CHAPTER 2

LITERATURE SURVEY

2.1 Material Handling

In order to get the finished product or service, there must be the move in the production system. Material handling system consists of the preparation of area and material's location to facilitate its movement or storage. To get the appropriate Material handling system on any specific production environment, we are required to use both science and art in design and select the system.

Area of Interest	Activities
1. Packaging and packing at the suppliers' plant	1. Handling methods
2. Loading at suppliers' docks	2. Storage methods
3. Transportation from suppliers	3. Loading and unloading techniques (methods)
4. Unloading activities at our plant	4. Packaging (consumer)
5. Receiving operations	5. Packing (protective)
6. Storage of both material and supplies	6. Testing packaging, loading, and handling methods
7. Issuing material to Production	7. Setting specifications and stands for handling, packing, and storage
8. In-Process storage	8. Equipment feasibility studies
9. In-Process handling	9. Handling and storage equipment selection
10.Work place handling	10.Auxiliary equipment evaluation and selection
11.Intra-department handling	11.Selection of containers (shop, packing, shipping)
12.Inter-department handling	12.Handling equipment repair and maintenance policy and procedure.
13.Intra-plant handling	13.Damage prevention (material and product)
14.Handling related to auxiliary functions	14.Safety
15.Packaging (consumer)	15.Training
16.Warehousing of finished goods	16.Surveys to uncover saving opportunities
17.Packing (Protective)	17.Handling costs and cost control methods
18.Loading and shipping	18.Keeping up to date on equipment, methods, procedure, etc.
19.Transportation to customers	19.Related paperwork, control and communication system
20.Inter-plant transportation	
21.Related record keeping	

Table 2-1: Material Handling Interests and Activities

The material handling analyst is concerned with a wide range of interest areas that have an effect on the overall efficiency of production. Table 2-1 is the list of some of the areas and activities in which the handling analyst or engineer of well managed company would be active investigating, analyze, writing specification, setting stands and conducing more formal studies and surveys.

2.2 Material Handling Interests and Activities

In order to analyze the material handling system we have to consider on the concerned interests and activities in material handling system. In table 2-1, the interests and activities that concern with material handling system are listed. In order to get the right system, we have to be active investigating, analyzing, writing specifications, setting standards, and conducting more formal studies and surveys.

2.3 Objectives of Material handling

Since the goal of every profit making organization is the long term profit, one of the common goals for each particular organization is to reduce the production costs. This general objective is more easily understood if it is divided into five following categories.

2.3.1 Increase capacity

2.3.2 Improved working conditions

2.3.3 Improved customer service

2.3.4 Increase equipment and space utilization

2.3.5 Reduced costs

In order to achieve each goal, there are a lot of concerns on material handling system so the material handling engineers must be related in many parts of the cost reduction theme.

2.4 Material handling system's component

In Material handling system, there are four major components to be considered.

2.4.1 Motion: Movement is the conveying of material or goods from one point to another point. The move for each kind of material or goods is different.

2.4.2 Time: One of the most important factors, it indicates the efficiency of the movement. Moreover, time also prescribe the movement of the material and finished goods.

2.4.3 Quantity: The quantity of transferred material or goods must be related to the requirement or capacity of each operation, synchronize to the system time and cost effective.

2.4.4 Space: Space is the important factor of the movement because the motion or material transportation need to occupy the space to install the handling system, store the material, work in process or finished goods.

2.5 Purpose and Benefit of Material Handling

The purpose and benefit of the effective material handling system can be grouped into 4 categories which are

2.5.1 Cost reduction

2.5.2 Increase work efficiency

2.5.3 Improve working environment

2.5.4 Improve sales and service

2.6 Important of Material handling system

In the production system, we can classify the main function into 3 categories.

2.6.1 Operation: Focus on the manufacturing process

2.6.2 Material handling: Concentrate on the material handling.

2.6.3 Control: Take control on the relationship and integration of operation and material handling in order to achieve the high performance manufacturing system.

2.7 Activities and Area of interest in Material handling system

In Material handling system, there are many activities related to the system that the designer and Plant layout team should be tuned into to improve the system effectiveness. These activities are:

2.7.1 Material handling methods

2.7.2 Storage methods

2.7.3 Loading methods

2.7.4 Packing methods

2.7.5 Packaging testing

2.7.6 Feasibility study for Material handling system.

2.7.7 System selections

2.7.8 Material handling systems

2.7.9 Material container selections

2.7.10 Safety of the systems

2.7.11 System operator and concerned person training

2.7.12 Safety of the systems

2.7.13 Cost estimation and control

After Material handling system analysis, the overview of the system can be illustrated. Furthermore the Designer and Plant layout team should consider about the area required to support the operation. Those area are Packaging area, Loading area, Inspection area, Warehouse and Storage area, Area for work in process, and Area for Material handling system.

2.8 Material Handling Equation

Material handling problem is the important part of the industry. We cannot evade from the material handling problem but we can look for the way to eliminate or less it. One of the approaches to understand and analyze Material handling problem is "Material Handling Equation" as shown in the following picture.

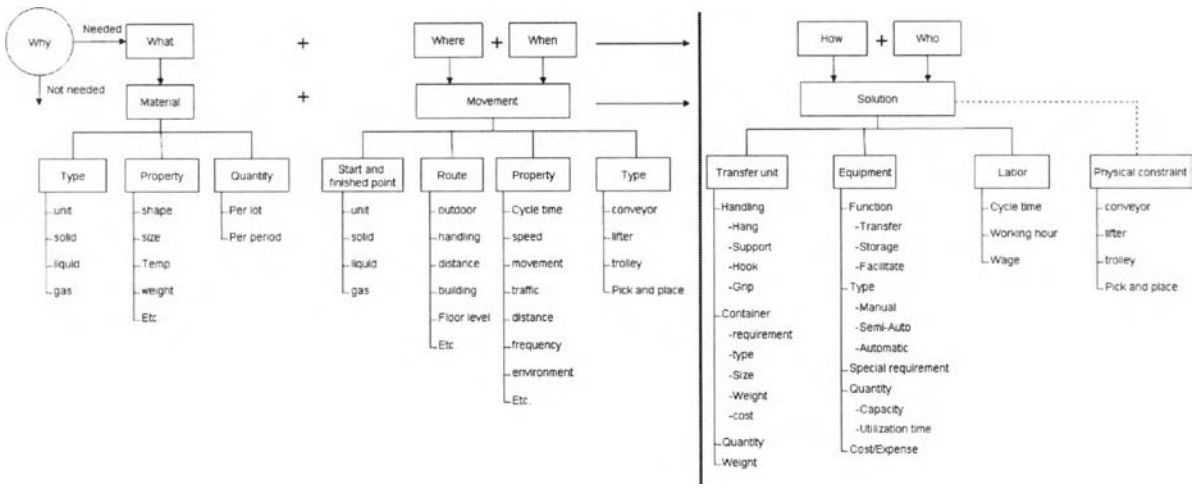

Figure 2-1: Material Handling Equation

From the figure 2-1, there are six important questions in the equation which are why, what, where, when, how and who. We can also derive from the picture that the study of Material handling problem can be divided in 3 main stages.

2.8.1 Material

2.8.2 Movement

2.8.3 Solution

2.9 Type of Material Handling Equipment

The purpose of Material handling equipment is to transfer, store and packing the material or goods. The selection of Material handling equipment must match with the factory layout. We can categorize the Material handling equipment by space occupation into 3 main categories which are

Major Categories	*Equipments*
1. Fixed route	Lift, Conveyor, Pulley
2. Limited space	Crane
3. Unlimited space	Trolley, Truck, Plane, Ship

From this kind of categorizing, the types of material handling are roughly divided. In order to analyze and understand the material handling system, we can divide the system categorizing into 3 types.

1. by the type of equipment
2. by the function of equipment
3. by the movement of equipment

2.10 System categorizing by the type of equipment

The American Material Handling Society divides the Material handling equipment by system type as following;

2.10.1 Conveyor

2.10.2 Crane, Lift or Lifter

2.10.3 Material Locator

2.10.4 Industrial Vehicle

2.10.5 Car or Truck

2.10.6 Train

2.10.7 Plane

2.10.8 Container and Storage

2.11 System categorizing by the function of equipment

The categorizing by the equipment function is related to the route and the movement of the transportation. Each type of equipment is related and appropriated for the type transportation.

In the system design or equipment selection, the components of material movement must be taken into account. The components of material movement are consisted of the following items:

1. **Movement route characteristic** The movement route characteristic can be considered in two perspectives; Top view and Side view. If we look at the movement in the side view, we will see the movement in the vertical aspect. If we look at the movement in the top view, we will see the horizontal part of the movement.
2. **Movement route** This component consider the movement if it is on the fixed or free route. In the train industry, the route of the train must be on rail which is the fixed route. While in the transportation of the material by trolley, the trolley can go anywhere which is the free route.
3. **Type of the movement** Normally, there are three types of the movement which are cycled movement that continuously transfer the material as a cycle such as the conveyor in the manufacturing, station to station movement that transfer the material back and forth between two station such as lift and free movement that transfer the material freely such as the transfer by the trolley.

From the components of the material movement in material handling, we can use this information to design and select the material handling system. The type of material handling equipment can be categorized by the function as following.

1. **Transporting equipment** This type of equipment transports the material in the horizontal axis both on the straight or curved route. The route and direction can be change. It could be manual or machine driven. The samples of transportation equipment are trolleys and carts as shown in figure 2-2.

