CHAPTER 7
Material Handling Principles, Equipment, and System Design

INTRODUCTION
Art & science involving all of the basic operations involved in the movement of bulk, packaged, and individual products in a semisolid or solid state by means of machinery, and within the limits of a place of business.

Material Handling Institute

Movement: relocate, loading & unloading
Product: raw material, semi-finished, finished
Equipment: selection & investment
Bulk: large unpackaged volumes
Things to ponder …

1. M.H. can account for 30-75% of production cost
2. M.H. can reduce operational costs by 15-30%
3. M.H. affects building requirements, layout, production time/unit

Objectives of Material Handling

1. Increase efficiency of material flow
2. Reduce material-handling cost
3. Improve facility utilization
4. Improve safety and working conditions
5. Facilitate the manufacturing process
6. Increase productivity
• A **principle** is a general rule, fundamental, or other statement of an observed truth.

• The principles of material handling are often useful in **analyzing, planning and managing** material handling activities and systems.

• At the very least they form a basic foundation upon which one can begin building expertise in material handling.
1. Planning
2. Automation
3. System
4. Standardization
5. Accounting & Life Cycle Cost
6. Work
7. Environmental Design
8. Safety & Ergonomics

**P: PLANNING PRINCIPLE**

All material handling should be the result of a deliberate plan where the needs, performance, objectives and functional specification of the proposed methods are completely defined at the outset.

**Definition**

In its simplest form a material handling plan defines the material (what) and the moves (when and where); together they define the method (how and who).
A: AUTOMATION PRINCIPLE

Material handling operations should be mechanized and/or automated \textit{where feasible} to improve operational efficiency, increase responsiveness, improve consistency and predictability, decrease operating costs and to eliminate repetitive or potentially unsafe manual labor.

\textit{Definition}

Automation is a technology concerned with the application of electro-mechanical devices, electronics and computer-based systems to operate and control production and service activities.

S1: SYSTEM PRINCIPLE

Material movement and storage activities should be fully \textit{integrated} to form a coordinated, operational \textit{system} which spans receiving, inspection, storage, production, assembly, packaging, unitizing, order selection, shipping, transportation and the handling of returns.

\textit{Definition}

A system is a collection of interacting and/or interdependent entities that form a unified whole.
**S2: STANDARDIZATION PRINCIPLE**

Material handling methods, equipment, controls and software should be standardized within the limits of achieving overall performance objectives and without sacrificing needed flexibility, modularity and throughput.

*Definition*

Standardization means less variety and customization in the methods and equipment employed.

**UNIT LOAD**

Unit loads shall be appropriately sized and configured in a way which achieves the material flow and inventory objectives at each stage in the supply chain.

*Definition*

A unit load is one that can be stored or moved as a single entity at one time, such as a pallet, container or tote, regardless of the number of individual items that make up the load.

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**A: ACCOUNTING and LIFE CYCLE COST PRINCIPLE**

A thorough economic analysis should account for the entire life cycle of all material handling equipment and resulting systems.

*Definition*

Life cycle costs include all cash flows that will occur between the time the first dollar is spent to plan or procure a new piece of equipment, or to put in place a new method, until that method and/or equipment is totally replaced.
G: WORK PRINCIPLE (Gravity)
Material handling work should be minimized without sacrificing productivity or the level of service required of the operation.

Definition
The measure of work is material handling flow (volume, weight or count per unit of time) multiplied by the distance moved.

E: ENVIRONMENTAL DESIGN PRINCIPLE
Environmental impact and energy consumption should be considered as criteria when designing or selecting alternative equipment and material handling systems.

Definition
Environmental consciousness stems from a desire not to waste natural resources and to predict and eliminate the possible negative effects of our daily actions on the environment.

SPACE UTILIZATION
Effective and efficient use must be made of all available space.

Definition
Space in material handling is three dimensional and therefore is counted as cubic space.
**S3: SAFETY & ERGONOMICS PRINCIPLE**

Human capabilities and limitations must be recognized and respected in the design of material handling tasks and equipment to ensure safe and effective operations.

