulting the warehouse manager. Such decisions may include determination of lot size, order quantities, safety stock levels, and so on.

Nevertheless, there are several decisions and operational policies for which the warehouse manager is often held directly responsible. According to Richard E. Ward (17), one such set of decisions relates to matters of space utilization, equipment selection, and equipment utilization. Another set relates more to the handling of inventory transactions and keeping track of items stored in the warehouse.

James A. Tompkins (15) believes that a successful warehouse maximizes the effective use of the warehouse resources while satisfying customer requirements. The resources of a warehouse are space, equipment, and personnel.
The equipment resources of a warehouse are many. They include: material-handling equipment, storage equipment, data processing equipment, and dock equipment. Because the equipment represents a sizable capital investment in a warehouse, the proper selection and use of equipment to obtain an acceptable rate of return on the investment is critical.

1.5 Statement of the Problem

Warehousing does not add value to a product. On the contrary, warehousing is strictly an additional cost activity. It is a portion of the business system which affects the relationship of materials and packaging to the product, facility, and customer without adding usable worth or changing the nature of the product (10). The activities of warehousing are receiving the material, storing, picking, and shipping. Although these activities do not change the nature of the product, they are essential for the business because of the timing of goods flow.

Warehousing is part of the distribution cost, specifically that which deals with outbound movement of material from the point of manufacture to the point of consumption (15). Table 1.1 shows the distribution cost component for various industries according to the United States Department of Commerce. Note that the distribution cost for department stores and variety stores is nearly 50% of the total product cost. Twenty one (21) percent of distribution
Table 1.1 Distribution cost as a percentage of total cost including advertising.

<table>
<thead>
<tr>
<th>Type of Industry</th>
<th>%</th>
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<tr>
<td>Food</td>
<td>18</td>
</tr>
<tr>
<td>Auto parts</td>
<td>27</td>
</tr>
<tr>
<td>Department store (chains)</td>
<td>43</td>
</tr>
<tr>
<td>Variety store (chains)</td>
<td>49</td>
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Cost is the warehousing cost, therefore, more than 10% of the product cost is a warehousing cost. Figure 1.1 depicts warehousing cost as part of distribution cost.

* Order Processing, administration, etc.

Figure 1.1 Breakdown of distribution cost (From Andre J. Martin and Oliver Wright (8), Distribution Resources Planning, Limited Publications And Prentice Hall, Englewood Cliffs, NJ, 1983, chap 1, p. 8).

Since warehousing is a necessary and additional cost activity, it is important to reduce the warehousing costs by selecting the most appropriate and cost effective material-handling equipment.

This research will investigate a methodology by which the
selection of the proper material handling for pallet handling and order picking in a distribution warehouse can be determined.

1.6 The Objectives of This Research

The primary objective of this research is to create a software package which will:

1. Select material-handling equipment for a distribution warehouse based on the lowest annual cost, the required capacity, the operation requirements, and the building conditions (for existing buildings).

2. Determine the amount of equipment and labor required to perform the needed operations based on the equipment selected in (1) above.

3. Define the area, number of building modules, and docks needed.

The selection is constrained by:

1. The characteristics of the material being handled and stored (shape, environment, stackability).

2. Existing building limitations which include dimensional and structural design characteristics such as aisles, overhead clearances, floor loading, door dimensions, column spacing, elevator capacity, ceiling height, etc.

3. Cost, as it applies to the price paid by the
warehouse owner and consumer for warehousing services.

4. Available funding.

5. Operational safety.

In short, although warehousing is a necessary activity for business, it is strictly an additional cost activity. This research will attempt to determine a methodology for reducing the cost of a warehouse, particularly a distribution warehouse, by selecting the appropriate material handling method and equipment, defining the required quantity of equipment and labor, and determining the necessary area.
2.1 Material-Handling Equipment

Material handling is concerned with the movement, storage, and control of materials (5). The material handling equipment must be capable of dealing with product size and weight variations, as well as be flexible enough to accommodate alternate routing throughout the facility. Richard E. Ward (17) emphasizes that material handling can play an important role in the control of inventory in a warehouse. He suggested that the selection of material-handling systems and the utilization of such systems must consider several factors, including 1) matching a system's capability and versatility to the needs and handling ability of the items to be transported and 2) system sizing with regard to throughput capacity and load carrying capacity.

E. Ralph Sims (10) suggests that the selection of material-handling equipment should consider the proper classification by application of equipment, the reliability of the material handling selected to do the job, economics, management, financing, labor relations, safety, plant characteristics, environment, and many others. Sims also points out that the major proportion of the indirect costs in manufacturing are included in the cost of material handling. Because of this, selection of the material-handling
system should consider both the initial system costs and the costs of operating the system. Sims suggested that the selection of material-handling equipment for industrial facilities is based upon the ability of the equipment to:

1. Reduce handling cost.
2. Reduce inventory requirements.
3. Improve space utilization.
4. Shorten work cycles.

The Warehouse Modernization and Layout Planning Guide (18) explains that the storage and material-handling system is basically a function of the items to be handled, the activity pattern, and the building conditions in which the operation is to be performed. It also suggests that the first step toward the establishment of storage and material handling equipment in the warehouse is to define the function or mission and activity profile of the facility under consideration. The next step is to determine the availability of standard storage and material-handling equipment with dimensions and characteristics which are compatible with and appropriate to the inventory profile, activity pattern, and material module to be handled. The choice of equipment types is determined by the product characteristics, handling modules, and transaction rates which in turn determine the dimensional patterns of the facility layout and the configuration of the handling system.

The Practical Handbook of Warehousing (1) describes that
a warehouse is more than a mere building; it is the selection and use of the equipment that goes inside that can spell the difference between profit and loss. The equipment choice is usually governed by the following criteria:

1. Degree of desired flexibility for different uses.
2. Nature of the warehouse building (for an existing building).
3. Nature of the handling job—bulk, unit load, individual package, or broken package distribution.
4. Volume to be handled by the warehouse.
5. Reliability.
6. Total system cost.

*Warehouse Operations Planning and Management* (3) lists five points which must be analyzed for the purpose of evaluating equipment:

1. Material to be handled.
2. Jobs to be covered.
3. Volume to be handled.
4. Production capacity of equipment.
5. Handling condition and situations.

It is important to consider three things with regard to the material to be handled: Material types, or general composition and style of the unit to be handled such as palletized, tote-box, carton, box, etc.; the material size and the physical proportions of the material; and the material weight with respect to the capacity of the equipment.
The job to be performed must be defined in detail before warehouse equipment is selected. It is necessary not only to consider what materials are to be handled, but also what jobs have to be covered. In the warehouse, the material-handling system can be divided into two major categories: Pallet storage systems and order picking systems (18). These two systems have different functions and consequently they have special jobs to be performed.

The volume to be handled is related to the material to be handled and deals with the weight to be moved, the number of units to be moved, or the items to be moved in a certain period of time.

The production capacity of the equipment is directly related to the volume to be handled. Production capacity is equal to the equipment capacity related to total speed and weight or volume to be handled in a man-hour. In calculating the production capacity of the equipment, it is assumed that the equipment is fully loaded at all times, which is not always true. Generally, the equipment runs unloaded half of the time, that being on its return to the loading area. In any event, the production capacity has to be considered in the selection of equipment in order to determine how many pieces of equipment are needed.

Handling conditions and situations are usually building limitations such as ceiling height, aisle width, and other building characteristics. E. Ralph Sims (10) lists building
limitations such as floor loading, door dimensions, column spacings, elevator capacities, ceiling heights, and many other installation characteristics which must be considered before a particular type of equipment is chosen for the job. In addition to the factors just discussed, the selection of material-handling equipment must also consider the total cost of the equipment.

2.2 Computer Aided Warehouse Design

Several computer software packages have been developed for warehouse design, most of them on mainframe computers. One such package CM-529 (18), was developed by the David W. Taylor Naval Ship Research and Development center (DTNSRDC). CM-529 is both interactive and 'user-friendly'.

CM-529 determines the least cost system and storage height which satisfies the criteria specified by the user. It also determines the least cost system at other applicable storage heights so that the user can examine systems at other specified heights regardless of system costs. The selection of a system to meet the specified requirements is under the control of the user who makes a selection considering unique requirements that can not be specified in the model.

DTNSRDC has also developed the 'Orr Construction Management System'. This model, referred to as CM-ORR, is commercially available. Data required for input of the model are generated by CM-529. Construction cost generated by this software is
more precisely detailed than that estimated in CM-529. CM-ORR can be used as a follow up to CM-529 in the development of budget estimates.

COFAD, which stands for Computerized Facilities Design, jointly determines a layout module and selects material-handling equipment. The inputs required by COFAD are alternative material-handling systems or equipment, a from-to chart for each equipment alternative, and an initial layout. The approach used by COFAD to develop a layout and select a material-handling system is based upon the following procedure:

1. Determine a layout.
2. Select a material-handling system.
3. Apportion the cost of the handling system to the individual moves.
4. Return to step 1.

COFAD then compares the cost of material-handling systems of the just completed procedure with prior procedures. The process is repeated until a steady state solution is reached.

In summary, in selecting a material-handling, there are several things to consider. Among them are the kind of material to be handled, the jobs to be covered, the volume to be handled, the production capacity of the equipment, and handling conditions and situations such as building limitations. The other important consideration is the total material handling system cost. The optimal material handling
system does not always produce the least cost, and vice versa. This research will choose the least cost material handling which can satisfy warehouse operation requirements.
CHAPTER III
SYSTEM DESIGN

This section discusses the hardware and software requirements for the algorithm designed in this thesis, and the specific requirements for the system environment so as to meet the objectives of this research.

3.1 Hardware Requirements

This package requires the IBM Personal Computer AT or XT, or IBM PC compatible with two disk drives or one hard disk and one floppy disk drive, a monitor for input and output on the screen, and a printer for hard copies.

3.2 Software Requirements

1. This package uses the dBase III Plus or higher version software package, or dBASE software compatible such as Fox Base.

2. The Operating system for the computer is DOS version 3.2 or higher.

3. The configuration system must have file equal to 30 and buffer = 20.

3.3 Program Requirements

1. A menu driven format designed to guide the user. The program assumes that the user does not have any computer programming experience.
2. A user's manual to supply detailed instructions, supporting help, and explanations of the program.

3. The program should provide on-line instructions to users for successful execution of the program.

4. The user should be able to choose to display the result either on the screen or printer. If the user chooses the output on the screen, it should remain on the screen until the user verifies the result.

5. A signal should be given whenever the user is inputing incorrect data or responses.

6. The screen output display and hard copy print out should be easy to read and well organized so that the user can interpret the results correctly.

7. To allow future enhancements to the program, the program should be well documented and easy to modify.

3.5 Output Requirements

The program should:

1. Select material handling equipment which meets the conditions of the warehouse operating parameters and determine the least annual cost for different zones in the warehouse.

2. Choose the most applicable equipment for pallet rack and rackable order picking based on equipment compatibility.

3. Calculate the required numbers of equipment units and laborers to support the operation requirement.
4. Compute the area needed in every zone in the warehouse to support the inventory profile and transaction rate.
5. Define the number of docks required to support the activities in receiving and shipping.

3.6 Model Design

The objective of this thesis is to develop and present a design model which can be used to determine the material handling equipment, space arrangements, and support functions (such as docks) necessary to operate a distribution warehouse. The selection of material handling equipment and space arrangement is basically a function of the items to be handled, the activity pattern, and the building conditions in which the operation is to be performed.

3.6.1 Dimensional Considerations

The relationship between the material handling equipment, performance characteristics and building dimensions, play a critical role and are factors in the development of warehouse operations. There are a number of material handling equipment and storage systems available on the market. Every equipment type or system has its own characteristics such as aisle width, speed, acceleration, etc. Storage systems such as racks and shelves have a variety of internal dimensions, e.g. column and rail thickness, etc.

Consequently, the design of a warehouse must consider the characteristics of the material to be handled and stored
(shape, environment, stackability, etc.), the volume flow pattern through the facility (transaction and cube movement rate profile), the inventory pattern (item count, item cube, quantity mix, and inventory turnover patterns), and the flexibility of the equipment to accommodate all conditions of material mix and movement, and level of activity of the warehouse.

The material handling equipment should consider the limitations of the building such as building height and column pattern. The optimal equipment and storage types must conform to those limitations. In a new building, the building structure must be designed to accommodate the optimum material handling system. In other words, the selection of material handling equipment which considers the activity profile of the warehouse is done before the building is designed.

3.6.2 Handling Classifications

According to the Warehouse Modernization and Layout Planning Guide there are three basic handling classes of storage to be considered in the warehouse system. They are as follows:

1. Bulk material: The term bulk material refers to high cube and large lots of items. Bulk material is usually stored in bulk storage. Bulk material must be capable of being stacked. An example of bulk material is paper products.

2. Palletized material: Various sizes, shapes, and
configurations of packaged products are usually stored in a pallet. These items can be classified as pallet rack type merchandise and usually packed in single units or manhandlable packages and stored in multiples on pallets.

3. Shelf or bin material: This material category includes hand picked items such as electronic and mechanical components, tools, etc.

3.6.3 The Selection Of Material Handling Equipment

A general methodology for the selection of material handling equipment is shown in Figure 3.1. A more detailed procedure for the selection of material handling equipment is discussed in Chapter Five. In general, the selection of material handling equipment is based on least annual cost and operating parameters and can be described as follows:

1. Determine whether the facility under consideration is an existing building or a new building.

2. Establish the activity profile of the warehouse in terms of inventory profile and expected transactions rate.

3. Classify the inventory into handling by characteristics, such as bulk storage, pallet rack and bin storage.

4. Determine the load rates of the material to be handled.

5. Determine the building limitations for an existing building. For a new building, building limitations might be appropriate if there are foundation restrictions.

6. Select the equipment system which has the capacity to
MODEL SELECTION OF MATERIAL HANDLING EQUIPMENT

START

1. DETERMINE THE FACILITY UNDER CONSIDERATION

2. ESTABLISH THE ACTIVITY PROFILE OF A WAREHOUSE

3. CLASSIFY THE INVENTORY AND TRANSACTIONS INTO HANDLING CHARACTERISTICS

4. DETERMINE THE LOAD RATES OF THE MATERIAL BEING HANDLED

5. DETERMINE THE BUILDING LIMITATION FOR AN EXISTING BUILDING

6. SELECT THE EQUIPMENT WHICH CAN HANDLE THE LOAD RATE

7. EXAMINE WHETHER THE EQUIPMENT MEETS BUILDING LIMITATIONS

8. BASED ON THE ACTIVITY PROFILE, DETERMINE THE INVENTORY & TRANSACTIONS RELATED COST

9. CALCULATE THE ANNUAL COST BASED UPON THESE TWO COSTS

10. SELECT THE EQUIPMENT WHICH HAS THE LEAST ANNUAL COST

11. ESTABLISH THE EQUIPMENT SYSTEM IN THE WAREHOUSE

12. ESTABLISH THE STORAGE AREA NEEDED, NO. OF EQUIPMENT, LABORERS, AND DOCKS REQUIRED TO SUPPORT THE ACTIVITY PROFILE

Figure 3.1
handle the load rates for a particular storage system.

7. Choose the equipment which complies with the building limitations.

8. Determine the transaction related cost and inventory related cost.

Transaction cost is determined by the transaction time needed to store or retrieve the material placed in storage. These transaction times have been determined by the Warehouse Modernization and Layout Planning Guide. Based upon the transaction time, the vehicle and labor hours can be established. Labor and vehicle cost are calculated by using the standard cost for vehicle and labor.

The inventory related cost is determined by two elements. The first is the area required by a common denominator such as a pallet, tote-box, box, etc. Based upon the area required, the building cost can be calculated using the standard cost for building construction and maintenance cost which has been developed by the Chesapeake Division of NAVFAC. The second element of inventory cost is storage cost. The storage cost uses standard cost per unit common denominator for a particular type of storage times the number of inventory units in the inventory profile.

9. After the transaction and inventory cost are established, the annual cost can be established by summing these two
costs.
10. Repeat for other equipment systems in the same storage system.
11. Select the least annual cost among the equipment selected for a particular storage system.
12. Repeat the evaluation for all other storage systems, from (6) to (11).
13. Choose the equipment systems for pallet rack and rackable order picking which have the least cost and equipment compatibility.
14. Lastly, the model establishes the storage area required to support the inventory profile, and the number of equipment units, number of laborers, and number of docks to support the activity level.

For the purpose of analyzing the selection of material handling systems and equipment, the package uses data from the Warehouse Modernization and Layout Planning Guide. The data presented in this book is based on 1983 costs. The adjustment of the cost data presented in this thesis to current costs is necessary for the best analytical use of the model. The model does not need to be modified to run current data.
A basic concept which must be dealt with in the design of warehouse operations is that the distribution warehouse is a physical manifestation of marketing policy. A distribution warehouse has such characteristics as highly diverse packages, varying order rates, fluctuating inventory levels, a wide range of merchandise values, varying product mix, and a large variety of outbound transportation modes and schedules.

A warehouse is essentially an integrated system of several elements or subsystems. Figure 4.1 illustrates a warehouse system and its subsystems. The subsystems of a warehouse generally reflect its functions: receiving, storing, picking, and shipping of the goods.

4.1 Receiving

Receiving can be defined as that activity concerned with the orderly receipt of all material coming into the warehouse, the necessary activities to ensure that the quantity and quality of such material is as ordered, and the disbursement of the materials to the organizational functions requiring them. The primary objectives of a receiving system are (15):

1. Safe and efficient unloading of carriers.
2. Prompt and accurate processing of receipts.
3. Checking the material quantity and inspecting the quality.
Figure 4.1
4. Maintaining accurate records of activities.
5. Disbursing receipts to appropriate locations for subsequent use.

The receiving function is primarily one of information processing rather than physical handling. Consequently, it is desirable to plan and concentrate the information-related tasks into as few steps as possible. Figure 4.2 and figure 4.3 illustrate the flow chart of the steps in receiving as related to information processing and physical handling. The flow chart is divided into two areas. The first relates to the carrier which brings the material to the warehouse and the second relates to the supplier which sends the material.

4.2 Storing

The primary objective of a warehouse is the storing and distributing of the inventory. After the materials have been accepted by the receiving department, they must be stored. To provide an effective design for physical storing, the materials should be unitized on pallets, tote boxes or other containers. To determine the storage destination the materials are identified. Once the materials are properly identified, the control system will determine where the materials should be stored. Figure 4.4 and Figure 4.5 show the flowchart for moving material from receiving to storage.

This thesis assumes that there are three levels of storage in the warehouse: bulk or floor storage, pallet rack storage,
RECEIVING FLOWCHART
(CARRIER RELATED)

MAT'L COMING AT RECEIVING DOCK

EXPECTING

CHECK TO PURCH. DOC.

ACCEPT?

Y

N

UNLOAD MAT'L

COUNT THE NUMBER OF CONTAINERS

COMPARE TO BILL OF LADING

ANY DIFFERENCE?

NOTE THE DIFFERENCE IN THE NUMBER CONTAINERS

Y

N

INSPECT THE CONTAINERS

ANY DAMAGE?

NOTE NUMBER OF CONTAINERS DAMAGED

Y

N

APPROVED BILL OF LADING
SEND THE MAT'L TO QTY CHECKING

Figure 4.2
RECEIVING FLOWCHART (CONT.)
(SUPPLIER RELATED)

1A

INSPECT THE QTY

DOES QTY = ORDER?

N

NOTIFY PURCH. DEPT. ABOUT THE DIFFERENCE

Y

CONFIRM THE QTY HAS BEEN CHECKED

ACCEPT?

N

RETURN TO VENDOR

Y

ACCEPT?

RETURN TO VENDOR

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CONFIRM THE QTY HAS BEEN CHECKED

ACCEPT?

RETURN TO VEN...
STORING FLOWCHART

Figure 4.4
STORING FLOWCHART (CONT)

1

IDENTIFY MAT'L & DECIDE WHERE TO PUT IT

DESTINATION ASSIGNED

Y
TRANSPORT MAT'L TO ACCUMULATION
ROUTE TO ACCUMULATION POINT

N
TRANSPORT MAT'L TO STORAGE DEST.

ROUTE THE MAT'L TO STORAGE DESTINATION

STACK ?

Y

ACCUMULATE

N

FULL ?

Y

DEPOSIT THE MATERIAL

GO TO NEXT ITEM

N

DEPOSIT THE MATERIAL

GO TO NEXT ITEM

Figure 4.5
and bin or shelf storage. These storage areas have distinct characteristics in terms of the way material is stored.

4.2.1 Bulk Storage

The term bulk storage refers to the storage of palletized or packaged material having a relatively large quantity of loads per item.

The objective of bulk storage is primarily to maximize access while minimizing aisle loss. The application of bulk storage practices is common for items which have the physical capability of being stacked and have a large quantity of inventory. Figure 4.6 shows a typical bulk storage system. The rule of thumb for using bulk storage methods is to apply them to items which have at least four pallets of inventory. According to the Warehouse Modernization and Layout Planning Guide, it is advantageous to store four pallet loads of an item in a single depth lane. The choice of using bulk storage versus other kinds of storage such as storage racks, should be based on the number of high inventory items. If only a few items have large lots, it may be more costly to have bulk storage. On the other hand, if a large number of items represents a significant part of the total units in inventory, a bulk storage technique may be used.

There are two types of equipment used for bulk storage: the counterbalance truck and the reach truck (Figure 4.7). To determine the type of equipment that will be used for bulk
Figure 4.6 Typical Bulk Storage (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
Figure 4.7 Counterbalance truck and Reach truck (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
storage the designer should consider column spacing, overhead clearance of the building and the maximum lifting capability of the machine.

4.2.2 Pallet Storage

Pallet storage is primarily used for storing pallet loads or a wide variety of shapes and sizes of merchandise. The criteria for deciding which items will be stored on a pallet rack is usually based upon handling criteria. Figure 4.8 shows a typical pallet rack storage. A simple rule of thumb is: items with 32 cubic feet or more of inventory and not exceeding the equivalent of one stack of pallets (three, or four pallet stacks depending on warehouse stack height) or items which have two or more pallets but cannot be stacked should be stored on pallet racks.

The standard load size for pallets used in this thesis is adapted from The Warehouse Modernization and Layout Planning Guide. The size is 40 inches deep, 48 inches wide, and an average of 28.8 inches high including pallet. This load size occupies 32.0 cubic feet. The maximum load size permitted is 43 inches deep, 52 inches wide and an average of 36 inches high including pallet, providing load overhang on all sides. This is the U.S. Navy standard upon which the NAVSUP 529 is based. The GMA (Grocery Manufacture Association) pallet is 48" x 40" and if used would somewhat alter the calculations in this thesis.
Figure 4.8 Pallet Rack Storage (Adapted from Order Picking Systems, by E.R. Sims Jr., Wright State University, College of Continuing and Community Education, 1985.)
It is important to determine the type of equipment that will be used for pallet rack storage in the warehouse. Different equipment has distinct characteristics such as aisle requirements, lift height capacity, etc. These characteristics must be considered and accounted for in providing ample operation clearances in the pallet rack design so that the storage system can function properly. The types of equipment available for handling pallets are:

1. Counterbalanced (wide-aisle) (Figure 4.7)
2. Reach truck (narrow-aisle) (Figure 4.7)
3. Front/sideloader truck (Figure 4.9)
4. Turret truck (Figure 4.9)
5. Manned-up turret (Figure 4.9)
6. Hybrid truck (Figure 4.10)
7. Storage/Retrieval machine (Figure 4.11).

In designing a pallet rack storage system, several dimensions involving vertical and horizontal clearances must be defined. Figure 4.12 illustrates the vertical dimension considerations used for the development of overhead clearances. All overhead obstructions such as sprinkler pipes, heaters, drain lines etc. must be above the clearance line.

4.2.3 Binnable Storage

The primary function of a binnable storage system is to store small parts or packages. According to Donald J. Weiss and Michael A. Cramer (20) there are two classifications for
Figure 4.9 Front/sideloader truck, Turret truck, and Manned-up Turret truck (Adapted from The Sims Consulting Group, Inc., Lancaster, Ohio)
TYPICAL HYBRID TRUCK

Figure 4.10 Hybrid truck (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
TYPICAL
CONSOLE CONTROLLED S/R MACHINE

Figure 4.11 Storage/Retrieval Machine (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
ALL OVERHEAD OBSTRUCTIONS TO BE ABOVE THIS LINE

6 CLEARANCE ABOVE TOP PALLET
   (Will vary with equipment).

5 PALLET AND LOAD SIZE

4 PALLET RACK BEAM SIZE
   (Available in 3", 4", 5" and 6")

3 CLEAR OPERATING SPACE ABOVE PALLET
   (Will vary with equipment, elevation and operator)

2 VERTICAL PALLET RACK SPACING INCREMENTS
   (Available in 2", 3" and 4")

1 BOTTOM PALLET RACK BEAM SPACING
   (May vary from 0" to 20" above floor)

BUILDING PARAMETERS
ELEVATION REQUIREMENTS

---

Figure 4.12 Building Parameters Elevation Requirements
(Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
small parts storage: static and dynamic. The difference between the two concepts of storage is based upon how the stored material is accessed. A dynamic storage system moves the material from storage to a fixed personnel location where picking and stacking occur, while in a static storage system, the warehouse personnel access the storage by traveling to a stationary storage location. Typical equipment used in dynamic storage are the carousel, miniload S/R systems or manned S/R systems. Typical static storage systems are shelving, bins, modular drawers and roll through shelving.

4.2.3.1 Static Storage

4.2.3.1.1 Shelving Storage

The main objective of shelving storage is storing small hand stackable items which are not suited to mechanized handling and storage due to their handling characteristics, activity or quantity. For order picking purposes either manual or mechanized shelving is generally used for small parts storage. Shelving is a very basic storage method that affords the user significant flexibility in the type and quantity of goods that can be stored at a relatively low capital investment. Due to this advantage, shelving is a popular small-parts storage technique in the warehouse. Figure 4.13 shows typical shelving storage.

In spite of its benefits, shelving is not an inherently space-efficient storage technique. In fact, cubic space
utilization within a typical shelving installation is often less than 50 percent (15). There are two main reasons for this. The first is that shelving installations often make poor use of the vertical space available in the warehouse and the second is the potential for poor utilization of space in a given shelf opening.

In low level ceiling storage, low level shelving is the most appropriate. Low-level shelving is simply a single elevation of shelving units resting on the floor. This shelving unit is typically no more than 84 inches in height to allow warehouse personnel on the floor level access to the top-most shelf.

To improve space utilization, multiple deck shelving is desirable. In high level ceiling areas, consideration should be given to specific shelving mezzanines or high-rise shelving systems. Mezzanine shelving (Figure 4.13) typically consists of two or three elevations of the shelving units bolted together vertically, with a mezzanine walkway in the aisle of the upper elevation. The operator walks on the aisle mezzanine for access to the upper level.