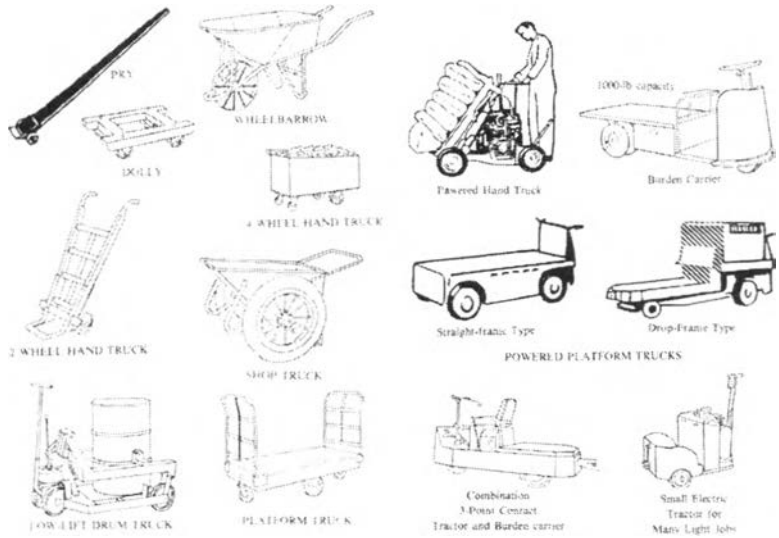

Figure 2-2: Transporting equipment

2. **Elevating equipment** This type of equipment transports the material in the vertical axis and incline route. This transportation is normally cycled movement or station to station movement. The examples of the elevating equipment are lifts and pulleys as shown in figure 2-3.

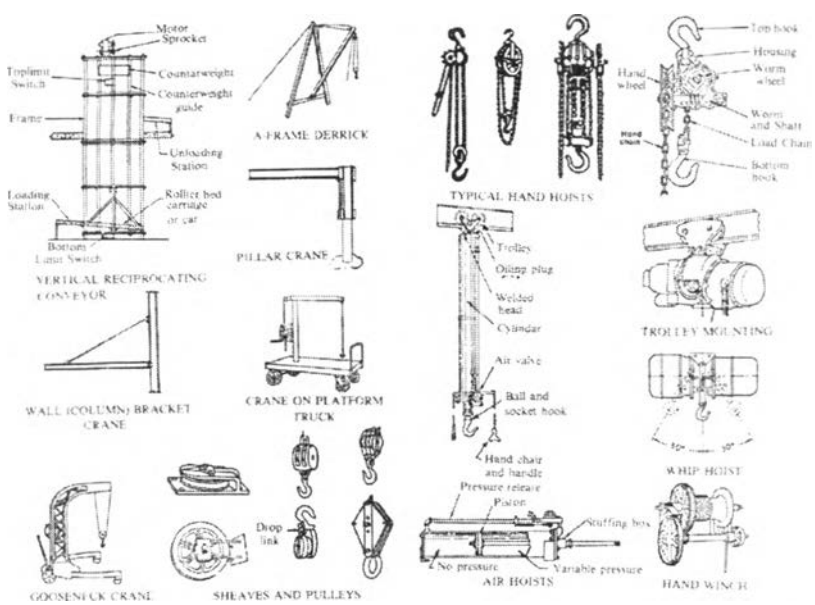

Figure 2-3: Elevating equipment

3. **Conveying equipment** This type of equipment transfers the material by the power from machine or from gravity. Material could be conveyed in any axis. The transportation route is normally fixed. The examples of the conveying equipment are conveyors as shown in figure 2-4.

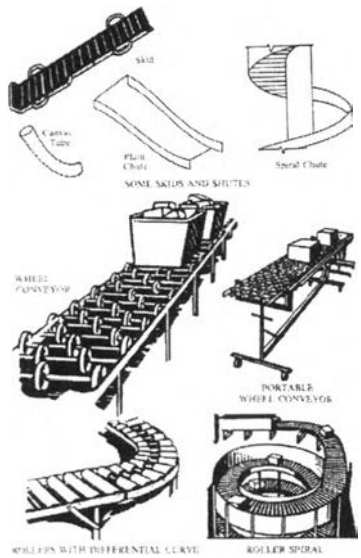

Figure 2-4: Conveying equipment

4. **Transferring equipment** This type of equipment is the machine that lifts the material from one point and place at another point. The transfer route is limited by machine type. It conveys the material from station to station. The examples of the transferring equipment are cranes and hoists as shown in figure 2-5.

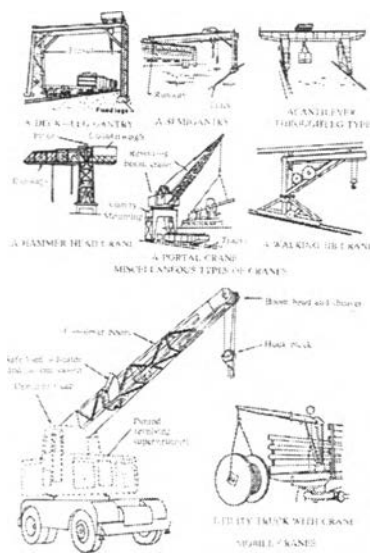

Figure 2-5: Transferring equipment

5. **Self loading equipment** This type of equipment is designed to transfer material by picking the material and move to another point without any

other tools assisting. The examples of the Self loading equipment are trucks as shown in figure 2-6.

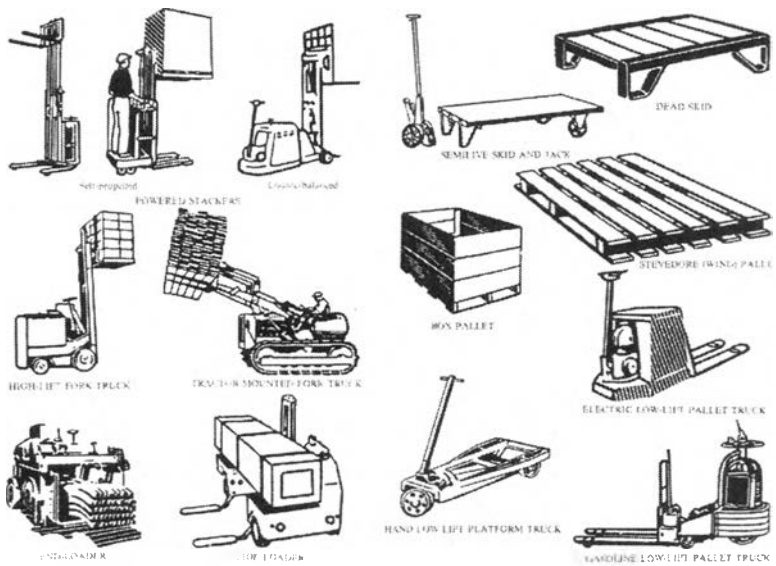

Figure 2-6: Self loading equipment

2.12 System categorizing by movement of the equipment

Material handling equipment can be categorized categorizing by the equipment movement into three following categories.

2.12.1 Continuous movement: The continuous movement equipment is the conveying equipment that continuously moved. The sample of this type of equipment is the conveyor system.

2.12.2 Discontinuous movement: The discontinuous movement equipment transfer the material in every direction but the movement is not continuous. The samples of this type of equipment are lift, truck and car that can move both in the fixed or free route.

2.12.3 Potential movement: The potential movement equipment transfers the material by the gravity. The examples of this type of equipment are silo and tank that keep the goods at high level and transfer by the gravity force.

2.13 The unit load concept

One basic rule of material handling is the collection of material for each trip of material transfer in order to reduce the transportation cost per unit. In this section, we will talk about unit load concept that can be applied to material handling system.

Unit load is the number of the item of the material that can be transfer in each trip of material transfer. The materials in unit load are set in a group to facilitate the material moving. The materials in unit load must be in good condition after the transportation. The unit load concept and requirement can be summarized as following items.

- Can eliminate the transportation of one piece of material per trip.
- Combine the transportation as a unit to economize material transfer and storage.
- Set the material to as a unit as soon as possible and keep material as a unit as long as possible.
- The packaging design must be appropriate and keep the material in safe condition.
- The size of unit should be as big as possible that match up with the building, transportation equipment and production environment.

From the concept and requirement of unit load, we can design the unit load from the material characteristic and other environment. The sample equipments that facilitate the shipping by using the unit load concept are showing in figure 2-7.

