

Departmental Elective Course

IE 473

Material Handling Systems

Dr. Nureddin KIRKAVAK

2010-11 Fall Semester
Çankaya University, Ankara

Material Handling Equipment

- The backbone of a MH System is the handling equipment. A wide variety of equipment is available, each having distinct characteristics and cost that distinguish it from the others.
- All such equipment, however, can be classified into three main types: **Conveyors, cranes, and trucks.**
- **Conveyors:** They are used for moving materials over a fixed path; roller, belt and chute conveyors ...
 - **Advantages:**
 - Their high capacity permits moving a large number of items,
 - Their speed is adjustable,
 - Handling combined with other activities such as processing and inspection is possible,
 - They are versatile and can be on the floor or overhead,
 - Temporary storage of loads between workstations is possible,
 - Load transfer is automatic and does not require the assistance of operators,
 - Straight line paths or aisles are not required,
 - Utilization of the cube is feasible through the use of overhead conveyors.
 - **Disadvantages:**
 - They follow a fixed path, serving only limited areas,
 - Bottlenecks can develop in the system,
 - A breakdown in any part of the conveyor stops the entire line,
 - Since conveyors are fixed in position, they hinder the movement of mobile equipment on the floor.

Material Handling Equipment

- **Cranes and hoists:** They are items of overhead equipment for moving loads intermittently within a limited area; bridge cranes, jib cranes, monorail cranes, and hoists.
 - **Advantages:**
 - Lifting as well as transferring of materials is possible,
 - Interference with the work on the floor is minimized,
 - Valuable floor space is saved for work rather than being utilized for installation of handling equipment,
 - Such equipment is capable of handling heavy loads,
 - Such equipment can be used for loading and unloading material.
 - **Disadvantages:**
 - They require heavy investments,
 - They serve a limited area,
 - Some cranes move only in a straight line and thus can not make turns,
 - Utilization may not be as high as desirable since cranes are used only for a short period of time during daily work,
 - An operator has to be available for operation some types; such as bridge crane.

Cranes are mostly used in places such as shipyards and heavy equipment production facilities.

Material Handling Equipment

- **Trucks:** Hand or powered trucks move loads over varying paths; lift trucks, hand trucks, fork trucks, trailer trains, and automated guided vehicles.
 - **Advantages:**
 - They are not required to follow a fixed path of movement and therefore can be used anywhere on the floor where space permits,
 - They are capable of loading, unloading, and lifting, in addition to transferring material,
 - Because of their unrestricted mobility, which allows them to serve different areas, trucks can achieve high utilizations.
 - **Disadvantages:**
 - They can not handle heavy loads,
 - They have limited capacity per trip,
 - Aisles are required; otherwise the trucks will interfere with the work on the floor,
 - Most trucks have to be driven by an operator,
 - Trucks do not allow handling to be combined with processing and inspection, as other types of equipment do.
- **Degree of mechanization:**
 - *Manual and dependent on physical effort;* manually driven equipment,
 - *Mechanized;* power instead of physical effort is used for driving the equipment,
 - *Mechanized complemented with computers;* the function of the computers is to generate documents specifying the moves and operations,
 - *Automated;* minimal human intervention is used for driving and operating the equipment; conveyors, AGV systems, AS/R System,
 - *Fully automated;* computers perform the additional task of on-line control, thus eliminating the need for human intervention.

Material Handling Equipment

- A wide variety of equipment is available for material handling. Which equipment to use under what conditions depends on the responsible person's judgment and knowledge of the machines and costs associated with the task of moving the materials.

The equipment can be characterized by the area it is intended to serve:

- **Between fixed points over a fixed path:** belt conveyor, roller conveyor, chute conveyor, slat conveyor, screw conveyor, chain conveyor, overhead monorail conveyor, trolley conveyor, wheel conveyor, tow conveyor, bucket conveyor, cat-on-track conveyor, pneumatic tube conveyor, ...
- **Over limited areas:** hoists, overhead cranes, hydraulic scissors lift, ...
- **Over large areas:** handcart/truck, tier platform truck, hand lift truck/pallet jack, power-driven handtruck, power-driven platform truck, forklift truck, narrow-aisle truck, tractor-trailer train, material lift, drum truck, drum lifter, dolly, agv system, ...
- *Containers and unitizing equipment* initiate the classification since they provide the common denominator in all material handling system designs.
- *Material transport equipments—conveyors industrial vehicles, and monorails, hoists, and cranes*—follow as the foundation for all material handling system designs.
- *Storage and retrieval equipment* is used to store and retrieve large and small loads.
- *Automatic identification and communication equipment* including bar code readers, radio frequency data terminals, and light- and voice directed communication devices are used to coordinate and control material handling.