High rise shelving provides efficient vertical space utilization and increases labor productivity by increasing the speed with which warehouse personnel move within the system.

4.2.3.1.2 Bins

In general applications, bin storage represents a small
CLOSED TYPE SHELVING WITH DIVIDERS BIN FRONT, BOXES, AND MULTI-LEVELS

TYPICAL MULTI-LEVEL SHELVING ARRANGEMENT

DOUBLE DECK MANUAL SHELF PICKING

TYPICAL MANUAL SHELVING SYSTEMS

Figure 4.13 Typical Manual Shelving Systems (Adapted from The Sims Consulting Group, Inc., Lancaster, Ohio)
part of the total storage system in terms of physical space. However, it may represent a significant portion of the total storage in terms of item positions. The application of bin storage and shelving are identical. The only difference is that bin storage is generally applied to smaller items which do not need the entire width of a conventional shelf module.

4.2.3.1.3 Modular Drawer

Modular drawer cabinets have certain advantages compared to shelving and bins for selected applications. As discussed above, the inherent disadvantage of shelving storage for small parts is the inefficient use of space within a given shelf opening. The smaller the items, the more difficult and expensive it is to shelve. Drawer cabinets provide an alternative storage method which enables one to fit the size of the space to the size of the items to be stored. Additionally, modular drawers can be portioned into much smaller storage cells. This provides higher density, improved organization, and greater utilization of storage space. Drawer cabinets can contribute other advantages such as providing secure enclosed storage for small or high value parts. According to a special report on storage (13), modular storage drawer systems can cut the space required to fifty percent (50%). Figure 4.14 shows a typical modular drawer.

The major disadvantage of modular drawer storage is its relatively high investment cost. The smaller the object to be
Figure 4.14 Typical Drawer Type Storage Cabinets (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
stored, the more economical the modular drawer. The larger the object to be stored, the more economical shelving storage becomes.

4.2.3.2 Dynamic Storage

High density mechanized binnable parts systems such as mini-load or carousel provide dense storage and maximize the use of available storage height. These systems are applicable for high transaction rates and large inventory levels (17). By delivering the part to the order picker, operator travel time is reduced. With additional packing, checking or processing, which is impractical for a mobile order picking unit, these systems provide an effective solution. Typical dynamic storages are carousel, miniload S/R systems, and manned S/R systems.

4.2.3.2.1 Carousels

A carousel can be specified as a series of bins or baskets that are linked together in a continuous chain and mounted on an elongated oval track. The baskets are moved around the carousel unit under operator or computer control. The characteristic operation of a carousel delivers the bin to the warehouse operator, rather than the operator going to the bin. Figure 4.15 illustrates the typical carousel.

Although the carousel can provide high density storage and minimize operator travel, carousels have a limited height of approximately 7 to 10 feet. Increased storage heights can
Figure 4.15 Carousel Conveyor (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
be obtain by installing a multi level system or additional units on mezzanine levels.

The major benefits of a carousel are labor savings, increased throughput, improved control, space saving, reduced fatigue, and increased cube utilization (15).

4.2.3.2.2 Miniload S/R Systems

In miniload S/R systems, parts are stored in trays, and a tray of parts is retrieved by the machine and delivered to the end of the aisle. At this point the warehouse operator selects and picks the proper quantity of each material or part to complete an order, then places the items in an order accumulation container. The equipment automatically returns the storage tray of material to the system.

A miniload S/R consists of shelves that are arranged to form two single depth rows facing each other and a center aisle that provides the area in which the mechanical device travels vertically and horizontally, carrying the container in and out of the storage shelf location. Figure 4.16 shows a typical miniload S/R system.

Major advantages of miniload S/R systems are floor space savings, cube utilization, throughput speed, manpower reduction, less fatigue, control, security, and better process control of parts (15).

4.2.3.2.3 Manned S/R Machine

A system similar to the miniload S/R is a manned S/R
Figure 4.16 Typical Miniload S/R Machine (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
system. The contrast between the two is that the manned S/R system delivers the man to the storage locator to pick the material. This system may be used for either pallet order picking or small part order picking. The order picker has full access to all levels in the operation aisle. Items can be picked from either pallets or multiple tote boxes. At the input/output end of the system, the pallet or tote box used for order picking can be automatically conveyed if necessary.

This machine permits maximum utilization of available building space and significantly reduces floor area when space restriction is considered (17).

4.3 Order Picking

In many warehouses order picking is the largest single expense in the operation. For this reason, the order picking operation is frequently considered to be the most important of all materials handling functions. In addition, this operation is critical because it offers the greatest opportunity for error. The cost of an order picking error has been estimated as ranging from $10.00 to $30.00 for each occurrence (1). These costs are derived from picking mistakes, the cost of handling returns, the cost of supplemental shipments, etc., and finally, the almost unmeasurable cost of customer dissatisfaction or loss of confidence.

From the business point of view, order picking can be defined as the conversion of sales information into product
motion. Figure 4.17 illustrates the flow of information from customers or retailers in the form of an order through a paper work system (or data processing) and then conversion into physical activity. More details of order information processing to fill the order can be seen in Figures 4.18 to 4.21. The information processing includes customer verification through checking a customer history file in the account receivable file, determining the availability of merchandise through the inventory file, posting an order, and release of an order for picking. The physical activity involves the collection of goods, packing, accumulation and dispatch of goods, and transfer to highway, railroad, sea, air, or internal transport.

4.3.1 Order Sequencing

Before sending the order to the order picker, it is important to sequence the order to make the picking operation efficient. There are two approaches to sequencing and controlling order picking: batch picking and zone picking.

Batch picking is preferable when a large volume of full case items is shipped to many customers. In batch picking one item is picked in the number of units needed to satisfy a multiple of customer orders. The sorting system then separates the goods into individual orders. The key element in this system is a central sorting system which distributes the batches into individual orders.
NOTE: MATERI AL MOVEMENT

----------- INFORMATION PROCESSING

Figure 4.17
ORDER INFORMATION PROCESSING FLOWCHART

START

INPUT: MAIL, TELEPHONE, FAX, TELEX ORDER

N

PHONE?

Y

INPUT: CUSTOMER NAME

INPUT: TELEPHONE NUMBER

SEARCH CUSTOMER RECORD ON CUSTOMER FILE

REGULAR CUSTOMER?

N

OPEN CUSTOMER FILE ADD A NEW RECORD

Y

CHECK CREDIT CLEARANCE

ANY LIMITATION ON ORDER

Y

NOTE THE LIMIT QUANTITY OF ORDER

N

SPECIFIC DELIVERY?

Y

NOTE THE SPECIAL DELIVERY ON ORDER

N

OPEN ORDER FILE

Figure 4.18
ORDER INFORMATION PROCESSING FLOWCHART (CONT)

1. A

NEXT ITEM

INPUT: SKU OF ITEM NEEDED

SEARCH SKU NUMBER IN MASTER FILE & INVENTORY

INPUT THE QTY NEEDED

CHECK THE QTY IN INVENTORY

ITEM N AVAILABLE?

Y

N

CHANGE ITEM N?

N

Y

BACK ORDER?

Y

OPEN BACK ORDER FILE
INPUT SKU, QTY, NAME AND CUSTOMER ADDRESS

ALLOCATE THE QTY NEEDED IN INVENTORY

CALCULATE THE CUBE OF MAT'L ORDERED

CALCULATE THE WEIGHT OF MAT'L ORDERED

CALCULATE THE COST OF MAT'L ORDERED

HAVE ALL ITEMS BEEN VERIFIED?

N

Y

Figure 4.19
ORDER INFORMATION PROCESSING FLOWCHART (CONT)

1. CALCULATE THE TOTAL CUBE & WEIGHT FOR ALL MAT'L ORDERED
2. CALCULATE THE TOTAL COST OF ALL MAT'L ORDERED
   - THE CUSTOMER WILL PICK THE MAT'L
   - INPUT THE DESTINATION (ADDRESS) OF ORDERED AND MODE OF SHIPMENT
3. CALCULATE THE TOTAL SHIPMENT COST BASED ON THE FREIGHT CLASS, WEIGHT, DESTINATION AND MODE OF SHIPMENT
   - INPUT : HOW THE CUSTOMER PAY THE BILL
   - CREDIT CARD
     - Y
     - N
   - CREDIT CHECK
     - Y
     - N
   - C.O.D.?
     - Y
     - N
   - CANCEL THE ORDER
     - END
   - IS THE ACC. NUM. OK?
     - Y
     - N
   - ASK THE CUSTOMER HOW TO PAY THE BILL
   - VERIFY
     - END
   - CONFIRM ABOUT THE DUE DATE
   - CHECK THE DUE DATE OK?
     - Y
     - N
   - CHANGE DUE DATE?
     - Y
     - N
   - CANCEL THE ORDER
     - END

Figure 4.20
ORDER INFORMATION PROCESSING FLOWCHART (CONT)

1. Sort the order by shipping date
2. Sort the order by zip code
3. Sort the order by freight class
4. Sort the order by carrier
5. Total the cube in the carrier

- Is the cube maximum?
  - Yes: Assigned a new carrier for order
  - No: Identify the order to put in the assigned carrier

- Is the weight maximum?
  - Yes: Assigned a new carrier for order
  - No: Send the order to account receivable

Print: The order, invoice & bill of lading

Figure 4.21
In zone picking an individual customer order is passed from one order picker to another to fill the entire order. Zone picking is a sequential operation in which individual items for a specific customer or group of customers are picked one after another by one or several order pickers.

4.3.2 Order Filling

One of the basic elements of order picking is the breakdown of unit loads into a lower level of unit for response to customer demand. Figure 4.22 demonstrates the concept of level by level package breakdown. The idea of package breakdown is that every order should be broken down into the highest common denominator, i.e. the order should be separated into full pallet loads from less than pallet quantities (tote-box, box, or pieces). For example suppose a customer wants 50 cases of one item, and assume that there are 24 cases per pallet. The order can be broken down into 2 pallets plus 2 more cases of the same item. The order picker can get a fork lift truck and pick up 2 pallets from the reserve section, and the remaining 2 cases will be hand selected from the order picking area and sent to the shipping area along with other miscellaneous items.

4.3.3 Order Picking Method

In this thesis, it is assumed that two different order picking methods take place in the warehouse operation; binnable order picking and rackable order picking.
Figure 4.22 Package Breakdown (Adapted from Order Picking Systems, by E.R. Sims Jr., Wright State University, College of Continuing and Community Education, 1985.)
Binnable order picking operations basically fill orders by picking a piece or pieces of material from trays, shelf containers, or open cartons. The operation usually involves grasping small items and possibly counting, bagging, and marking them.

Binnable order picking is assumed to occur within a storage system that is generally incapable of handling palletized merchandise. Replenishment of pick locations is generally performed by hand. The only exception is for the order picking truck, which can perform two tasks; it can accommodate a pallet, but it also satisfies the requirements for hand loading a storage location not designed to accept a pallet load.

Rackable order picking operations basically fill orders by picking unitized load quantities from a storage system. There are several types of storage for rack systems including decked pallet rack, conventional shelving, flow rack, or any other storage method which can accommodate palletized merchandise. The operation sequences in rackable order picking usually consist of selecting and stacking one or more carton sized items and marking or labelling the individual carton for identification and routing purposes.

Rackable order picking is assumed to occur within a specially decked pallet rack structure. Therefore, a rackable order picking system requires designing a pallet storage system when selecting the appropriate system. Replenishment
of order picking locations is restocked by palletized loads.

4.3.4 Order Picking Systems

Equipment generally used for binnable order picking includes manual pick carts, carousels, miniload storage retrieval (S/R) machines, manned S/R machines and order picking trucks.

A manual order picking cart system (Figure 4.23) is used for shelving higher than seven feet. By using a ladder cart, an 8' or 9' shelf height is feasible, thus increasing the space utilization.

The most common type of high volume order picking vehicle is the order picking truck (Figure 4.24). This equipment has dual capabilities; it is adaptable to pallet racks for rackable order picking and to high rise shelving systems for binnable order picking. Carousels, miniload S/R machines and manned S/R machine have been discussed in a previous section.

There are four equipment types which can be classified as rackable order picking equipment. These equipment types are order picking trucks, manned S/R machines (Figure 4.11), hybrid vehicles (Figure 4.10), and manned-up turret trucks (Figure 4.9).

4.4 Shipping

The main function of shipping is to deliver the material or merchandise to the appropriate customer. Shipping is the final warehousing activity and its success depends on the
Figure 4.23 Order picking cart with ladder (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
ORDER PICKER TRUCK

Figure 4.24 Order picker truck (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
previous activities in the warehouse.

The first step in shipping is to determine the common carriers or private carriage by which the goods will be shipped (15). There are many carriers available such as truck, trailer, air freight packages, U.P.S., U.S. Postal Service, etc. Each of them has specific rates and a quality of service. To select an appropriate carrier, consideration should be given to the physical characteristics of the product, quantities to be shipped, the quality of service desired by the customer, and the cost. An examination of service must include such factors as the speed of delivery, scheduling flexibility, consistency of service and reliability.

Once the shipping method has been decided, the loading of the vehicles is considered. The issues here are quantity, physical characteristics, and the distances the product will be moved. The principle of moving materials is that whenever the materials are delivered between two points, the materials should be palletized, unitized or on some type of transfer vehicle (15). Products that are relatively heavy, bulky, or come in small units should normally be palletized.

Another item to be accounted for is the staging area. The staging area is work spaces in the warehouse for accumulating goods and are located immediately behind the shipping and receiving docks. The truck loading method will, in turn, dictate the layout and utilization of the staging area. The rate of trucks coming into the warehouse, the
loading time, and the number of personnel determine the number of docks and size of the staging area required to support the warehouse activities.

As a summary, a distribution warehouse can be described as an integrated system of four subsystems. Each subsystem reflects its function in the warehouse, e.g. receiving, storing, picking and shipping. Receiving ensures that the quantity and quality of the material is as ordered. Storing stores and identifies the material so that it will easy to retrieve. Picking converts sales information into product motion. Picking activities include customer order processing, checking the availability of material, picking the material and packing the order. Shipping, last activity of a warehouse, delivers the material or merchandise ordered to the appropriate customer.
CHAPTER V
SYSTEM SELECTION PROCEDURE

The system selection procedure is divided into two main categories: new buildings and existing buildings. For an existing building, limitations are imposed by the building height, building area, column spacing, and column size, while a new building generally has no building limitations since the building can be designed around the system.

5.1 Basic Parameters

For the purpose of analysis there are several basic components adapted from the Warehouse Modernization and Layout Planning Guide which have been accepted as a basis for the development of decision criteria and procedures. Among these are:

1. The use of a standard 40" x 48" pallet dimension for the majority of operations.
2. The use of the standard 5.5" x 18" x 10" shelf box for all binnable order picking except the mini S/R (Storage/Retrieval). The mini S/R uses a 24" x 48" tray holding 15 boxes of 4.8" x 16" x 11".

5.2 New Building

Selecting a material-handling system for a new building is much easier than for an existing building. By designing the building around the system, almost any system can physically
meet the building shape and size requirements. This flexibility is inhibited by the use of modular or standard buildings with incompatible dimensions.

Figure 5.1 shows the flowchart of the system selection procedure for new buildings. The steps in selecting a system were discussed in section 3.6.4. These steps include: determine the required inventory capacity and expected transaction rate; classify the inventory into distinct storage groups and handling characteristics classes such as bulk storage, pallet rack, high turn over, low turn over, flammable, security item, refrigerated, etc.; determine the load rates of common denominators such as the pallet, tray, tote box, etc.; select the equipment system which has the capacity to handle the rated load; determine building limitations in terms of building height, if there is a foundation restriction; determine transaction related cost and inventory related cost for every equipment system which meets the previous requirement (a detailed explanation of how these two costs are calculated will be discussed later); calculate the annual cost based upon transaction and inventory related costs; rank the system based on least annual cost for every storage area in the warehouse; select the compatible equipment system for pallet rack and rackable order picking which have the least cost (compatibility is viewed only in terms of aisle compatibility); based on the system selected, determine the final building arrangement by establishing the
SYSTEM SELECTION PROCEDURE NEW BUILDING

INPUT INVENTORY PROFILE OF ALL ITEMS

DIVIDE THE INVENTORY INTO DISTINCT STORAGE: BULK, PALLET, BIN, HIGH TURN OVER, LOW TURN OVER, FLAMMABLE, REFRIGERATED, HAZARDOUS, ETC

INPUT DAILY TRANSACTION OF ITEMS

CLASSIFY THE TRANSACTION INTO ZONE TRANSACTION: BULK STORAGE, PALLET RACK, RACKABLE AND BINNABLE ORDER PICKING

SELECT EQUIPMENT SYSTEM WHICH HAS THE CAPACITY OVER THE LOAD RATE

BASED ON TRANSACTION & INVENTORY PROFILE, CALCULATE THE ANNUAL SYSTEM COST

SELECT THE SYSTEM WHICH HAS THE LEAST COST IN EACH ZONE

DETERMINE THE FINAL ARRANGEMENT OF THE SYSTEM FROM THE MOST COMPATIBLE OF THE SELECTED SYSTEMS BASED ON AISLE COMPATIBILITY

INVENTORY OF EACH ZONE

BUILDING HEIGHT

RECEIVING & SHIPPING ACTIVITIES

MODULAR LAYOUT OF SYSTEM SELECTED

MODULE REQUIRED OF EACH ZONE

STORAGE AREA NEEDED

FINAL BUILDING ARRANGEMENT WITHOUT STAGING AREA & SUPPORT AREA

INPUT: LOAD RATE OF COMMON DENOMINATOR (PALLET, TOTE BOX, CARTON)

Figure 5.1
storage area required to support inventory profile, the number of pieces of equipment, the number of laborers, and the number of docks.

The calculation of the area required to support the inventory profile will be discussed in section 5.5.1, "Modular Layout".

The storage area within the warehouse is divided into zones. To calculate the number of laborers required for each shift in each zone, the zone's support hours required for the shift is divided by man-hours available in the shift. The result is the number of laborers required to operate the system. A similar calculation is performed to determine equipment requirements.

The number of docks required by the warehouse is affected by the length of time trucks spend in receiving and shipping (docking time), the number of trucks coming, and the number of shifts available. The area required for docks can be determined by dividing the number of docks by the product of the number of docks per bay and the module area.

5.3 Existing Building

The selection of material handling equipment for existing buildings must deal with the limitations imposed by the design of the facility. Generally, the limitations take the form of area, clear storage height, floor load, and floor condition limitations.
In this thesis the limitations of the building include clear storage height, column spacing and building area. The clear storage height available within a given area is a function of the building design and construction and has the greatest effect on system selection.

Figure 5.2 shows the flowchart of the system selection procedure for an existing building. This procedure has been presented in section 3.6.4. The only difference from new building system selection is that with existing buildings, the building limitation (height, column spacing, and building area) must be considered.

In an existing building, the storage area required to support inventory profile is determined by the module layout (which should be developed prior to the evaluation) and the inventory profile. The concept of module layout will be discussed later.

5.4 Analysis Procedure

Material handling systems have been divided into two major categories: pallet storage systems and order picking systems.

Figure 5.3 shows functional classification of material handling systems. This classification is essential due to the difference in vehicle cost assignment. In 'Free Path' equipment, the equipment and the storage is separated, while in captive system equipment, the order picking hardware is an
SYSTEM SELECTION PROCEDURE EXISTING BUILDING

1. INPUT INVENTORY PROFILE OF ALL ITEMS
2. DIVIDE THE INVENTORY INTO DISTINCT STORAGE: BULK, PALLET, BIN, HIGH TURN OVER, LOW TURN OVER, FLAMMABLE, REFRIGERATED, HAZARDOUS, ETC
3. INPUT DAILY TRANSACTION OF ITEMS
4. CLASSIFY THE TRANSACTION INTO ZONE TRANSACTION: BULK STORAGE, PALLET RACK, RACKABLE AND BINNABLE ORDER PICKING
5. SELECT EQUIPMENT SYSTEM WHICH HAS THE CAPACITY OVER THE LOAD RATE
6. SELECT THE SYSTEM THAT MEETS BUILDING LIMITATIONS
7. BASED ON TRANSACTION & INVENTORY PROFILE, CALCULATE THE ANNUAL SYSTEM COST
8. SELECT THE SYSTEM WHICH HAS THE LEAST COST IN EACH ZONE
9. DETERMINE THE FINAL ARRANGEMENT OF THE SYSTEM FROM THE MOST COMPATIBLE OF THE SELECTED SYSTEMS BASED ON AISLE COMPATIBILITY

INPUT: LOAD RATE OF COMMON DENOMINATOR (PALLET, TOTE BOX, CARTON), BUILDING CONSTRAINTS: CLEAR HEIGHT, COLUMN SPACING, BUILD AREA

Figure 5.2
Figure 5.3
integral part of the storage system. Further classification is based on the different techniques for moving the man to the load or the load to the man. This classification shows that different approaches have different effects on the labor cost. When the load is brought to the man, the system is indirectly labor dependent and time value becomes a function of machine cycle time. In moving the man to the load, the system is directly labor dependent.

5.5 Elements of Analysis

The annual system cost is generated by two elements: inventory related cost and transaction related cost. Figure 5.4 illustrates the distribution of the cost. These two groups can be calculated for each element. The inventory related cost can be partitioned into building cost and storage equipment cost, while transaction related cost can be divided into labor cost and vehicle cost.

Building and storage equipment cost are functions of modular layout, while labor and vehicle cost are functions of transaction time.

5.5.1 Modular Layout

Building and storage cost analysis begins with the development of a standard layout planning module that defines a storage and aisle pattern. A typical composite layout planning module is shown in Figure 5.5. The purpose of these modules is to establish storage hardware and aisle patterns
ANNUAL SYSTEM COST BASED ON INVENTORY AND TRANSACTION RELATED COST

INVENTORY

BUILDING COST

BUILDING CONSTRUCTION COST (NEW)

BUILDING OPERATION COST

ANNUAL BUILDING CONSTRUCTION COST

ANNUAL BUILDING OPERATION COST

ANNUAL BUILDING COST PER PALLET POSITION

STORAGE EQUIPMENT COST

BUILDING AREA/PALLET POSITION

ANNUALIZED STORAGE EQUIP. COST/PALLET

STORAGE EQUIPMENT COST/PALLET

TRANSACTIONS

STANDARD TRANSACTION TIME PER ISSUE

LABOR COST

ANNUAL LABOR HRS/DAILY TRANSACTIONS

ANNUAL LABOR COST/DAILY TRANSACTIONS

VEHICLE COST

ANNUAL VEHICLE HRS/DAILY TRANSACTION

ANNUAL VEHICLE OPERATION COST/DAILY TRANSACTIONS

ANNUAL TRANSACTION RELATED COST/DAILY TRANSACTION

ANNUAL SYSTEM COST = (ANN. INV. RELATED COST/PALLET)*INVENTORY + (ANN. TRANSA. RELATED COST/DAILY TRANSAC.)*TRANSACTIONS
Figure 5.6 Typical Layout Rack Elevation (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
for each class of material handling equipment. The modules' sizes were established to be compatible with a standard building bay size of approximately 30 ft. x 50 ft. Bay sizes and aisle lengths for each system are based upon field proven designs of similar systems. The aisle lengths and widths represent the most practical relationship of lengths and widths established for each class of equipment. Standard pallet, shelf box and tray sizes used in this project comply with the basic parameters mentioned before.

The area occupied by each module can be combined with the module storage capacity to arrive at the floor area required to contain one stack of load. This area is independent of storage stack height and can be determined by dividing the gross storage area of the modules (SA) by the number of vertical storage levels contained in the module. Dividing this stack area (square feet/stack) by the storage height in loads (loads/stack) yields the area per storage unit (pallet or shelf box) in square feet per load. This factor can be used to proportion building size based upon the inventory quantity.

5.5.2 Building Cost

Building cost is divided into building construction cost and building maintenance cost. Building construction cost applies when new building warehouses are developed. Maintenance cost is the only factor considered in existing buildings.
Standard elevations for each system are a component of the layout planning module. A typical group elevation is shown in Figure 5.6. The elevation standards determine the required clearance height. Building cost and storage equipment cost can be estimated using this information. Table 5.1 shows the estimate of building construction cost per square foot. The building is designed to include the major building components such as floors, walls, roof, frame, etc. Straight line recovery over a 25 year economic life is used to establish the annual cost of building in dollars/square foot/year. The average annual building cost per load stored is equal to the product of the area needed for storage (from the modular layout) and the annual cost of the building/square foot/year. The operating cost of the building consists of lighting and heating cost per square foot. Table 5.2 shows the annual operating cost per square foot based on the building storage height. If the storage height limitation for each of the systems is known the operating cost per square foot can be obtained by referring to the table. Multiplying the required building area by the operating cost gives the annual operating cost of the building. The building cost estimates were developed by the Chesapeake Division of NAVFAC for a typical building configuration using Washington, D.C. costs as a base.

Throughout this thesis, it is assumed that the minimum height of two pallet levels is used because storage of only
Lowermost point of sprinkler heads, joist, rafters, beams, or roof trusses. (Ref. DOD 4145.19R-1)

10 PALLETS
40'-0" TOP OF LOAD (SH)

9 PALLETS
36'-0" TOP OF LOAD (SH)

8 PALLETS
32'-0" TOP OF LOAD (SH)

7 PALLETS
28'-0" TOP OF LOAD (SH)

6 PALLETS
24'-0" TOP OF LOAD (SH)

5 PALLETS
20'-0" TOP OF LOAD (SH)

4 PALLETS
16'-0" TOP OF LOAD (SH)

3 PALLETS
12'-0" TOP OF LOAD (SH)

2 PALLETS
8'-0" TOP OF LOAD (SH)

*12" shown for bottom beam elevation.
See specific system for rock elevation details.

Figure 5.6 Typical Layout Rack Elevation (Adapted from Warehouse Modernization and Layout Planning Guide, Department of Navy, NAVSUP Publication 529, 1985.)
## BUILDING CONSTRUCTION COST ANALYSIS

Cost in Dollars per Square Foot of Buildings as of 1 October 1981

Costs prepared by Chesapeake Division of NAVFAC

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Notes:

1. Fire protection provided in ceiling sprinklers only. In-floor sprinkler cost included in storage equipment costs.
2. Washington DC area basis for estimates.
3. 3,500 psi soil bearing pressure.
4. 44 psf/ft SM floor load factor.
5. Base facility size 192 ft x 198 ft, 56,016 sq. ft, with 6,326 sq. ft (32 sq. ft x 198 ft) as low level truck dock and office area.
6. NAVFAC structural frame cost for SM - 67.3 feet modified for each supported structure cost.
7. Facility costs depreciated on straight-line basis over 25 year life.
8. See section 19.1 for comments on Area 10 factor which includes seismic allowances.
## BUILDING OPERATING COST ANALYSIS

**Annual Operating Cost per Square Foot of Building as of 1 October 1983**

Utility demands developed by Chesapeake Division of MAHFAC

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<th>Annual Lighting Cost ($0.10)</th>
<th>Best Demand (1000 BTU/hr)</th>
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**Notes:**
1. Washington DC cost base, 8 hours operation per day, 365 days per year
2. Electricity cost of $0.09 per kWh
3. Building area of 38,016 sq. ft., used for estimates
4. Heating system based on fuel oil fired hot water heat with 10% pickup allowance for piping and hot water
5. Therms = 100,000 BTU's
6. Fuel cost based on 85% efficiency, $38,000 BTU's per gallon, $1.20 per gallon
one load does not require storage racks or any other special equipment. The minimum height of shelf systems is based upon the lowest machine height available for each system.