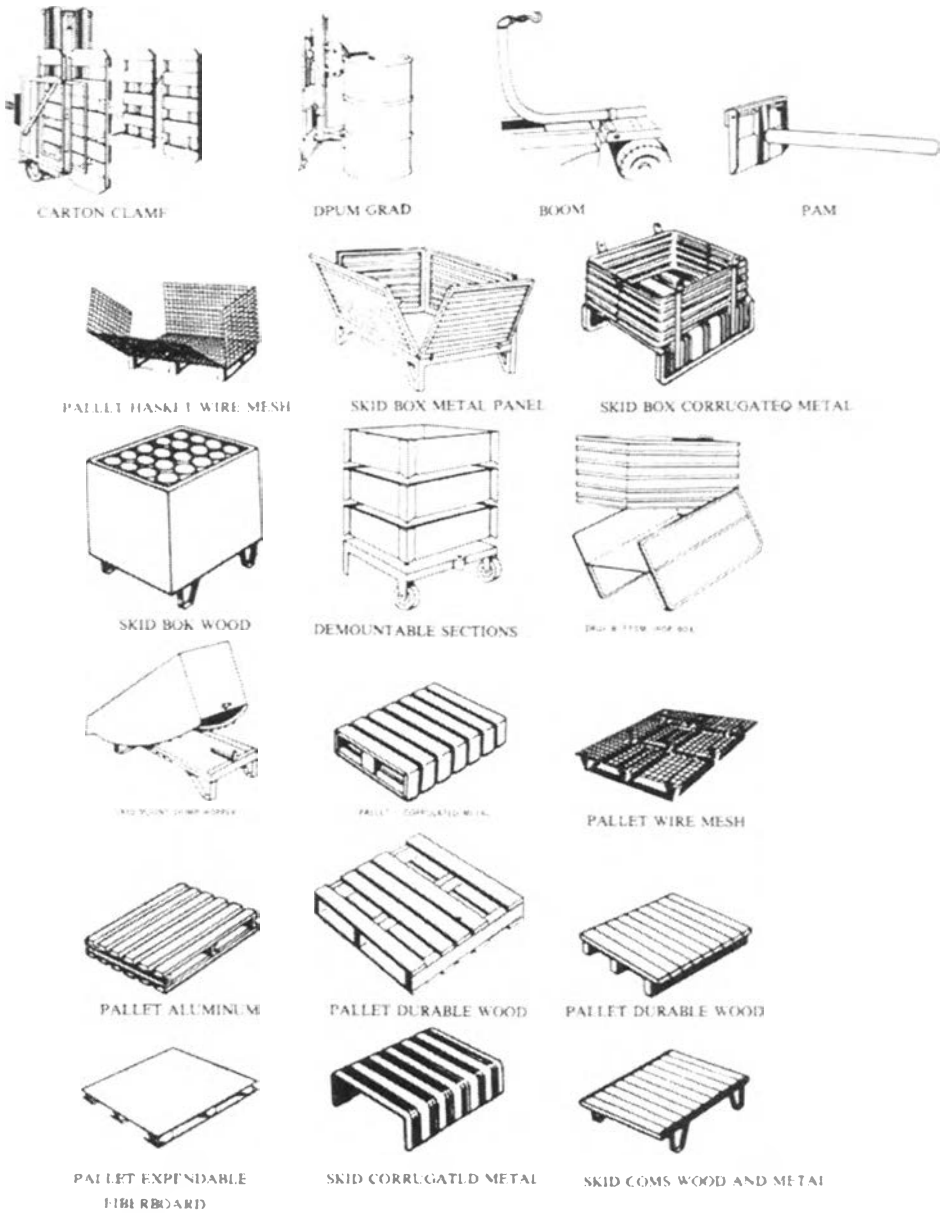

Figure 2-7: Unit load concept equipment

2.13.1 Advantages of unit load concept

2.13.1.1 Transfer more material per trip

2.13.1.2 Save transportation cost

2.13.1.3 Reduce transportation time

2.13.1.4 Reduce packaging cost

2.13.1.5 Maximize space utilization

2.13.1.6 Reduce the material lost rate

2.13.1.7 Reduce the material damaged rate

2.13.1.8 Increase safety in transportation

2.13.1.9 Reduce insurance cost

2.13.1.10 Improve customer satisfaction

2.13.1.11 Reduce label cost of material

2.13.1.12 Reduce the type of storage equipment

2.13.1.13 Reduce storage space

2.13.1.14 Improve material tracking system

2.13.2 Disadvantages of unit load concept

2.13.2.1 Increase cost from unit combination

2.13.2.2 Increase cost from unit separation

2.13.2.3 Need more equipment for unit transfer

2.13.2.4 Need more space for each unit storage

2.13.2.5 Increase weight from unit container

2.13.2.6 Empty container have to be transfer back

Type of unit load and transfer equipment

1. Unit combination on floor
2. Unit combination on plate or platform
3. Unit combination on rack or storage equipment
4. Unit combination on container
5. Unit combination by itself such as roll of metal sheet

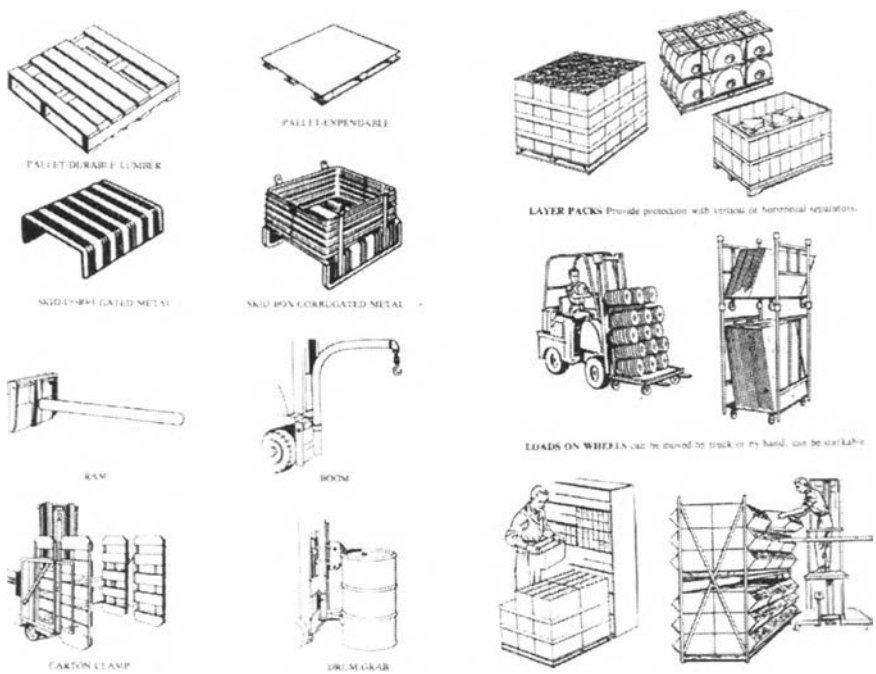

Figure 2-8: Unit load type and equipment

The unit load concept can be applied to the material handling system in the industrial. It can have an effect on plant layout and equipment selection. Moreover, it also have influence the house keeping and material control system of the company.

2.14 Types of material handling equipment

The following information is devoted to definitions, characteristics, uses, and illustrations of types of handling equipment commonly used in mechanically oriented enterprises.

2.14.1 Conveyors

2.14.1.1 Flat belt conveyor: An endless fabric, rubber, plastic, leather or metal belt operating over suitable drive, tail end , and bend terminals and over belt idlers or slider bed for handling material, packages, or objects placed directly upon the belt.

- Tip and return runs of belt may be utilized.
- Will operate on level, incline up to 28 degrees, or downgrade.
- Belt supported on flat surface is used as carrier of objects or as basis for an assembly line.
- Belt supported by flat rollers will carry bags, bales, boxes, etc.
- Metal mesh belts are used for applications subjected to head, cold, or chemicals.
- High capacity.
- Capacity easily adjusted.
- Versatile.
- Can elevate or lower.
- Provides continuous flow.
- Relatively easy maintenance.
- Used for:

  - Carrying objects (units, cartons, bags, bulk material).
  - Assembly lines.
  - Moving people.

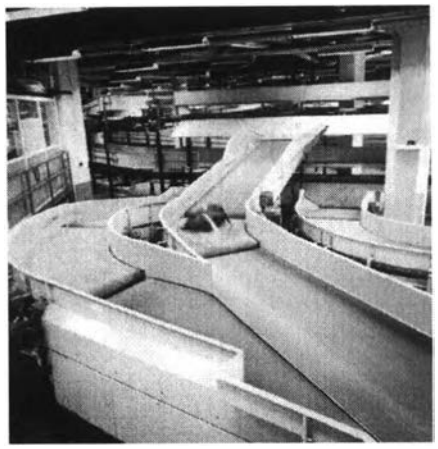

Figure 2-9: Flat belt conveyor

2.14.1.2 *Power and free conveyor:* A combination of powered trolley conveyors and unpowered monorail type free conveyors. Two sets of track are used; usually hang one above the other. The upper track carries the power trolley conveyor, and the lower is the free monorail track. Load-carrying free trolleys are engaged by pushers attached to the powered trolley conveyors. Load trolleys can be switched to and from adjacent unpowered free tracks.

- Free trolleys move by gravity, or by pushers supported from trolley conveyor on upper level.
- Interconnections may be manually or automatically controlled.
- Track switches may divert trolleys from power to free tracks.
- Dispatching may be automatically controlled.
- Free gravity tracks may be installed between two power tracks for storage.
- Speeds may be varied from one power section to another.
- Can include elevating and lowering units in free line.
- Can re-circulate loads on all or sections of system.
- Can be computer controlled.
- Used for:
  - Temporary storage of loads between points on machining, assembly, and test lines.

- Routing loads to selected points.
- Overhead storage for later deliver of loads to floor level.
- Integrating production assembly, and test equipment.
- Provides for surge storage against a breakdown.

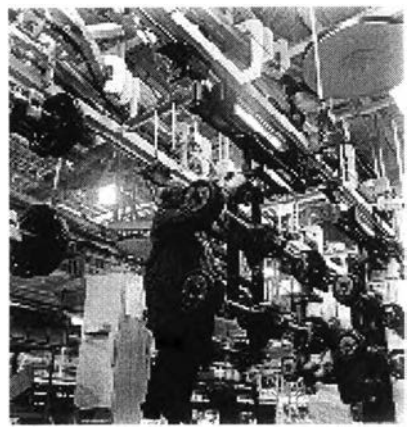

Figure 2-10: Power and free conveyor

2.14.1.3 *Slat conveyor:* A conveyor which carrying surface consists of spaced wood or metal slats, fastened at their ends to two strands of chain running in a suitable track or guide.

- Slats made of wood, metal or combination.
- Slats only ¼ to ½ inch apart provide a relatively continuous surface.
- Slats can serve as base for fixtures or be built as specially designed supports for specific objects.
- Slats can be mounted at work level or flush to floor-where slow speed permits foot traffic to cross over.
- A variation uses roller as slats.
- Sturdy, heavy duty, low maintenance.
- Inclines in a relatively short horizontal distance.
- For inclines over 10°, requires cleats; then can operate up to 30° to 40°
- Used for:

  - Heavy unit loads (crates, cartons, drums, rolls, bags, etc.).

- Hot material (castings, forgings, molds).
- Wet materials.
- Warehousing (goods to and from storage).

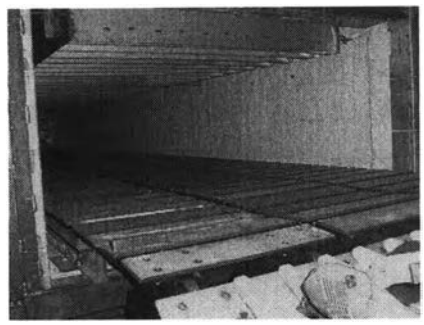

Figure 2-11: Slat conveyor

2.14.1.4 *Tow conveyor:* An endless chain supported by trolleys from an overhead track, running in a track flush with or on the floor or running in a track under the floor.