Material Handling Equipment

- I. Containers and Unitizing Equipment
 - A. Containers
 - 1. Pallets
 - 2. Skids and Skid boxes
 - 3. Tote Pans
 - A. Unitizers
 - 1. Stretchwrap
 - 2. Palletizers
- II. Material Transport Equipment
 - A. Conveyors
 - 1. Chute Conveyor
 - 2. Belt Conveyor
 - a. Flat Belt Conveyor
 - b. Telescopic Belt Conveyor
 - c. Troughed Belt Conveyor
 - d. Magnetic Belt Conveyor
 - 3. Roller Conveyor
 - 4. Wheel Conveyor
 - 5. Slat Conveyor
 - 6. Chain Conveyor
 - 7. Tow Line Conveyor
 - 8. Trolley conveyor
 - 9. Power and free Conveyor
 - 10. Cart-on-Track Conveyor
 - 11. Sorting Conveyor
 - a. Deflector
 - b. Push Diverter
 - c. Rake Puller
 - d. Moving Slat Conveyor
 - e. Pop-Up Skewed Conveyor
 - f. Pop-Up Belts and Chains
 - g. Pop-Up Rollers
 - h. Tilting Slat Conveyor
 - i. Tilt Tray Sorter
 - j. Cross Belt Sorter
 - k. Bombardier Sorter
 - B. Industrial Vehicles
 - 1. Walking
 - a. Hand Truck and Hand Cart
 - b. Pallet Jack
 - c. Walkie Stacker
 - 2. Riding
 - a. Pallet Truck

Material Handling Equipment

- b. Platform Truck
 - c. Tractor Trailer
 - d. Counterbalanced Lift Truck
 - e. Straddle Carrier
 - f. Mobile Yard Crane
3. Automated
- a. Automated Guided Vehicles
 - i. Unit Load Carrier
 - ii. Small Load Carrier
 - iii. Towing Vehicle
 - iv. Assembly Vehicle
 - v. Storage/Retrieval Vehicle
 - b. Automated Electrified Monorail
 - c. Sorting Transfer Vehicle
- C. Monorails, Hoists, and Cranes
- 1. Monorail
 - 2. Hoists
 - 3. Cranes
 - a. Jib Crane
 - b. Bridge Crane
- c. Gantry Crane
 - d. Tower Crane
 - e. Stacker Crane
- III. Storage and Retrieval Equipment
- A. Unit Load Storage and Retrieval
- 1. Unit Load Storage Equipment
 - a. Block Stacking
 - b. Pallet Stacking Frame
 - c. Single-Deep Selective Rack
 - d. Double-Deep Rack
 - e. Drive-In Rack
 - f. Drive-Thru Rack
 - g. Pallet Flow Rack
 - h. Push-Back Rack
 - i. Mobile Rack
 - j. Cantilever Rack
 - 2. Unit Load Retrieval Equipment
 - a. Walkie Stacker
 - b. Counterbalanced Lift Truck
 - c. Narrow Aisle Vehicles
 - i. Straddle Truck
 - ii. Straddle Reach Truck
 - iii. Sideloader Truck

Material Handling Equipment

- iv. Turret Truck
 - v. Hybrid Truck
 - d. Automated S/R Machines
- B. Small Load S/R Equipment
- 1. Operator-to-stock-Storage Equipment
 - a. Bin Shelving
 - b. Modular Storage Drawers in Cabinets
 - c. Carton Flow Rack
 - d. Mezzanine
 - e. Mobile Storage
 - 2. Operator-to-Stock-Retrieval Equipment
 - a. Picking Cart
 - b. Order Picker Truck
 - c. Person-abroad Automated S/R Machine
 - d. Robotic Retrieval
 - 3. Stock-to-Operator Equipment
 - a. Carousels
 - i. Horizontal Carousel
 - ii. Vertical Carousel
 - iii. Independent Rotating Rack
- b. Miniload AS/R Machine
 - c. Vertical Lift Module
 - d. Automatic Dispenser
- IV. Automatic Identification and Communication Equipment
- A. Automatic Identification and Recognition
- 1. Bar Coding
 - a. Bar Codes
 - b. Bar Code Reader
 - 2. Optical Character Recognition
 - 3. Radio Frequency Tag
 - 4. Magnetic Stripe
 - 5. Machine Vision
- B. Automatic Paperless Communication
- 1. Radio Frequency Data Terminal
 - 2. Voice Headsets
 - 3. Light and Computer Aids
 - 4. Smart Card

Material Handling Equipment

- ***Belt Conveyor***

It is an endless belt, driven by power rollers or drums at one or both ends and supported by flat beds or rollers. In order to carry ferrous metal or to separate ferrous from other types of metals, the belt may have a magnetic bed. The belt can be vibrated to feed assembly parts, position items, and deliver small amounts of bulk material.