5.5.3 Labor Cost

There are two different methods of allocating labor cost. The first is pallet handling and the second is order picking. These two are divided into sub-operations: systems delivering the man to the load and systems delivering the load to the man. Table 5.3 lists the wage grades and rates used for labor cost calculations.

5.5.3.1 Pallet Systems

Standard time for man-to-load free path pallet handling systems is determined by one complete round trip of entering the rack area, storing or retrieving a pallet, and returning. The equipment and man, traveling together have the same elapsed time in completing one assignment. The number of hours of equipment utilization and man-hours can be determined by using a standard time and a given transaction rate.

For the purposes of this thesis, seven pallet handling systems were selected for evaluation. These systems were the counterbalance truck, reach truck, front/sideloader, turret, man-up turret, hybrid trucks, and automated S/R system.

In pallet handling systems, a transaction is defined as the movement of a palletized load into storage from a staging area or the removal of a palletized load from a storage area.
### MATERIAL HANDLING LABOR COST

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<th>System</th>
<th>Wage Grade</th>
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<th>Annual labor cost</th>
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<td>$23,000</td>
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<td>S/R Machine</td>
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</table>

Notes:

1. Hourly rate average of all Naval Supply Centers as of 1 October 1983.
2. Wage rates include fringe benefits of approximately 30%.
3. Annual cost based on 2,000 hours per year.

Table 5.3
to a staging area. In the operation of the counterbalance, reach, and front/sideloader systems, movement is between a staging area and the storage system, but in the remaining systems, movement is between a centrally located pickup and delivery (P&D) station to the storage system. The time required for a pallet transaction includes a sequence of starts, stops, travel patterns, and operator actions which determine the total time required for the transaction. A more detailed operation sequence of pallet transaction time involves travel, start/stop, access, maneuver, document, lift time, and lower time. Table 5.4 and Table 5.5 show the standard transaction time for all pallet handling systems. The times have been summed and a 20% allowance added to provide for personal fatigue and delays. These standard transaction time and the 20% allowance are taken from the Warehouse Modernization and Layout Planning Guide.

The counterbalance, reach, and front/sideloader trucks are assumed to operate only within their rack storage area, therefore, additional capacity to transfer material to and from a rack area must be supplied by other support vehicles. It is assumed that 1.0 pallets are transferred per transaction cycle. The turret, man-up turret, hybrid and S/R machine units work within or at the ends of the system. These systems perform dual cycle operations for a portion of the transactions. A dual cycle consists of storing or retrieving a second load without returning to the P&D station between
<table>
<thead>
<tr>
<th>System</th>
<th>Storage Levels</th>
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<th>Travel Time</th>
<th>Start/Step Time</th>
<th>Access Time</th>
<th>Maneuver Time</th>
<th>Document Time</th>
<th>Lift Time</th>
<th>Lower Time</th>
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### Table 5.5

**Pallet Load Standard Transaction Time**

_Minutes per line item including 20% Personal Fatigue and Delay Allowances_

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<th>Travel Time</th>
<th>Start/Stop Time</th>
<th>Access Time</th>
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<th>Document Time</th>
<th>Lift Time</th>
<th>Lower Time</th>
<th>Total L/L Time</th>
<th>Total Time</th>
<th>Time With PFD</th>
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<td>0.120</td>
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<td>0.033</td>
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<td>(1.075)</td>
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<td>0.033</td>
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<td>(1.075)</td>
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<td>(1.075)</td>
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<td>0.095</td>
<td>0.896</td>
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<td>0.033</td>
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<td>0.966</td>
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<td>0.024</td>
<td>(0.846)</td>
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<td>0.966</td>
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<td>(0.846)</td>
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<td>0.034</td>
<td>0.024</td>
<td>(0.846)</td>
<td>(0.075)</td>
</tr>
</tbody>
</table>

( ) Total time based on document time of operator which exceeds machine cycle time.
[ ] Total time based on cycle time of machine which exceeds operator document time.
each load. The use of dual cycles increases the productivity of the machines. The equipment is assumed to have a 10 year economic life time.

The equipment operating cost calculations are based on the average purchase price for each unit of each type of equipment. Table 5.6 shows the operating cost and capacity of the equipment. A standard 2,000 hours per year is used to estimate an hourly operating cost. Typical load capacity of the equipment is also included to help the user in the selection of the appropriate equipment for the intended application.

5.5.3.2 Binnable Order Picking

Binnable order picking systems use manual pick carts, order picking trucks, manned S/R machines, carousels, and miniload systems. The standard unit used for binnable order picking follows the basic parameters and operations mentioned earlier.

The standard transaction time for binnable order picking is structured around a standard order picking cycle involving picks made from a standard binnables storage system. A pick cycle consists of a fixed number of orders and line item issues (documents) per cycle.

A consistent comparison reference was established for all systems by requiring the order picker to pass all item locations during execution of the pick cycle. This requirement establishes a pattern assuring equal access to all items and
### MATERIAL HANDLING VEHICLE/EQUIPMENT COST

**GALLET-STORED SYSTEMS**

Cost as of 1 October 1983

<table>
<thead>
<tr>
<th>System</th>
<th>Lift Height (feet)</th>
<th>Lift capacity (pound)</th>
<th>Purchase cost</th>
<th>Annual oper. cost</th>
<th>Total Hourly cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counterbalance 0 - 17</td>
<td>1,000 - 14,000</td>
<td>$20,000</td>
<td>$1,800</td>
<td>$1,900</td>
<td></td>
</tr>
<tr>
<td>Reach Truck 0 - 25</td>
<td>1,000 - 5,000</td>
<td>$28,000</td>
<td>$2,200</td>
<td>$2,500</td>
<td></td>
</tr>
<tr>
<td>Front/side-loader truck</td>
<td>0 - 23</td>
<td>5,000 - 8,000</td>
<td>$63,000</td>
<td>$2,500</td>
<td>$4.40</td>
</tr>
<tr>
<td></td>
<td>24 - 30</td>
<td>2,000 - 5,000</td>
<td>$72,000</td>
<td>$2,700</td>
<td>$4.95</td>
</tr>
<tr>
<td>Turret truck 0 - 16</td>
<td>2,500 - 3,500</td>
<td>$28,000</td>
<td>$2,500</td>
<td>$2,650</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17 - 22</td>
<td>2,500 - 3,500</td>
<td>$60,000</td>
<td>$3,000</td>
<td>$4.50</td>
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<tr>
<td></td>
<td>23 - 30</td>
<td>1,500 - 2,500</td>
<td>$70,000</td>
<td>$3,100</td>
<td>$5.05</td>
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<tr>
<td></td>
<td>31 - 40</td>
<td>1,000 - 2,000</td>
<td>$115,000</td>
<td>$3,200</td>
<td>$7.35</td>
</tr>
<tr>
<td>Man-up Turret 0 - 22</td>
<td>2,000 - 3,000</td>
<td>$70,000</td>
<td>$3,200</td>
<td>$5.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 - 30</td>
<td>1,500 - 2,500</td>
<td>$80,000</td>
<td>$3,300</td>
<td>$5.65</td>
</tr>
<tr>
<td></td>
<td>31 - 40</td>
<td>1,000 - 1,500</td>
<td>$125,000</td>
<td>$3,400</td>
<td>$7.95</td>
</tr>
<tr>
<td>Hybrid truck 30 - 45</td>
<td>3,000 - 4,000</td>
<td>$100,000</td>
<td>$2,000</td>
<td>$6.00</td>
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<tr>
<td></td>
<td>45</td>
<td>2,000 - 3,000</td>
<td>$113,000</td>
<td>$2,000</td>
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<td>$125,000</td>
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<td>$10.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>4,000 - 6,000</td>
<td>$180,000</td>
<td>$4,500</td>
<td>$11.25</td>
</tr>
</tbody>
</table>

**Notes:**

1. Purchase cost includes battery, charger, and guidance equipment. Guidance not included for counterbalance, reach, and 0 - 16 ft. turret truck.
2. Annual ownership cost based on 10 year equipment life.
3. Annual operating cost based on 2,000 hours per year and includes maintenance and fuel for vehicles as well as lighting/power for other systems.
4. Equipment depreciated on straight-line basis over 10 year life.

Table 5.6
provides proper determination of pick time with increasing system size.

The time element has been grouped into segments corresponding to travel, maneuvering, pick/document, lift/lower, and replenishment functions. These segments are further classified into fixed (base) time and inventory variable (travel) time functions.

Base time consists of non-variable time elements determined by the characteristics of the storage/order picking system and order picking procedure. The primary component is pick/document time which generally accounts for 50% - 85% of the total time. The remaining time represents travel components related to horizontal aisle movement. The proportion is relatively small and covers 1% - 25% of the total time. This shows that order picking time is mostly determined by fixed components which are relatively independent of inventory quantity. Table 5.7 shows the elements of transaction time of binnable order picking for 20,000 shelf boxes. Table 5.8 shows transaction time for a different inventory.

Table 5.9 shows the operating cost for binnable order picking equipment systems. The hourly equipment costs are based on an average purchase price allocated over 10 years economic life time. Maintenance costs are included, and a standard year is assumed to be 2000 hours. Typical load capacities are also included to assist in selecting a unit
<table>
<thead>
<tr>
<th>System</th>
<th>Storage Levels</th>
<th>Density Factor</th>
<th>Average System Height</th>
<th>Travel Time</th>
<th>Maneuver Time</th>
<th>Pick/Document Time</th>
<th>Lift/Lower Time</th>
<th>Replenish/Document Time</th>
<th>Misc. Time</th>
<th>Total Time</th>
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<td>28</td>
<td>3.50</td>
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<td>1.620</td>
<td>0.000</td>
<td>0.014</td>
<td>0.122</td>
<td>1.889</td>
</tr>
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<td>Order Picking</td>
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<td></td>
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<td>10.50</td>
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<td>0.009</td>
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<td>0.014</td>
<td>0.120</td>
<td>1.210</td>
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<td>14.00</td>
<td>0.031</td>
<td>0.008</td>
<td>1.620</td>
<td>0.157</td>
<td>0.014</td>
<td>0.120</td>
<td>1.450</td>
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<td>136</td>
<td>17.50</td>
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<td>0.007</td>
<td>1.620</td>
<td>0.203</td>
<td>0.014</td>
<td>0.120</td>
<td>1.992</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine</td>
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<td>10.50</td>
<td>0.024</td>
<td>0.000</td>
<td>1.440</td>
<td>0.099</td>
<td>0.014</td>
<td>0.130</td>
<td>1.609</td>
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<td>0.130</td>
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<td>0.031</td>
<td>1.069</td>
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<td>0.389</td>
<td>0.703</td>
<td>0.000</td>
<td>0.014</td>
<td>0.031</td>
<td>1.069</td>
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<td>19.50</td>
<td>0.093</td>
<td>0.389</td>
<td>0.703</td>
<td>0.000</td>
<td>0.014</td>
<td>0.031</td>
<td>1.069</td>
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</table>

[1] Total time based on document time of operator which exceeds machine cycle time.
### BINHALES ORDER PICKING STANDARD TRANSACTION TIME

*Minutes per Line Item Issue Including 20% Personal Fatigue and Delay Allowance*

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<th>System</th>
<th>Storage Levels</th>
<th>Pick Area Inventory in Shelf Boxes</th>
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<td>1.890</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>1.935</td>
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<tr>
<td></td>
<td>34</td>
<td>1.980</td>
</tr>
<tr>
<td>Manned S/R Machine</td>
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<td>(1.589)</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>(1.590)</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>(1.591)</td>
</tr>
<tr>
<td>Carousel</td>
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<td>(1.454)</td>
</tr>
<tr>
<td>Mini-Load</td>
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</tr>
<tr>
<td></td>
<td>23</td>
<td>(1.330)</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>(1.231)</td>
</tr>
</tbody>
</table>

[1] Aisle length less than 100 ft. or greater than 400 ft.
[3] Aisle length less than 150 ft. or greater than 400 ft.
### MATERIAL HANDLING VEHICLE/EQUIPMENT COST

**BINNABLES ORDER PICKING SYSTEMS**

Cost as of 1 October 1983

<table>
<thead>
<tr>
<th>System</th>
<th>Lift Height (feet)</th>
<th>Lift Capacity (pound)</th>
<th>Purchase cost</th>
<th>Annual oper. cost</th>
<th>Total Hourly cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Cart</td>
<td>---</td>
<td>250 - 5000</td>
<td>$500</td>
<td>---</td>
<td>$0.03</td>
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<td>2,000 - 3,000</td>
<td>$26,000</td>
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<tr>
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<td>17 - 24</td>
<td>1,000 - 2,500</td>
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<td>$2,200</td>
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</tr>
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<td>$10.55</td>
</tr>
<tr>
<td>Machine</td>
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<td>$189,000</td>
<td>$4,500</td>
<td>$11.70</td>
</tr>
<tr>
<td>Carousel</td>
<td>1 level</td>
<td>300 - 1,200</td>
<td>$27,000</td>
<td>$1,200</td>
<td>$1.95</td>
</tr>
<tr>
<td></td>
<td>2 levels</td>
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<td>$1,900</td>
<td>$4.40</td>
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<td></td>
<td>3 levels</td>
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<td>$116,000</td>
<td>$2,600</td>
<td>$7.10</td>
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<tr>
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**Notes:**

1. Purchase cost includes battery, charger, and guidance equipment. Guidance not included for manual cart system.
2. Annual ownership cost based on 10 year equipment life.
3. Annual operating cost based on 2,000 hours per year and includes maintenance and fuel for vehicles as well as lighting/power for other systems.
4. Equipment depreciated on straight-line basis over 10 year life.
5. Load capacity for carousel is per basket, for Mini S/R is per tray.

Table 5.9
with the appropriate lift capacity for intended application.

5.5.3.3 Rackable Order Picking

The equipment used for rackable order picking consists of the man-up turret truck, order picking truck, hybrid truck and manned S/R machine. These equipment types were selected based on their functional capability. Rackables order picking occurs within pallet rack storage systems.

The development of standard transaction time for rackable order picking systems follows a procedure similar to that used for binnable order picking. Only the type of storage and equipment differs.

Transaction time elements were established for travel, maneuver, pick/document, lift/lower, replenishment, and miscellaneous operations. Like binnable order picking, a fixed time component constitutes most of the standard transaction time. The travel component of rackable order picking represents a larger portion of the total time because the aisle item density is much lower for palletized storage than for the shelf box storage. The density factor ranges between 8.65 to 0.86 items per aisle foot in the rackable systems compared to a range of 14 to 439 items per aisle foot in the binnable systems. Table 5.10 shows the elements of transaction time for rackable order picking 2,000 pallets. Table 5.11 shows the transaction time for different types of inventory.

Table 5.12 shows the equipment operating cost for rackable equipment systems. The costs are based on an average
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### SACKABLES ORDER PICKING STANDARD TRANSACTION TIME

(Minutes per Line Item including 20% Personal Fatigue and Delay Allowance)

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1) Aisle length less than 150 ft. or greater than 400 ft.
### MATERIAL HANDLING VEHICLE/EQUIPMENT COST
### RACKABLES ORDER PICKING SYSTEMS

**Cost as of 1 October 1983**

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<th>Lift Capacity (pound)</th>
<th>Purchase Cost</th>
<th>Annual Operat. Cost</th>
<th>Total Hourly Cost</th>
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<td>1,500 - 2,500</td>
<td>$125,000</td>
<td>$2,000</td>
<td>$7.25</td>
</tr>
<tr>
<td>S/R Machine</td>
<td>40</td>
<td>4,000 - 6,000</td>
<td>$160,000</td>
<td>$4,300</td>
<td>$10.15</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>4,000 - 6,000</td>
<td>$180,000</td>
<td>$4,500</td>
<td>$11.25</td>
</tr>
</tbody>
</table>

**Notes:**

1. Purchase cost includes battery, charger, and guidance equipment.
2. Annual ownership cost based on 10 year equipment life.
3. Annual operating cost based on 2,000 hours per year and includes maintenance and fuel for vehicles as well as lighting/power for other systems.
4. Equipment depreciated on straight-line basis over 10 year life.

---

Table 5.12
purchase price allocated over 10 years economic life time. Maintenance costs are included, a standard year is 2000 hours. Typical load capacities are also included to assist in selecting a unit with the appropriate lift capacity for the intended application.

5.5.4 Storage Equipment Cost

The cost of storage equipment, such as pallet racks and shelving, and associated items like aisle guide rails or electronic guide wire equipment has been estimated based on component costs. Pallet system costs are estimated on the basis of upright height plus a fixed cost per pallet for the beams and guide rails/guide wire (Table 5.13). All costs are averaged over a 10 year economic life to determine the average annual cost of the storage equipment in dollars per year per storage position. Table 5.14, Table 5.15, Table 5.16, and Table 5.17 show the elements of cost of all binnable storage systems. Table 5.18 shows the elements of cost of an automated S/R system rack while Table 5.19 shows the elements of cost of a hybrid vehicle pallet rack.
## CONVENTIONAL PALLET RACK COST ANALYSIS
Costs as of 1 October 1983

<table>
<thead>
<tr>
<th>Element</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright Height</td>
<td>48&quot;</td>
<td>96&quot;</td>
<td>144&quot;</td>
<td>192&quot;</td>
<td>240&quot;</td>
<td>288&quot;</td>
<td>336&quot;</td>
<td>384&quot;</td>
<td>432&quot;</td>
</tr>
<tr>
<td>Upright/Pallet</td>
<td>0.280</td>
<td>0.187</td>
<td>0.160</td>
<td>0.142</td>
<td>0.093</td>
<td>0.040</td>
<td>0.070</td>
<td>0.062</td>
<td>0.056</td>
</tr>
<tr>
<td>Upright Cost/Unit</td>
<td>0.722</td>
<td>0.732</td>
<td>0.741</td>
<td>0.751</td>
<td>0.760</td>
<td>0.770</td>
<td>0.779</td>
<td>0.789</td>
<td>0.798</td>
</tr>
<tr>
<td>Beam Pairs/Day</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Beam Pairs/Pallet</td>
<td>0.250</td>
<td>0.333</td>
<td>0.375</td>
<td>0.400</td>
<td>0.417</td>
<td>0.429</td>
<td>0.428</td>
<td>0.500</td>
<td>0.500</td>
</tr>
<tr>
<td>Guidance Cost/Pallet</td>
<td>$ 4.63</td>
<td>$ 3.00</td>
<td>$ 2.31</td>
<td>$ 1.85</td>
<td>$ 1.32</td>
<td>$ 1.16</td>
<td>$ 1.16</td>
<td>$ 4.63</td>
<td></td>
</tr>
<tr>
<td>Sprinkler Levels</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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</tr>
<tr>
<td>Sprinkler Heads/Pallet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinkler Cost/Pallet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Per Pallet</td>
<td>$ 9.70</td>
<td>$ 13.16</td>
<td>$ 16.96</td>
<td>$ 18.25</td>
<td>$ 17.76</td>
<td>$ 18.78</td>
<td>$ 18.78</td>
<td>$ 19.31</td>
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<tr>
<td>Uprights</td>
<td>20.00</td>
<td>26.64</td>
<td>30.00</td>
<td>32.00</td>
<td>33.26</td>
<td>34.32</td>
<td>35.04</td>
<td>40.00</td>
<td>40.00</td>
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<tr>
<td>Beam/Load Bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinklers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total W/O Guidance</td>
<td>$ 29.70</td>
<td>$ 39.16</td>
<td>$ 44.96</td>
<td>$ 48.15</td>
<td>$ 50.32</td>
<td>$ 56.56</td>
<td>$ 57.24</td>
<td>$ 65.78</td>
<td>$ 65.56</td>
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<tr>
<td>Guidance</td>
<td>$ 4.63</td>
<td>$ 3.00</td>
<td>$ 2.31</td>
<td>$ 1.85</td>
<td>$ 1.32</td>
<td>$ 1.16</td>
<td>$ 1.03</td>
<td>$ 0.93</td>
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<tr>
<td>Total With Guidance</td>
<td>$ 34.33</td>
<td>$ 42.16</td>
<td>$ 47.25</td>
<td>$ 50.00</td>
<td>$ 51.88</td>
<td>$ 57.88</td>
<td>$ 59.40</td>
<td>$ 66.81</td>
<td>$ 66.49</td>
</tr>
</tbody>
</table>

### NOTES:
1. 100 linear feet increases for uprights from 2-10 storage levels.
2. Beam/Load Bar cost constant at $80.00 per 2 pallet pair with load bar.
3. Ratio of upright to pallets varies by system from 0.60:1 for Counterbalance Track to 0.53:1 for Turret Track.
4. Average of 0.56:1 used for comparisons.
5. In-row sprinklers located at alternate pallet positions with a density of 0.25 heads per pallet rack per row of sprinklers, $125 per head.
6. Seismic allowances for modification of pallet system costs:
   Zones 1-1 - Use baseline data; Zone 2, +$25; Zone 3, +$50; Zone 4, +$75

---

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**MEZZANINE SHELVING COST ANALYSIS**

Cost as of 1 October 1983

<table>
<thead>
<tr>
<th>Element</th>
<th>Shelving Module Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Shelf Storage Levels</td>
<td>7</td>
</tr>
<tr>
<td>Uprights/Shelf Box</td>
<td>0.020</td>
</tr>
<tr>
<td>Upright Cost</td>
<td>$ 7.54</td>
</tr>
<tr>
<td>Shelves/shelf Box</td>
<td>0.190</td>
</tr>
<tr>
<td>Shelf cost</td>
<td>$16.09</td>
</tr>
<tr>
<td>Side Panels/shelf Box</td>
<td>0.025</td>
</tr>
<tr>
<td>Side Panel cost</td>
<td>$17.72</td>
</tr>
<tr>
<td>Back Panels/shelf Box</td>
<td>0.014</td>
</tr>
<tr>
<td>Back Panel Cost</td>
<td>$33.22</td>
</tr>
<tr>
<td>Shelf Box Cost</td>
<td>$ 0.650</td>
</tr>
<tr>
<td>Mezzanine Area/shelf box</td>
<td>---</td>
</tr>
<tr>
<td>Mezzanine Cost/sq.ft.</td>
<td>---</td>
</tr>
<tr>
<td>Sprinkler Levels</td>
<td>---</td>
</tr>
<tr>
<td>Sprinkler Heads/Shelf Box</td>
<td>---</td>
</tr>
<tr>
<td>Sprinkler Cost/Shelf Box</td>
<td>---</td>
</tr>
<tr>
<td>Cost Per Shelf Box</td>
<td>$ 0.151</td>
</tr>
<tr>
<td>Uprights</td>
<td>3.057</td>
</tr>
<tr>
<td>Shelves</td>
<td>0.443</td>
</tr>
<tr>
<td>Side Panels</td>
<td>0.465</td>
</tr>
<tr>
<td>Back Panels</td>
<td>---</td>
</tr>
<tr>
<td>Mezzanine</td>
<td>---</td>
</tr>
<tr>
<td>Sprinklers</td>
<td>0.650</td>
</tr>
<tr>
<td>Boxes</td>
<td>0.650</td>
</tr>
<tr>
<td>Total</td>
<td>$ 4.766</td>
</tr>
</tbody>
</table>

**Notes:**

1. Cost estimate based on use of 18" D x 36" W x 87" H shelf cabinets with 7 shelf levels per unit not including top.
2. Storage configuration of 7 shelves of 6 shelf boxes per cabinet module.
3. Sprinklers located on 10 ft. centers in order picking aisle. Priced at $ 125 per head.
4. Equipment depreciated on straight-line basis over 10 year life.
5. Seismic allowance for modification of bin system costs:
   - zones 0, 1; use baseline data; 2, +8%; 3, +15%; 4, +25%.

Table 5.14
### HIGH RISE SHELVING COST ANALYSIS

Cost as of 1 October 1983

<table>
<thead>
<tr>
<th>Element</th>
<th>Shelving Module Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Shelf Storage Levels</strong></td>
<td>13</td>
</tr>
<tr>
<td><strong>Uprights/Shelf Box</strong></td>
<td>$7.54</td>
</tr>
<tr>
<td><strong>Shelves/shelf Box</strong></td>
<td>$0.179</td>
</tr>
<tr>
<td><strong>Side Panels/shelf Box</strong></td>
<td>$0.026</td>
</tr>
<tr>
<td><strong>Back Panels/shelf Box</strong></td>
<td>$0.016</td>
</tr>
<tr>
<td><strong>Cost Per Shelf Box</strong></td>
<td>$0.324</td>
</tr>
<tr>
<td><strong>Total without guide</strong></td>
<td>$4.847</td>
</tr>
<tr>
<td><strong>Wire Guide/shelf Box</strong></td>
<td>$0.077</td>
</tr>
<tr>
<td><strong>S/R Rail Guide/shelf box</strong></td>
<td>$4.808</td>
</tr>
<tr>
<td><strong>Cost with wire guide</strong></td>
<td>$4.924</td>
</tr>
<tr>
<td><strong>Cost with S/R Rail guide</strong></td>
<td>$9.655</td>
</tr>
</tbody>
</table>

**Notes:**

1. Cost estimate based on use of 18" D x 36" W x 87" H shelf cabinets with 7 shelf levels per unit.
2. Storage configuration of 6 shelf boxes per cabinet module.
3. Wire guidance based on guide wire installed in floor at $4.00/aisle foot. Stack cost consists of 2 shelf box stacks per aisle position with 0.50 aisle feet per pair of stacks or 0.25 aisle feet per stack at a cost of $1.00 per stack.
4. S/R guidance consists of upper and lower guide rails and aisle electrification. Cost estimated at $250/aisle foot. Stack cost consist of 2 shelf box stacks per aisle position with 0.25 aisle feet per stack at cost $62.50 per stack.
5. Equipment depreciated on straight-line basis over 10 year life.
6. Seismic allowance for modification of bin system costs: zones 0, 1: use baseline data; 2, +8%; 3, +15%; 4, + 25%.