- Performs somewhat same function as tractor-trailer train.
- Cart can be specially designed for specific loads.
- Track can be equipped with sidings or spurs.
- Rugged, easy maintenance.
- Automatic programmed pick up and release of carts.
- Carts removed from conveyor become free and portable to any point.
- Can include moderate inclines and declines.
- Can make use of carts required for other purposes.
- Requires no operator.
- Paces activity.
- Relatively low cost per weight handled.
- Used for:
  - Boxes, barrels, crates, carton, freight.
  - Warehousing:
  - Loads between receiving, storage, and shipping.

- Order picking; operator attaches free cart to conveyor.
- Intra plant move.
- Assembly line.
- Continuous moving storage.

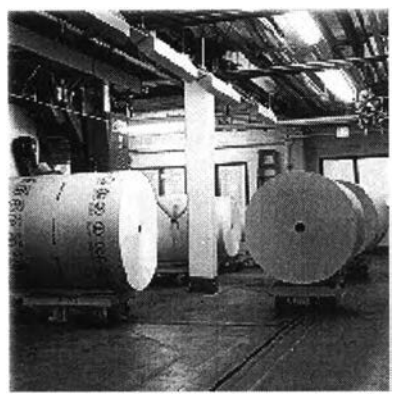

Figure 2-12: Tow conveyor

2.14.1.5 *Trolley conveyor:* A series of trolleys supported from or within an overhead track and connected by an endless propelling medium such as chain, cable, or other linkage, with loads usually suspended form the trolleys.

- Trolleys run on flanges of structural tracks, or inside rectangular or round tubes.
- Multi-wheel trolleys or multiple-trolleys with load bar between used to distribute weight of large loads.
- Load carriers suspended form trolleys and usually designed for optimum handling of object being moved.
- Propelling medium can be chain, cable, or solid link.
- May use sprocket wheel or caterpillar drive.
- Functions in 3 dimensions (horizontal, vertical, and incline)
- Track 8 or 9 ft above the floor.
- Track may be elevated for move then dip for access to operator or process.
- Track easily routed around obstructions.

- Frees floor space; no interference with other traffic.
- Entire length can be used; i.e., no empty return run.
- Relatively inexpensive to install and relocate.
- Salvage value high.
- Low operating and maintenance cost.
- Relatively unlimited length and path.
- Can follow complicated paths.
- Easy to alter, shorten, or lengthen path.
- Paces activity.
- Can be made automatic, or computer controlled.
- Loads can be automatically switched to or from conveyor.
- Can be hung form floor mounted supports.
- Used for:
  - Moving nearly any material or load.
  - Overhead moving storage.
  - Intraplant movement.
  - Interplant movement.
  - Interfloor movement.
  - Recirculating materials.
  - Order picking, with goods on conveyor and picker selecting as items go past the picker.
  - Moving objects through continuous processes such as painting, baking, or degreasing.

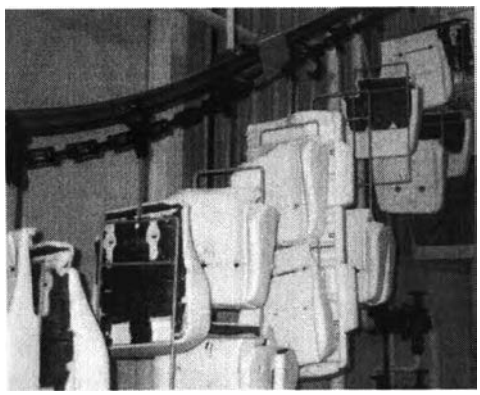

Figure 2-13: Trolley conveyor

2.14.1.6 *Gravity chute:* A slide made of metal or other material shaped to guide objects or materials moved from one location to another. It may be used on horizontal or declined planes, or a spiral between levels.

- Usually slopes downward to utilize gravity.
- Running surface may be wood and metal composition.
- May be straight, curved, or spiral; open or closed.
- Spiral can be multiple flights.
- Frequently custom designed and home made.
- Low cost-no power, low maintenance.
- Makes economical use of space (spiral).
- Rate of descent determined by:
  - Contacting surface.
  - Atmospheric conditions.
  - Pitch.
  - Length.
- Can be variable pitch; portable.
- Used for:
  - Many kinds of materials and objects.
  - Inter-floor moves.
  - Inter-level moves.
  - Warehouses, stores, terminal, industry.
  - Loading and unloading carriers.

- Fire escapes.
- Between machines; storage ahead of a machine.
- From machines to container on floor.

Figure 2-14: Gravity chute

2.14.1.7 *Gravity roller conveyor:* A conveyor which supports the load on a series of roller, turning on fixed bearings, and mounted between side rails at fixed intervals determined by the size of the object to be carried, which is usually moved manually or by gravity.

- Rollers usually cylindrical tubing with a bearing on each end.
- Rollers range from ¾ to 3½ inches in diameter, with length governed by load.
- Curved sections used for turns.
- Rollers may be tapered for turns, or arranged differentially.
- Tight corners may use ball table.
- Requires 3 rollers under load at all times.
- Rollers may be formed to conform to shape of load.
- Standard roller spacing is 3, 4, and 6 inches.
- Inexpensive, easy to install, minimum maintenance, long life.
- Runs can include switches, spur, gates, scales, deflectors, up-enders, processing and packaging equipment.
- Can be arranged in spiral (chute) form.

- Belt boosters used between levels.
- In spite of apparent simplicity often the basis for highly engineered installation.
- Used for:
  - Almost any load with rigid riding surface that will contact 3 or more rollers
  - Movers between areas, machines, buildings.
  - Storage between work stations.

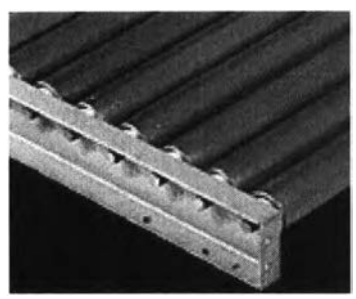

Figure 2-15: Gravity roller conveyor

2.14.1.8 *Live roller conveyor:* Similar to gravity roller, except that power is applied to some or all of the rollers to propel the loads. Generally used for same purposes as gravity rollers except for following features. Therefore, it is also similar to belt conveyor but better for heavy duty.

- Power usually applied by:
  - Chain on sprockets.
  - Belting (underneath) held up against rollers at intervals by other rollers or other devices.
- Can move objects on level runs, up slight grades, or restrain descent on down grades.
- Permit controlled flow articles are spaced.
- Inclines possible to about 10° declines to 17°.
- Curves can be powered.
- More rugged than belt conveyors.
- More expensive than gravity or belt conveyors.

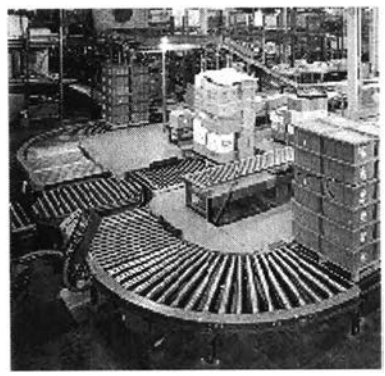

Figure 2-16: Live roller conveyor

2.14.1.9 *Wheel conveyor: A conveyor which supports the load on a series of skate-like wheels, mounted on common shafts in a frame or on parallel spaced rails, and with the wheels spaced to accommodate the size of the load to be carried. It also adapted to live, rack, and spiral versions as in the roller conveyor.*

- Very similar to the roller conveyor:
- Objects usually moved by hand or gravity.
- Wheels 2 inches in diameter and up, and staggered on shafts.
- Lighter weight construction compared to roller conveyor.
- Frequently made of aluminum with plastic wheels.
- Easily portable.
- Less expensive than roller.
- Requires about 50% as much grade as rollers, except when used for storage.
- Easy to set up and put away.
- Low maintenance.
- Comes in 5 and 10 ft. sections.
- Number of wheels per foot determines load capacity.
- Must have 6 wheels under load.
- Pitch of 1½ to 3 in. per 10 ft. section advisable.
- Used for:

- Warehousing.
- Frequently carried in trucks for use in unloading and loading.
- Ideal for curves, due to differential characteristics of construction.
- Single wheeled rails useful in flow rack construction on two sides of a lane.
- Single rails useful as guides.

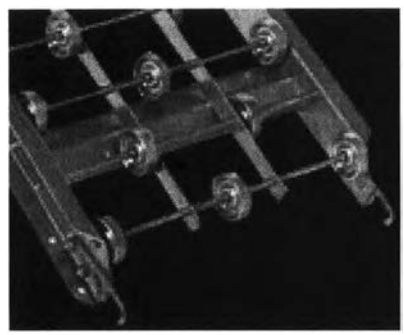

Figure 2-17: Wheel conveyor

2.14.2 Cranes, Hoists, Monorails

2.14.2.1 Jib crane: A lifting device traveling on a horizontal boom that is mounted on a column or mast, which is fastened to floor, floor with top support, or wall bracket or rail.

- Can rote to 360 (degree)
- Inexpensive and versatile.
- Adapted to portable use by an outrigger-equipped wheeled stand.
- Sometimes mounted on wheels and top and bottom rails along a wall or dock.
- Heavy duty (hammer-head type) used for loads up to 350 tons.
- Used for:
  - Serving individual work places in machine shops, etc., anywhere within its radius.
  - Loading and unloading carriers.
  - Handling molds in a foundry.

- Supplementing an overhead traveling crane.