It can be operated at the horizontal or on an incline of up to 30 degrees.

It can be used to carry light objects in assembly lines.

Roller belts can be used to carry heavy boxes, bags or other containers.

Trough rollers can be used to carry bulk material such as coal mine.

- ***Roller Conveyor***

It consists of rollers attached to side rails supported by a steel frame. The load is carried on the rollers, each of which rotates about a fixed axis. The type of roll (steel, rubber or wood), its shape (cylindrical or wheel), and its spacing depend on the load being carried.

It can be either gravity-operated (with a slight downward slope) or power-driven (some of the rollers are driven by chains or belts).

Material can be moved between stations.

Loads must have a firm, even base. Uneven or fragile objects can be carried in boxes, containers, or pallets placed on the conveyor.

Material Handling Equipment

- ***Overhead Monorail***

It is a track to transport carrying devices such as trolleys and hooks. The track itself can form a closed loop, and each trolley can be either powered or manually operated.

It can be designed to carry heavy objects.

They are often used in transporting units to a spray paint booth or a baking oven where a uniform rate of travel is necessary with the entire unit suspended in the air.

- ***Overhead Bridge Crane***

This is an overhead handling unit resembling a bridge that is mounted on a pair of tracks travelling lengthwise. Within the bridge is a cable and hoist that can be positioned at any point along the bridge.

Such a crane covers all the area within the rectangle over which it travels. It provides three-dimensional coverage while moving up and down, sideways and lengthwise.

With various accessories such as buckets, electromagnetic disks, and chains, it can handle almost any material from light tools to heavy, flat metal plates.

Variations: Stacker, tower, gantry, jib cranes.

- ***Pneumatic Tube System***

It consists of a cylinder in which messages or small items are carried over a predetermined path by compressed air or vacuum. To transport lightweight objects rapidly to and from stations, but expensive and complicated.

Material Handling Equipment

- ***Handcart/Truck***

It is a wheel mounted platform with handles to manually push or pull the unit.

It is the simplest and most inexpensive method of transporting a load.

It requires smooth and mainly level floors.

It is used to move material a short distance with frequent stops for loading and unloading.

- ***Forklift Truck***

It is an operator-ridden, power-driven truck with forks in front that lift and carry heavy loads on skids or pallets.

It can be used to load and unload trucks or railroad boxcars.

It is used extensively in storage and warehousing.

It can be operated on gas or electricity.

- ***Tractor-Trailer Train***

It is a series of carts pulled by a self-propelled tractor.

It is used for long-distance moves and it can carry relatively heavy loads.

It allows for a variety of load movement, such as platforms, bins and racks.

It allows many trains to be driven by the same tractor. The tractor can be disconnected and used to pull another train while the first is being loaded or unloaded.

It is mainly used for stop-and-go operations carrying loads from different points and delivering them to various destinations.

Material Handling Equipment

- ***Automated Guided Vehicle System***

It is a system in which the use of computer controls has been extended by a system operator at a station can control the vehicles by causing them to move along a predetermined path and to perform certain duties.

These machines can load themselves, travel to their destinations, unload, and return to the place of origin or any other desirable location.

Human interaction is held at a minimum thereby reducing labor costs, human error, and the possibility of injury.

There are two basic types of automated guided vehicles: dumb and smart. They are categorized on the basis of how much control is given the guide paths and other elements outside the vehicle and how much control is in the vehicle itself.

A system that has the entire control outside the vehicle is built on a zone arrangement. The route are divided into zones, and the vehicle is not allowed to enter a region unless other traffic in the zone is cleared.

A vehicle can be made smarty by using on-board microprocessors and radio transmitters. Different levels of communication between outside control and vehicles can be developed.

A more sophisticated system can have a host computer controlling the movement of all vehicles: Here, the computer is instructed as to what is to be moved, and then it selects the available vehicle closest to the job and issues orders to the vehicle to perform the task.

