MATERIAL HANDLING

There exist a strong relationship between the layout design function and the material handling design function. Whether the material being handled is:

- mail in a postal system,
- money in a banking system,
- units of product in a production system,
- people in a transportation system

many of the same principles apply.

In a typical factory, material handling accounts for:

- 25% of all employee,
- 55% of all factory space, and
- 87% of production time.

Material handling is estimated to represent between 15% and 70% of the total cost of a manufactured product.

One of the first places to look for: - cost reduction, - quality improvement.

*: MINIMIZE or EVEN ELIMINATE MATERIAL HANDLING.

Redesign studies in General Electric in 1983:

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<th>Before</th>
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<tbody>
<tr>
<td>Unit cost</td>
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<td>70</td>
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<td>Inventory turns</td>
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<td>Reject Rates</td>
<td>40%</td>
<td>3%</td>
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<td>Output/Employee</td>
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<tr>
<td># of times unit handled</td>
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Definitions. There is no unique, all encompassing definition of material handling. In fact, the Materials Handling Handbook [23] lists nine definitions on its opening page. Nonetheless, the following two definitions should convey the key points.

1. Material handling is the art and science of moving, storing, protecting, and controlling material.
   - **Art:** Material handling can be described as an art because material handling problems and material handling systems cannot be explicitly solved/depicted solely with scientific formulas or math models. Material handling requires an “appreciation” for right and wrong, which accompanies significant practical experience in the field.
   - **Science:** Material handling can be described as a science because the engineering method—define the problem, collect and analyze data, generate alternative solutions, evaluate alternatives; select and implement preferred alternative—is an integral part of the material handling problem solving and system design process. In addition, mathematical models and quantitative techniques of analysis are a very valuable part of the process.
   - **Moving:** Moving material is required to create time and place utility (i.e., the value of having the material at the right time and at the right place). Any movement of material requires that the size, shape, weight, and condition of the material, as well as the path and frequency of the move be analyzed.
   - **Storing:** Storing material provides a buffer between operations, facilitating the efficient use of people and machines, and providing for efficient organization of material. Material storage considerations include the size, weight, condition, and stackability of the material; the required throughput; and building constraints such as floor loading, floor condition, column spacing, and clear height.
   - **Protecting:** The protection of material includes both the packaging, packing, and utilizing done to protect against damage and theft of material, as well as the use of safeguards on the information system to include protection against the material being mishandled, misplaced, misappropriated, and processed in the wrong sequence. Continuous improvement programs strive to eliminate “inspecting quality into a product, by designing quality into the product.” In a similar fashion, the material handling system should be designed to minimize the need for inspections and costly methods of protecting the material.
   - **Controlling:** Truly controlling material requires physical and status material control. Physical control is control of the orientation of, sequence of, and space between material. Status control is the real-time awareness of the location, amount, destination, origin, ownership, and schedule of material. Care must be taken to ensure that too much control is not exerted over the material handling system. Maintaining the correct degree of control is a challenge, because the right amount of control depends upon the culture of the organization and the people who manage and perform the material handling functions.
   - **Material:** We define “material” very broadly, including bulk material and unit loads, in any form—solid, liquid, or gas. Furthermore, occasionally, we will include paperwork and information as material, depending upon the application setting. From potato chips to semiconductor chips, from coin, currency, and negotiable securities to sides of beef, from sailing ships to printed circuit boards, the principles and approaches we present are applicable in the movement, storage, control, and protection of material.

2. Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position, in the right sequence, and for the right cost, by using the right method(s). Naturally, if the right methods are being used, then the material handling system will be safe and damage free.
Scope of Material Handling:

1. The primary emphasis is on the movement of materials from one location to another, usually within the same facility. Very little attention is given to the interrelationships of the individual handling tasks.

2. Attention centers on the overall flow of materials in a plant or warehouse; interrelationships between handling tasks are analyzed, and an effort is made to develop an integrated material handling plan.