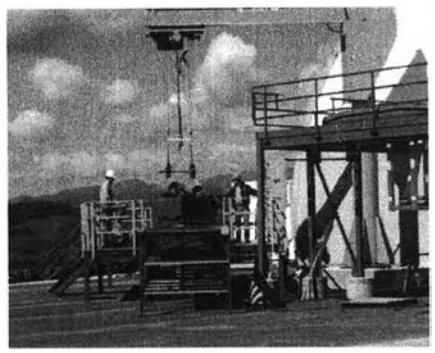

Figure 2-18: Jib crane

2.14.2.2 *Bridge crane*: A lifting device mounted on a bridge consisting of one or two horizontal girders, which are supported at each end by truck riding on runways installed at right angles to the bridge. Runways are installed on building columns, overhead trusses, or frames. Lifting device moves along bridge while bridge moves along runway.

- Cover any spot within the rectangular area over which the bridge travels, i.e., length of one bay.
- Can be provided with cross over to adjacent bay.
- Provides 3 dimensional travel.
- Designed as:

  - Top running, where end trucks ride on top of runway tracks.

  - Bottom-running (under-hung) where end trucks are suspended from lower flanges of runway tracks.
- Hoist can also be top or bottom running.
- Bottom-running usually limited to about 10 tons.
- Bridge propelled by hand chained gearing or power.
- Two hoists (light and heavy duty) may be mounted on one crane.
- Usually designed and built by specialist companies.
- Does not interfere with work on floor.
- Can reduce aisle space requirements.
- Can reach areas otherwise not easily accessible.

- Crane-ways can extend out of building.
- Can be pendant or radio controlled from the floor.
- Used for:

  - Low to medium volume.

  - Large, heavy and awkward objects.

  - Machine shops, foundries, steel mills, heavy assembly and repair shops.

  - Intermittent moves.

  - Warehousing and yard storage.

  - With attachments such as magnets, slings, grabs, and buckets, can handle an extremely wide range of loads.

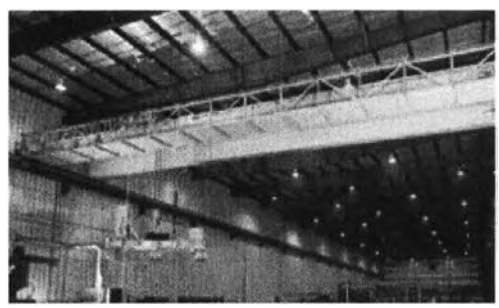

Figure 2-19: Bridge crane

2.14.2.3 *Monorail conveyor:* A handling system on which loads are suspended from wheeled carriers or trolleys that usually roll along the top surface of the lower flange of the rail forming the overhead track or in a similar fashion with other track shapes

- Relatively low installation cost.
- Low operating cost.
- Little maintenance.
- Track may be pipe, T, I, flat-bar or other formed structural shape.
- Can be hand or motor propelled on both travel and lift.
- Motor may be controlled by pendant switches, from integral cab, or automatically.
- Removes traffic from floor.

- Releases floor space.
- Makes use of overhead space.
- Easily extended.
- Switches, spurs, transfer bridges, drop sections, swinging sections, cross-over, turntables provide flexibility.
- Used for:
  - Point to point moves.
  - Fixed path handling.
  - Low volume moves.
  - Intermittent handling tasks.
  - Semi live storage.
  - Loading and unloading carriers.
  - Handling through processes.
  - Connecting buildings.
  - Pouring metal.

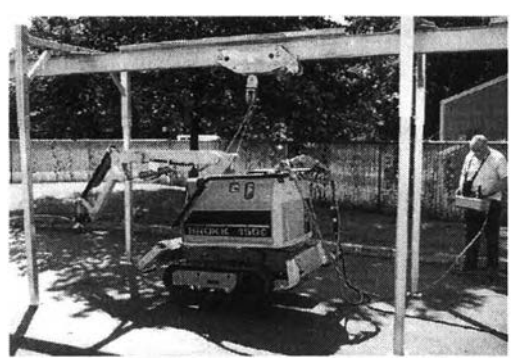

Figure 2-20: Monorail conveyor

2.14.2.4 *Stacker crane:* A device with a rigid upright mast or supports, suspended form a carriage mounted on an overhead traveling (bridge) crane and fitted with forks or a platform to permit it to place in or retrieve items from racks on either side of the aisle it traverses.

- Requires aisles only 4 to 6 in. wider than load.
- Little if any obstruction of aisle when in raised position or out aisle.

- Serves both side of aisle.
- Saves both square feet and cubic feet.
- Permits high selectivity.
- Reduces order selection time.
- Can be manned, pendant, electronic, card, or even computer controlled.
- Can be transferred from aisle to aisle by Transfer Bridge.
- Operator may ride in cab with load-carrying device.
- Helps assure orderly storage operations.
- Minimizes inventory control problems.
- Usually require one operator.
- Used for:
  - Handling unit or containerized bulk loads.
  - Storage and warehousing operations.
  - Adaptable to automatic warehousing operations
  - With attachments can handle a wide variety of loads.
  - Excellent for long loads (metal bar, tubes, etc.).

Figure 2-21: Stacker crane

2.14.2.5 *Storage retrieval unit:* An outgrowth of the stacker crane concept, commonly consisting of a mast or upright supports; suspended from a crane bridge, fastened to rack-mounted rails, suspended from a top-mounted monorail, supported from the floor (or wheeled truck), or supported between top and bottom rails or tracks. Integral in the uprights are forks or a platen device that moves up and down the support, permitting it to place items in, or retrieve items from, the racks on either side of the relatively narrow aisle in traverses. It may be captive, within the aisle it serves; portable, by means of a transfer car at the end of the aisles, to permit it to be moved from one aisle to another; or mobile, on its own wheels, with power to move to any racks located on a suitable running surface.

- Permits random storage.
- Provides high selectivity.
- Require minimum building, heat, and light (only as required by product).
- Can be manual, electronic, punched card, or computer controlled.
- Permits automatic perpetual inventory.
- Can guarantee first-in, first-out stock rotation.
- Some can stack loads 2 deep, therefore increasing output by 25%.
- Cost breakdown, approximately
  - Racks, 40 to 50%.
  - Stacker and controls, 15 to 35%.
  - Conveyor and related equipment, 15 to 20% (all, plus building cost).
- About 5% are computer controlled.
- User for:
  - Storage of materials and supplies.
  - Finished goods warehousing.

- In process storage.
- Nearly any load on pallet or in container.

2.14.3 Industrial trucks

2.14.3.1 Four wheel hand truck: A rectangular load carrying platform with 4 to 6 wheels, for manual pushing, usually by means of a rack or handle at one or both ends. Some have 2 larger wheels at center of platform for easy maneuverability.

- May be fitted with box or other special body for variety of handling tasks.
- Inexpensive.
- Versatile.
- Used for:
  - Manual handling of large loads.
  - Supplementing mechanical handling.
  - Low frequency moves.
  - Low volume movement.
  - Short distances.
  - Relatively light loads.
  - Temporary storage; in-process storage.
  - Handling awkward shapes.
  - Weak floors.
  - Small elevators.
  - Narrow aisles.
  - Crowded areas.

Figure 2-22: Four wheel hand truck

2.14.3.2 *Hand lift truck:* Essentially a wheeled platform that can be rolled under a pallet or skid, and equipped with a lifting device designed to raise loads just high enough to clear the floor and permit moving the load. Propulsion is by hand and lift is by hydraulic or other mechanism. Platform type is used for handling skids, and for type for handling pallets.

- Low cost.
- Durable, minimum maintenance.
- Light weight.
- Compact.
- Simple to operate.
- Versatile.
- Used for:
  - Loading or unloading carriers.
  - Supplementing powered trucks, spotting loads.
  - Moderate distances (50 to 200 ft).
  - Intermittent, low-frequency use.
  - Low volume moves.
  - Increasing utilization of powered equipment.
  - Captive use in a local area (economical).
  - Loading and unloading elevators.
  - Tight quarters; narrow aisles.

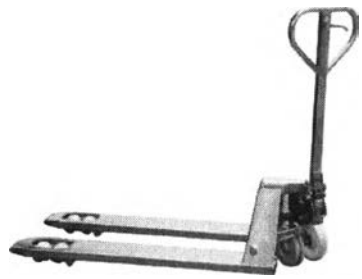

Figure 2-23: Hand lift truck

2.14.3.3 *Fork lift truck:* A self loading, counterbalanced, self propelled, wheeled vehicle, carrying an operator, and designed to carry a load on a fork (or other attachment) fastened to telescoping mast mounted ahead of the vehicle to permit lifting and stacking of loads.

- May be powered by gasoline, diesel, battery, or LP gas engine.
- Mast may be tilted forward or backward to facilitate loading and unloading.
- Operator may ride in center or at backend of truck or, with special attachments, on the lifting mechanism, with the load.
- Operator may sit or stand.
- Used with a wide variety of attachments to provide an extremely flexible and adaptable handling device.
- Carries own power source, therefore, useful away from power lines.
- Wheels and tires can be provided for a variety of floor conditions or operations locations: wood, concrete, highway, or yard.
- Wide range of capabilities.
- Electric type especially useful where reduced noise or no fumes desired.
- Used for:
  - Lifting, lowering, stacking, un-stacking, loading, unloading, or maneuvering.
  - Variable and flexible paths.

- Medium to large unites loads.
- Uniform shaped loads.
- Low to medium volume of material.
- Intermittent moves.

Figure 2-24: Fork lift truck

2.14.3.4 *Platform truck (powered):* A fixed-level, non-elevating, load-carrying powered industrial truck supporting the load on a platform. Smaller capacity models are referred to as load carriers or burden carriers for handling lighter loads and pick up use.

- Straight frame-carrying surface above wheels.
- Drop frame-carrying surface closer to floor with smaller wheels at end opposite power source.
- Operator normally stands.
- May be gas, diesel or battery powered.
- Versatile.
- Adaptable with special chassis or attachments.
- Used for:
  - Heavy loads.
  - Occasional use.
  - Relatively long loads with offset driver's seat-wall board, pipe, wood, etc.
  - Bulky loads.