**Definition**

Ergonomics is the science that seeks to adapt work or working conditions to suit the abilities of the worker.

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**MATERIAL HANDLING EQUIPMENT**

1. Conveyors
2. Hoists & Cranes
3. Trucks
SELECTION FACTORS

1. The characteristic of the material
2. The physical characteristic of the workplace
3. The nature of the process using the equipment

A. CONVEYORS

Used for moving materials continuously over a fixed path (point-to-point)

A.1 TYPICAL CONVEYORS

1. Roller Conveyor
2. Belt Conveyor
3. Wheel Conveyor
4. Chain: Flight, Apron, Bucket, Slat
5. Chute Conveyor
A.2 CONVEYOR CONTROL

Current or Voltage Sources \rightarrow Input Interface \rightarrow Control System Logic Device \rightarrow Memory

Lower-Power Logic Commands \rightarrow Output Electromechanical Devices

A.3 TYPICAL ACCESSORIES

1. Pallets
2. Boxes
3. Tote pans
4. Skids
5. Optical code or bar code reader
COMMON TYPES OF GENERAL PURPOSE SKIDS

A. Metal Skid
Standard skid formed from a single piece of steel corrugated to give added strength.

B. Wooden Skid with Metal Frame
A.5 ADVANTAGES

1. Adjustable speed
2. High capacity (moving a large number of items)
3. Permits other activity (processing & inspection)
4. Versatile (floor or overhead)
5. Temporary storage of loads between work stations
6. Automatic load transfer (less supervision)
7. Straight line paths or aisles are not required
8. Utilization of the cube (overhead conveyors)

A.6 DISADVANTAGES

1. Fixed paths serve limited areas
2. Bottlenecks can develop
3. Hinder movement of mobile equipment on factory floor
B. CRANES

Equipment for raising, shifting, and lowering heavy weights by means of a projecting swinging arm or with the hoisting apparatus supported on an overhead track

B.1 TYPES
1. Jib crane
2. Bridge crane
3. Hoist

B.2 ADVANTAGES
1. Lifting as well as transferring of materials
2. Heavy loads
3. Loading & unloading operations

B.3 DISADVANTAGES
1. Large investments
2. Serve limited area
3. Utilization not very high (used for short periods)
C. INDUSTRIAL TRUCKS

Equipment for carrying loads over varying paths.

C.1 TYPES

1. Lift trucks
2. Hand trucks
3. Fork trucks
4. Trailer trains

C.2 ADVANTAGES

1. Not required to follow fixed paths
2. Capable of loading, unloading & lifting, as well as transferring
3. Highly utilized due to their flexibility

C.3 DISADVANTAGES

1. Cannot handle heavy loads
2. Limited capacity per trip
3. Most must be driven by an operator
4. Cannot combine handling with processing & inspection
A. Conveyors

Chute Conveyor
A chute conveyor is a slide, generally made of metal, which guides materials as they are lowered from a higher-level to a lower-level workstation. The shape of the chute can be straight or spiral to save space.
Wheel Conveyor

It consists of wheels attached to side rails supported by a steel frame. The load is carried on the wheels, each of which rotates about a fixed axis. It can be gravity-operated or power-driven. Wheels can be made of steel, aluminum, or plastic. Most flat-bottomed surfaces will convey satisfactorily on wheel conveyors. If the part does not have a flat surface, it may ride in a box or on a small pallet.
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 roller (steel, rubber, and wood) and the spacing of rollers depend on the type of load to be carried.
• It can be gravity-operated or power-driven.
• Gravity-operated conveyors have a slight downward slope (pitch), commonly equal to 3-6 inches per 10-ft section.
• On the power-driven conveyor, some of the rollers are driven by chains or belts to provide the motion for the material on the conveyor.
**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. The belt is made of rubber, woven wires, metal or fabric. Occasionally it can be magnetic. Portable belt conveyors are so popular they come in standard units.