3. The systems perspective, defining material handling as all activities involved in handling material from all suppliers, handling material within the manufacturing or distribution facility, and distributing finished goods to customers.

Material Handling Principles

The material handling principles provide concise statements of the fundamentals of MATERIAL HANDLING practice.

Rather than being design axioms, the principles serve as rough guides or rules of thumb for material handling system design.

Based on the principles, a number of checklists have been developed to facilitate the identification of improvement opportunities for existing systems.
<table>
<thead>
<tr>
<th>Conditions indicating possible productivity improvement opportunities</th>
<th>Condition exists here (/)</th>
<th>To correct this, we need:</th>
<th>Supervisor attention (/)</th>
<th>Management attention (/)</th>
<th>Analytical study (/)</th>
<th>Capital investment (/)</th>
<th>Other (for comments)</th>
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<td>1. Delays in material moving</td>
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<td>3. Production equipment idle for material shortage</td>
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<td>9. Insufficient handling equipment</td>
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<td>10. Unbalanced sequence of operations</td>
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<td>11. Idle handling equipment</td>
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<td>12. Obstacles to material flow</td>
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<td>117. Aisle lengths unplanned</td>
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<td>118. Excessive honeycombing in storage</td>
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<td>119. Poor quality pallets, not standardized</td>
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<td>120. Manual sorting in order accumulation</td>
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<td>121. Poor work-in-process control</td>
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<td>122. Energy-inefficient lighting</td>
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<td>123. Lights, heaters, and fans poorly located</td>
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<td>125. Excessive heating, ventilation, and air conditioning for material stored</td>
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<td>126. Poorly insulated walls and roof</td>
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<td>127. Poorly designed enclosures for environmentally controlled areas</td>
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<td>128. Lack of scheduled energy use to reduce peak loads</td>
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<td>129. Unclean floors</td>
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<td>130. Battery charging too frequently</td>
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<td>Table 6.2  <strong>Material Handling Principles</strong></td>
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<td>1. <strong>Orientation Principle:</strong> Study the problem thoroughly prior to preliminary planning in order to identify existing methods and problems, physical and economic constraints, and to establish future requirements and goals.</td>
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<td>2. <strong>Planning Principle:</strong> Establish a plan to include basic requirements, desirable options, and the consideration of contingencies for all material handling and storage activities.</td>
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<td>3. <strong>Systems Principle:</strong> Integrate those handling and storage activities that are economically viable into a coordinated system of operations, including receiving, inspection, storage, production, assembly, packaging, warehousing, shipping, and transportation.</td>
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<td>4. <strong>Unit Load Principle:</strong> Handle product in as large a unit load as practical.</td>
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<td>5. <strong>Space Utilization Principle:</strong> Make effective utilization of all cubic space.</td>
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<td>6. <strong>Standardization Principle:</strong> Standardize handling methods and equipment wherever possible.</td>
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<td>7. <strong>Ergonomic Principle:</strong> Recognize human capabilities and limitations by designing material handling equipment and procedures for effective interaction with the people using the system.</td>
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<td>8. <strong>Energy Principle:</strong> Include energy consumption of the material handling systems and material handling procedures when making comparisons or preparing economic justifications.</td>
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<td>9. <strong>Ecology Principle:</strong> Use material handling equipment and procedures that minimize adverse effects on the environment.</td>
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<td>10. <strong>Mechanization Principle:</strong> Mechanize the handling process where feasible to increase efficiency and economy in the handling of materials.</td>
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<td>11. <strong>Flexibility Principle:</strong> Use methods and equipment that can perform a variety of tasks under a variety of operating conditions.</td>
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<td>12. <strong>Simplification Principle:</strong> Simplify handling by eliminating, reducing, or combining unnecessary movements and/or equipment.</td>
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<td>13. <strong>Gravity Principle:</strong> Utilize gravity to move material wherever possible, while respecting limitations concerning safety, product damage, and loss.</td>
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<td>14. <strong>Safety Principle:</strong> Provide safe material handling equipment and methods that follow existing safety codes and regulations in addition to accrued experience.</td>
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<td>15. <strong>Computerization Principle:</strong> Consider computerization in material handling and storage systems, when circumstances warrant, for improved material and information control.</td>
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<td>16. <strong>Stream Flow Principle:</strong> Integrate data flow with physical material flow in handling and storage.</td>
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<td>17. <strong>Layout Principle:</strong> Prepare an operation sequence and equipment layout for all viable system solutions, then select the alternative system which best integrates efficiency and effectiveness.</td>
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<td>18. <strong>Cost Principle:</strong> Compare the economic justification of alternate solutions in equipment and methods on the basis of economic effectiveness as measured by expense per unit handled.</td>
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<td>19. <strong>Maintenance Principle:</strong> Prepare a plan for preventive maintenance and scheduled repairs on all material handling equipment.</td>
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<td>20. <strong>Obsolescence Principle:</strong> Prepare a long-range and economically sound policy for replacement of obsolete equipment and methods with special consideration to after-tax life cycle costs.</td>
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MATERIAL HANDLING SYSTEM DESIGN