- Maintenance work-carrying tools to work or work to shop.
- Where platform lift or fork lift is not warranted by handling volume.

Figure 2-25: Platform truck (Powered)

2.14.3.5 *Narrow aisle truck:* In general, any one of several types of powered trucks capable of operating in a narrow aisle (6 ft down to 30 in. wide.).

- Uses less aisle space.
- Relatively maneuverable
- Indoor models usually electric.
- Used for:
  - Order Picking.
  - Congested area.

2.14.3.6 *Order picking truck:* A truck designed or adapted to facilitate the order picking process by making it easier for the operator to control the truck lift and travel while selecting orders. The vehicle is sometimes only 26 to 30 in. wide, with guide rollers or wheels on chassis which engage rails on bottom of racks to eliminate need for steering, and with operator riding on a platform so that he can pick from both sides of the narrow aisle.

2.14.3.7 *Reach truck:* A variation of the straddle truck in which the fork reaches out for the load on a pantograph type device permitting the fork to travel forward to engage the load, lift it, and then retract it to the mast for traveling.

- Uses less aisle space.
- Maneuverable
- Weighs about 2,000 lb less than counter balanced equivalent.
- Some models can stack loads 2 deep on racks.
- Used for:
  - Warehousing
  - Narrow aisles.
  - Tight quarters.
  - Low floor load areas.
  - Loading/unloading vehicles.

2.14.3.8 *Side loading lift truck:* A powered, 4 wheeled truck that picks up the load from the side by means of a mast, with forks centrally mounted on a bay at the center of the truck chassis. This arrangement permits the mast to travel transversely across the chassis and, in the extreme outboard position, lift loads within reach of the forks. The load is then retracted and place on the chassis or deck for carrying.

- No need to turn into the load.
- May be gas, diesel, or battery powered.
- Fast load pick up.
- Very maneuverable, for size of load.
- Quick, safe transport and stacking.
- Can climb 15 to 20% grade.
- One man operation, even for most large loads.
- Some have pneumatic tires for outdoor use.
- Can travel on highway (about 25 mph).
- Truck width equals load plus about 3 ft.

- Heavy duty models have jacks for stabilizing while loading and unloading.
- Can have guide rollers for use in narrow aisles.
- Used for:
  - Narrow aisles.
  - Long loads, 40 ft or more.
  - Storing long loads (pipe, lumber, steel shapes, sheet metal, bar stock, etc.) on racks or in piles.
  - With attachment can tandem store 2 loads deep, therefore eliminating 2 aisles out of 5 aisles.
  - Yard storage work.

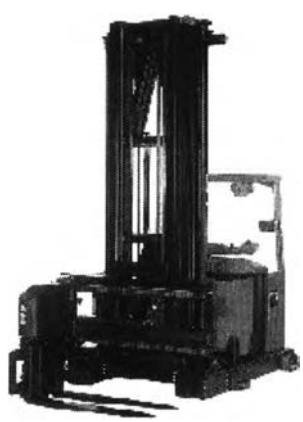

Figure 2-26: Side loading lift truck

2.14.3.9 *Straddle truck (outrigger):* A variation of the lift truck where vehicle is equipped with wheeled outrigger arms extending forward on the floor along either side of the load; arms perform the function of a counterbalance and keep the truck from overturning.

- Uses less aisle space.
- Can be equipped with reach attachment.
- Generally battery powered, therefore quiet, no fumes, low operating cost.
- Operator rides, usually in stand up position at rear of truck.

- Maneuverable.
- Relatively lightweight, about 2,000 lb less than counterbalanced truck of equal capacity.
- Used for:
  - Narrow aisles (6 ½ ft).
  - Tight quarters.
  - Low capacity floors.
  - Loading elevators, trucks, etc.
  - Warehousing (stacking, picking, etc.)

2.14.3.10 Tractor trailer train: A handling system consisting of a 3 or 4 wheeled, self propelled vehicle designed for pulling loaded carts or trailers. Common versions are rider type, walkie type, and electronically guided type.

- Motive power is not tied up while trailers are being loaded or unloaded.
- One power unit pulls several load units.
- One tractor can keep three sets of trailers in use: one loading, one unloading, and one in transit, if loading and unloading labor is available at terminal points.
- Low cost movement of large quantities.
- Flexible route.
- Three wheeled type tractor extremely maneuverable.
- Electronically guided type requires no operator and follows a path described by wire embedded in the floor (or a line, or tape) and can be programmed for automatic dropping of trailers and sounding horn or signaling arrival at intersections.
- Used for:
  - Greater volume than fork lift truck.
  - Distances of 200 to 300 ft and above.

- Warehousing operations to haul loaded trailers fro order picking area to order assembly area, and from receiving to storage.
- Receiving and shipping in conjunction with fork lift truck for loading and unloading carriers.
- Specific loads, with specially designed trailers, such as platforms, boxes, and racks.
- Order picking where driver can also pick orders.
- Collecting or delivering loads to a number of locations, as on a route.

2.14.3.11 Walkie truck: A term applied to many of the basic truck types preciously described, when designed to be power propelled, and usually power operated but with the operator walking and operating the truck by means of controls on the handle. They are designed to fill the gap between the hand trucks and the rider trucks, although some are designed as rider walkies. Common types are fork lift, narrow aisle, order picker, pallet, platform, reach, skid, stacker (portable elevator), straddle (outrigger), and tractor.

- Smaller then rider types.
- Lighter than rider types.
- Slower than rider types.
- Usually battery powered.
- Lower cost.
- Adaptable.
- Dependable.
- Used for:
  - Lighter loads.
  - Hauls (up to 250 ft).
  - Congested areas.
  - Occasional use.

- Servicing elevators.
- Low floor load areas.
- Supplement rider trucks.

2.14.4 Auxiliary Equipment

2.14.4.1 Dock board: A specially designed platform device to bridge the gap between the edge of the dock and the carrier floor, sometimes known as bridge plated. Carrier floor vary from 44 in. for rail cars, to 48 in. for pick up trucks, to 52 in. for highway trucks, plus special bodies of even lower design.

- Made in formed shape to provide strength and side guards.
- Usually lightweight metal.
- Often designed with loops to permit mobbing by fork truck.
- Can be fastened to dock edge.
- Some can be slid along a rail from one location to another.
- Often have pins to lock lateral position.
- Have non-skid surfaces.
- May be flared for narrow (shallow) dock.
- Should be carefully selected for intended use.

2.14.4.2 Dock levelers: A platform like device built into the dock surface (or edge) and hinged to permit rising and lowering to accommodate truck height when bridging the gap between dock and truck floor.

- Permits extension of dock floor into carrier.
- Adjusts up and down, left and right, or for vehicle tilt.
- May be counterbalanced or hydraulically operated.
- May be automatic, such as adjustment to truck initiated upon bumping by vehicle.
- Has lip, to level out vehicle end of platform.

2.14.4.3 *Shipping container:* A large container designed for consolidating material or goods to facilitate shipment by common carrier usually 500 to 2,500 cu ft; sometimes classified as pallets, cargo and van containers.

- Common sizes: 8 by 8 ft cross section, and 10, 20, 30, or 40 ft long; pallet sizes; 50 to 100 cu ft.
- Sealed by shipper.
- Handled as a unit, usually direct to customer.
- Reduced pilferage, damage contamination, etc.
- Reduced handling time (vs. individual items).
- Reduced packaging and packing costs.
- Lower insurance rates.
- May be made of metal, wood, plastic, rubber, etc.
- Some are collapsible.
- Some have drop bottoms.
- Many are designed for attachment to carriers.
- Used for:
  - Over the road, rail shipment.
  - Bulk, liquid, or unit materials.

2.14.4.4 *Shop container:* Any one of a number of varieties of relatively small containers for handling material through the shop.

- May be made of sheet metal, wire, wood, fiber board, corrugated board, or plastic.
- Permit easy handling of small parts.
- May be consolidated into unit loads.
- May be easily stacked or placed in racks.
- Custom liners or inserts permit safe handling of odd shaped or fragile items.

- Used for:
  - Consolidating items.
  - Elimination of smaller containers such as bags, with attendant handling.
  - Increasing use of storage space.
  - Reducing freight cost.

2.14.4.5 *Pallet:* A horizontal platform device used as a base for assembling storing and handling materials as a unit load. Usually consists of two flat surfaces, separated by three stringers.

- May be expendable, general purpose, or special purpose.
- May be single or double faced.
- May be flush stringer, single or double wing.
- May be one way, two ways, or four ways entry.
- Made of wood, plywood, metals, corrugated, plastic, etc.
- Protects goods being moved from damaged pilferage, etc.
- Facilitates inventorying.
- Promotes cleanliness and good housekeeping.
- Keep material off floor, therefore easier to handle,
- Used for:
  - Fork truck based systems.
  - Unitizing items.
  - Utilizing building cube.
  - Increasing load size.
  - Reducing handling of individual items.
  - Minimizing packing of individual items.

2.14.4.6 *Skid:* A load carrying platform supported from the floor by two parallel stringers or supports.

- Similar to the pallet

- Usually heavier and stronger than pallets.
- Usually for use with heavier loads.
- May be wood or metal.
- May be build into a shipping container for ease of handling.
- Used for same general purposes as pallets.
- Semi-live skids have 2 wheels and 2 legs for use with skid jack.

2.14.4.7 *Rack:* A framework designed to facilitate the storage for loads, usually consisting of upright columns and horizontal members for supporting the loads, and diagonal bracing for stability.

- May be classified as Selective:
  - Bolted.
  - Lock fit.
  - Palletless.
  - Cantilever.
  - Bar stock.
  - A frame.
  - Custom.

or Bulk

  - Drive in.
  - Drive through.
  - Live.

or Portable

  - Integral unit.
  - Rigid.
  - Knock down.
  - Collapsible.
  - Pallet stacking frame.
  - Bolt on.
  - Snap fit.
  - Independent of pallet.