Table 5.15
### CAROUSEL SYSTEM COST ANALYSIS

Cost as of 1 October 1983

<table>
<thead>
<tr>
<th>Element</th>
<th>Shelving Module Levels</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>System per Module</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Baskets/system</td>
<td></td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Shelf Boxes/ basket</td>
<td></td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Shelf Boxes/ system</td>
<td></td>
<td>1,400</td>
<td>1,400</td>
<td>1,400</td>
</tr>
<tr>
<td>System cost</td>
<td></td>
<td>$26,000</td>
<td>$26,000</td>
<td>$26,000</td>
</tr>
<tr>
<td>Shelf Box Cost</td>
<td></td>
<td>$0.650</td>
<td>$0.650</td>
<td>$0.650</td>
</tr>
<tr>
<td>Mezzanine Area/shelf box</td>
<td>---</td>
<td>0.673</td>
<td>0.898</td>
<td></td>
</tr>
<tr>
<td>Mezzanine Cost/sq.ft.</td>
<td>---</td>
<td>$8.20</td>
<td>$9.43</td>
<td></td>
</tr>
<tr>
<td>Sprinkler Levels</td>
<td>---</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sprinkler Heads/Shelf Box</td>
<td>---</td>
<td>0.002</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Sprinkler Cost/Shelf Box</td>
<td>---</td>
<td>$0.250</td>
<td>$0.333</td>
<td></td>
</tr>
<tr>
<td>Cost Per Shelf Box</td>
<td></td>
<td>$18.571</td>
<td>$18.571</td>
<td>$18.571</td>
</tr>
<tr>
<td>System</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Mezzanine</td>
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<td>5.519</td>
<td>8.468</td>
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<tr>
<td>Sprinklers</td>
<td>---</td>
<td>0.250</td>
<td>0.333</td>
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</tr>
<tr>
<td>Boxes</td>
<td>0.650</td>
<td>0.650</td>
<td>0.650</td>
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<tr>
<td>Total</td>
<td>$19.221</td>
<td>$24.990</td>
<td>$28.022</td>
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</tbody>
</table>

Notes:

1. Cost estimate based on use of 18" D x 24" W x 85" H basket with 7 shelf levels per unit.
2. Storage configuration of 7 shelves of 4 shelf boxes per basket.
3. Sprinklers located on 10 ft. centers between carousel units and in order picking aisle; priced at $125 per head.
4. Equipment depreciated on straight-line basis over 10 year life.
5. Seismic allowance for modification of bin system costs: zones 0,1; use baseline data; 2, +8%; 3, +15%; 4, +25%.

Table 5.16
### MINI-LOAD S/R SYSTEM COST ANALYSIS

**Cost as of 1 October 1983**

<table>
<thead>
<tr>
<th>Element</th>
<th>System Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 ft.</td>
</tr>
<tr>
<td>Tray Storage Levels</td>
<td>15</td>
</tr>
<tr>
<td>Tray/Aisle</td>
<td>1.050</td>
</tr>
<tr>
<td>Shelf Boxes/Tray</td>
<td>16</td>
</tr>
<tr>
<td>Shelf Boxes/system</td>
<td>16,800</td>
</tr>
<tr>
<td>System Engineering</td>
<td>$35,000</td>
</tr>
<tr>
<td>Tower/Controller cost</td>
<td>$88,000</td>
</tr>
<tr>
<td>Tray &amp; rack cost</td>
<td>$43,500</td>
</tr>
<tr>
<td>Aisle Electrification</td>
<td>$21,000</td>
</tr>
<tr>
<td>Shelf box cost</td>
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</tr>
<tr>
<td>Cost Per Shelf Box</td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td>$2.083</td>
</tr>
<tr>
<td>Tower/controller</td>
<td>5.238</td>
</tr>
<tr>
<td>Tray &amp; Rack</td>
<td>2.589</td>
</tr>
<tr>
<td>Aisle Electrification</td>
<td>1.250</td>
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<tr>
<td>Boxes</td>
<td>0.650</td>
</tr>
<tr>
<td>Total</td>
<td>$11.810</td>
</tr>
</tbody>
</table>

**Notes:**
1. Cost estimate based on use of 48" D x 24" W x 12" H tray with 16 shelf boxes per tray.
2. Equipment depreciated on straight-line basis over 10 year life.
3. Seismic allowance for modification of bin system costs:
   - zones 0, 1: use baseline data
   - 2, +8%
   - 3, +15%
   - 4, +25%

Table 5.17
## Hybrid Vehicle Pallet Rack Cost Analysis

Costs as of 1 October 1983

<table>
<thead>
<tr>
<th>Element</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
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<tbody>
<tr>
<td>Upright Height</td>
<td>306&quot;</td>
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<td>402&quot;</td>
<td>450&quot;</td>
<td>498&quot;</td>
<td>546&quot;</td>
<td>594&quot;</td>
<td>642&quot;</td>
<td>690&quot;</td>
<td>738&quot;</td>
</tr>
<tr>
<td>Uprights/Pallet</td>
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<td>0.064</td>
<td>0.057</td>
<td>0.051</td>
<td>0.047</td>
<td>0.043</td>
<td>0.040</td>
<td>0.037</td>
<td>0.034</td>
<td>0.032</td>
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<tr>
<td>Beam Pallets/Row</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam Pallets/Pallet</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
</tr>
<tr>
<td>Guidance Cost/Pallet</td>
<td>$8.33</td>
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<td>$6.48</td>
<td>$5.83</td>
<td>$5.30</td>
<td>$4.86</td>
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<td>$4.17</td>
<td>$3.89</td>
<td>$3.65</td>
</tr>
<tr>
<td>Sprinkler Levels</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinkler Heads/Pallet</td>
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<td>0.056</td>
<td>0.050</td>
<td>0.045</td>
<td>0.042</td>
<td>0.038</td>
<td>0.036</td>
<td>0.030</td>
<td>0.063</td>
</tr>
<tr>
<td>Sprinkler Cost/Pallet</td>
<td>$4.30</td>
<td>$3.88</td>
<td>$7.00</td>
<td>$6.25</td>
<td>$5.63</td>
<td>$5.25</td>
<td>$4.75</td>
<td>$4.25</td>
<td>$3.85</td>
<td>$3.85</td>
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<td>$9,700</td>
<td>$9,700</td>
<td>$9,700</td>
<td>$9,700</td>
<td>$9,700</td>
<td>$9,700</td>
<td>$9,700</td>
<td>$9,700</td>
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</tr>
<tr>
<td>Cost Per Pallet</td>
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<td>$38.99</td>
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<td>$40.97</td>
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<tr>
<td>Sprinklers</td>
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<td>7.00</td>
<td>6.25</td>
<td>5.63</td>
<td>5.25</td>
<td>4.75</td>
<td>4.25</td>
<td>3.85</td>
<td>3.85</td>
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<td>5.54</td>
<td>4.49</td>
<td>4.17</td>
<td>3.90</td>
<td>3.65</td>
</tr>
<tr>
<td>Guidance Costs</td>
<td>8.33</td>
<td>7.29</td>
<td>6.48</td>
<td>5.83</td>
<td>5.30</td>
<td>4.86</td>
<td>4.49</td>
<td>4.17</td>
<td>3.90</td>
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<tr>
<td>Total</td>
<td>$97.95</td>
<td>$95.99</td>
<td>$98.18</td>
<td>$96.47</td>
<td>$95.86</td>
<td>$95.06</td>
<td>$97.15</td>
<td>$96.36</td>
<td>$95.17</td>
<td>$94.98</td>
</tr>
</tbody>
</table>

**Notes:**

1. Uplift linear cost increase per pallet level.
2. Base load cost constant at $80.00 per 2 pallet pair with load base.
3. In-row sprinklers located at alternate pallet positions with a density of 0.25 heads per pallet stack per row of sprinklers, $123 per head.
4. Guidance consists of upper and lower guide rails and aisle electrification. Cost estimated at $25 per aisle foot. Stack cost consists of 3 pallets per position with 4,667 aisle feet per pair of stacks or 2,333 feet per stack at a cost of $58.33 per stack.
5. Equipment depreciated over a straight-line basis over 10 years life.
6. Seismic allowances for modification of pallet system cost:
   - Zones 0-1: Use baseline data; Zone 2, +20%; Zone 3, +30%; Zone 4, +38%
<table>
<thead>
<tr>
<th>Element</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upright Weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upright/Pallet</td>
<td>497&quot;</td>
<td>541&quot;</td>
<td>591&quot;</td>
<td>635&quot;</td>
<td>685&quot;</td>
<td>729&quot;</td>
<td>779&quot;</td>
<td>823&quot;</td>
<td>873&quot;</td>
<td>917&quot;</td>
<td>967&quot;</td>
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<td>Upright Cost/Pallet</td>
<td>$1.166</td>
<td>$1.164</td>
<td>$1.170</td>
<td>$1.171</td>
<td>$1.176</td>
<td>$1.172</td>
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<td>$1.187</td>
<td>$1.182</td>
<td>$1.184</td>
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<td><strong>Support Poles/Boy</strong></td>
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</tr>
<tr>
<td>Support Poles/Pallet</td>
<td>10</td>
<td>13</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td><strong>Guidance Cost/Pallet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guidance Cost/Pallet</td>
<td>$59.30</td>
<td>$53.98</td>
<td>$49.48</td>
<td>$45.67</td>
<td>$42.41</td>
<td>$39.58</td>
<td>$37.11</td>
<td>$34.93</td>
<td>$32.99</td>
<td>$31.25</td>
<td>$29.69</td>
</tr>
<tr>
<td><strong>Sprinkler Levels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinkler Heads/Pallet</td>
<td>0.050</td>
<td>0.065</td>
<td>0.063</td>
<td>0.058</td>
<td>0.054</td>
<td>0.067</td>
<td>0.063</td>
<td>0.059</td>
<td>0.070</td>
<td>0.066</td>
<td>0.075</td>
</tr>
<tr>
<td>Sprinkler Cost/Pallet</td>
<td>$6.25</td>
<td>$6.63</td>
<td>$7.08</td>
<td>$7.25</td>
<td>$6.75</td>
<td>$8.38</td>
<td>$7.80</td>
<td>$8.75</td>
<td>$8.25</td>
<td>$9.30</td>
<td>$9.30</td>
</tr>
<tr>
<td><strong>Cost Per Pallet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uprights</td>
<td>$83.63</td>
<td>$83.82</td>
<td>$84.64</td>
<td>$85.14</td>
<td>$85.62</td>
<td>$86.95</td>
<td>$86.96</td>
<td>$88.34</td>
<td>$88.36</td>
<td>$88.65</td>
<td>$90.34</td>
</tr>
<tr>
<td>Beams</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
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<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Sprinklers</td>
<td>6.25</td>
<td>5.63</td>
<td>7.08</td>
<td>7.25</td>
<td>6.75</td>
<td>6.80</td>
<td>7.80</td>
<td>7.20</td>
<td>8.25</td>
<td>9.00</td>
<td>9.30</td>
</tr>
<tr>
<td><strong>Total W/O Guidance</strong></td>
<td>$117.88</td>
<td>$117.45</td>
<td>$120.32</td>
<td>$120.39</td>
<td>$120.37</td>
<td>$123.33</td>
<td>$123.84</td>
<td>$123.72</td>
<td>$125.09</td>
<td>$124.90</td>
<td>$128.22</td>
</tr>
<tr>
<td><strong>Guidance</strong></td>
<td>$59.30</td>
<td>$53.98</td>
<td>$49.48</td>
<td>$45.67</td>
<td>$42.41</td>
<td>$39.58</td>
<td>$37.11</td>
<td>$34.93</td>
<td>$32.99</td>
<td>$31.25</td>
<td>$29.69</td>
</tr>
<tr>
<td><strong>Total W/ Guidance</strong></td>
<td>$177.26</td>
<td>$171.43</td>
<td>$169.80</td>
<td>$166.06</td>
<td>$162.78</td>
<td>$162.91</td>
<td>$159.95</td>
<td>$158.65</td>
<td>$154.15</td>
<td>$157.91</td>
<td>$157.91</td>
</tr>
<tr>
<td><strong>Conveyor/Control per Aisle</strong></td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
<td>$98,000</td>
</tr>
<tr>
<td><strong>Tower &amp; Controller per Aisle</strong></td>
<td>$160,000</td>
<td>$163,000</td>
<td>$166,000</td>
<td>$169,000</td>
<td>$172,000</td>
<td>$175,000</td>
<td>$177,000</td>
<td>$179,000</td>
<td>$181,000</td>
<td>$183,000</td>
<td>$185,000</td>
</tr>
</tbody>
</table>

**Table 5.19**

**NOTES:**

1. 10% linear cost increase for uprights from 10-20 storage levels.
2. Beam/support cost constant at $20.00 per pallet position.
3. Ratio of uprights to pallets constant at 1.05:1.
4. In-row sprinklers located at alternate pallet positions with a density of 0.25 heads per pallet stock per row of sprinklers, $125 per head.
5. Guidance consists of upper and lower guide rails and aisle electrification. Cost estimated at $250 per aisle foot. Stock cost consists of 2 pallet stockers per aisle position with 4.750 aisle feet per pair of stacks or 2.375 feet per stack at a cost of $393.75 per stack.
6. Aisle modules consist of 150 floor positions per aisle.
7. Equipment depreciated on straight-line basis over 10 year life.
8. Seismic allowances for modification of pallet system costs:
   - Zones 0, 0 - See baseline data; Zones 2, +25%; Zones 3, +20%; Zones 4, +15%
6.1 Model Testing

During model development, a detailed trace of the program was periodically printed to verify that the software was functioning correctly. Various examples were tested to ensure that the result given by the program was correct according to the boundaries of warehouse operating parameters.

After final system integration, tests were performed to ensure that the package operated properly as a single entity. Several example cases of warehousing operations were tested. The conclusions of the software package were compared to manual calculations. Except for a small difference due to rounding, the software model results were identical to the manual calculations.

For testing purposes, a representative problem given in the *Warehouse Modernization and Layout Planning Guide* was used. The problem was to design a warehouse for storage and order picking. Storage height was limited to 40 feet due to the foundation restrictions. Pallet stacking for bulk storage was restricted to a four pallet height. The warehouse operated on one shift.

The objective was to determine the most cost effective equipment while satisfying operating parameters. The solution is given in terms of the required area for inventory storage,
The objective was to determine the most cost effective equipment while satisfying operating parameters. The solution is given in terms of the required area for inventory storage, the required number of docks, and other related functions. Table 6.1 shows operating parameters of the warehouse in this problem.

Table 6.1 Operating Parameters Problem 1

<table>
<thead>
<tr>
<th>Storage Category</th>
<th>Number of items</th>
<th>Quantity</th>
<th>No. of Transactions/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>270</td>
<td>830 pallets</td>
<td>26</td>
</tr>
<tr>
<td>Rack storage</td>
<td>4,500</td>
<td>4,962 pallets</td>
<td>646</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>2,300</td>
<td>2,300 pallets</td>
<td>140</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>6,300</td>
<td>6,300 shelf boxes</td>
<td>632</td>
</tr>
</tbody>
</table>

Figure 6.1 shows the profile of inventory and transactions scenario. The transaction scenario illustrated in Figure 6.1 includes the following details:

There are eight hundred and thirty pallets in the bulk storage category. Fifteen pallets per day will be picked from the bulk storage area for full pallet shipping. Fifteen pallets per day will be received by bulk storage. Twenty five percent (25%) of the loads can be handled in dual transactions. The remaining are in single transactions. The number of transactions per day in bulk storage = (25% x 15) + 2(75% x 15), i.e. 26 transaction per day.
Material Flow Diagram

- **Bulk Pallet Storage - 830 Pallets**
- **Pallets Rack Storage - 4,962 Pallets**
- **Rackable Order Picking - 2,300 Pallets**
- **Binnable Order Picking - 6,300 Shelf Boxes**

- Total Pallets Shipped: 487
- Total Pallets Received: 477
- Total Pallets in Rack: 442
- Total Pallets in Rackable Order Picking: 14
- Total Pallets in Binnable Order Picking: 8

**Figure 6.1**
rackables order picking area. Analysis of activity patterns shows that 60% of the loads can be handled in dual transactions. The number of transactions required per day = (60% x 462) dual + 2(40% x 462) single transactions, i.e. 646 transactions per day.

There are two thousand, three hundred (2,300) pallets in rackable order picking. One full pallet is depleted on average every 10 rackable order picks. There are one hundred and forty (140) order picks (transactions) per day for shipment. Seventy percent (70%) of the order picking activity is shipped and 30% is used as replenishment for binnables order picking. The equivalent of 14 pallets will be shipped and 6 pallets will be moved to binnable order picking each day. Analysis of load characteristics shows that the average pallet is only 65% filled when order picking is completed. Therefore, the 22 pallets actually shipped each day, are equal to 14 full pallets (65% x 22).

Figure 6.1 shows binnable order picking has six thousand three hundred (6,300) shelf boxes. One full pallet is equivalent to an average of 100 binnable order picks (assume tote boxes or shelving on pallets). The average binnable order picking is 632 picks per day.

The equivalent of 6 full pallets will be shipped each day from binnable order picking. Analysis of load characteristics shows that the average pallet is 75% full when order picking is completed. Therefore, 8 pallets will be physically shipped...
each day.

The average number of pallets per truck coming into the warehouse is 15 pallets/day. The average number of pallets per truck shipped from the warehouse is 12 pallets/day. Dock turn-around time is 1 hour for receiving and 1.5 hours for shipping.

After the warehouse operations have been initialized, the data input can begin. Table 6.2 shows the program input.

Table 6.2 Input data

<table>
<thead>
<tr>
<th>Zone Storage</th>
<th>Inventory*</th>
<th>Transaction*</th>
<th>Max. load**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>830</td>
<td>26</td>
<td>1,000</td>
</tr>
<tr>
<td>Pallet Rack</td>
<td>4,962</td>
<td>646</td>
<td>1,000</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>2,300</td>
<td>140</td>
<td>1,000</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>6,300</td>
<td>632</td>
<td>250</td>
</tr>
</tbody>
</table>

Building clear height = 40 feet

Note:
* In common denominator
** In pounds

6.2 Results

The following discussion is an explanation of calculations for the given problem. The algorithm for solving the problem in detail can be seen in the flowchart in Appendix A.

The first step in the selection of the material handling system is choosing the equipment from the database. The equipment must be tested as to its ability to handle the load.
rate. If the equipment can handle the load, then the selected equipment is tested for the clearance height.

The analysis of clearance height begins by considering the lowest feasible operating height of all possible equipment systems. The design of some equipment is such that operation in warehouses with storage heights lower than a certain limit is not economically feasible (an example would be the man-up turret truck which cannot be economically operated in a storage system which is less than 4 levels). If the lowest feasible operating height of the first equipment system selected is below or equal to the clearance height designated, then the calculation of annual equipment cost begins, otherwise the program will search for other equipment from the database. Each qualified equipment system is evaluated for each succeeding storage level.

The annual cost is based upon the transaction related cost and the inventory related cost. Transaction related cost is based upon the standard transaction time for the given inventory, labor cost, and vehicle cost. Inventory related cost is based upon the inventory profile, standard storage area per common denominator, building cost, and storage cost.

After calculating the annual equipment cost at the lowest feasible operating height, the program considers the selected equipment for the next higher storage level and calculates the annual equipment system cost. This process continues until the
maximum capabilities of the equipment are reached, or the clearance height of the building is reached. If the maximum capability of the selected equipment is reached, it is eliminated from consideration for the next level.

All equipment selected by the above criteria is filed for further analysis. The selected systems are compared for each storage level (equipment elevation) in the same zone (the term "zone" refers to pallet rack or order picking operations). The least annual cost for each storage level is chosen. The best candidate of equipment systems for a particular zone in warehousing is selected from among those with the least annual cost.

After all equipment systems for each zone in the warehouse have been examined and the best candidate for each zone selected, the program selects the most compatible system based on the selected candidates in pallet rack and rackable order picking. The two categories of equipment are compared for aisle compatibility. The program uses the pallet storage system as a reference to examine order picking equipment, since pallet rack contributes the largest annual cost compared to other zones in the warehouse. The program determines whether the lowest annual system cost in pallet rack storage has a compatible aisle width with the lowest annual system cost in rackable order picking. If it does, the program chooses the selected equipment as the recommended system equipment in the warehouse. If not, the program will
test the system with the next lowest annual equipment cost in rackable order picking. This process continues until the program finds aisle compatibility, or if there is no compatible equipment the program will not make a recommendation for pallet rack order picking.

The calculation of the area required to support the inventory profile is based on the given modular layout (see section 5.5.1). The modular layout contains the column spacing of the bay and the number of common denominator units such as pallets, boxes or tote boxes. The required modular layout computed is based on the inventory profile and the capacity of the modular layout for the selected system. The area required is developed from the number of modular layouts required times the standard area of the modular layout.

The number of laborers and equipment units required to support the operation of the warehouse is determined by the number of hours of labor and equipment utilization for each zone. The calculation is based upon the hours needed to support the operations divided by the number of hours available for the equipment and laborers in a given shift.

Lastly the number of docks required by the warehouse to support the receiving and shipping activities is determined. The number of docks required is calculated based on the rate of trucks in receiving and shipping, docking time of each activity, and the number of shifts available. Assuming the warehouse is using the standard bay, the area required for
docks can be determined from the number of docks divided by the number of docks per bay times the module area. Page 117 to 130 shows the program output.

Four other warehouse problems were tested. Each of the problems has different conditions in terms of the warehouse operations and building conditions, such as building clearance height, maximum load, inventory and transaction profile. Table 6.3 shows the operation parameters of the second problem.

### Table 6.3 Operating Parameters Problem 2

<table>
<thead>
<tr>
<th>Zone Storage</th>
<th>Inventory*</th>
<th>Transaction*</th>
<th>Max. load**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>1,100</td>
<td>78</td>
<td>4,000</td>
</tr>
<tr>
<td>Pallet Rack</td>
<td>3,400</td>
<td>750</td>
<td>4,000</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>2,300</td>
<td>230</td>
<td>4,000</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>6,000</td>
<td>1,200</td>
<td>500</td>
</tr>
</tbody>
</table>

Building clear height = 60 feet

Note:
* In common denominator
** In pounds

The conditions of this warehouse operation are almost the same as the problem developed by the Warehouse Modernization and Layout Planning Guide. The only difference in the two is the maximum load of the common denominator. The maximum load in the second problem is 4,000 pounds while in the first problem it is 1,000 pounds. Some of the equipment cannot be considered because of incompatible load handling capabilities.
For example, the turret truck, which has the least annual cost in the example, problem is not considered as a candidate for pallet rack order picking (see the print out result of this case in the Appendix E) because the turret truck's load range is from 1000 to 3,500 pounds (see Table 5.6). Only equipment which has a capacity equal to or above 4,000 pounds is evaluated. The storage/retrieval machine is the best equipment for pallet rack order picking.

A similar circumstance occurs when evaluating equipment for rackable order picking. The manned-up turret truck cannot be considered as a candidate for rackable order picking due to its limited load-handling capabilities. Instead, the hybrid truck and manned S/R machine are the best equipment for rackable order picking.

In binnable order picking, the situation is a little different. All equipment candidates for binnable order picking are evaluated because all equipment can handle the maximum load. The manned pick cart appears to be the best equipment.

The recommended system equipment based on least annual cost and system compatibility for the second problem is the S/R machine for pallet rack, the manned S/R machine for rackable order picking, the manned pick cart for binnable order picking and the reach truck for bulk storage. The manned S/R machine is chosen because it has the same aisle width requirements as the S/R machine. Table 6.4 shows the operation parameters of the third problem.
Table 6.4 Operating Parameters Problem 3

<table>
<thead>
<tr>
<th>Zone Storage</th>
<th>Inventory*</th>
<th>Transaction*</th>
<th>Max. load**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>1,000</td>
<td>45</td>
<td>2,000</td>
</tr>
<tr>
<td>Pallet Rack</td>
<td>30,000</td>
<td>1,200</td>
<td>4,000</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>5,000</td>
<td>300</td>
<td>4,000</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>70,000</td>
<td>3,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Building clear height = 60 feet

Note:
* In common denominator
** In pounds

The results show that the least costly equipment for pallet rack is the front sideloader truck. The candidates for equipment for pallet rack are the same as the candidates in the second problem. The key elements of the third problem which cause the program to choose the front sideloader truck instead of the S/R machine is that the front sideloader truck has less storage cost than the S/R machine (see the print out results in the appendixes), while the transaction cost of the S/R machine is less than the front sideloader truck. In conditions where the inventory is high and the transaction rate is low and the maximum load is greater than or equal to 4000 pounds, it is likely the front sideloader will be chosen for pallet racks, whereas in conditions where the inventory is low and the transaction rate is high, the S/R machine will be chosen.

In rackable order picking, the hybrid truck has the least
equipment cost compared to other rackable order picking equipment, but the program does not recommend this equipment due to incompatibility of the aisle with the pallet rack equipment.

In contrast, the program selects the order picking truck for binnable order picking instead of the manned pick cart. It is reasonable that the order picking truck is chosen for this situation, since the manned pick cart cannot handle the maximum load of 1,000 pounds and consequently is not evaluated.

The recommended equipment for problem 3 shows that the front sideloader is chosen for pallet rack due to its least annual cost. For rackable order picking the program does not recommend any systems because no systems are compatible with the aisle width of the pallet rack equipment. In this case the decision maker should determine the best equipment based on his/her knowledge of the system.

In problem number four the inventory of binnable is 100,000 units. This is the maximum inventory that this package can handle. The maximum load is reduced to 3,000 pounds for pallet rack, rackable order picking and bulk storage. Table 6.5 shows the operation parameters of the fourth problem.

Calculations by the program show the turret truck to have the least annual cost for pallet rack. Since the turret truck can handle the maximum load of 3,000 pounds, it is one of the candidates for pallet rack. In fact, the turret truck has the
Table 6.5 Operating Parameters Problem 4

<table>
<thead>
<tr>
<th>Zone Storage</th>
<th>Inventory*</th>
<th>Transaction*</th>
<th>Max. load**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>1,200</td>
<td>550</td>
<td>3,000</td>
</tr>
<tr>
<td>Pallet Rack</td>
<td>60,000</td>
<td>7,500</td>
<td>3,000</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>10,000</td>
<td>1,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>100,000</td>
<td>1,500</td>
<td>750</td>
</tr>
</tbody>
</table>

Building clear height = 60 feet

Note:
* In common denominator
** In pounds

lowest inventory cost at storage level five, and transaction cost at storage level two.

In rackable order picking, the hybrid truck has the least equipment cost. Although the hybrid truck also has the least annual cost, it is not recommended by the program for rackable order picking due to aisle width incompatibility with pallet rack equipment.