Engineering Design Process

1. Define the objectives and scope for the material handling system,
2. Analyze the requirements for moving, storing, protecting, and controlling material,
3. Generate alternative designs for meeting material handling system requirements,
4. Evaluate alternative material handling system designs,
5. Select the preferred design for moving, storing, protecting, and controlling material,
6. Implement the preferred design:
   - selection of supplies,
   - training of personnel,
   - installation, debug and startup of equipment,
   - periodic audits of system performance.

Development of Alternative System Design

IDEAL SYSTEMS APPROACH

1. AIM for the theoretical system is a perfect system having zero cost, perfect quality, no safety hazards, no wasted space, and no management inefficiencies,
2. CONCEPTUALIZE the ultimate ideal system is a system that probably would be achievable in the future, but is not achievable now because of "lack of available technology",
3. DESIGN the technologically workable ideal system,
4. INSTALL the recommended system, is a cost-effective system that will work now, with no obstacles to implement.
Figure 6.2 The ideal systems approach. (From [12] with permission.)

Figure 6.3 Material handling system equation.

liberal use of "WHY?" is essential to separate what must be from what has been.
FACTORS TO BE CONSIDERED IN ANALYZING M/H PROBLEMS:
- types of materials, and their physical characteristics,
- the quantities to be moved,
- the sources and destinations for each move,
- the frequencies or rates at which moves must be made,
- the equipment alternatives,
- the units (unit load) to be handled.

The combination of material characteristics and move or flow requirements is referred to as MATERIAL FLOW.

BENEFITS of M/H improvements:
- Reduce costs,
- Reduce damage,
- Increase space and equipment utilization,
- Increase throughput,
- Increase productivity,
- Improve working conditions.

DISBENEFITS of M/H improvements:
- Increased capital requirements,
- Decreased flexibility,
- Decreased reliability, maintainability, and operability.

THE IMPORTANCE OF QUESTIONING IN DESIGNING M/H SYSTEM:

\[ \text{moves} \times [\text{WHY (WHERE + WHAT + WHEN)}] \]

- can the move be eliminated?
- can the move be combined with another?
- can the move be simplified?
- can the sequence of moves be changed?
1. Why
   a. Is handling required?
   b. Are the operations to be performed as they are?
   c. Are the operations to be performed in the given sequence?
   d. Is material received as it is?
   e. Is material shipped as it is?
   f. Is material packaged as it is?

2. What
   a. Is to be moved?
   b. Data are available and required?
   c. Alternatives are available?
   d. Are the benefits and disbenefits (costs) for each alternative?
   e. Is the planning horizon for the system?
   f. Should be mechanized/automated?
   g. Should be done manually?
   h. Shouldn't be done at all?
   i. Other firms have related problems?
   j. Criteria will be used to evaluate alternative designs?
   k. Exceptions can be anticipated?