![Belt Conveyor Image](image)

**Chain Conveyor**

An **endless chain** transmits power from a motor to a carrying surface or unit. The **carrying unit** can be quite varied. Specific examples of chain conveyors are **flight conveyors** (flights are "blades" attached perpendicular to the chain), **apron conveyors**, **bucket conveyors**, and **slat conveyors**. An apron conveyor is similar to a slat conveyor, the only difference being the partial overlapping of the slats in the apron conveyor to provide a continuous moving surface.

![Chain Conveyor Image](image)
B. HOISTS & CRANES
Overhead Monorail

A track to transport carrying devices such as trolleys and hooks. The track itself can form a closed loop. Often used in transporting units to spray paint booths or baking ovens. Generally placed at 8 to 9 feet from floor.

A telpher is a light car suspended from and running on aerial cables. It is usually propelled by electricity.
Hoist

It is a lifting device attached to monorails, cranes, or a fixed point. It can be powered manually or by electric or pneumatic motors. Major types:

- chain hoist: serves a fixed spot directly beneath the hoist
- monorail hoist: free to move along an overhead rail
- jib hoist: serves any area circumscribed by the jib in a 360-degree rotation
**Crane**

Piece of **overhead equipment** consisting of a **boom or bridge** along which a **handling device**, such as a hoist, traverses.

**Monorail Crane**

It consists of a **beam**, which supports a **carrying device** mounted on wheels, which run along the beam.

**Jib Crane**

Lifting device (**hoist**) traveling on a **horizontal boom** mounted on a vertical mast. The horizontal boom can rotate to achieve a wide range of coverage.

- pillar jib crane
- bracket jib crane
- cantilever jib crane
Bridge Crane

Lifting device mounted on a bridge, which is supported at each end by tracks riding on or suspended from runways installed at right angles to the bridge

- stacker crane
- tower crane
- gantry crane
**Stacker Crane**

A crane with a vertical beam suspended from a carriage, mounted on a device similar to a bridge crane, and fitted with forks or a platform to permit it to place items into or retrieve items from storage racks on either side of the aisle it traverses.
**Tower Crane**

A hoist that travels on a horizontal boom attached at one end to a vertical post, with the other end of the boom being supported by a guy line to the top of the post.

**Gantry Crane**

Basically a bridge crane with the boom supported at one or both ends by vertical gantry legs traveling on rails installed at ground level (instead of on an overhead runway).
Handcart/Truck

A handcart or hand-truck is a wheel-mounted platform with handles to manually push or pull the unit.
Dolly
A hand truck consisting of a small rectangular, triangular or circular load carrier with one or more rollers, casters, or wheels. It is used for transporting relatively light weights and low volumes short distances.

Tier Platform Truck
A tier platform truck is a hand-truck with one or more additional platforms stacked vertically.
**Hand Lift Truck/Pallet Jack**

This is a hand-operated truck that can raise loads hydraulically or mechanically to clear the floor before transporting them to the desired destination.

![Hand Lift Truck and Pallet](image)

**Power-Driven Hand-truck**

Similar to a hand lift truck, except that it is driven by a battery-operated electric motor.

![Power-driven Hand Pallet Truck](image)
**Power-Driven Platform Truck**

A much larger device than the power-driven hand-truck. It carries load and operator. A diesel or gasoline engine or an electric motor supplies power.

![High-Lift Elevating Platform Truck](image)

**Forklift Truck**

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

![Fork Truck](image)
**Tractor-Trailer Train**
This is a series of carts pulled by a self-propelled tractor. It is mainly used for stop-and-go operations carrying loads within 200 to 300 feet

**Narrow-Aisle Truck**
- *side-loader truck* (forks on the side)
- *straddle truck* (with out-riggers to balance loaded truck)
• **order-picker truck** (with a platform that lifts operator)

• **reach truck** (fork truck with telescoping forks)

• **turret truck** (with forks that can rotate left or right to place or pick up a load without the truck having to turn in an aisle)

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**Automated Guided Vehicle System**

An AGV is a computer-controlled vehicle that moves along a predetermined path and performs certain duties, according to instructions sent by a system operator located at a station. AGVs were introduced into the U.S. from Europe in the mid-1970s and were used almost exclusively to interface with automated storage and retrieval systems.