The carousel is selected as the least annual cost in problem four. The manned pick cart is not evaluated since it cannot handle the maximum load. Compared to the picking truck, the carousel has a lower transaction cost, but it has a higher inventory cost than the order picking truck. In situations where the inventory is high, but the transaction rate is low, the order picking truck is preferable.

The program recommends the turret truck for pallet rack,
and the man-up turret truck for rackable because of its aisle width compatibility. The carousel is chosen for binnable order picking because it has the lowest annual cost, and the reach truck is chosen for bulk storage because it has a narrow aisle which will support the pallet rack system. Table 6.6 shows the operation parameters of the fifth problem.

Table 6.6 Operation Parameters Problem 5

<table>
<thead>
<tr>
<th>Zone Storage</th>
<th>Inventory*</th>
<th>Transaction*</th>
<th>Max. load**</th>
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<tr>
<td>Bulk Storage</td>
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<td>250</td>
<td>4,000</td>
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<tr>
<td>Pallet Rack</td>
<td>20,000</td>
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<td>4,000</td>
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<tr>
<td>Rackable O/P</td>
<td>10,000</td>
<td>1,500</td>
<td>4,000</td>
</tr>
<tr>
<td>Binnable O/P</td>
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<td>8,500</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Building clear height = 60 feet

Note:
* In common denominator
** In pounds

Calculations by the program show that the storage/retrieval machine is chosen as the lowest annual cost for pallet rack. As in the second problem where the inventory is not high, while the transaction rate is extremely high and the maximum load is also high, the S/R machine is likely to be chosen for because it has a lower transaction cost, but higher inventory cost.

The hybrid truck is preferred for rackable order picking for this problem. Even though this equipment has lower
inventory and transaction costs compared to the manned S/R machine which is the second best equipment, it is again not selected by the program because of aisle width constraints.

The carousel is chosen as the least annual cost. Again in this situation the manned pick cart is not evaluated due to its incapability to handle the maximum load which is 1,000 pounds. In situations where the load is less or equal to 500 pounds, the manned pick cart is selected as the least annual cost.

The recommended system configuration for this particular problem is the S/R machine for pallet rack and the manned S/R machine as rackable equipment. The carousel has the lowest cost but is not compatible with the pallet rack equipment because it has a different function. The reach truck is selected for bulk storage because it has narrow aisle requirements which is required to support the pallet rack equipment.
CANDIDATE EQUIPMENT SELECTED
PALLETS RACK ORDER PICKING

STORAGE HEIGHT : 40.00 FEET
INVENTORY RATE : 7262 PALLETS
TRANSACTION RATE : 646 TRANSACTIONS/DAY

NO. EQUIPMENT SYSTEM STORAGE STORAGE INVENT TRANSAC ANN.SYS.COST
HEIGHT(FT) LEVEL COST($) COST($)  

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment System</th>
<th>Storage Height(FT)</th>
<th>Level</th>
<th>Cost($)</th>
<th>Cost($)</th>
</tr>
</thead>
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<td>Transaction Ann. Sys. Cost ($)</td>
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<td>---------------</td>
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</table>
CANDIDATE EQUIPMENT SELECTED
PALLETT RACK ORDER PICKING BASED ON EACH LEVEL

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>$282592.74</td>
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<td>9</td>
<td>TURRET TRUCK</td>
<td>39.00</td>
<td>10</td>
<td>$285422.30</td>
</tr>
</tbody>
</table>
THE BEST CANDIDATE SELECTED EQUIPMENT
PALLET RACK ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 40.00 FEET
INVENTORY RATE : 7262 PALLETS
TRANSACTION RATE : 646 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TURRET TRUCK</td>
<td>23.00</td>
<td>6</td>
<td>$ 255946.72</td>
</tr>
<tr>
<td>2</td>
<td>TURRET TRUCK</td>
<td>31.00</td>
<td>8</td>
<td>$ 256859.72</td>
</tr>
<tr>
<td>3</td>
<td>TURRET TRUCK</td>
<td>27.00</td>
<td>7</td>
<td>$ 259219.38</td>
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</table>
## Candidate Equipment Selected

### Rackable - Order Picking

**Storage Height**: 40.00 Feet  
**Inventory Rate**: 2300 Pallets  
**Transaction Rate**: 140 Transactions/Day

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment System</th>
<th>Storage Height (FT)</th>
<th>Level</th>
<th>Ann. Sys. Cost ($)</th>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING BASED ON EACH LEVEL

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<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>LEVEL</th>
<th>STORAGE ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
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</table>
THE BEST CANDIDATE SELECTED EQUIPMENT
RACKABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 40.00 FEET
INVENTORY RATE : 2300 PALLETS
TRANSACTION RATE : 140 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment System</th>
<th>Storage Height (ft)</th>
<th>Storage Level</th>
<th>Annual System Cost</th>
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CANDIDATE EQUIPMENT SELECTED
BINNABLE - ORDER PICKING

STORAGE HEIGHT : 40.00 FEET
INVENTORY RATE : 6300 BOXES
TRANSACTION RATE : 632 TRANSACTIONS/DAY

<table>
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<th>STORAGE HEIGHT(FT)</th>
<th>LEVEL</th>
<th>INVENTORY RATE</th>
<th>TRANSACTION RATE</th>
<th>ANN.SYS.COST</th>
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<td>MANNED S/R MACHINE</td>
<td>35.00</td>
<td>34</td>
<td>0.78</td>
<td>150.86</td>
<td>$ 100247.52</td>
</tr>
<tr>
<td>16</td>
<td>MINI S/R MACHINE</td>
<td>40.00</td>
<td>42</td>
<td>0.86</td>
<td>141.05</td>
<td>$ 94535.76</td>
</tr>
</tbody>
</table>
### CANDIDATE EQUIPMENT SELECTED
**BINNABLE - ORDER PICKING BASED ON EACH LEVEL**

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment System</th>
<th>Storage Height (FT)</th>
<th>Storage Level</th>
<th>Annual System Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MANNED PICK CART</td>
<td>7.00</td>
<td>7</td>
<td>$58846.99</td>
</tr>
<tr>
<td>2</td>
<td>ORDER PICKING TRUCK</td>
<td>14.00</td>
<td>13</td>
<td>$74435.23</td>
</tr>
<tr>
<td>3</td>
<td>MANNED PICK CART</td>
<td>15.00</td>
<td>14</td>
<td>$59080.82</td>
</tr>
<tr>
<td>4</td>
<td>ORDER PICKING TRUCK</td>
<td>21.00</td>
<td>20</td>
<td>$78733.85</td>
</tr>
<tr>
<td>5</td>
<td>MANNED PICK CART</td>
<td>23.00</td>
<td>21</td>
<td>$59205.59</td>
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<tr>
<td>6</td>
<td>ORDER PICKING TRUCK</td>
<td>28.00</td>
<td>27</td>
<td>$79802.38</td>
</tr>
<tr>
<td>7</td>
<td>MINI S/R MACHINE</td>
<td>30.00</td>
<td>11</td>
<td>$97876.64</td>
</tr>
<tr>
<td>8</td>
<td>ORDER PICKING TRUCK</td>
<td>35.00</td>
<td>34</td>
<td>$81937.18</td>
</tr>
<tr>
<td>9</td>
<td>MINI S/R MACHINE</td>
<td>40.00</td>
<td>42</td>
<td>$94535.76</td>
</tr>
</tbody>
</table>
THE BEST CANDIDATE SELECTED EQUIPMENT  
BINNABLE - ORDER PICKING  
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 40.00 FEET  
INVENTORY RATE : 6300 BOXES  
TRANSACTION RATE : 632 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MANNED PICK CART</td>
<td>7.00</td>
<td>7</td>
<td>$58846.99</td>
</tr>
<tr>
<td>2</td>
<td>MANNED PICK CART</td>
<td>15.00</td>
<td>14</td>
<td>$59080.82</td>
</tr>
<tr>
<td>3</td>
<td>MANNED PICK CART</td>
<td>23.00</td>
<td>21</td>
<td>$59205.59</td>
</tr>
</tbody>
</table>
### Recommended System Equipment Based on the Lowest Annual Cost & System Compatibility

<table>
<thead>
<tr>
<th>Zone</th>
<th>Equipment System</th>
<th>Storage Height (FT)</th>
<th>Storage Level</th>
<th>Annual System Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallet Rack</td>
<td>Turret Truck</td>
<td>23.00</td>
<td>6</td>
<td>$255,946.72</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>Man-Up Turret Truck</td>
<td>31.00</td>
<td>8</td>
<td>$584,563.38</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>Manned Pick Cart</td>
<td>7.00</td>
<td>7</td>
<td>$588,469.99</td>
</tr>
<tr>
<td>Bulk Storage</td>
<td>Reach Truck</td>
<td>20.00</td>
<td>5</td>
<td>---</td>
</tr>
</tbody>
</table>
### PRELIMINARY BUILDING LAY-OUT

<table>
<thead>
<tr>
<th>ZONE</th>
<th>COLUMN SPACING</th>
<th>MODULE SIZE</th>
<th>MODULES</th>
<th>AREA (SQUARE FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RACK STORAGE</td>
<td>26.167 * 38.833</td>
<td>26.167 * 163.2</td>
<td>13</td>
<td>55533</td>
</tr>
<tr>
<td>BULK STORAGE</td>
<td>26.167 * 38.833</td>
<td>26.167 * 163.2</td>
<td>6</td>
<td>25631</td>
</tr>
<tr>
<td>BINNABLE GAP</td>
<td>31.000 * 61.000</td>
<td>31.000 * 61.000</td>
<td>1</td>
<td>1891.0</td>
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</tbody>
</table>
## Manpower and Vehicles Requirement

<table>
<thead>
<tr>
<th>Zone</th>
<th>Equipment System</th>
<th>Total Hrs. Per Year</th>
<th>Number of Equipment</th>
<th>Number of Labors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallet Rack</td>
<td>Turret Truck</td>
<td>7790.76</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>Man-Up Turret Truck</td>
<td>1251.60</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>Manned Pick Cart</td>
<td>4803.20</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
**SHIPPING AND RECEIVING REQUIREMENT**

NO. OF SHIFT = 1

<table>
<thead>
<tr>
<th>ZONE</th>
<th>NO. OF PALLETS</th>
<th>NO. OF TRUCKS</th>
<th>DOCKING TIME</th>
<th>NO. OF DOCKS REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECEIVING</td>
<td>477</td>
<td>15</td>
<td>1.00</td>
<td>5.0</td>
</tr>
<tr>
<td>SHIPPING</td>
<td>487</td>
<td>12</td>
<td>1.50</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Total number of docks required = 14

Assume 2 docks per 30 foot building bay
Number of bays required = 7.0
Assume 50 foot dock depth
Staging area requirements = 10500.0 square feet
7.1 CONCLUSIONS

The significant contribution of this software package is the evaluation of several alternative material handling equipment configurations in the warehouse which satisfy the warehouse operating parameters. The selection of the preferred alternative is based on the least annual cost in each zone of the warehouse; and the establishment of the system configuration is based upon the most compatible equipment for the layout. Compatibility of the equipment is viewed only in terms of aisle suitability.

Five different problem scenarios of a warehouse were studied and several conclusions are drawn:

1. The turret truck is preferred when the inventory of pallet rack is high, the transaction rate is high, and the maximum load is less than or equal to 3,500 pounds.

2. The S/R machine is the preferred equipment when the inventory level is moderate, the transaction rate is extremely high and the maximum load is equal to or greater than 4,000 pounds. This is considered to be sophisticated equipment with great storage and retrieval capability, however it is quite expensive. Consequently, this equipment is preferred only when the transaction rate is very high.

3. A hybrid truck is preferred for rackable order picking
equipment when the inventory is high and the transaction is high. It is never selected in the five example problems due to aisle width incompatibility with pallet rack equipment. When the transaction rate is low, manned-up turret is preferable. In addition, this equipment has a limited capacity of 4,000 pounds. When the load is more than 4,000 pounds, only S/R equipment can be selected.

4. The manned pick cart is preferred for binnable order picking in a situation where the inventory level is high, but the transaction rate is not high and the maximum load is below or equal to 500 pounds. When the load is more than 500 pounds, the choice is between the order picking truck and the carousel. The carousel is preferred when the inventory level is high and the transaction rate is also high.

Other issues addressed by the software package include the capability of estimating the number of equipment units required in every zone of the warehouse and the number of laborers needed to operate the equipment.

Last, but not the least, the system addresses the configuration of the building required for a new or existing building. The software package has the ability to estimate the area needed for each module to support the inventory profile.

In addition to the building configuration, the software package also provides information concerning the number of
docks needed to support the receiving and shipping activities.

It is necessary to be aware of the different heights of storage level suggested by the software package. The example problem illustrates that the pallet rack equipment has different storage heights for rackable order picking and also for binnable and bulk storage. The user must decide whether to use the same building height for all the storage area or to use a separate construction for each storage. There is a trade off between the maintenance cost of the building and the construction cost.

Because the warehouse may change in the future, the software package provides the user with the ability to update and add data to the databases.

Another important issue concerning this package is that the procedures and values outlined in this thesis are primarily for comparative studies and will not provide absolute answers. For these reason, the user is advised not to accept the annual cost figures or any other results as absolutely accurate for a particular design. A clear definition of the problem and the environment should be initially developed before using this package.

7.2 Recommendations

The PC Warehouse Material Handling Equipment Selection Package Software may be enhanced. Ideas for future work are:

1. Investigate whether the selected material handling system
can accommodate the projected peak load while also considering the down time of the equipment. Further analysis through simulation of the results should be conducted.

2. Modules could be added to the package to allow for a wider application such as the calculation of support areas of the warehouse and staging areas. If these two modules were added, the complete configuration of the warehouse could be determined.

3. Further analysis may be done on transferring these results to a layout software package for the purpose of warehouse layout analysis.

4. The operation parameters for evaluation of the material handling equipment can be extended to include floor load capacity, and physical characteristics of material such as dimensions, shape, palletization capability and not only limited to the building height and equipment capacity.
BIBLIOGRAPHY


19. "Warehouse Renovation Lifts Storage Capacity 40 %", 

APPENDIX A
FLOWCHART
EQUIPMENT SELECTION FLOWCHART BASED ON ANNUAL SYSTEM COST

INPUT: INVENTORY PROFILE, TRANSACTION RATE, LOAD RATE OF EACH ZONE

NEW BUILDING?

Y

INPUT: CLEAR HEIGHT

N

OPEN EQUIPMENT DATABASE FILE

PICK ANY EQUIPMENT IN DATABASE OF ASSIGNED ZONE

4

DOES THE CAPACITY ≥ LOAD RATE?

Y

START WITH THE LOWEST LEVEL OF EQUIPMENT HEIGHT

3

N

FITS WITH THE BUILDING LIMIT

DETERMINE STANDARD TRANSACTION TIME FOR STORING & RETRIEVING BASED ON THE INVENTORY PROFILE

CALCULATE ANNUAL LABOR HRS PER DAILY TRANSACTIONS = STANDARD TRANS. TIME * NO. OF ISSUE/DAY * NO. OF DAYS/YEAR

ANNUAL LABOR COST/DAILY TRANSACTIONS = ANNUAL LABOR HRS/DAILY TRANSACTION * HOURLY RATE

GOTO NEXT EQUIPMENT
EQUIPMENT SELECTION FLOWCHART BASED ON ANNUAL SYSTEM COST (CONT)

1

VEHICLE HOURS = LABOR HOURS

ANNUAL VEHICLE OPERATION COST / DAILY TRANSACTIONS = VEH.HRS. / DAILY TRANSACTIONS * VEH.RATE COST

ANNUAL TRANSACTION RELATED COST / DAILY TRANSACTION = ANN. LABORS COST + ANN. VEH. COST

NEW BUILDING?

Y

CALCULATE BUILDING CONSTRUCTION PER SQUARE FOOT

N

ANNUAL BUILDING CONSTRUCTION COST = 0

CALCULATE ANNUAL BUILDING CONSTRUCTION COST PER SQUARE FOOT

DETERMINE ANNUAL BUILDING COST PER SQUARE FOOT

INPUT MODULAR LAYOUT PER PALLET FOR EQUIPMENT ASSIGNED

CALCULATE ANNUAL BUILDING COST/PALLET POSITION = (ANN.BLD.CONSTRUCTION COST + ANN BLD OPERATION COST) * BLD AREA PER PALLET POSITION

INPUT: STORAGE EQUIPMENT COST ELEMENT PER PALLET

CALCULATE STORAGE EQUIPMENT COST PER PALLET POSITION

NOTE:
The unit denominator, pallet, can be changed to others such as carton, box, etc.
EQUIPMENT SELECTION FLOWCHART BASED ON ANNUAL SYSTEM COST (CONT)

2

DETERMINE ANNUAL STORAGE EQUIPMENT COST PER PALLET POSITION

ANNUAL INVENTORY RELATED COST = ANNUAL BUILDING COST/PALLET + ANNUAL STORAGE/PALLET POSITION

ANNUAL SYSTEM COST FOR ASSIGNED EQUIPMENT = (ANNUAL INVENTORY RELATED COST/PALLET) * INVENTORY + (ANNUAL TRANSACTION RELATED COST/DAILY TRANS) * TRANSACTIONS

SAVE THE RESULT OF CALCULATION IN TEMPORARY FILE

3

INCREASE THE LEVEL OF EQUIPMENT BY ONE

Y

IS THE HEIGHT OF PALLET > CLEAR HEIGHT

N

SELECT ANOTHER EQUIPMENT SYSTEM WHICH MEETS THE REQUIREMENTS OF LOAD AND BUILDING LIMITATION

FOLLOW THE SAME PROCEDURE TO GET ANNUAL SYSTEM COST FOR EVERY LEVEL HEIGHT OF THE EQUIPMENT

4

HAVE ALL EQUIP. BEEN CHECKED?

Y

SELECT THE EQUIPMENT SYSTEM BASED ON THE LOWEST ANNUAL SYSTEM COST
EQUIPMENT SELECTION FLOWCHART BASED ON ANNUAL SYSTEM COST (CONT)

5

DO THE SAME PROCEDURE FOR OTHER ZONE IN THE WAREHOUSE

OPEN TEMPORARY FILE WHICH HAS THE RESULT OF CALCULATION, SORT THEM BY THE LOWEST COST IN EACH ZONE

BASED ON THE BEST SELECTED EQUIPMENT IN EACH ZONE, EXAMINE WHETHER THE EQUIPMENT FITS EACH OTHER

DOES IT FIT EACH OTHER

Y

SELECT THE NEXT BEST

N

BASED ON SELECTED EQUIPMENT, DETERMINE THE MODULE & AREA IN SQ. FEET FOR EACH ZONE

DETERMINE THE NUMBER OF MAN-HOURS AND VEHICLE HOURS REQUIRED, BASED ON THE SELECTED EQUIPMENT AND NO. OF TRANSACTIONS

NUMBER OF LABORS REQUIRED = MAN-HOURS NEEDED / NO. OF MAN-HOURS/YEAR

NUMBER OF EQUIPMENT REQUIRED = VEHICLE HOURS REQUIRED / NO. OF VEHICLE HOURS/YEAR

CALCULATE NO. OF DOCKS, BASED ON NO. OF TRUCKS ARRIVE IN RECEIVING & NO. OF TRUCKS LEAVE IN SHIPPING, DOCKING TIME AND WORKING HOURS/DAY

STOP
APPENDIX B

USER'S MANUAL
The Warehouse Material Handling Selection Software Package has been designed for use by those who have little or no knowledge of computers or computer programming. The user interacts with the programs by selecting options, answering questions, and supplying the required information. A menu format provides the user with a friendly environment. The user of this package is assumed to have a knowledge of warehousing operations.

Hardware and Software Requirements

To operate the software package the user must have an IBM Personal Computer or fully IBM PC compatible computer. The configuration of the hardware is one or two floppy disk drives, a hard disk, a monitor, and a printer. The software required to operate the package is dBase IV or higher version. The operating system for the IBM PC uses PC DOS, version 3.1 or higher.

Getting Started

To boot the system, the user needs PC DOS. The system configuration requires a hard disk drive to support the applications. If your system has a hard disk, PC DOS will probably be resident on that disk and will boot automatically when you turn on the PC. If your C drive (hard disk) does not have DOS, load it manually from the A drive. To load DOS,
place the DOS diskette in the A disk drive and turn on the computer. Once DOS has been loaded, the following prompt will be displayed: A>. This signals that the computer system is ready to run any application program in the A drive.

Once you are in DOS environment, you need to load your software package into C drive in the dBase directory. To load the package, remove the DOS disk, place the package disk in the A drive, close the drive, and type "copy *.* c:\dBASE".

The dBase IV compiler must be on the C drive to allow the program to run. If your current drive is not the C drive, change the current logged drive to the C drive by simply typing "C:" and pressing return.

Once you get the C> prompt you are ready to load your dBase compiler. To load dBase simply type dBase after the C> prompt. The dBase logo will appear on the screen. You are now in the dBase environment. To run the program you must have the dot prompt (.). In the dBase IV environment you can get this prompt by pressing the Fl0 function key and then selecting the dot prompt by using the arrow key. Once you are in dot prompt (.) within the dBase environment you are ready to run the software package.

Using The Software Package

To start the program you type DO MAINN at the dot prompt, then press return and the following menu will appear on the screen.
The user must select an option by typing the corresponding number and pressing the return key. The program corresponding to the selected item will be executed.

If the user types 1 (Adding Data File), then presses return, another menu will appear. This menu is for adding data in an existing file. The menu is as follows:

Choice number 1 is for adding transaction times for pallet racks. Choice 2 is for adding transaction times for rackable order picking. Choice 3 is for adding transaction times for binnable order picking. Choice 4 adds vehicle and labor cost. Choice 5 is for building construction and maintenance cost. Choice 6 adds modular layout and choice 7 returns to the main menu.

If the user selects option 2 in main menu, the updating
data menu for an existing data file will appear. This menu is similar to adding a data file, with the only difference being that updating a data file corrects data in an old data record instead of adding a new record to the file.