3. Where
   a. Is material handling required?
   b. Do material handling problems exist?
   c. Should material handling equipment be used?
   d. Should material handling responsibility exist in the organization?
   e. Will future changes occur?
   f. Can operations be eliminated, combined, simplified?
   g. Can assistance be obtained?
   h. Should material be stored?

4. When
   a. Should material be moved?
   b. Should I automate?
   c. Should I consolidate?
   d. Should I eliminate?
   e. Should I expand (contract)?
   f. Should I consult vendors?
   g. Should a postaudit of the system be performed?

5. How
   a. Should material be moved?
   b. Do I analyze the material handling problem?
   c. Do I sell everyone involved?
   d. Do I learn more about material handling?
   e. Do I choose from among the alternatives available?
   f. Do I measure material handling performance?
   g. Should exceptions be accommodated?

6. Who
   a. Should be handling material?
   b. Should be involved in designing the system?
   c. Should be involved in evaluating the system?
   d. Should be involved in installing the system?
   e. Should be involved in auditing the system?
   f. Should be invited to submit equipment quotes?
   g. Has faced a similar problem in the past?

7. Which
   a. Operations are necessary?
   b. Problems should be studied first?
   c. Type equipment (if any) should be considered?
   d. Materials should have real-time control?
   e. Alternative is preferred?
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<td>1</td>
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<td>Bar stock in storage (2200)</td>
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<td>2</td>
<td>X</td>
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<td>From Stores to Saw Dept.</td>
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<td>LDDSE (FK,TRK)</td>
<td>2.5' x 3.5'</td>
<td>75 lb</td>
<td>10 bars</td>
<td>3 times daily</td>
<td>16 ft Fork lift</td>
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<td>Store in Saw Department</td>
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<td>From Saw to Grinding</td>
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<td>TOTE pan</td>
<td>15' x 12' x 7'</td>
<td>30 lb</td>
<td>30</td>
<td>Twice daily</td>
<td>10 ft Platform hand truck</td>
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<td>6</td>
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<td>Store in Grinding</td>
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<td>Grind to length</td>
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<td>TOTE pan</td>
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<td>30 lb</td>
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<td>Twice daily</td>
<td>13 ft Platform hand truck</td>
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<td>9</td>
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<td></td>
<td>Store in Deburring</td>
<td>Deburring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Deburr</td>
<td>0301</td>
<td>Deburring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>From Deburring to Dr. Frs</td>
<td></td>
<td></td>
<td>TOTE pan</td>
<td>15' x 12' x 7'</td>
<td>30 lb</td>
<td>30</td>
<td>Twice daily</td>
<td>16 ft Platform hand truck</td>
</tr>
<tr>
<td>12</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Store in Drill Press</td>
<td>Drill Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Dr. (4) holes tap, ream, c's/k</td>
<td>0401</td>
<td>Drill Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>From Dr. Press to Tur. Lathe</td>
<td></td>
<td></td>
<td>TOTE pan</td>
<td>15' x 12' x 7'</td>
<td>30 lb</td>
<td>30</td>
<td>Twice daily</td>
<td>33 ft Platform hand truck</td>
</tr>
</tbody>
</table>

Figure 6.4 Material handling planning chart for an air flow regulator. Key: Operation—O, transportation—T, storage—S, inspection—I.
UNIT LOADS in M/H System

A unit load can be defined simply as the unit to be moved or handled at one time.

The unit load includes the container, carrier, or support that will be used to move materials.

The primary advantage of using unit loads is the capability of handling more items at a time and reducing the number of trips, handling costs, loading and unloading times, and product damage.