Material Handling Equipment

- **Advantages of Automated Guided Vehicle Systems**

- *Material control:* More accurate accounting of the use and transfer of material is possible.
- *More efficient use of personnel:* Many fork-lift truck operators are no longer required.
- *Efficient work environment:* They allow loading and unloading of each station independently of other stations, thus permitting each operator to work at his or her own pace and not limiting the operator to the speed of the conveyor.
- *Flexibility:* The routes can be changed and new ones added with considerably greater ease.
- *Better use of floor space:* Buried guide lines in the floor do not permanently occupy floor space as do the conveyors fixed on the floor.
- *Adaptability to automation:* They can operate efficiently with other automated and computer-controlled systems.
- *Integration within plants:* They can provide a link between different cells of automation within the plant.
- *Adaptability to existing facilities:* A new AGV system can be installed within an existing plant with a minimum of structural changes in the plant building.

Material Handling Equipment

- **Accessories**

A variety of accessories is currently available to facilitate material handling economically.

- *Pallet:* It is a platform on which material can be stacked in unit loads and handled by lifting equipment such as the forklift truck. Pallets are made of wood, plastic, metal, or a combination of the three and are available in various sizes.

Pallets are constructed so that the forks of the forklift truck can enter from either two or four sides. Types of pallets are single-faced, double-faced, and box pallets.

- *Box:* It is a portable container in which parts or material can be stored in unit loads. Boxes are made of cardboard, wood, plastic, or metal and are available in various sizes.

Boxes can store and move parts or material that is small or varying in size without crushing or dropping the units.

- *Tote pan:* It is a portable container that is smaller in size than a box.
- *Skid:* It is similar to a pallet, except that the construction does not permit stacking of loaded skids on top of each other.

They can be moved by power-driven or hand-operated devices and can be made portable by attaching two wheels on one end and a carrying dolly at the other.

- *Optical/Bar Code reader:* It is a hand-held device that can read an optical code to identify the product or handling device on which the code is affixed.

They can be used to keep track of inventory or products as items are moved from station to station.

Material Handling Systems

- **Packaging:** The specifications for the product package very much depend on the product design, and any change in design can cause a significant change in package requirements.

It is therefore essential to consider packaging in the design, production, and material handling phases of the product, separately.

The size, shape, and colors of the packaging can be very instrumental in product sales.

- **Packaging** mainly serves to protect a product from damage caused by handling or exposure to environmental conditions involving heat, moisture, light, and even electronic interference and radiation.

The type of packaging also contributes to formation of the unit load, which is necessary in the selection and use of the type of material handling equipment.

- There are three major categories in **packaging**: consumer, industrial, and military.
 - **consumer packaging**, which can be subdivided into retail and institutional, is characterized by small units of products handled in large numbers.
 - When the packaging is for **retail** purposes its appearance should be emphasized,
 - On the other hand, for **institutional** use, protection, cost, and convenience are much more important than appearance.
 - Quite commonly, large-sized units of a product indicate **industrial packaging**,
 - **Military packaging**, is specified by the government.

Material Handling Systems

- Two major aspects in designing the package are careful consideration and evaluation of all available material that can be used. Of particular importance are the static electricity, humidity, temperature, and barrier qualities; the material should keep out water and moisture, greases, oils, gasses, and odors while holding in the product.

The most common type of packaging materials are glass, steel, aluminum, paper, cardboard, wood, and petrochemical products such as synthetic rubber and plastics.

- Once a product is ready for shipment, it must be securely placed in the appropriate package and sealed for shipping and handling.
 - Box flaps and bag openings have been folded closed and sealed in preparation for palletization.
 - Full pallets and irregularly shaped objects might require strapping to secure them.
 - Bottles must be packed to prevent breakage during shipping.
- Some of the equipment available for this purpose:
 - automatic adhesive sealers,
 - automatic tape sealers,
 - stitchers,
 - staplers,
 - strappers,
 - wrappers, and palletizers.

Storage and Warehousing

- In managing a storage and warehouse facility, one must perform many different activities related to the processing of raw materials, semi-finished products, and finished goods. These tasks range from receiving, inspecting, and storing raw materials, to packing, labeling, and shipping orders:
 - **Receiving:**
 - The warehouse receives the material from outside suppliers and accepts responsibility,
 - The receiving operation consists of unloading the goods from trucks and/or railroad cars and unpacking the containers.
 - **Identifying and sorting:**
 - Material is identified and then recorded by using tags, codes, or other means,
 - The items are sorted to find any breakage, and shortages are determined by checking receipts versus packing slips,
 - Appropriate action is taken to inform the shippers and vendors of any discrepancies,
 - **Put-away or dispatching to storage:**
 - The goods are transferred to appropriate areas of storage.
 - **Storing:**
 - The units are held in inventory until needed.
 - **Picking the order:**
 - Items needed for an order are retrieved from storage,
 - Picking of items for a particular order can be accomplished by one or more people depending upon the number of items and their locations in the warehouse.
 - **Assembling the orders:**
 - All items in a single order are grouped together,
 - Any shortage, breakage, or non-conforming item is recorded, and the item is replaced or the order is modified.