If the user selects option 3 the user may select material handling equipment. There are two options, the first is for an existing building while the second is for new building. The menu is as follows:

```
==*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=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```

The option of selecting equipment for an existing building or a new building is dependant upon the user's problem. Either of these selections require input in order to select the appropriate equipment. The input data needed by the program is as follows:

**INPUT DATA DECLARATION**

<table>
<thead>
<tr>
<th>Zone Storage</th>
<th>Inventory*</th>
<th>Transaction*</th>
<th>Max. load**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>----</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Pallet Rack</td>
<td>----</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Rackable O/P</td>
<td>----</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Binnable O/P</td>
<td>----</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Building clear height = -- feet

Note:
* In common denominator  ** In pounds
The user must provide the data which represents the activities of a warehouse. Zone column designates the storage area, inventory rate depicts the inventory profile of each storage, transaction rate shows the transaction rate of unit common denominator in each storage, and the maximum lift shows the maximum load rates. Each column must be completed in order to evaluate the materials handling equipment. There is a range limit for the inventory for rackable and binnable order picking. Rackable order picking has an inventory range of 1000 to 10,000 pallets, while binnable order picking has inventory limit from 2,000 to 100,000 boxes. These limitations are due to the transaction times available in the table. The software package can not evaluate equipment beyond these limitations.

Once the user has input the data the program will allow the user to edit the data. The program will next ask the user whether the results are to be displayed on the screen or on the printer. You can not print the result after you choose the screen option.

The program will now begin the selection of material handling equipment. The user is required to interact with the program during execution, i.e. the program will prompt the user while the program is running.

The sequence of the results will appear on the screen as shown in the Chapter Six in section 6.2 "Results".

Once the computer has selected the material handling
equipment, the program will automatically return to the selection of material handling equipment menu. To exit the program, the user must return to the main menu. After exiting, the user is in the dBase environment. To quit the dBase environment simply type quit at the dot prompt, then press return. The prompt C>dBase> will show up on your screen. You are now in DOS environment.
APPENDIX C

DATABASE STRUCTURE
The design of databases is a critical phase in creating a software package. The design and size of the database is crucial since it effects the computer time and the performance of the program. For this reason, the data base should be designed efficiently and effectively, so that the program can easily access and retrieve the data in a file.

There are 14 databases in the software package (see List 1). These databases were created using the Fox Base software, and then they transferred to dBase IV.

<table>
<thead>
<tr>
<th>Database Files</th>
<th># Records</th>
<th>Last Update</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALSTOR.DBF</td>
<td>9</td>
<td>01/01/80</td>
<td>247</td>
</tr>
<tr>
<td>TRANSC.DBF</td>
<td>448</td>
<td>01/01/80</td>
<td>10498</td>
</tr>
<tr>
<td>TRANPAL.DBF</td>
<td>51</td>
<td>01/01/80</td>
<td>2987</td>
</tr>
<tr>
<td>BINNA.DBF</td>
<td>224</td>
<td>01/01/80</td>
<td>5346</td>
</tr>
<tr>
<td>VEHICLE.DBF</td>
<td>30</td>
<td>01/01/80</td>
<td>1280</td>
</tr>
<tr>
<td>BUILDING.DBF</td>
<td>18</td>
<td>01/01/80</td>
<td>432</td>
</tr>
<tr>
<td>MODUL.DBF</td>
<td>14</td>
<td>01/01/80</td>
<td>1780</td>
</tr>
<tr>
<td>PALSTORE.DBF</td>
<td>66</td>
<td>01/01/80</td>
<td>1580</td>
</tr>
<tr>
<td>BINCO.DBF</td>
<td>16</td>
<td>01/01/80</td>
<td>658</td>
</tr>
<tr>
<td>TEMP2.DBF</td>
<td>14</td>
<td>01/01/80</td>
<td>1227</td>
</tr>
<tr>
<td>TEMP1.DBF</td>
<td>33</td>
<td>01/01/80</td>
<td>2500</td>
</tr>
<tr>
<td>BULK.DBF</td>
<td>9</td>
<td>01/01/80</td>
<td>170</td>
</tr>
<tr>
<td>TEMP4.DBF</td>
<td>93</td>
<td>01/01/80</td>
<td>6024</td>
</tr>
<tr>
<td>TEMP3.DBF</td>
<td>16</td>
<td>01/01/80</td>
<td>1361</td>
</tr>
</tbody>
</table>

List 1

Each of these databases has a unique file structure. Each file contains several records. A record is a single piece of information which may consist of several record fields.

The first column of List 1 indicates the database file names, the second column shows the number of records in each
database file, the third column shows the date of last update for that file (the column shows the same date for all files, because of a problem in the Fox Base software), and the last column shows the size of the file (the number of bytes).

Palstore Dbf is used as a substitute for Palstor Dbf in this software. The Palstore file contains the storage cost for a particular storage level of the equipment used. It has 66 records in the file and 5 fields in every record (see list 2).

Structure for database: C:\DBASE\PALSTORE.DBF
Number of data records: 66
Date of last update : 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CODE</td>
<td>Character</td>
<td>3</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>LEVEL</td>
<td>Numeric</td>
<td>2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>NON_GUIDE</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>WITH_GUIDE</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>EQUIP_COST</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
</tbody>
</table>

** Total ** 21

List 2

The Code field identifies the material handling equipment used, the Level field refers to the storage level of the equipment used, while the Non_guide field refers to the cost of storage if the equipment does not use a guide. The With_guide field refers to the cost of storage if the equipment use a guide and Equip_Cost field refers to the equipment operating cost for Storage/Retrieval systems.

Transac Dbf contains the transaction times of rackable order picking equipment. It has 224 records and each record
has 5 fields. Every record indicates the transaction time of equipment for a given inventory level. The Code field again identifies the equipment, Avg_Inv refers to Average inventory, Stg_Level refers to storage level height, Height refers to the height in feet of the storage level and Tottime refers to the total time of transaction needed for a particular type of equipment (see List 3).

Structure for database: C:\DBASE\TRANSAC.DBF
Number of data records: 448
Date of last update : 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CODE</td>
<td>Character</td>
<td>3</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 AVG_INV</td>
<td>Numeric</td>
<td>6</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 STG_LEVEL</td>
<td>Numeric</td>
<td>2</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 HEIGHT</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>5 TOTTIME</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>** Total **</td>
<td></td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List 3

Binna Dbf has the same database structure as Transac Dbf. The only difference between the two is that Binna dbf contains the transaction times of binnable order picking equipment while transac Dbf contains the transaction time of rackable order picking equipment (see List 4).

Tranpal Dbf stores the transaction times of pallet rack order picking or pallet rack storing. Tranpal Dbf has 51 records and each record has 11 fields. Except for the first two fields, each field defines the time of one transaction. Travel field contains the time to travel from the start to the
Structure for database: C:\DBASE\BINNA.DBF
Number of data records: 224
Date of last update: 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CODE</td>
<td>Character</td>
<td>3</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>AVG_INV</td>
<td>Numeric</td>
<td>6</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>STG_LEVEL</td>
<td>Numeric</td>
<td>2</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>HEIGHT</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>TOTTIME</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
</tr>
</tbody>
</table>

** Total **

List 4

destination, the Stop field contains the equipment stop time, the Access field has the time needed to access the material, the Maneuver field has the time needed to make a maneuver, the Document field has the time needed to finish all documents, the Lift and Lower fields contain the time needed to lower and to lift the equipment, and Tot_ll is the total time needed to complete one transaction, including a 20% personal fatigue and delay allowance (see List 5).

Vehicle Dbf contains the characteristics of the equipment. Vehicle Dbf has 30 data records, each record has 8 fields. Minlevel refers to minimum level at which the equipment can retrieve material, while Maxlevel is the opposite. Minlift and Maxlift is the load range that the equipment can lift. Purchase refers to the price of the equipment, Operate refers to the annual operating cost of the equipment and Labor refers to labor cost per hour of the equipment (see List 6).

Building Dbf contains building construction and
Structure for database: C:\DBASE\TRANPAL.DBF
Number of data records: 51
Date of last update: 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>CODE</td>
<td>Character</td>
<td>3</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>LEVEL</td>
<td>Numeric</td>
<td>2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TRAVEL</td>
<td>Numeric</td>
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<td>3</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>STOP</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>ACCESS</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>MANUVER</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
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<td>Numeric</td>
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<td>3</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>LIFT</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>9</td>
<td>LOWER</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>10</td>
<td>HEIGHT</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>11</td>
<td>TOT_LL</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
</tbody>
</table>

**Total** 51

Structure for database: C:\DBASE\VEHICLE.DBF
Number of data records: 30
Date of last update: 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CODE</td>
<td>Character</td>
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</tr>
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<td>MINLEVEL</td>
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<td>N</td>
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</tr>
<tr>
<td>4</td>
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<td>Numeric</td>
<td>5</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>MAXLIFT</td>
<td>Numeric</td>
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<td>N</td>
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</tr>
<tr>
<td>6</td>
<td>PURCHASE</td>
<td>Numeric</td>
<td>6</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>OPERATE</td>
<td>Numeric</td>
<td>4</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>LABOR</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
</tbody>
</table>

**Total** 33

maintenance cost for a particular height of the building.

Building Dbf has 18 records, each record has 4 fields.

The Construc field refers to the construction building cost for a certain range of heights, represented by Minheight and Maxheight. The Maintain field refers to the maintenance cost for given height ranges of the building (see List 7).

Modul Dbf contains information about the modular layout
Structure for database: C:\DBASE\BUILDING.DBF
Number of data records: 18
Date of last update: 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MINHEIGHT</td>
<td>Numeric</td>
<td>2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CONSTRUC</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>MAINTAIN</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>MAXHEIGHT</td>
<td>Numeric</td>
<td>2</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>** Total **</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List 7

of particular equipment. Modul Dbf has 14 records which represents the number of equipment choices available for the material handling system. Each record has 13 fields. The Name field refers to the equipment name, Aisle refers to the aisle width needed for particular equipment, Lengtha refers to the module length and Lengthb refers to the space between the columns. Widtha, Widthb, and Widthh refer to the width of primary, alternate and hazardous/flammable modular layout, Colspac refers to column spacing of the module, Unita and Unitb refer to the number of units of pallet or other unit storage for the primary and alternate module. Maxh and Minh refers to the maximum and minimum level of storage (see List 8).

Binco Dbf contains the cost of the binnable storage system. Binco has 16 data records, and each record has 5 fields. System field refers to the system cost of the storage equipment, the Sprinkler field refers to additional cost due to additional height of the storage. Mezzanine refers to the
cost of building a mezzanine for additional storage. Boxes refers to the number of boxes which can be carried (see List 9).

Structure for database: C:\DBASE\MODUL.DBF
Number of data records: 14
Date of last update: 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CODE</td>
<td>Character</td>
<td>3</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>NAME</td>
<td>Character</td>
<td>30</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>AISLE</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>LENGETA</td>
<td>Numeric</td>
<td>6</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>LENGTHB</td>
<td>Numeric</td>
<td>6</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>WIDTHA</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>WIDTHB</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>WIDTHH</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>9</td>
<td>COLSPAC</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>10</td>
<td>UNITA</td>
<td>Numeric</td>
<td>5</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>UNITB</td>
<td>Numeric</td>
<td>5</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>MAXH</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>13</td>
<td>MINH</td>
<td>Numeric</td>
<td>5</td>
<td>2</td>
<td>N</td>
</tr>
</tbody>
</table>

**Total**: 95

List 8

Structure for database: C:\DBASE\BINCO.DBF
Number of data records: 16
Date of last update: 01/01/80

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CODE</td>
<td>Character</td>
<td>3</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>LEVEL</td>
<td>Numeric</td>
<td>2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SYSTEM</td>
<td>Numeric</td>
<td>6</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>SPRINKLER</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>MEZZANINE</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>BOXES</td>
<td>Numeric</td>
<td>5</td>
<td>3</td>
<td>N</td>
</tr>
</tbody>
</table>

**Total**: 27

List 9

Temp1 Dbf, Temp2 Dbf, and Temp3 Dbf all have the same data base structure. They are all temporary databases. Temp1 dbf stores the results of calculation in pallet storage. Temp2 dbf is for Rackable order picking and Temp3 is for Binnable order picking. The structure of the databases is shown in list
10. Temp1 Dbf represented Temp2, and Temp3 Dbf since all three have the same structure. The first four fields have been explained previously. Inv_cost refers to the inventory related cost for a particular equipment level of storage, Tra_cost refers to transaction related cost, Tot_cost refers to the total cost of the equipment for a particular storage height, and Anulab refers to annual labor cost.

Structure for database: C:\DBASE\TEMP1.DBF
Number of data records: 33
Date of last update: 01/01/80
Field Field Name Type Width Dec Index
1 CODE Character 3 N
2 NAME Character 30 N
3 LEVEL Numeric 3 N
4 HEIGHT Numeric 5 2 N
5 INV_COST Numeric 5 2 N
6 TRA_COST Numeric 6 2 N
7 TOT_COST Numeric 9 2 N
8 ANULAB Numeric 5 2 N
** Total ** 67

List 10

Note Temp4 Dbf is not used in the program. It exists for sample databases only.

The last database is Bulk Dbf. The bulk Dbf contains the module layout for bulk storage. Bulk Dbf has 9 data records and each record has 2 fields. Column and Pallet fields explain how many pallet can be arranged for a particular column length (see List 11).

Structure for database: C:\DBASE\BULK.DBF
Number of data records: 9
Date of last update: 01/01/80
Field Field Name Type Width Dec Index
1 COLUMN Numeric 5 2 N
2 PALLET Numeric 2 N
** Total ** 8

List 11
APPENDIX D

PROGRAM LISTING
mainn.prg 01/01/80

* ---- Program creating main menu
* ---- for selection of material handling equipment
* ---- by Adi Saptari 04/16/90

set talk off
set echo off
set status off
set safety off
do while .t.
clear
@ 4,20 SAY "=================================
@ 6,25 SAY " MAIN MENU "
@ 7,24 SAY "----------"
@ 9,20 SAY "1. ADDING DATA FILE "
@ 10,20 SAY '2. UPDATE DATA FILE '
@ 11,20 SAY '3. EQUIPMENT SELECTION '
@ 12,20 SAY '4. EXIT FROM THE PROGRAM '
@ 13,20 SAY "=================================

INPUT " SELECT YOUR CHOICE ..." TO SELECT
set color to GR+/B
clear
do case
    case select = 1
do main1
case select = 2
do main2
case select = 3
do main3
case select = 4
    exit
endcase
endo
do while .t.
clear
set color to
main1.prg 01/01/80

* ---- Sub menu from main menu
* ---- Program creating adding data menu
* ---- for selection of material handling equipment
* ---- by Adi Saptari 04/16/90

set talk off
set echo off
set status off
set safety off

do while .t.
clear

@ 5,15 say "==============================
@ 7,20 say " ADDING DATA FILE ">
@ 8,19 SAY "------------------------
@ 10,15 SAY '1. TRANSAC. TIME OF PALLET RACK'
@ 11,15 SAY '2. TRANSAC. TIME OF RACKABLE'
@ 12,15 SAY '3. TRANSAC. TIME OF BINNABLE'
@ 13,15 SAY '4. VEHICLE AND LABOR COST'
@ 14,15 SAY '5. BUILDING CONSTRU.& MAINTAIN.'
@ 15,15 SAY '6. MODULAR LAY-OUT'
@ 16,15 say '7. RETURN TO MAIN MENU'
@ 17,15 SAY "=================================="

INPUT " SELECT YOUR CHOICE ..." TO SELECT

do case
   case select = 1
do input1
case select = 2
do input3
case select = 3
do input4
case select = 4
do input6
case select = 5
do input5
case select = 6
do input2
case select = 7
exit
endcase
endo
doi
return
set color to
main2.prg 01/01/80

* ---- Sub menu from main menu
* ---- Program creating updating data menu
* ---- for selection of material handling equipment
* ---- by Adi Saptari 04/16/90

set talk off
set echo off
set status off
set safety off

Do while .t.
clear

 5,15 say "===================================
 7,20 say " UPDATING DATA FILE 
 8,19 say "-----------------
10,15 say '1. TRANSAC. TIME OF PALLET RACK '
11,15 say '2. TRANSAC. TIME OF RACKABLE '
12,15 say '3. TRANSAC. TIME OF BINNABLE '
13,15 say '4. VEHICLE AND LABOR COST '
14,15 say '5. BUILDING CONSTRU.& MAINTAIN. '
15,15 say '6. MODULAR LAY-OUT '
16,15 say '7. RETURN TO MAIN MENU '
17,15 say "===================================

INPUT " SELECT YOUR CHOICE ... " TO SELECT

do case
  case select = 1
do updat1
case select = 2
do updat2
case select = 3
do updat3
case select = 4
do updat4
case select = 5
do updat5
case select = 6
do updat6
  case select = 7
  exit
endcase
dendo
return
set color to
* ---- Program creating menu
* ---- for selection of material handling equipment
* ---- by Adi Saptari 04/16/90
set talk off
set echo off
set status off
set safety off
do while .t.
clear
@ 5,15 say "==============================================================="
@ 7,15 say " SELECTION OF MATERIAL HANDLING EQUIPMENT"
@ 8,15 say "==============================================================="
@ 10,15 say '1. EXISTING BUILDING '
@ 11,15 say '2. NEW BUILDING '
@ 12,15 say '3. RETURN TO MAIN MENU'
@ 13,15 say "==============================================================="
* INPUT " SELECT YOUR CHOICE ..." TO SELECT
do case
    case select = 1
        do cobal with select
    case select = 2
        do cobal with select
    case select = 3
        exit
endcase
endo
dereturn
Program inputting data for selection of mat'1 handling equipment

New Building & existing building

parameters opt

set talk off

set status off

set color to GR+/B

choice = 1

ch = 1

clear
do while .t.

if choice <> 2

store 0 to minvel, minve2, minve3, minve4,;
transc1, transc2, transc3, transc4,;
lift1, lift2, lift3, lift4

store 0.00 to mheight

endif

4.26 SAY "INPUT DATA DECLARATION"

5.26 SAY " "

8.8 SAY "=====================================

9.12 SAY "ZONE"

9.21 SAY "INVENTORY RATE"

9.38 SAY "TRANSACTION RATE"

9.57 SAY "MAXIMUM LIFT"

10.8 SAY "=====================================

12.8 SAY "BULK STORAGE"

13.8 SAY "PALLET STORAGE"

14.8 SAY "RACKABLE O/P "

15.8 SAY "BINNABLE O/P "

16.8 SAY "=====================================

18.18 SAY "INPUT BUILDING HEIGHT : "

12.25 get minvel pict "999999"

12.43 get transc1 pict "999999"

12.59 get lift1 pict "999999"

13.25 get minve2 pict "999999"

13.43 get transc2 pict "999999"

13.59 get lift2 pict "999999"

14.25 get minve3 pict "999999"

14.43 get transc3 pict "999999"

14.59 get lift3 pict "999999"

15.25 get minve4 pict "999999"

15.43 get transc4 pict "999999"

15.59 get lift4 pict "999999"

18.42 get mheight pict "999"

read

if minvel = 0

set color to

exit

endif

20.25 say " READY = 1"

20.37 say " EDIT = 2"

20.49 say " CANCEL = 3"

21.27 say " Your choice ..." get choice pict "99"

read

do case

  case choice = 1
cobal.prg 01/01/80

clear
@ 22,15 say "Send output to >> "
@ 22,35 say " SCREEN = 1"
@ 22,48 say " PRINTER = 2"
@ 23,15 say "Your choice ..." get ch pict "99"
read
if ch = 2
    @ 8,20 say "Set the printer ready !!"
    @ 10,20 say "Set paper on top of the printer "
    @ 13,20 say " "
    wait
    set device to printer
endif
do built with rnheight, rninve2, transc2, opt, ch,lift2
do racka with rnheight, minve3, transc3, opt, ch,lift3
do bin with rnheight, minve4, transc4, opt, ch,lift4
do resume with lift1
do layout with minve1,minve2,minve3, minve4
do labor with transc2, transc3, transc4
do dock with ch
set device to screen
exit
    case choice = 2
endcase
enddo
return
Program calculating Transaction & Inventory

Related cost per unit denominator

For pallet rack

3/22/90 by Adi Saptari

parameters mheight, minve, transc, opt2, ch, lift

select 1
use tranpal index tranpal
select 2
use vehicle index vehicle
select 3
use palstore index palstore
select 4
use building
select 5
use modul index modul
select 6
use templ index tlevel,tot

delete all
pack
ch1 = 1
select 1
clear
do while height <= mheight .and. not. eof()

IF (CODE = 'HBT') .OR. (CODE = 'TTC')
TRANSAC = (TRAVEL+STOP+ACCESS+MANUVER+DOCUMENT+TOT_LL)*1.2
ELSE
IF (CODE = 'MAC')
TRANSAC = DOCUMENT*1.2
ELSE
TRANSAC = :
(TRAVEL+STOP+ACCESS+MANUVER+DOCUMENT+LIFT+LOWER)*1.2
ENDIF

vcode = code
mlevel = level
vtheight = height

do while mcode = code
if (mlevel >= minlevel).and.(mlevel <= maxlevel):

ANLAB = (TRANSAC*250)/60
LABCOST = ANLAB*LABOR
HOURVEH = ((PURCHASE/10) + OPERATE)/2000
VEHCOST = HOURVEH*ANLAB
VEHOPCOST = (VEHCOST+LABCOST)

do while mcode = code

STORCOST = (WITH_GUIDE+EQUIP_COST)/10
EXIT
ELSE
IF (MCODE = 'HBT') .AND. (MLEVEL = LEVEL)
STORCOST = (NON_GUIDE+WITH_GUIDE)/10
EXIT
ELSE
IF (MCODE = 'CNT') .AND. (MLEVEL = LEVEL)
STORCOST = NON_GUIDE/10
else

STORCOST = NON_GUIDE/10
EXIT
ELSE
IF (MCODE = 'FST') .AND. (MLEVEL = LEVEL);
.OR. (MCODE = 'MTT') .AND. (MLEVEL = LEVEL);
.OR. (MCODE = 'TTC') .AND. (MLEVEL = LEVEL)
STORCOST = WITH_GUIDE/10
EXIT
ELSE
ENDIF
ENDIF
ENDIF
ENDIF
SKIP
ENDIF
enddo
select 4
  do while .not. eof()
    if (theight > minheight).AND. (theight <= maxheight)
      if opt2 = 2
        CONCOST = CONSTRUC/25
      else
        CONCOST = 0.0
      endif
      MAIN = MAINTAIN
      exit
    else
      skip
    endif
  enddo
select 5
  seek mcode
    STORAGE = LENGHTA*WIDTHA
    UNITAR = STORAGE/UNITA
    BUILDAR = UNITAR/MLEVEL
    BUILCOS = (CONCOST+MAIN)*BUILDAR
    ANSTOR = (BUILCOS + STORCOST)
    MTOT = (ANSTOR*MINVE) + (VEHOPCOST*TRANSC)
    MNAME = NAME
  select 6
    appe blank
    replace code with mcode, name with mname, level with mlevel,:
    height with theight, inv_cost with anstor,:
    tra_cost with vehopcost, tot_cost with mtot,;
    anulab with anlab
    select 2
    exit
    else
      skip
    endif
  enddo
select 1
skip
enddo
  close databases /
  do tempo with mheight, minve, transc, ch, ch1
close databases
return
**Program calculating Transaction & Inventory**

* Related cost per unit denominator
* For Rackable Order Picking
* 3/22/90 by Adi Saptari

**Parameters: mheight, minve, transc, optl, ch, lift**

```plaintext
select 1
use transac index transac
select 2
use vehicle index vehicle
select 3
use palstore index palstore
select 4
use building
select 5
use modul index modul
select 6
use temp2 index tlevel2, tot2
delete all
pack
select 1
clear
store 'aaa' to mcode
chl = 2
```