The determination of the size of the unit load, as well as the method of containing it, is influenced by a number of factors:

- the material to be unitized,
- the number of times the unit load is handled,
- the quantity of material to be handled,
- the environmental conditions,
- the susceptibility of the material to damage,
- the security aspects,
- the method of receiving, storing, shipping and handling,
- the other unit loads,

... door widths, column spacing, aisle widths, turning radii of vehicles, and clear stacking heights.

Simultaneous determination of UNIT LOAD and M/H SYSTEM DESIGN.

Cube utilization per pallet varies, depending on the pattern employed.
Figure 6.6  Stacking patterns for different pallet sizes. (a) Block pattern. (b) Row pattern. (c) Pinwheel pattern. (d) Honeycomb pattern. (e) Split-row pattern. (f) Split-pinwheel pattern. (g) Split-pinwheel pattern for narrow boxes. (h) Brick pattern. (From [6] with permission.)
Figure 6.5 Shapes and sizes of pallets. (a) Standard single-deck wooden pallet. (b) Double-faced nonreversible pallet for pallet truck handling. (c) Four-way block-leg pallet. (d) Double-wing-type (stevedore) pallet. (e) Three-board single-deck expendable shipping pallet.
M/H EQUIPMENT

The focus should be first on the material, second on the move, and third on the method.

The categories defined to facilitate the description of material handling equipment are:

- containers and utilizing equipment,
- material transport equipment,
- storage and retrieval equipment,
- automatic identification and communication equipment.
I. Containers and Unitizing Equipment
   A. Containers
      1. Pallets
      2. Skids and Skid Boxes
      3. Tote Pans
   B. Unitizers
      1. Stretchwrap
      2. Palletizers
II. Material Transport Equipment
   A. Conveyors
      1. Chute Conveyor
      2. 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
   B. Industrial Vehicles
      1. Walking
      2. Riding
      3. Automated
   C. Monorails, Hoists, and Cranes
      1. Monorail
      2. Hoist
      3. Cranes
III. Storage and Retrieval Equipment
   A. Unit Load Storage and Retrieval
      1. Unit Load Storage Equipment
      2. Unit Load Retrieval Equipment
   B. Small Load Storage and Retrieval Equipment
      1. Operator-to-Stock—Storage Equipment
      2. Operator-to-Stock—Retrieval Equipment
      3. Stock-to-Operator Equipment
IV. Automatic Identification and Communication Equipment
   A. Automatic Identification and Recognition
      1. Bar Coding
      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 Headset
      3. Light and Computer Aids
      4. Smart Card
It is important for the facilities planner to cultivate and maintain a number of reliable information sources. The following are suggested.

1. Trade Associations
   a. The Material Handling Institute, Inc.
      8720 Red Oak Boulevard
      Suite 200
      Charlotte, North Carolina 28217
   b. Conveyor Equipment Manufacturers Association
      1000 Vermont Avenue, N.W.
      Washington, D.C. 20005
   c. Material Handling Equipment Distributors Association
      104 Wilmont Road
      Suite 208
      Deerfield, Illinois 60015

2. Technical and Professional Societies
   a. Institute of Industrial Engineers
      25 Technology Park—Atlanta
      Norcross, Georgia 30092
   b. Materials Handling and Management Society
      8720 Red Oak Boulevard
      Suite 224
      Charlotte, North Carolina 28217
   c. Council of Logistics Management
      2803 Butterfield Road
      Suite 380
      Oak Brook, Illinois 60521-1156
   d. Society of Manufacturing Engineers
      20501 Ford Road
      Dearborn, Michigan 48218
   e. Warehouse Education and Research Council
      1100 Jorie Boulevard
      Suite 170
      Oak Brook, Illinois 60521

3. Trade Journals
   a. Modern Materials Handling
      Cahners Publishing
      275 Washington Street
      Newton, Massachusetts 02158
   b. Material Handling Engineering
      Penton Publishing
      614 Superior Avenue
      Cleveland, Ohio 44113
   c. Warehousing Management
      Chilton Publishing
      1 Chilton Way
      Radnor, Pennsylvania 19089