- Made of metal, wood, pipe, etc.
- May be fixed or adjustable in shelf height.
- Usually built for pallets, but may be used or adapted for skids, rolls, drums, reels, bars, boxes, etc.
- May have shelves for storage of loads, but may be designed for drive in or drive through applications.
- Facilitates inventory taking.
- Rugged; minimum maintenance.
- Live racks are designed for loads to flow to the unloading position.
- Cantilever racks best for long items.
- Used for:
  - Increasing utilization or storage space.
  - Increasing selectivity of goods stored.
  - Protecting goods.
  - Control of inventory.
  - Improving housekeeping.

From the available material handling equipment in the market, the basic concept and general material handling system used in the typical manufacturing enterprise as well as in many other type of business have been mentioned. For the more specific equipment, we have to consult the material handling special so they can give the more appropriate system to each specific operation.

The next section will talk about the design of material handling system by having the specify environment and operation to match the system with that individual environment and constraint in the specific site and operation.

2.15 Design the Material Handling System

There are a lot of preliminary works before enough information has been developed to design a handling system into the layout. In term of the overall facility design process, it should be pointed out that potential handling systems and equipment alternatives have very likely been given serious consideration during the design stages previously carried out. It is at this point in the planning process that idea must be cleared, and preparation made for designing or procuring any handling equipment required.

Design the Handling system into the Layout: Effective material handling does not just happen. It comes about only through a careful analysis and evaluation of the entire operation, with the objective of implementing a well-planned material flow pattern by means of appropriate methods and equipment. If there is such a thing as a procedure for doing thins, it would be somewhat as reflected in the headings that outline the following information.

2.15.1 Understand the system concept.

2.15.2 Review the system design criteria: Try to keep them in mind while designing the handling system

a. Increased production (productivity)
b. Cost reduction
c. Improve safety
d. Storage capacity
e. Expandability
f. Minimum product damage
g. Optimum control
h. Improved working condition
i. Improve quality
j. Reduced dependency on labor
k. Dependability

l. Easy, low maintenance

m. Back up capability

n. Continuous flow

o. Flexibility

p. Information handling capability

q. Optimum space requirements

r. Standardized components

s. Adaptability

t. Combine handling with other function

u. Optimize material flow

v. Handle as large as a load as possible

w. Judicious use of mechanization

x. Minimum down time

y. Planned for progressive mechanization

z. Make full use of equipment

aa. Meet system objectives

bb. Improved customer service

cc. Comply with present (and future) law, codes, regulations

dd. Be compatible with balance of plant

2.15.3 *Establish objective of the handling system*: to be sure it is properly stated and compatible with the overall facility objectives and plans.

2.15.4 *Obtain data required.*

2.15.5 *Develop preliminary flow patterns.*

2.15.6 *Identify activities and plan activity interrelationship.*

2.15.7 *Determine space requirements and make area allocation.*

2.15.8 *Establish material flow pattern.*

2.15.9 *Identify and document move requirement.*

a. Path: Process Chart, Flow Process Chart, Flow Diagram

b. Characteristics: Material handling equation, Preliminary characteristics (scope, source and destination, distance, path, frequency, speed, rate, etc.

2.15.10 *Analyze material characteristics.*

a. Quantity

b. Unit volume

c. Unit weight

d. Type, form

e. Uniformity

f. Properties

2.15.11 *Establish desired or existing building characteristics.*

a. Loading level

b. Unloading level

c. Column spacing

d. Clear height

e. Running surface

2.15.12 *Study basic handling system.*

a. Equipment oriented

b. Material (load) oriented

c. Method oriented

d. Production oriented

e. Function oriented

2.15.13 *Determine feasibility and desirability of mechanization.* Some of the many factors determining the feasibility and level of mechanization are shown in table 2-2, as a general guideline.

No Equipment	Equipment		
1. Low volume 2. Low rate of flow 3. Non-uniform flow 4. Small items 5. Short distances 6. Limited area 7. Infrequent handling 8. Occasional handling 9. Varying paths 10. Small percentage of time spent into handling 11. Little cost attributable to handling 12. Complex flow pattern 13. Obstacles in flow path 14. No alternative	*A. General* 1. Loads over 20 kg. (or other predetermined limit) 2. Two man handling tasks 3. Travel time excees lifting and placing time 4. Unused space above floor *B. Manual* 1. Relatively light loads 2. Limited volume 3. Physical restrictions 4. Equipment equally useful for storage 5. Limited capital 6. Minimum maintenance facilities 7. Stand by use 8. Wide variety of small or infrequent handling tasks (requiring flexibility of manual equipment) 9. Efficiency of manual methods relatively high 10. Low cost operation 11. Complex flow pattern	*C. Mechanized* 1. High volume 2. Continuous movement necessary 3. Much handling required 4. Direct labor performing handling tasks 5. Need for controlled rate of flow 6. Increased capacity 7. Hazardous materials 8. Operatiors waiting for materials 9. Manual handling undesirable 10. Production bottlenecks 11. Unit loads practicable 12. Dependable handling necessary 13. Limited space 14. Wasted cube 15. Flexible types of equipment adaptable to handling tasks	D. Automated 1. High volume 2. High precentage of handling in operation 3. Uniform product; material 4. Stable product 5. Practicable to combine movement with production or other operations 6. Maintain process control 7. Reduce cost 8. Limited number of paths 9. Moves relatively fixed 10. Relatively fixed materila flow pattern

Table 2-2: Equipment Selection Guidelines

Before a decision can be made on equipment to be used for a specific situation, consideration must be given to determining a more specific degree of mechanization. However, it may not necessarily be the same for every handling operation in the process. Only by means of a complete analysis can the optimum level be reached for each handling task in the system.

Power	Control	Level of Mech.	Description of Levels of Mechanization of Material handling
Electric or Internal combustion engine	Computer	10	Automated online, self regulating, instruction&control by central computer
		9	Mechanized with instruction&control by integrated mini computer
	Elec.	8	Mechanized with control by manual insertion of tape, card, etc.
	Push butt	7	Power propulsion and/or lift remote control by push button, switch, etc.
	Manual	6	Power propulsion and/or lift rider control at site
		5	Power propulsion, walkie, conveyor, etc.
Gra-vity		4	Level of gravity conveyor, chute, etc. equipment indicated below
Manual		3	Hand trucks with shelving, racks, etc. to permit manual access to height
		2	Hand trucks, carts, etc. equipment carrries load, man propels equipment
		1	Hand man carries load

Table 2-3: A summary of the Levels of Mechanization of Material Handling Equipment

The concept of level of mechanization has been adapted for application to material handling, shown in table 2-3. Although the chart may not resolve the problem, it does show the thinking process involved in making the decision on the appropriate level of handling mechanization.

The selection of the level of mechanization becomes a problem of economic feasibility. After the total handling system has been conceptualized, it is necessary to make engineering economic analyses of each move.

2.15.14 Relate the material characteristics and move requirement to systems and equipment capabilities.

Move number (from process chart	Material							Move																				Method										Physical Restrictions						
	1. Type	2. Characteristics			3. Quantity			4. Source and Destination			5. Logistics						6. Characteristics										7. Type	8. Handling Unit				9. Equipment			10. Manpower								
	Unit, Bulk, Liquid, Gas	How received	Dimensions	Weight/Unit	Annual Usage	Maximum inventory	Quant./Move	External-internal	Load/Unload Level	Load/Unload method	Point to Point	Area	Plane	Profile	Path	Level	Distance	Frequency	Rate	Speed	Motion type	Traffic	Environment	%Transp.	%Handling	Sequence	Transp., convey, Manen	Load support method	Container	Weight	Items/Handl. Unit	Hand. units per Tot. Qt.	Type	Capacity	No. of Units	Hours per year	Number of men	Column spacing	Clear height	Aisle width	Floor load capacity	Overhead load capacity	Floor condition	Elevator capacity

Table 2-4: Material Handling analysis re-cap table

In table 2-4, Material handling analysis re-cap table, may be helpful in documenting steps 9 to 13, it is based on the three major aspects of a material handling problem: the material, the movement, and the method. The selected sub-factors under each phase must be taken into consideration in solving the problem. The material handling analysis re-cap table, is a attempt to do just this. It will not select the equipment, but if the material handling analyst has the proper background, it will guide his thinking toward the equipment type by focusing his attention on the kinds of equipment that come closest to matching the characteristics of the material and the requirement of the move.

2.15.15 Make preliminary selection of basic handling systems and equipment types.

	Task and Equipment Characteristics	Conveyors Moving uniform loads continuously from point to point over fixed paths where primary function is transporting	Cranes and Hoists Moving varying loads intermittently to any point within a fixed area	Industrial Trucks Moving mixed or uniform loads intermittently over various paths with suitable surfaces where primary function is maneuvering
Material	Volume	high	low, medium	low, medium, relatively high
	Type	individual item, unit load, bulk	individual item, unit load, variety	individual item, unit load, variety
	Shape	regular, uniform, irregular	irregular	regular, uniform
	Size	uniform	mixed, variable	mixed or uniform
	Weight	low, medium, heavy, uniform	heavy	medium, heavy
Move	Distance	any, relatively unlimited	moderate, withing area	moderate, 250 to 300 ft
	Rate, Speed	uniform, variable	variable, irregular	variable
	Frequency	continuous	intermittent, irregular	intermittent
	Origin, Destination	fixed	may vary	may vary
	Area covered	point to point	confined to area within rails	variable
	Sequence	fixed	may vary	may vary
	Path	mechanical, fixed pt. to fixed pt	may vary	may vary
	Route	fixed, area to area	variable, no path	variable, but over defined path
	Locaiton	indoors, outdoors	indoors, outdoors	indoors, outdoors
	Cross Traffic	problem in by-passing	can by-pass, no effect	can by-pass, maneuver, no effect
	Primay function	transport, process/store in move	lift&carry, position	stack, maneuver, carry, load, unload
	% Transport in operation	should be high	should be low	should be low
Method	Load support method	none, or in containers	suspension; pallet, skid, none	from beneath; pallet, skid, container
	Load/unload charactenstics	automatic manual, designated points	manual, self, any point	self; any point on available path
	Oper. Accompany load	no	may or may not, usually does	usually does; may be remote
Building Char.	Cost of floor space	low, medium	high	medium, high
	Clear height	if enough, conv. Can go overhead	high	low, medium, high
	Floor load capacity	depends on type conv.&mat'l	depends on activity	medium, high
	Running surfaces	not applicable	not applicable	must be suitable
	Aisles	not applicable	not applicable	must be sufficient
	Congested areas	fair	good	poor

Table 2-5: interrelationships between the factors and the general capabilities of the basic type of handling equipment

In addition to the above consideration of material handling problem factors and levels of mechanization, the equipment selection process still depends largely on the analyst's knowledge of handling equipment. Table 2-5 shows some of the interrelationships between the factors and the general capabilities of the basic type of handling equipment. It represents the thinking process the analyst uses in applying his experience to the task of equipment selection, to determining the type best suited to each individual move or to the process as a whole.