```plaintext
do while height <= mheight .and. .not. eof()
    if (mcode = code).and.(mlevel = stg_level)
        skip
    else
        if AVG_INV >= MINVE
            TRANS = TOTTIME
            mcode = code
            mlevel = stg_level
            theight = height
        select 2
        seek mcode
        do while mcode = code
            if (mlevel = minlevel).and.(mlevel <= maxlevel);
                .and.(lift <= maxlift)
                ANLAB = (TRANS*250)/60
                LABCOST = ANLAB*LAVOR
                HOURVEH = ((PURCHASE/10) + OPERATE)/2000
                VEHCost = HOURVEH*ANLAB
                VEHOPCOST = (VEHcost+LABcost)
        select 3
        seek mcode
        do while mcode = code
            if (mcode = 'ASR').and.(mlevel = LEVEL)
                STORCOST = (WITH_GUIDE+EQUIP_COST)/10
            exit
            else
                if (mcode = 'HBT').and.(mlevel = LEVEL)
                    STORCOST = (WITH_GUIDE)/10
                exit
                else
                    if (mcode = 'OPT').and.(mlevel = LEVEL)
                        STORCOST = (WITH_GUIDE)/10
                    exit
                    else
                        ENDIF
                ENDIF
            ENDIF
        ENDwhile
    ENDIF
 ```
SKIP
ENDIF
enddo
select 4
  do while .not..eof()
    If (theight >= minheight).AND.(theight <= maxheight)
      if optl = 2
        CONCOST = CONSTRUC/25
      else
        CONCOST = 0.0
      endif
      MAIN = MAINTAIN
      exit
    else
      skip
    endif
  enddo
select 5
select 6
  appe blank
  replace code with mcode, name with mname,;
  level with mlevel, height with theight,;
  inv_cost with anstor, tra_cost with vehopcost,;
  tot_cost with mtot, anulab with anlab
select 2
  exit
else
  skip
endif
endo
select 1
else
endif
endif
skip
endo
close databases
do tempo with mheight, minve, transc, ch, chl
close databases
return
Program Calculating Transaction & Inventory
Related Cost per unit denominator
For Binnable Order Picking
3/22/90 by Adi Saptari

Parameters: mheight, minve, transc, opt, ch, lift

Introduction:

select 1
use binna index binna
select 2
use vehicle index vehicle
select 3
use binco index binco
select 4
use building
select 5
use modul index modul
select 6
use temp3 index tot3, tlevel3

delete all
pack
select 1
clear
store 'aaa' to mcode
ch1 = 3
do while height <= mheight .and. .not. eof()
  if (mcode = code) .and. (mlevel = stg_level)
    skip
  else
    if AVG_INV >= MINVE
      TRANS = TOTTIME
      mcode = code
      mlevel = stg_level
      theight = height
      select 2
      seek mcode
      do while mcode = code
        if (mlevel >= minlevel) .and. (mlevel <= maxlevel);
          .and. (lift <= maxlift)
          ANLAB = (TRANS*250)/60
          LABCOST = ANLAB*LABOR
          HOURVEH = ((PURCHASE/10) + OPERATE)/2000
          VEHV = HOURVEH*ANLAB
          VEHOP = (VEHCOST+LABCOST)
        select 3
        seek mcode
        do while mcode = code
          IF LEVEL = MLEVEL
            STORCOST = (SYSTEM+MEZZANINE+SPRINKLER+BOXES)/10
            EXIT
            ELSE
              SKIP
            ENDFI
        enddo
    enddo
    select 4
    do while .not. eof()
      if (theight >= minheight) .and. (theight <= maxheight)
        if opt = 2
          CONCOST = CONSTRUC/25
        else
          CONCOST = 0.0
        endif
      endif
    enddo
endif
MAIN = MAINTAIN
exit
else
skip
endif
enddo

select 5
seek mcode

STORAGE = LENGHTA*WIDTHA
UNITAR = STORAGE/UNITA
IF (CODE = 'CRL').OR.(CODE = 'MPC')
BUILDAR = UNITAR/(MLEVEL*7)
ELSE
IF (CODE = 'SRM').OR.(CODE = 'MNML')
BUILDAR = UNITAR/MLEVEL
ENDIF
ENDIF
BUILDOS = (CONCOST+MAIN)*BUILDAR
ANSTOR = (BUILDOS + STORCOST)
MTOT = (ANSTOR*MINVE) + (VEHOPCOST*TRANSC)
MNAME = NAME
select 6
appe blank
replace code with mcode, name with mname, level with mlevel,;
height with theight, inv_cost with anstor, tra_cost with;
vehopcost, tot_cost with mtot, anulab with anlab
select 2
exit
else
skip
endif
enddo
select 1
else
endif
endif
skip
enddo

close databases /
  do tempo with mheight,minve,transc,ch,ch1
close databases

return
tempo.prg 01/01/80

* ------ Program printing the result of
* ------ selection of candidate for equipment
* ------ by Adi Saptari 04/04/90

parameters mheight, minvel, transcl, ch, chx

clear
select 1
use temp1 index tlevel, tot
select 2
use temp2 index tlevel2, tot2
select 3
use temp3 index tlevel3, tot3
store 0 to no
store 16 to row, lowe
store " PALLET RACK ORDER PICKING " to A
store " RACKABLE - ORDER PICKING " to B
store " BINNABLE - ORDER PICKING " to C
store " PALLETS " to D
store " BOXES " to E
if chx = 1
X = A
Y = D
else
if chx = 2
X = B
Y = D
else
X = C
Y = E
endif
endif
5,25 SAY "CANDIDATE EQUIPMENT SELECTED"
6,25 SAY + X
7,25 SAY 
9,19 SAY ", STORAGE HEIGHT : "+STR(MHEIGHT, 5, 2)
9,46 SAY "FEET"
10.19 SAY " INVENTORY RATE : "+STR(MINVEL, 6)
10.46 SAY + Y
11.19 SAY " TRANSACTION RATE : "+STR(TRANSCL, 6)
11.46 say "TRANSACTIONS/DAY"
12,3 SAY "==================================
13,3 SAY "NO. "
13,7 SAY "EQUIPMENT SYSTEM 
13,30 SAY "STORAGE"
13,38 SAY "STORAGE"
13,46 SAY "INVENT"
13,54 SAY "TRANSAC"
13,62 SAY "ANN.SYS.COST"
14,29 SAY "HEIGHT(FT)"
14,39 SAY "LEVEL"
14,46 SAY "COST($)"
14,54 SAY "COST($)"
15,3 SAY "==================================

if chx = 1
select 1
set index to tlevel
else
if chx = 2
select 2
tempo.prg 01/01/80

    set index to tleve12
else
    select 3
    set index to tleve13
endif
endif
GO TOP

do while .not. eof() 
    if ch = 1
        if row >= 20
            wait
            clear
            row = 4
        endif
        row = row + 1
        no = no + 1
        row,3  say +str(no,2)
        row,6  say +name
        row,31 say +str(height,5,2)
        row,41 say +str(level,2)
        row,46 say +str(inv_cost,6,2)
        row,54 say +str(tra_cost,6,2)
        row,63 say "$ 
        row,65 say +str(tot_cost,9,2)
    else
        if lowe >= 40
            eject
            4,22 say "CANDIDATE FOR SELECTION (CONTINUE)"
            5,22 SAY " 
            8,3 SAY "========================================
            9,3 SAY "NO. 
            9,7 SAY "EQUIPMENT SYSTEM 
            9,30 SAY "STORAGE"
            9,38 SAY "STORAGE".
            9,46 SAY "INVENT"
            9,54 SAY "TRANSAC"
            9,62 SAY "ANN.SYS.COST"
            10,29 SAY "HEIGHT(FT)"
            10,39 SAY "LEVEL"
            10,46 SAY "COST($)"
            10,54 SAY "COST($)"
            11,3 SAY "=======================================
            ==-============
            no = no + 1
            lowe = lowe + 1
            lowe,3 say +str(no,2)
            lowe,6 say +name
            lowe,30 say +str(height,5,2)
            lowe,41 say +str(level,2)
            lowe,46 say +str(inv_cost,5,2)
            lowe,54 say +str(tra_cost,6,2)
            lowe,63 say "$ 
            lowe,65 say +str(tot_cost,9,2)
        endif
    endif
    skip
enddo
clear
tempo.prg 01/01/80

go top
  @ 2,29 SAY "CANDIDATE EQUIPMENT SELECTED"
  @ 3,22 SAY +X
  @ 3,49 SAY "BASED ON EACH LEVEL"
  @ 4,22 SAY "
  @ 5,3 SAY "="
  @ 6,3 SAY "="
  @ 7,3 SAY "NO.  
  @ 7,7 SAY "EQUIPMENT SYSTEM  
  @ 7,37 SAY "STORAGE"
  @ 7,48 SAY "STORAGE"
  @ 7,57 SAY "ANNUAL SYSTEM COST"
  @ 8,36 SAY "HEIGHT (FT)"
  @ 8,49 SAY "LEVEL"
  @ 9,3 SAY "="
  @ 10,3 SAY "="

no = 0
row = 9
do while .not. eof()
  mlevel = level
  mtot = 20000000.00
  do while level = mlevel
    if tot_cost < mtot
      mname = name
      mlevel = level
      theight = height
      mtot = tot_cost
      vehopcost = tra_cost
      anstor = inv_cost
    endif
    skip
  enddo
  row = row +1
  no = no +1
  @ row,3 say +str(no,2)
  @ row,6 say +mname
  @ row,37 say +str(theight,5,2)
  @ row,50 say +str(mlevel,2)
  @ row,62 say "$  
  @ row,64 say +str(mtot,9,2)
  if row >= 20
    wait
    clear
    row = 10
  @ 3,27 SAY "SELECTED CANDIDATE (CONTINUE)"
  @ 4,27 SAY "
  @ 6,3 SAY "="
  @ 7,3 SAY "NO.  
  @ 7,7 SAY "EQUIPMENT SYSTEM  
  @ 7,37 SAY "STORAGE"
  @ 7,48 SAY "STORAGE"
  @ 7,57 SAY "ANNUAL SYSTEM COST"
  @ 8,36 SAY "HEIGHT (FT)"
  @ 8,49 SAY "LEVEL"
  @ 9,3 SAY "="
  endif
endo
wait
tempo.prg 01/01/80

clear
if chx = 1
    select 1
    set index to tot
else
    if chx = 2
        select 2
        set index to tot2
    else
        select 3
        set index to tot3
    endif
endif
go top
row = 16
no = 0
• 4,21 SAY "THE BEST CANDIDATE SELECTED EQUIPMENT"
• 5,25 SAY +X
• 6,21 SAY "BASED ON THE LOWEST ANNUAL SYSTEM COST"
• 7,21 SAY "
• 9,20 SAY " STORAGE HEIGHT : "+STR(MHEIGHT,5,2)
• 9,47 SAY "FEET"
• 10,20 SAY " INVENTORY RATE : "+STR(MINVE1,6)
• 10,47 SAY +Y
• 11,20 SAY " TRANSACTION RATE : "+STR(TRANS1,6)
• 11,47 SAY "TRANSACTIONS/DAY"
• 12,3 SAY "================================================
• 13,3 SAY "NO. 
• 13,7 SAY "EQUIPMENT SYSTEM "
• 13,37 SAY "STORAGE"
• 13,48 SAY "STORAGE"
• 13,57 SAY "ANNUAL SYSTEM COST"
• 14,36 SAY "HEIGHT (FT)"
• 14,49 SAY "LEVEL"
• 15,3 SAY "================================================

do while .not. eof()
    if no >3
        exit
    endif
    row = row + 1
    no = no +1
    row,3 say +str(no,2)
    row,6 say +name
    row,37 say +str(height,5,2)
    row,50 say +str(level,2)
    row,62 say "$ 
    row,64 say +str(tot_cost,9,2)
    skip
enddo
close databases
return
* ------ Program calculating labor &
* ------ equipment requirement
* ------ Adi Saptari 04/10/90
parameters transc2, transc3, transc4
set talk off
select 1
use templ index tot.
select 2
use temp2 index tot2
select 3
use temp3 index tot3
select 4
use modul index modul
select 5
use vehicle index vehicle
clear
no = 0
row = 9
  3,22 SAY "MANPOWER AND VEHICLES REQUIREMENT"
  4,22 SAY ""
  6,3 SAY "="
  7,40 SAY "TOTAL HRS."
  7,54 SAY "NUMBER OF"
  7,66 SAY "NUMBER OF"
  8,7 SAY "ZONE"
  8,18 SAY "EQUIPMENT SYSTEM"
  8,41 SAY "PER YEAR"
  8,54 SAY "EQUIPMENT"
  8,67 SAY "LABORS"
  9,3 SAY "="
do while .not. eof()
  select 1
  go top
  mcode = code
  man_hr = transc2*anulab
  man = int((man_hr/2000.0) + 1)
  select 4
  seek mcode
do while mcode = code
    mcol = colspac
    row = row +1
    no = no +1
    row,3 say "PALLET RACK"
    row,18 say +name
    row,41 say +str(man_hr,7,2)
    row,56 say +str(man,2)
    row,68 say +str(man,2)
  exit
enddo
select 2
  go top
  do while .not. eof()
    ncode = code
    man_hr = transc3*anulab
    man = int((man_hr/2000.0) + 1)
    select 4
    seek ncode
    if mcol = colspac...
labor.prg 01/01/80

row = row +1
no = no +1
@ row,3 say "RACKABLE O/P"
@ row,18 say +name
@ row,41 say +str(man_hr,7,2)
@ row,56 say +str(man,2)
@ row,68 say +str(man,2)
exit
else
  select 2
  skip
endif
endo
dogo top
do while .not. eof()
mcode = code
man_hr = transc4*anulab
man = int((man_hr/2000.0) + 1)
select 4
seek mcode
do while mcode = code
  row = row +1
  no = no +1
  @ row,3 say "BINNABLE O/P"
  @ row,18 say +name
  @ row,41 say +str(man_hr,7,2)
  @ row,56 say +str(man,2)
  @ row,68 say +str(man,2)
  @ row+1,1 say " "
  exit
endo
exit
endo
dogo select 1
exit
endo
close databases
return
layout.prg 01/01/80

* ------ Program determining the module
* ------ building lay-out and area required
* ------ Adi Saptari 04/10/90
parameters minve1, minve2, minve3, minve4
set talk off
select 1
use templ index tot
select 2
use temp2 index tot2
select 3
use temp3 index tot3
select 4
use modul index modul
select 5
use vehicle index vehicle
select 6
use bulk
clear
no = 0
row = 9
@ 3,23 SAY "PRELIMINARY BUILDING LAY-OUT"
@ 4,23 SAY ""'
@ 6,3 SAY "========================================; 
====================================
do while .not. eof()
select 1
go top
mcode = code
mlevel = level
select 4
seek mcode
do while mcode = code
xwid = widtha
xlen = lengta
mcol = colspac
MODUL = int((minve2+minve3)/unita)/mlevel + 1)
AREA = (WIDTHA*LENGHTA)*MODUL
row = row +1
no = no +1
@ row,3 say "RACK STORAGE .
@ row,18 say +str(widtha,6,3)
@ row,25 say "*"+str(colspac,6,3)
@ row,37 say "area"+str(widtha,6,3)
@ row,44 say '*'+str(lenght a,5,2)
@ row,56 say +str(modul,2)
@ row,66 say +str(area,6,3)
exit
endo
do while .not. eof()
select 6
mlevel = 4
if column < xwid
   xxwid = column
   pal = pallet
   skip
else
   exit
endif
enddo

MODUL = int((minvel/(pal*7*mlevel)) + 1)
AREA = (XWID*XLENG)*MODUL
row = row +1
no = no +1
@row,3 say "BULK STORAGE "
@row,18 say +str(xwid,6,3)
@row,25 say "* "+str(mcol,6,3)
@row,37 say +str(xwid,6,3)
@row,44 say "* "+str(xleng,5,2)
@row,56 say +str(modul,2)
@row,66 say +str(area,6,3)
select 3
  go top
  do while .not. eof()
     mcode = code
     mlevel = level
     select 4
     seek mcode
     do while mcode = code
        row = row +1
        no = no +1
        MODUL = int((minvel4/unita)/mlevel + 1)
        AREA = (WIDTH*LENGHTA)*MODUL
        @row,3 say "BINNABLE O/P "
        @row,18 say +str(width,6,3)
        @row,25 say "* "+str(lenghta,6,3)
        @row,37 say +str(width,6,3)
        @row,44 say "* "+str(lenghta,5,2)
        @row,56 say +str(modul,2)
        @row,66 say +str(area,6,3)
        @row+1,1 say " "
        exit
    enddo
    exit
  enddo
enddo
close databases
return
Program choosing the equipment based on the lowest cost & system compatibility

parameters lift
set talk off
select 1
use templ1 index tot
select 2
use temp2 index tot2
select 3
use temp3 index tot3
select 4
use modul index modul
select 5
use vehicle index vehicle
clear
no = 0
row = 9

2,22 SAY "RECOMMENDED SYSTEM EQUIPMENT BASED ON"
3,18 SAY "THE LOWEST ANNUAL COST & SYSTEM COMPATIBILITY"
4,18 SAY "========================================;=================================== "
6,3 SAY "========================================;=================================== "
7,40 SAY "STORAGE"
7,53 SAY "STORAGE"
7,64 SAY "ANNUAL SYSTEM"
8,7 SAY "ZONE"
8,18 SAY "EQUIPMENT SYSTEM"
8,39 SAY "HEIGHT (FT)"
8,54 SAY "LEVEL"
8,67 SAY "COST"
9,3 SAY "========================================;=================================== "

do while .not. eof()
    select 1
    go top
    mcode = code
    mlevel = level
    theight = height
    mtot = tot_cost
    select 4
    seek mcode
do while mcode = code
    mcol = colspac
    row = row +1
    no = no +1
    row,3 say "PALLET RACK"
    row,18 say +name
    row,41 say +str(theight,5,2)
    row,56 say +str(mlevel,2)
    row,66 say "$"
    row,68 say +str(mtot,9,2)
    exit
endo
select 2
go top

M CODE = CODE
THEIGHT = HEIGHT
resume.prg 01/01/80

MLEVEL = LEVEL
MTOT = TOT_COST
select 4
seek ncode
  if mcode = colspac
    row = row +1
    no = no +1
    row,3 say "RACKABLE O/P"
    row,18 say +name
    row,41 say +str(theight,5,2)
    row,56 say +str(mlevel,2)
    row,66 say "$ "
    row,68 say +str(mtot,9,2)
    exit
  else
    select 2
    skip
  endif
endo
desc 3
go top
do while .not. eof()
  MCODE = CODE
  MLEVEL = LEVEL
  THEIGHT = HEIGHT
  MTOT = TOT_COST
  select 4
  seek mcode
  do while mcode = code
    mcol = colspac
    row = row +1
    no = no +1
    row,3 say "BINNABLE O/P"
    row,18 say +name
    row,41 say +str(theight,5,2)
    row,56 say +str(mlevel,2)
    row,66 say "$ "
    row,68 say +str(mtot,9,2)
    exit
  enddo
  exit
endo
desc 5
set index to vehicle
go top
do while .not. eof()
  lcode = code
  if (lcode = 'CNT').and.(maxlift >= lift)
    mlevel1 = maxlevel
    lcode = code
    select 4
    go top
    seek lcode
    mais = aisle
    theight1 = maxh
  else
    if (code = 'RTC').and.(maxlift >= lift)
      mlevel2 = maxlevel
      lcode = code
      select 4
    endif
endo
resume.prg 01/01/80

    seek lcode
    nais = aisle
    theight2 = maxh
    exit
    endif
endif
select 5
skip
endo
do if mais > nais
    lcode = 'RTC'
    mlevel = mlevel2
    theight = theight2
else
    lcode = 'CNT'
    mlevel = mlevel1
    theight = theight1
endif
select 4
    seek lcode
    row = row +1
    no = no +1
    @ row,3 say "BULK STORAGE"
    @ row,18 say +name
    @ row,41 say +str(theight,5,2)
    @ row,56 say +str(mlevel,2)
    @ row,66 say "$ "
    @ row,70 say "---"
    @ row+1,1 say " "
    wait
    select 1
    exit
endo
close databases
return
* -------- Program for calculating Shipping &
* -------- Receiving docks and Staging Area
* -------- by Adi Saptari 04/17/90

parameter prin
set talk off
set color to GR+/B
set device to screen
clear
@ 4.26 say "INPUT DATA RECEIVING & SHIPPING"
@ 5.26 SAY ''
@ 8.15 SAY "===================================================
@ 9.18 SAY "ZONE"
@ 9.29 SAY "NO. OF"
@ 9.43 SAY "NO. OF"
@ 9.55 SAY "DOCKING"
@ 10.29 SAY "PALLETS"
@ 10.43 SAY "TRUCKS"
@ 10.56 SAY "TIME"
@ 11.15 SAY "==================================================="
@ 12.17 SAY "RECEIVING"
@ 13.17 SAY "SHIPPING"
@ 14.15 SAY "==================================================="
@ 15.15 SAY "INPUT NUMBER OF SHIFT : 
store 0 to pall, pal2, truck1, truck2, shift
store 0.00 to timel, time2
store 'square feet' to aa
@ 12.29 get pall pict "999999"
@ 12.43 get truck1 pict "9999"
@ 12.55 get time1 pict "99.99"
@ 13.29 get pal2 pict "999999"
@ 13.43 get truck2 pict "9999"
@ 13.55 get time2 pict "99.99"
@ 15.39 get shift pict "99"
read
ship1 = pall/truck1
dock1 = int(ship1/((shift*7)/timel) + 1)
ship2 = pal2/truck2
dock2 = int(ship2/((shift*7)/time2) +1)
dock = (dock1+dock2)
clear
if prin = 2
   set device to printer
else
   set device to screen
endif
@ 4.24 say "SHIPPING AND RECEIVING REQUIREMENT"
@ 5.24 SAY 
@ 6.31 SAY "NO. OF SHIFT = "+str(shift,2)
@ 8.10 SAY "==================================================="
@ 9.13 SAY "ZONE"
@ 9.24 SAY "NO. OF"
@ 9.36 SAY "NO. OF"
@ 9.48 SAY "DOCKING"
@ 9.60 SAY "NO. OF DOCKS"
@ 10.24 SAY "PALLETS"
@ 10.36 SAY "TRUCKS"
@ 10.49 SAY "TIME"
@ 10.60 SAY "REQUIRED"
@ 11.10 SAY "===================================================";
dock.prg 01/01/80

=========

@ 12,10 SAY "RECEIVING"+space(4)+str(pall,6)+space(9);
+str(truckl,3)+space(8)+str(time1,5,2)+space(9)+str(dockl,3,1)
@ 13,10 SAY "SHIPPING"+space(5)+str(pall2,6)+space(9);
+str(truck2,3)+space(8)+str(time2,5,2)+space(9)+str(dock2,3,1)
@ 14,10 SAY "=====================================

@ 15,28. SAY "Total number of docks required = "+str(dock,3)
@ 17,10 SAY "Assume 2 docks per 30 foot building bay"
@ 18,10 SAY "Number of bays required = "+str((dock/2),3,1)
@ 19,10 say "Assume 50 foot dock depth"
@ 20,10 say "Staging area requirements = ";
+str(((dock/2)*30)*50,7,2)+space(2)+aa
@ 21,10 say ""

* close databases
return
updatl.prg 01/01/80

* ---- Updating transaction time for
* ---- pallet rack data
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/B
use tranpal
set index to tranpal
clear
choice = .1
do while .T.
  store 0 to mlevel
  store space(3) to mcode
  @ 8,15 say "UPDATING PALLET RACK TRANSACTION TIME"
  @ 9,15 say ""
  @ 11,15 say "INPUT EQUIPMENT CODE : " get mcode pict "@!
  @ 12,15 say "LEVEL OF PALLET RACK : " get mlevel pict "99"
  @ 16,15 say "JUST PRESS ESCAPE TO EXIT"
read
  if mcode = space(3)
    set color to
    exit
  else
    go top
    seek mcode
    do while mcode = code
      if level = mlevel
        if choice <> 3
          mcode = code
          mlevel = level
          mheight = height
          mtravel = travel
          mstop = stop
          maccess = access
          manuv = manuver
          doc = document
          mlift = lift
          mlow = lower
        endif
      clear
      @ 6,15 say "UPDATING TRANSACTION TIME FOR PALLET RACK"
      @ 8,15 say "Equipment code : " get mcode
      @ 9,15 say "Storage level : " get mlevel
      @ 10,15 say "Rack height : " get mheight
      @ 11,15 say "Travel time : " get mtravel
      @ 12,15 say "Start/Stop time : " get mstop
      @ 13,15 say "Access time : " get maccess
      @ 14,15 say "Manuver time : " get manuver
      @ 15,15 say "Document time : " get doc
      @ 16,15 say "Lift time : " get mlift
      @ 17,15 say "Lower time : " get mlow
      read
      @ 20,18 say "SAVE = 1"
      @ 20,28 say "EDIT = 2"
      @ 20,38 say "CANCEL = 3"
      @ 21,18 say "Your choice ..." get choice pict "99"
      read
      do case
        case choice = 1
repl code with mcode, level with mlevel,;
height with mheight, travel with mtravel,;
stop with mstop, access with maccess,;
manuver with manuv, document with doc,;
lift with mlift, lower with mlow
exit
case choice = 2
mcode = code
mlevel = level
case choice = 3
exit
delse
skip
endif
endo
dendif
clear
endo
close databases
return
* ----- Updating Rackable Order Picking
* ----- transaction time data
* ----- 3/17/90
* ----- by Adi Saptari

set talk off
set color to GR+/B

clear

choice = 1

do while .T.
    store 0.00 to mheight
    store 0 to aver
    store space(3) to mcode
    @ 8,15 say "UPDATING RACKABLE TRANSACTION TIME"
    @ 9,15 say ""
    @ 11,15 say "INPUT EQUIPMENT CODE : " get mcode pict "@!"
    @ 12,15 say "AVERAGE INVENTORY : " get aver pict "99999"
    @ 13,15 say "STORAGE HEIGHT : " get mheight pict "99.99"
    @ 16,15 say "JUST PRESS ESCAPE TO EXIT"

    read
    if mcode = space(3)
        set color to
        exit
    else
        use transac index transac
        go top
        seek str(mheight,5,2)
        do while mheight = height
            if (MCODE = CODE).AND.(AVER = AVG_INV)
                if choice (> 3.
                    mlevel = stg_level
                    tot = tottime
                endif
            endif
        enddo

        clear
        @ 6,15 say "UPDATING TRANSACTION TIME FOR PALLET RACK"
        @ 8,15 say "Equipment code : " get mcode
        @ 9,15 say "Average inventory : " get aver
        @ 10,15 say "Storage level : " get mlevel
        @ 11,15 say "Storage height : " get mheight
        @ 12,15 say "Total time : " get tot
        read
    @ 20,18 say " SAVE = 1"
    @ 20,28 say " EDIT = 2"
    @ 20,38 say " CANCEL = 3"
    @ 21,18 say " Your choice ..." get choice pict "99"
    read
    do case
        case choice = 1
            repl code with mcode, stg_level with mlevel,;
            height with mheight, tottime with tot,;
            avg_inv with aver
            exit
        case choice = 2
            mcode = code
            mlevel = stg_level
            mheight = height
        case choice = 3
            exit
    endcase
else
updat2.prg 01/01/80

    skip
   endif
endo
endif.
clear
endo
close databases
return.
updat3.prg 01/01/80

* ----- Updating Binnable Order Picking
* ----- transacion time data
* ----- 3/17/90
* ----- by Adi Saptari

set talk off
clear
choice = 1
do while .T.
    store 0.00 to mheight
    store 0 to aver
    store space(3) to mcode
    @ 8,15 say "UPDATING BINNABLE TRANSACTION TIME"
    @ 9,15 say ""
    @ 11,15 say "INPUT EQUIPMENT CODE : " get mcode pict @!
    @ 12,15 say "AVERAGE INVENTORY : " get aver pict 9999999"
    @ 13,15 say "STORAGE HEIGHT : " get mheight pict 99.99"
    @ 16,15 say "JUST PRESS ESCAPE TO EXIT"
    READ
    if mcode = space(3)
        set color to
        exit
    else
        use binna index binna
        go top
        seek str(mheight,5)
        do while mheight = height
            if (MCODE = CODE).AND.(AVER = AVG_INV)
                if choice <> 3
                    mlevel = stg_level
                    tot = tottime
                endif
            clear
        @ 6,15 say "UPDATING TRANSACTION TIME FOR PALLET RACK"
        @ 8,15 say "Equipment code : " get mcode
        @ 9,15 say "Average inventory : " get aver
        @ 10,15 say "Storage level : " get mlevel
        @ 11,15 say "Storage height : " get mheight
        @ 12,15 say "Total time : " get tot
        read
        @ 20,18 say " SAVE = 1"
        @ 20,28 say " EDIT = 2"
        @ 20,38 say " CANCEL = 3"
        @ 21,18 say " Your choice ..." get choice pict 99
        read
        do case
            case choice = 1
                repl code with mcode, stg_level with mlevel,;
                height with mheight, tottime with tot,;
                avg_inv with aver
                exit
case choice = 2
    mcode = code
    mlevel = stg_level
    mheight = height
    case choice = 3
    exit
endcase
else
updat3.prg 01/01/80

skip
endif
enddo
endif
clear
enddo
close databases
return .
updat4.prg 01/01/80

* ---- Updating data file of
* ---- Material Handling vehicle/equipment cost
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/B
use vehicle index vehicle
choice = 1
clear
do while .t.
  store 0 to mminlev
  store space(3) to mcode
  @ 8,20 say "UPDATING VEHICLE & LABOR COST"
  @ 9,20 SAY "
  @ 11,20 say "INPUT EQUIPMENT CODE : " get mcode pict "0!"
  @ 12,20 say "MINIMUM LEVEL OF RACK : " get mminlev pict "99"
  @ 16,20 say "PRESS ESCAPE TO EXIT .. "
  READ
  if mcode = space(3)
    set color to
    exit
  else
    go top
    seek mcode
    do while mcode = code
      if mminlev = minlevel
        if choice <> 3
          mmaxlev = maxlevel
          mminlif = minlift
          mmxlif = maxlift
          mpurchase = purchase
          moperate = operate
          mlabor = labor
        endif
      clear
      @ 5,18 say "UPDATING VEHICLE & LABOR COST"
      @ 6,18 say "
      @ 8,15 say "Equipment code : " get mcode
      @ 9,15 say "Minimum level : " get mminlev
      @ 10,15 say "Maximum level : " get mmaxlev
      @ 11,15 say "Minimum lift capacity : " get mminlif
      @ 12,15 say "Maximum lift capacity : " get mmxlif
      @ 13,15 say "Purchase Cost : " get mpurchase
      @ 14,15 say "Operate Cost : " get moperate
      @ 15,15 say "Labor cost/hour : " get mlabor
      read
      @ 20,18 say " SAVE = 1"
      @ 20,28 say " EDIT = 2"
      @ 20,38 say " CANCEL = 3"
      @ 21,18 say " Your choice ..." get choice pict "99"
      read
      do case
        case choice = 1
          replace code with mcode, minlevel with mminlev,;
          maxlevel with mmaxlev, minlift with mminlif,;
          maxlift with mmxlif, purchase with mpurchase,;
          operate with moperate, labor with mlabor
          exit
        case choice = 2

updat4.prg 01/01/80

    mcode = code
    mminlev = minlevel
    case choice = 3
    exit
    endcase
    else
        skip
    endif
    enddo
enddo
endif
clear
databases
close
return
updat5.prg 01/01/80

* ---- Updating building and maintenance cost data
* ---- based on height
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/a
choice = 1
clear
do while .t.
  use building index building
  go top
  if choice <> 2
    store 0 to mheight
  endif
@ 7.20 say "UPDATING BUILDING CONSTRUCTION"
@ 8.20 say " AND MAINTANANCE COST"
@ 9.20 say ""
@ 11.20 say "INPUT BUILDING HEIGHT : " get mheight pict "99"
@ 14.20 say "PRESS ESCAPE TO EXIT .. "
READ
if mheight = 0
  set color to
  exit
else
  clear
  seek str(mheight,2)
do while mheight = maxheight
    mmheight = minheight
    mconstruc = construe
    mmaintain = maintain
    @ 5.18 say "UPDATING BUILDING CONSTRUCTION"
    @ 6.18 say " AND MAINTANANCE COST"
    @ 7.18 say ""
    @ 9.15 say "Maximum building height : ";
      get mheight pict "99"
    @ 10.15 say "Minimum building height : ";
      get mmheight pict "99"
    @ 11.15 say "Construction/square feet : ";
      get mconstruc pict "99.99"
    @ 12.15 say "Maintanance/square feet : ";
      get mmaintain pict "9.999"
read

@ 15.18 say " SAVE = 1"
@ 15.28 say " EDIT = 2"
@ 15.38 say " CANCEL = 3"
@ 16.18 say " Your choice ..." get choice pict "99"
read
do case
case choice = 1
  replace maxheight with mheight,;
  construe with mconstruc,;
  minheight with mmheight,;
  maintain with mmaintain
  exit
  case choice = 2
  mheight = maxheight
  case choice = 3
  exit
endcase
updat5.prg 01/01/80

  enddo
  endif
  clear
  enddo
  close databases
  return
* ---- Updating for modular lay-out data
* ---- 3/17/90
* ---- By Adi Saptari
set talk off
set color
set menu off
set status off
use modul index modul
choice = 1
clear
do while .t.
  store space(3) to mcode
  @ 8,20 say "UPDATING MODULAR LAY-OUT DATA"
  @ 9,20 say ""
  @ 11,20 say "INPUT EQUIPMENT CODE : " get mcode pict "@!"
  @ 14,20 say "PRESS ESCAPE TO EXIT .."
READ
if mcode = space(3)
  set color to
  exit
else
  use modul index modul
  go top
  seek mcode
  do while mcode = code
    if choice <> 2
      mname = name
      maisle = aisle
      mlenga = lengtha
      mlengb = lengthb
      mwidth = widtha
      mwidthb = widthb
      mwidthh = widthh
      mcol = colspac
      munita = unita
      munitb = unitb
      mmin = minh
      mmax = maxh
    endif
clear
  @ 3,25 say "UPDATING MODULAR LAY-OUT DATA"
  @ 4,25 say ""
  @ 6,15 say "Equipment code : " get mcode pict "@!"
  @ 7,15 say "Equipment name : " get mname pict "@!"
  @ 8,15 say "Equipment aisle : " get maisle pict "@9"
  @ 9,15 say "Modular length primary : " get mlenga pict "@9"
  @ 10,15 say "Modular length net : " get mlenbg pict "@9"
  @ 11,15 say "Modular width primary : " get mwidtha pict "@9"
  @ 12,15 say "Modular width alternate : " get mwidthb pict "@9"