Storage and Warehousing

- **Packaging:**
 - All units in an order are packed together.
- **Dispatching the shipment:**
 - Appropriate shipping orders and documents are prepared, and the order is sent to the transport vehicles.
- **Maintaining records:**
 - Records such as the following are kept for each item: the amount received, on-hand inventory, orders received, and orders processed.
- Within a storage facility, several policies influence its layout, locations of storage cells, and assignment of items to these cells:
 - **Physical similarity:** Items with similar physical characteristics are grouped together in one area. This allows the use of similar material handling and similar physical care for each area. Also, special environmental controls such as refrigeration, humidity, and fire safety can be concentrated in one area as the needs of the items dictate.
 - **Functional similarity:** Functionally related items can be stored together.
 - **Popularity:** Every warehouse has items that are retrieved more often than others. In such systems, these fast-moving items are stored close to receiving and shipping areas, and the slow-moving items are assigned to spaces that are farther away. This arrangement minimizes the distance traveled in picking orders.
 - **Reserve stock separation:** It may be advantageous to separate reserve stocks from working stocks.
All working stocks are kept together in a compact area from which picking is relatively easy, Reserve stocks from outlying areas replenish the working stocks as the need arises.

Storage and Warehousing

- **Randomized storage:** Today with modern information-processing systems (computerized inventory control systems) it is no longer necessary to assign a fixed and unique location to an individual stock item.
Changing from dedicated storage to randomized storage might result in considerable savings in the space requirement for the warehouse. The items are stored in spaces that are available when needed without reserving any space for items that are not currently in stock.
- **High security storage:** If there are particularly valuable items and subject to significant pilferage, an area might be needed that is under lock and/or other security measure.
- Another important factor affecting the performance and layout of a warehouse is the policy followed in filling an order, called order picking:
 - **Area system:** Items are stored in the warehouse in some logical manner. The personnel circulate through the area, picking the items required for an order until the entire order is filled.
 - **Modified area system:** This system is applicable where reserve stocks are separated from working stocks. Order picking follows the area system, while secondary personnel are utilized to replenish the working stock from the reserve stock.
 - **Zone system:** The warehouse is divided into zones, and the order is distributed among the order pickers, each picking units from his or her assigned zone.
 - **Sequential zone system:** Each order is divided into zones as in the zone system, but the order is passed from one zone to another as it is assembled. Any orders can be processed simultaneously as each proceeds from one zone to the next.
 - **Multiple-order or schedule system:** A group of order is collected and analyzed to determine the total items needed from each zone. The items are picked by making one trip through each zone, then the orders are assembled in a common area for further dispatching.
 - A slight variation of this is scheduling simultaneous arrival of parts from each zone associated with each order, then putting them together for dispatching.

Storage and Warehousing

- The **area system** is the simplest of all and is widely used when the average number of items in an order is not large. If this number increases, the order is either picked simultaneously (**zone system**) or sequentially (**sequential zone system**). The multiple-order system is beneficial only when there are large numbers of orders, each containing a few items to be processed.
- For storing individual and/or small items, various accessories are available: bins, shelves, racks, stacking, conveyor storage, and yard storage.
- **Missions of a warehouse:**
 - It may hold inventory that is used to **balance and buffer** the variations between production schedules and demand.
For this purpose, the warehouse is usually located near the point of manufacture and may be characterized by the flow of full pallets in and full pallets out assuming that the product size and volume warrant pallet-sized loads.
A warehouse serving only this function may have demands ranging from monthly to quarterly replenishment of stock to the next level of distribution.
 - A warehouse may be used to **accumulate and consolidate** products from various points of manufacture within a single or from several firms, for combined shipment to common customers. Such a warehouse may be located central to either the production locations or the customer base. Product movement may be typified by full pallets in and full cases out.
The facility is typically responding to regular weekly or monthly orders.
 - Local warehouses may be distributed in the field in order to shorten transportation distances to permit **rapid response to customer demand**.
Frequently, single items are picked, and the same item may be shipped to customers every day.