2.15.16 *Narrow the choice.* The analyst might review each move in terms of equipment capabilities required, and review the layout in terms of equipment alternatives. Where the handling problem is more complex or more of a system problem, the analyst may want to:

a. Conceptualize system possibilities.

b. Structure alternative systems.

c. Simulate potential systems.

d. Select feasible system.

2.15.17 *Evaluate the alternatives.* Having narrowed the choice to a relatively few types or pieces of equipment, it is now necessary to carefully evaluate the alternatives. This is consists of several approaches to evaluation. First, there is the qualitative evaluation, by reviewing the objective of a method or system, and such equipment selection criteria as the following: does the method, equipment, or system:

a. Fit into the handling system?

b. Combine handling with other functions (production, storage, inspection, packing, etc.)?

c. Optimize material flow?

d. Seem as simples as practicable?

e. Utilize gravity wherever possible?

f. Require a minimum of space?

g. Handle as large a load as practical?

h. Make the move safely, in terms of both manpower and material?

i. Use mechanization judiciously?

j. Have flexibility, adaptability?

k. Have a low dead-weight to pay-load ratio?

l. Utilize a minimum of operator time?

m. Require a minimum of loading, unloading, and re-handling?

n. Call for as little maintenance, repair, power, and fuel as possible?

o. Have a long useful life?

p. Have the capability of capacity utilization?

q. Perform the handling operation efficiently and economically?

Each alternative under consideration can be informally rated against each of the stated criteria. The cost comparison can also be used to evaluate the system and a more formal examination of the intangible aspect, which may outweigh the cost factors.

2.15.18 *Make the decision*, based on the declared analysis involving;

a. Move requirements.

b. Material characteristics.

c. Equipment capabilities.

d. Cost and economic factors.

e. Intangible factors.

f. System objectives.

g. Selection criteria.

2.15.19 *Check the selection for compatibility*. One of the concerned criteria is the fitting of the equipment into the overall system. During the selection process, the attention should be given to the compatibility of prospective equipment types with other equipment in use. Each segment of the solution must be carefully integrated with the other segments.

2.15.20 *Prepare Performance Specifications*. A careful study of the type of equipment selected will be necessary to familiarize the analyst with what details should be specified, and the permissible variations he can allow. If the equipment requires design work, it should be done at this step.

In complex system, where several suppliers may be working together, and much design work is necessary, extra care must be taken in stating the first broad system specification. If vendors are not allowed enough freedom in designing their portions of the system, it is possible that the

analyst may have limited the flexibility and imagination of the vendor's designers.

2.15.21 *Procure the equipment.* Once the specifications have been established, the procurement process can begin. If the analyst does not have knowledge of sources of supply, he should consult the trade magazines and directories. After the quotation and specification have been received, the engineer should evaluate them carefully. Table 2-6 shows one of the common formats being used in comparing specification and technical details of alternative pieces of equipment.

General	Bidder A		Bidder B	
1. Capacity	20/5 Ton		20/5 Ton	
2. Span	90' 0"		90' 0"	
3. Lift	35' 0"		35' 0"	
4. Total Net weight	88,000 lb.		77,000 lb.	
Hoist	**Main Hoist**	**Aux. Hoist**	**Main Hoist**	**Aux. Hoist**
1. Hoist speed	25 FPM	54 FPM	25 FPM	54 FPM
2. HP of Hoist Motor and Rating	40 HP 30 M -55°C	20 HP	40 HP	20 HP
3. Computed HP required	39 HP	19.7 HP	39 HP	19.7 HP
4. Number and Parts of Rope	8 parts 5/8"	4-1/2"	8-9/16"	4-3/8"
5. Type of Wire Rope	6/19 improved Plow steel	6/19 improved Plow steel	6/19 improved Plow steel	6/19 improved Plow steel
6. Diameter of Hoist Drum	20"	15"	15"	10"
7. Material in Drum	Welded Steel	Cast Iron	Cast Iron	Cast Iron
8. Type of Bearing	Hyatt Roller	Hyatt Roller	Hyatt Roller	Hyatt Roller
9. Make&Typer of Gears&Pinions	Spur Gears Welded Steel Forged Steel Pinions	Spur Gears Welded Steel Forged Steel Pinions	Spur Gears Welded Steel Forged Steel Pinions	Spur Gears Welded Steel Forged Steel Pinions
10. Material of Gears and Pinions	Gears SAE 8630 Pin. SAE 8742 Heat Treated Hardened	Gears SAE 8631 Pin. SAE 8743 Heat Treated Hardened	Gears SAE 1040 Pin. SAE 1045	Gears SAE 1040 Pin. SAE 1045
Trolley				
1. Trolley Speed	200 FPM		125 FPM	
2. HP of Trolley Motor and Rating	7 1/2 HP		3 HP	
3. Computed Running HP required	3.5 HP		1.96 HP	
4. Service Factor Used	2.14		1.53	
5. Diameter of Trolley Wheels	13 1/2"		12"	
6. Spread of Trolly	8' 0"		7' 0"	
7. Type of Bearing	Hyatt 5214		Hyatt 5212	
8. Make&Typer of Gears&Pinions	Welded Spur Gears Forged Steel Pinions		Welded Spur Gears Forged Steel Pinions	
9. Material of Gears and Pinions	Gears SAE 8630 Pinions SAE 8742 Heat Treated Hardened		Gears SAE 1040 Pinions SAE 1045	
10. Weight of Trolley complete	18,400 lbs.		13,000 lbs.	
Bridge				
1. Bridge Speed	300 FPM		300 FPM	
2. HP of Bridge Motor and Rating	25 HP		20 HP	
3. Computed Running HP required	8.85		8.75	
4. Service Factor Used	2.83		2.29	
5. Grinder Section at Center of Span	Top-28 x 1/4" Bot.-28 x 1/2" Webs-60 x 1/4"		Top-28 x 5/8" Bot -28 x 3/8" Webs-54 x 5/16"	
6. Number&Dia. of Bridge Wheels	4-24"		4-21"	
7. Maximum Wheel Load	50,600 lb.		44,000 lb.	
8. Wheel Base	13' 8"		12' 3"	
Electrical				
Control:				
Make&Type of Hoist Control	Semi-Magnetic Drum		Drum Control	
Make&Type of Aux. Hoist Control	Semi-Magnetic Drum		Drum Control	
Make&type of Hoist Limit Switched	Motor Circuit		Control Circuit	
Make&Type of Trolley Control	Drum		Drum	
Make&Type of Aux. Bridge Control	Drum		Drum	
Make&type of Overload Protection	Overload Relays		Fuses	

Table 2-6: Sample of the common format used in comparing specification and technical details of alternative pieces of equipment

2.15.22 *Actual implementation.* This process requires long and careful planning in order to insure that all details are taken into consideration. Although some may have been considered earlier, they will include:

a. Developing a tentative budget.

b. Preparing a justification report or presentation.

c. Obtaining final approval.

d. Vendor follow-up.

e. Problems in delivery of equipment.

f. Scheduling the installation; involving the time frame, manpower, trade, etc.

g. Supervising installation.

h. Orientation and training of personnel involved.

i. Human relations considerations.

j. Start-up and debugging of the installation.

k. Auditing the performance; at installation, as well as periodically in the future.

l. Formal acceptance; of payment and approval.

The above list embodies many important details that should be carefully reviewed and thought through to make sure nothing important is overlooked.

The information about the material handling design described how to design and implement the handling system to convert a static material flow pattern into a dynamic flow of material, in an efficient and economical manner. This process is often indefinable and complex task. In order to avoid the mistakes of the snap judgment or off the cuff decisions, a rather detailed procedure has been described. But since each problem differs form others, it will be found necessary to vary the procedure to better fit the problem at hand.

2.16 Critical Success Factor (CSF)

Critical Success Factor is a method developed at MIT's Sloan school by John Rockart to guide businesses in creating and measuring success. It is widely used for technology and architectural planning in enterprise IT. A top-down methodology that is especially suitable for designing systems as opposed to applications. This tool is a reductionist method for going from an abstract vision to concrete requirements. The following statement will explain the Critical Success Factor:

- A key area where satisfactory performance is required for the organization to achieve its goals
- A means of identifying the tasks and requirements needed for success
- At the lowest level, CSFs become concrete requirements
- A means to prioritize requirements

2.16.1 Steps in CFS method

- Start with a vision: mission statement
- Develop 5-6 high level goals
- Develop hierarchy of goals and their success factors
- Leads to concrete requirements at the lowest level of decomposition (a single, implementable idea)
- Along the way, identify the problems being solved and the assumptions being made
- Cross-reference usage scenarios and problems with requirements

2.16.2 Results of the Analysis

- Mission statement
- Hierarchy of goals and CSFs
- Lists of requirements, problems, and assumptions
- Analysis matrices
- Problems vs. Requirements matrix
- Usage scenarios vs. Requirements matrix
- Solid usage scenarios