  @ 13,15 say "Modular width haz/flame : " get mwidthh pict "@9"
  @ 14,15 say "Column spacing : " get mcol pict "@9"
  @ 15,15 say "No. of pallet primary : " get munita
  @ 16,15 say "No. of pallet alternate : " get munitb pict "@9"
  @ 17,15 say "Minimum height : " get mmin pict "@9"
  @ 18,15 say "Maximum height : " get mmax pict "@9"
read
  @ 20,15 say " SAVE = 1"
  @ 20,25 say " EDIT = 2"
  @ 20,35 say " CANCEL = 3"
@ 21.15 say "Your choice ..." get choice pict "99"
read
do case
case choice = 1
  replace code with mcode, name with mname,;
  aisle with maisle, lengtha with mlenga,;
  lengthb with mlengb, widtha with mwidtha,;
  widthb with mwidthb, widthh with mwidthh,;
  colspac with mcol, unita with munita,;
  unitb with munitb, minh with mmin,;
  maxh with mmax
  exit
  case choice = 2
  mcode = code
  case choice = 3
  exit
endcase
enddo
endif
clear
enddo
close databases
return
input1.prg 01/01/80

* ---- Input transaction time data for
* ---- pallet rack
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/B
use tranpal index tranpal
choice = 1
clear
do while .t.
  if choice <> 2
    store 0 to mlevel
    store 0.00 to mheight
    store 0.000 to mtravel, rstop, raccess, rmanuver, rdoc, rlift, rlow
    store space(3) to mcode
  endif
  @ 5,15 say "ADDING TRANSACTION TIME DATA"
  @ 6,15 say "PALLET RACK"
  @ 8,15 say "Equipment code : " get mcode pict "@!
  @ 9,15 say "Storage level : " get mlevel pict "999"
  @ 10,15 say "Rack height : " get mheight pict "99.99"
  @ 11,15 say "Travel time : " get mtravel pict "99.999"
  @ 12,15 say "Start/Stop time : " get mstop pict "99.999"
  @ 13,15 say "Access time : " get maccess pict "99.999"
  @ 14,15 say "Manuver time : " get mmanuver pict "99.999"
  @ 15,15 say "Document time : " get mdoc pict "99.999"
  @ 16,15 say "Lift time : " get mlift pict "99.999"
  @ 17,15 say "Lower time : " get mlow pict "99.999"
  @ 19,15 say "PRESS ESCAPE TO EXIT .."
read
  if mcode = space(3)
    set color to
    exit
  endif
  @ 20,15 say " SAVE = 1"
  @ 20,25 say " EDIT = 2"
  @ 20,35 say " CANCEL = 3"
  @ 21,15 say " Your choice ..." get choice pict "99"
read
do case
  case choice = 1
    append blank
    replace code with mcode, level with mlevel,;
    travel with mtravel, stop with mstop,;
    access with maccess, manuver with mmanuver,;
    document with mdoc, lift with mlift,;
    lower with mlow, height with mheight
  case choice = 2
endcase
endo
close databases
return
* ---- Input modular lay-out data
* ---- based on each equipment aisle
* ---- 3/17/90
* ---- By Adi Saptari
set talk off
set color to GR+/B
set menu off
set status off
use modul index modul
choice = 1
clear
do while .t.
  if choice <> 2
    store 0 to munita,munitb
    store 0.00 to rnaisle,mlenga,mlengb,mwida,mwidb,mwidh,mcol,;
    mmax,mmin
    store space(3) to mcode
    store space(30) to mname
  endif
  @ 4,25 say "ADDING MODULAR LAY-OUT DATA"
  @ 6,15 say "Equipment code : " get mcode pict "0!"
  @ 7,15 say "Equipment name : " get mname pict "0!"
  @ 8,15 say "Equipment aisle : " get maisle pict "09"
  @ 9,15 say "Modular length primary : " get mlenga pict "09"
  @ 10,15 say "Modular length net : " get mlengb pict "09"
  @ 11,15 say "Modular width primary : " get mwida pict "09"
  @ 12,15 say "Modular width alternate : " get mwidb pict "09"
  @ 13,15 say "Modular width haz/flame : " get mwidh pict "09"
  @ 14,15 say "Column spacing : " get mcol pict "09"
  @ 15,15 say "No. of pallet primary : " get munita
  @ 16,15 say "No. of pallet alternate : " get munitb pict "09"
  @ 17,15 say "Minimum height : " get mmin pict "09"
  @ 18,15 say "Maximum height : " get mmax pict "09"
  @ 20,15 say "PRESS ESCAPE TO EXIT . . ."
read
  if mcode = space(3)
    set color to
    exit
  endif
  @ 22,20 say " SAVE = 1"
  @ 22,30 say " EDIT = 2"
  @ 22,40 say " CANCEL = 3"
  @ 23,20 say " Your choice . . . " get choice pict "99"
read
do case
case choice = 1
  append blank
  replace code with mcode, name with mname,;
  aisle with maisle, length with mlenga,;
  length with mlengb, width with mwida,;
  width with mwidb, width with mwidh,;
  colspac with mcol, unita with munita,;
  unitb with munitb, minh with mmin,;
  maxh with mmax
endcase
otherwise
dendo
* ---- Input transaction time data
* ---- for rackable order picking
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/B
use transac index transac
choice = 1
clear
do while .t.
   if choice <> 2
      store 0 to mlevel, minv
      store 0.00 to mheight
      store 0.000 to mtot
      store space(3) to mcode
   endif
   @ 5,17 say "ADDING TRANSACTION TIME DATA"
   @ 6,19 say "RACKABLE ORDER PICKING"
   @ 8,15 say "Equipment code : " get mcode pict "@!"
   @ 9,15 say "Storage level : " get mlevel pict "999"
   @ 10,15 say "Equipment height: " get mheight pict "99.99"
   @ 11,15 say "Inventory rate : " get minv pict "999999"
   @ 12,15 say "Total transaction time : " get mtot pict "99.999"
   @ 14,15 say "PRESS ESCAPE TO EXIT ..."
   read
   if mcode = space(3)
      set color to
      exit
   endif
   @ 16,18 say "SAVE = 1"
   @ 16,28 say "EDIT = 2"
   @ 16,38 say "CANCEL = 3"
   @ 17,18 say "Your choice ..." get choice pict "99"
   read
do case
   case choice = 1
      append blank
      replace code with mcode, stg_level with mlevel,;
      height with mheight, tottime with mtot,;
      avg_inv with minv
   case choice = 2
   otherwise
endcase
enddo
close databases
return
* ---- Input transaction time data
* ---- for binnable order picking
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/B
use binna index binna
choice = 1
clear

do while .t.
    if choice <> 2
        store 0 to mlevel, minv
        store 0.00 to mheight
        store 0.000 to mtot
        store space(3) to mcode
    endif
say "ADDING TRANSACTION TIME DATA"
say "BINNABLE ORDER PICKING"
say "Equipment code : " get mcode pict "@!"
say "Storage level : " get mlevel pict "999"
say "Equipment height: " get mheight pict "99.99"
say "Inventory rate : " get minv pict "999999"
say "Total transaction time : " get mtot pict "99.999"
say "PRESS ESCAPE TO EXIT .."
read
    if mcode = space(3)
        set color to
        exit
    endif
say " SAVE = 1"
say "EDIT = 2"
say "CANCEL = 3"
say " Your choice ..." get choice pict "99"
read
do case
    case choice = 1
        append blank
        replace code with mcode, stg_level with mlevel,;
            height with mheight, tottime with mtot,;
            avg_inv with minv
    case choice = 2
    otherwise
    endcase
endo
close databases
return
input5.prg 01/01/80

* ---- Input building and maintenance cost data
* ---- based on height
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+B
use building index building
choice = 1
clear
do while .t.
   if choice <> 2
      store 0.00 to mconstruc
      store 0.000 to mmaintain
      store 0 to mheight,xheight
   endif
   @ 5,20 say "ADDING BUILDING CONSTRUCTION"
   @ 6,20 say " AND MAINTANANCE COST"
   @ 9,15 say "Minimum building height: " get mheight pict "999"
   @ 9,15 say "Maximum building height: " get xheight pict "999"
   @ 10,15 say "Construction /sq. feet: " get mconstruc pict "99.99"
   @ 11,15 say "Maintenance /sq. feet: " get mmaintain pict "9.99"
   @ 13,15 say "PRESS ESCAPE TO EXIT .."
   read
   if mheight = 0
      set color to
      exit
   endif
   @ 15,18 say " SAVE = 1"
   @ 15,28 say " EDIT = 2"
   @ 15,38 say " CANCEL = 3"
   @ 16,18 say " Your choice ..." get choice pict "99"
   read
do case
   case choice = 1
      append blank
      replace minheight with mheight, construc with mconstruc,
      maxheight with xheight, maintain with mmaintain
   case choice = 2
   otherwise
endcase
endo
close databases
return
* ---- Input Material Handling vehicle/equipment cost
* ---- 3/17/90
* ---- by Adi Saptari
set talk off
set color to GR+/B
use vehicle index vehicle
choice = 1
clear
do while .t.
   if choice <> 2
      store 0 to mminlev,mmaxlev,mminlif,mmaxlif,mpurchase,;
      moperate
      store 0.00 to mlabor
   store space(3) to mcode
endif
@ 6,16 say "ADDING VEHICLE & LABOR COST DATA"
@ 8,15 say "Equipment code :" get mcode pict "@!"
@ 9,15 say "Minimum level :" get mminlev pict "999"
@ 10,15 say "Maximum level :" get mmaxlev pict "999"
@ 11,15 say "Minimum lift capacity :" get mminlif pict "99999"
@ 12,15 say "Maximum lift capacity :" get mmaxlif pict "99999"
@ 13,15 say "Purchase Cost :" get mpurchase pict "999999"
@ 14,15 say "Operate Cost :" get moperate pict "9999"
@ 15,15 say "Labor cost/hour :" get mlabor pict "99.99"
@ 17,15 say "PRESS ESACAPE TO EXIT .."
read
if mcode = space(3)
   set color to
   exit
endif
@ 19,18 say " SAVE = 1"
@ 19,28 say "EDIT = 2"
@ 19,38 say "CANCEL = 3"
@ 20,18 say " Your choice ..." get choice pict "99"
read
do case
   case choice = 1
      append blank
      replace code with mcode, minlevel with mminlev,;
      maxlevel with mmaxlev, minlift with mminlif,;
      maxlift with mmaxlif, purchase with mpurchase,;
      operate with moperate,labor with mlabor
   case choice = 2
   otherwise
endcase
endo
close databases
return
APPENDIX E
RESULT OF EXAMPLES
CANDIDATE EQUIPMENT SELECTED
PALLETS RACK ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 3400 PALLETS
TRANSACTION RATE : 750 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>LEVEL</th>
<th>COST ($)</th>
<th>ANNUAL SYSTEM COST ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COUNTERBALANCE TRUCK</td>
<td>7.00</td>
<td>2</td>
<td>60.72</td>
<td>310.83</td>
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<tr>
<td>2</td>
<td>REACH TRUCK</td>
<td>8.00</td>
<td>2</td>
<td>45.28</td>
<td>347.69</td>
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<tr>
<td>3</td>
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<td>11.00</td>
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<td>42.48</td>
<td>314.16</td>
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<td>4</td>
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<td>11.00</td>
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<td>27.62</td>
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<td>32.18</td>
<td>353.50</td>
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<td>6</td>
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<td>15.00</td>
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<td>33.37</td>
<td>317.45</td>
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<td>7</td>
<td>FRONT SIDE LOADER TRUCK</td>
<td>15.00</td>
<td>4</td>
<td>22.22</td>
<td>360.46</td>
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<td>REACH TRUCK</td>
<td>16.00</td>
<td>4</td>
<td>25.65</td>
<td>359.31</td>
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<td>9</td>
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<td>5</td>
<td>28.79</td>
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<td>22.38</td>
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<td>12</td>
<td>FRONT SIDE LOADER TRUCK</td>
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<td>18.10</td>
<td>368.57</td>
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<td>17.31</td>
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<td>14</td>
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<td>7</td>
<td>28.42</td>
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<td>15</td>
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<td>31.00</td>
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<td>16.32</td>
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<td>16</td>
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<td>27.26</td>
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<td>17</td>
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<td>41.42</td>
<td>10</td>
<td>42.42</td>
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<td>18</td>
<td>S/R MACHINE</td>
<td>45.08</td>
<td>11</td>
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<td>21</td>
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<td>57.08</td>
<td>14</td>
<td>34.96</td>
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# CANDIDATE EQUIPMENT SELECTED

**PALLETT RACK ORDER PICKING BASED ON EACH LEVEL**

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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<tbody>
<tr>
<td>1</td>
<td>REACH TRUCK</td>
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<td>$ 414720.69</td>
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<td>2</td>
<td>FRONT SIDE LOADER TRUCK</td>
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<td>FRONT SIDE LOADER TRUCK</td>
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<td>4</td>
<td>$ 345900.04</td>
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<td>4</td>
<td>COUNTERBALANCE TRUCK</td>
<td>19.00</td>
<td>5</td>
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<tr>
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<td>FRONT SIDE LOADER TRUCK</td>
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<tr>
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<td>$ 253594.40</td>
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<td>HYBRID TRUCK</td>
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<td>S/R MACHINE</td>
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<td>12</td>
<td>S/R MACHINE</td>
<td>57.08</td>
<td>14</td>
<td>$ 197493.77</td>
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</table>
THE BEST CANDIDATE SELECTED EQUIPMENT
PALLET RACK ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 3400 PALLETS
TRANSACTION RATE : 750 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO. EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 S/R MACHINE</td>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 2300 PALLETS
TRANSACTION RATE : 230 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
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<th>INVENTORY COST ($)</th>
<th>TRANSACTION COST ($)</th>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING BASED ON EACH LEVEL

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THE BEST CANDIDATE SELECTED EQUIPMENT
RACKABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 2300 PALLETs
TRANSACTION RATE : 230 TRANSACTIONS/DAY

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<th>NO.</th>
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CANDIDATE EQUIPMENT SELECTED
BINNABLE - ORDER PICKING BASED ON EACH LEVEL

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<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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</thead>
<tbody>
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THE BEST CANDIDATE SELECTED EQUIPMENT  
BINNABLE - ORDER PICKING  
BASED ON THE LOWEST ANNUAL SYSTEM COST  

STORAGE HEIGHT : 60.00 FEET  
INVENTORY RATE : 6000 BOXES  
TRANSACTION RATE : 1200 TRANSACTIONS/DAY  

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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## RECOMMENDED SYSTEM EQUIPMENT BASED ON THE LOWEST ANNUAL COST & SYSTEM COMPATIBILITY

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<th>ANNUAL SYSTEM COST</th>
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<tr>
<td>PALLET RACK</td>
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### PRELIMINARY BUILDING LAY-OUT

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<th>ZONE</th>
<th>COLUMN SPACING</th>
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<th>MODULES REQUIRED</th>
<th>AREA (SQUARE FEET)</th>
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### SHIPPING AND RECEIVING REQUIREMENT

**NO. OF SHIFT = 1**

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Total number of docks required = 25

Assume 2 docks per 30 foot building bay

Number of bays required = 13

Assume 50 foot dock depth

Staging area requirements = 18750.0 square feet
CANDIDATE EQUIPMENT SELECTED
PALLET RACK ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 30000 PALLETS
TRANSACTION RATE : 1200 TRANSACTIONS/DAY

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<th>EQUIPMENT SYSTEM</th>
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<th>COST ($)</th>
<th>ANN. SYS. COST ($)</th>
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CANDIDATE EQUIPMENT SELECTED
PALLETT RACK ORDER PICKING BASED ON EACH LEVEL

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<th>NO.</th>
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<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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<tr>
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THE BEST CANDIDATE SELECTED EQUIPMENT
PALLET RACK ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

- STORAGE HEIGHT : 60.00 FEET
- INVENTORY RATE : 30000 PALLETS
- TRANSACTION RATE : 1200 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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<tbody>
<tr>
<td>1</td>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 5000 PALLETs
TRANSACTION RATE : 300 TRANSACTIONS/DAY

<table>
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<tr>
<th>NO.</th>
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<th>STORAGE HEIGHT (FT)</th>
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<th>INVENTORY COST ($)</th>
<th>TRANSACTIONS COST ($)</th>
<th>ANNUAL SYSTEM COST ($)</th>
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<td>1</td>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING BASED ON EACH LEVEL

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THE BEST CANDIDATE SELECTED EQUIPMENT
RACKABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 5000 PALLETS
TRANSACTION RATE : 300 TRANSACTIONS/DAY

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CANDIDATE EQUIPMENT SELECTED
BINNABLE - ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 70000 BOXES
TRANSACTION RATE : 3000 TRANSACTIONS/DAY

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<th>TRANSACTION RATE</th>
<th>ANN. SYS. COST</th>
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### CANDIDATE EQUIPMENT SELECTED

**BINNABLE - ORDER PICKING BASED ON EACH LEVEL**

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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<td>$410,873.29</td>
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<td>MINI S/R MACHINE</td>
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</table>
THE BEST CANDIDATE SELECTED EQUIPMENT
BINNABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 70000 BOXES
TRANSACTION RATE : 3000 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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</thead>
<tbody>
<tr>
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<td>ORDER PICKING TRUCK</td>
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RECOMMENDED SYSTEM EQUIPMENT BASED ON
THE LOWEST ANNUAL COST & SYSTEM COMPATIBILITY

<table>
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<th>STORAGE (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALLET RACK</td>
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<td>$956584.33</td>
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<td>AREA (SQUARE FEET)</td>
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## MANPOWER AND VEHICLES REQUIREMENT

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<th>ZONE</th>
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<th>NUMBER OF EQUIPMENT</th>
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**SHIPPING AND RECEIVING REQUIREMENT**

**NO. OF SHIFT = 1**

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<th>NO. OF PALLETS</th>
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<td>12</td>
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</table>

**Total number of docks required = 37**

Assume 2 docks per 30 foot building bay
Number of bays required = 19
Assume 50 foot dock depth
Staging area requirements = 27750.0 square feet
CANDIDATE EQUIPMENT SELECTED
PALLET RACK ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 60000 PALLETS
TRANSACTION RATE : 7500 TRANSACTIONS/DAY

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<th>INVENTORY</th>
<th>TRANSACTION</th>
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# Candidate Equipment Selected

## Pallet Rack Order Picking Based on Each Level

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THE BEST CANDIDATE SELECTED EQUIPMENT
PALLETT RACK ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 60000 PALLETs
TRANSACTION RATE : 7500 TRANSACTIONS/DAY

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<th>NO.</th>
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<th>ANNUAL SYSTEM COST</th>
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### CANDIDATE EQUIPMENT SELECTED

**RACKABLE - ORDER PICKING BASED ON EACH LEVEL**

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<th>EQUIPMENT SYSTEM</th>
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THE BEST CANDIDATE SELECTED EQUIPMENT
RACKABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 10000 PALLETs
TRANSACTION RATE : 1000 TRANSACTIONS/DAY

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CANDIDATE EQUIPMENT SELECTED
BINNABLE - ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 100000 BOXES
TRANSACTION RATE : 1500 TRANSACTIONS/DAY

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THE BEST CANDIDATE SELECTED EQUIPMENT
BINNABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 100000 BOXES
TRANSACTION RATE : 1500 TRANSACTIONS/DAY

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RECOMMENDED SYSTEM EQUIPMENT BASED ON THE LOWEST ANNUAL COST & SYSTEM COMPATIBILITY

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### Preliminary Building Lay-Out

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<td>26.167 * 38.833</td>
<td>26.167 * 163.2</td>
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<td>33.000 * 162.0</td>
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</table>
### Manpower and Vehicles Requirement

<table>
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<tr>
<th>Zone</th>
<th>Equipment System</th>
<th>Total Hrs. Per Year</th>
<th>Number of Equipment</th>
<th>Number of Labors</th>
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<tbody>
<tr>
<td>Pallet Rack</td>
<td>Turret Truck</td>
<td>85575.0</td>
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<td>12585.0</td>
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### Shipping and Receiving Requirement

**No. of Shift = 1**

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<tr>
<th>Zone</th>
<th>No. of Pallets</th>
<th>No. of Trucks</th>
<th>Docking Time</th>
<th>No. of Docks Required</th>
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<tr>
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</table>

**Total number of docks required = 223**

Assume 2 docks per 30 foot building bay  
Number of bays required = 112  
Assume 50 foot dock depth  
Staging area requirements = 167250 square feet
CANDIDATE EQUIPMENT SELECTED
PALLET RACK ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 20000 PALLETS
TRANSACTION RATE : 2300 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT(FT)</th>
<th>LEVEL</th>
<th>COST($)</th>
<th>ANN.SYS.COST($)</th>
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<td>$ 1372044.1</td>
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<td>Level</td>
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<tr>
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<tr>
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</table>
THE BEST CANDIDATE SELECTED EQUIPMENT
PALLETS RACK ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 20000 PALLETS
TRANSACTION RATE : 2300 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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<tbody>
<tr>
<td>1</td>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 10000 PALLETS
TRANSACTION RATE : 1500 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE</th>
<th>INVENT</th>
<th>TRANSAC</th>
<th>ANN.SYS.COST</th>
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<td>LEVEL</td>
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CANDIDATE EQUIPMENT SELECTED
RACKABLE - ORDER PICKING BASED ON EACH LEVEL

<table>
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<th>No.</th>
<th>Equipment System</th>
<th>Storage Height (ft)</th>
<th>Storage Level</th>
<th>Annual System Cost</th>
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<tbody>
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</table>
THE BEST CANDIDATE SELECTED EQUIPMENT
RACKABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 10000 PALLETS
TRANSACTION RATE : 1500 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO. EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 HYBRID TRUCK</td>
<td>32.50</td>
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<td>14</td>
<td>$ 769078.84</td>
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</table>
CANDIDATE EQUIPMENT SELECTED
BINNABLE - ORDER PICKING

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 80000 BOXES
TRANSACTION RATE : 8500 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT(FT)</th>
<th>LEVEL</th>
<th>COST($)</th>
<th>INVENT</th>
<th>TRANSAC</th>
<th>ANN.SYS.COST</th>
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# CANDIDATE EQUIPMENT SELECTED

**BINNABLE - ORDER PICKING BASED ON EACH LEVEL**

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment System</th>
<th>Storage Height (FT)</th>
<th>Storage Level</th>
<th>Annual System Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>8.00</td>
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<td>Carousel</td>
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<td>Carousel</td>
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THE BEST CANDIDATE SELECTED EQUIPMENT
BINNABLE - ORDER PICKING
BASED ON THE LOWEST ANNUAL SYSTEM COST

STORAGE HEIGHT : 60.00 FEET
INVENTORY RATE : 80000 BOXES
TRANSACTION RATE : 8500 TRANSACTIONS/DAY

<table>
<thead>
<tr>
<th>NO.</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
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<td>7</td>
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<tr>
<td>2</td>
<td>CAROUSEL</td>
<td>17.00</td>
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<td>$ 1055127.4</td>
</tr>
<tr>
<td>3</td>
<td>ORDER PICKING TRUCK</td>
<td>14.00</td>
<td>13</td>
<td>$ 1062107.2</td>
</tr>
</tbody>
</table>
RECOMMENDED SYSTEM EQUIPMENT BASED ON THE LOWEST ANNUAL COST & SYSTEM COMPATIBILITY

<table>
<thead>
<tr>
<th>ZONE</th>
<th>EQUIPMENT SYSTEM</th>
<th>STORAGE HEIGHT (FT)</th>
<th>STORAGE LEVEL</th>
<th>ANNUAL SYSTEM COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALLET RACK</td>
<td>S/R MACHINE</td>
<td>57.08</td>
<td>14</td>
<td>$940347.52</td>
</tr>
<tr>
<td>RACKABLE O/P</td>
<td>MANNED S/R MACHINE</td>
<td>57.08</td>
<td>14</td>
<td>$769078.84</td>
</tr>
<tr>
<td>BINNABLE O/P</td>
<td>CAROUSEL</td>
<td>8.00</td>
<td>7</td>
<td>$885761.99</td>
</tr>
<tr>
<td>BULK STORAGE</td>
<td>REACH TRUCK</td>
<td>20.00</td>
<td>5</td>
<td>$---</td>
</tr>
</tbody>
</table>
PRELIMINARY BUILDING LAY-OUT

<table>
<thead>
<tr>
<th>ZONE</th>
<th>COLUMN SPACING</th>
<th>MODULE SIZE</th>
<th>MODULES</th>
<th>AREA (SQUARE FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RACK STORAGE</td>
<td>23.167 * 45.833</td>
<td>23.167 * 378.6</td>
<td>8</td>
<td>70181</td>
</tr>
<tr>
<td>BULK STORAGE</td>
<td>23.167 * 45.833</td>
<td>23.167 * 378.6</td>
<td>18</td>
<td>157908</td>
</tr>
<tr>
<td>PINNACLE C/P</td>
<td>12.500 * 59.000</td>
<td>22.500 * 59.000</td>
<td>12</td>
<td>22600</td>
</tr>
</tbody>
</table>
## MANPOWER AND VEHICLES REQUIREMENT

<table>
<thead>
<tr>
<th>ZONE</th>
<th>EQUIPMENT SYSTEM</th>
<th>TOTAL HRS. PER YEAR</th>
<th>NUMBER OF EQUIPMENT</th>
<th>NUMBER OF LABORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALLET RACK</td>
<td>S/R MACHINE</td>
<td>10304.0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>RACKABLE O/P</td>
<td>MANNED S/R MACHINE</td>
<td>17595.0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>BINNABLE O/P</td>
<td>CAROUSEL</td>
<td>51510.0</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>
### SHIPPING AND RECEIVING REQUIREMENT

**NO. OF SHIFT = 1**

<table>
<thead>
<tr>
<th>ZONE</th>
<th>NO. OF PALLETS</th>
<th>NO. OF TRUCKS</th>
<th>DOCKING TIME</th>
<th>NO. OF DOCKS REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECEIVING</td>
<td>2750</td>
<td>15</td>
<td>1.00</td>
<td>27</td>
</tr>
<tr>
<td>SHIPPING</td>
<td>2785</td>
<td>12</td>
<td>1.50</td>
<td>50</td>
</tr>
</tbody>
</table>

Total number of docks required = 77

Assume 2 docks per 30 foot building bay
Number of bays required = 39
Assume 50 foot dock depth
Staging area requirements = 57750.0 square feet