Material Handling System Design

Material Handling (MH) Analysis

- Developing a **MH system** involves selection of material handling equipment, unit load and assignment of the equipment to the moves and determining their routes.
- Questions concerning the **materials** involve their type, size, shape, quantity, and weight.
- Questions concerning the **moves** involve their origin and destination, length, frequency of movement, and duration of the move.
- Determining the **methods** depends on the information obtained from studying the material and the moves.
- The interrelation between **material handling** and **plant layout** as was explained previously is highly significant.
- The **existence of a large variety of equipment** with different capabilities and limitations that renders evaluating and comparing all of them is an impossible task. Undoubtedly, some good alternatives might be ignored.
- Some of the characteristics of the equipment (like flexibility) are **difficult to quantify**, either for comparison between different types of equipment or for inclusion in an analytical model.
- Although the most common objective of the design is to ensure a **system with minimum cost**, other objectives (like maximum utilization) have to be considered.
- Some of the data required for designing the system (such as move time and equipment operating cost) **cannot be known** exactly unless the system is already operating. Therefore, **those data must be estimated**. A poor estimate will result in extra work or loss of confidence to the model.
Material Handling System Design

• **Assuming there is a layout plan on hand, the steps to be followed in designing a material handling system:**

  – State the **intended function of the handling system**; whether it is for a warehouse whose function is storing, packaging, inspection, and shipping to customer or for a **manufacturing system** where the function is to move items or partial assemblies from station to station.
  
  – **Collect the necessary data about the material**, such as its characteristics and the quantities involved.
  
  – Identify the **moves, their origin and destination, their path, and their length**.
  
  – Determine the **basic handling system** to be used and the degree of mechanization desired. Here, an idea is to establish whether a conveyor, a truck, or a crane will be best suited for the situation.
  
  – Perform an **initial screening of suitable equipment** and select a set of candidate equipment among them. Evaluate the candidate equipment on the basis of such measures as cost and utilization. Always match the equipment with the material characteristics.
  
  – Select a **set of suitable unit loads** and match them with material and equipment characteristics.

Material Handling System Design

• **Important factors that influence the designer in making decisions at each step of designing process:**

  – **Costs of equipment and unit loads** and **availability of funds**. This will affect the **degree of mechanization** to be achieved in the design.

  – **Physical characteristics of the building** and the **available space**. **Aisle width and number** will be affected by the available space, which in turn will influence decisions regarding **mobile equipment**. **Overhead equipment** may or may not be considered, depending on the height of the ceiling.

  – Management attitude toward **safety and employee welfare**, which will affect the degree of **involvement of material handling personnel in manual handling**.

  – **Degree of involvement between handling and processing**.

• **During the design process, the objectives and the principles of MH should be kept in mind. Achieving as many of the objectives and principles as possible will result in a satisfactory and efficient design.**

• **A good MH design should possess most or all of the following characteristics:**

  – Well planned, handling combined with processing, mechanical, minimized manual handling, minimized handling by production personnel, safe, protection of material, minimized variation in equipment types, maximized utilization of equipment, minimized backtracking, minimized congestion or delay, and finally economical.
Material Handling System Design

To analyze an existing MH system is to determine whether it is functioning efficiently without creating any bottlenecks or excessive inventories and is transporting the units when and where needed.

- The problems in an existing MH system will be evident if one can observe one or more of the following symptoms in the system:
  - Backtracking in material flow path,
  - Built-in hindrances to flow,
  - Cluttered aisles,
  - Confusion at the dock,
  - Disorganized storage,
  - Excess scrap,
  - Excess handling of individual pieces,
  - Excess manual effort,
  - Excess walking,
  - Failure to use gravity,
  - Fragmented operations,
  - High indirect labor costs,
  - Idle machines,
  - Inefficient use of skilled worker,

It is also a good idea to examine the entire material handling system in the plant with a checklist and identify the problems. One can develop a more specific checklist for a particular plant.
<table>
<thead>
<tr>
<th>Conditions indicating possible productivity improvement opportunities</th>
<th>Condition exists here (✓)</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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<tr>
<td>30. Operators halving for supplies, material</td>
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<td>31. Supplies moved by poor techniques</td>
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<td>32. High indirect payroll</td>
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<td>33. Material waiting for papers</td>
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<td>34. Excessive demurrage</td>
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<td>35. Unexplained delays</td>
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<td>36. Idle labor</td>
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<td>37. Inspection not properly located</td>
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<td>38. Excessive scrap</td>
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<td>39. Hazardous lifting by hand</td>
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<td>40. Misdirected material</td>
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<tr>
<td>41. Clumsy, dangerous &quot;homemade&quot; handling rig</td>
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<td>42. Lack of standardization on handling equipment</td>
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<td>43. Long travel distances for material, equipment, and personnel</td>
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<tr>
<td>44. Backtracking of material</td>
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<td>45. Overstressed process routing</td>
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<td>46. Opportunity for group technology layout</td>
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<td>47. Opportunity for product layout</td>
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<td>48. Opportunity for process layout</td>
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<td>49. No real-time dispatching of equipment</td>
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<tr>
<td>50. No modular MH system</td>
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<tr>
<td>51. No modular work stations</td>
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<td>52. Automatic identification system not used</td>
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<td>53. No one-way aisles</td>
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<tr>
<td>54. MH equipment running empty</td>
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<td>55. Different things treated same</td>
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<td>56. Excessive trash removal</td>
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<tr>
<td>57. Centralized storage</td>
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<tr>
<td>58. Decentralized storage</td>
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</tbody>
</table>
## Material Handling System Design

### Sheet 4

<table>
<thead>
<tr>
<th>Conditions indicating possible productivity improvement opportunities</th>
<th>Condition exists here ( )</th>
<th>To correct this, we need:</th>
</tr>
</thead>
<tbody>
<tr>
<td>84. Obsolete and inactive material</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>85. Floor-stacked material in receiving, QC, and shipping</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>86. Aisles and storage locations not clearly marked</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>87. Manual stock locator system</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>88. Lack of standardization in part numbers</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>89. Cycle counting for physical inventory</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>90. No formal audit program in use</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>91. No guards to protect racks and columns</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>92. Guided aisles without guide rail entry</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>93. Load overhanging pallet</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>94. Excessive floor, rack, and structural loading</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>95. Equipment operating at excessive speed</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>96. Front-to-back rack members not provided</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>97. MH equipment does not fit through doors</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>98. No sprinklers and smoke detectors</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>99. Hazardous and flammable material not segregated and identified</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>100. Lack of ventilation in battery charging area</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>101. Entrances and exits not secured</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>102. Waste and trash containers located near docks</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>103. Inadequate number of fire extinguishers</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>104. No contingency plan for fire loss</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>105. Sagging load beams and bent tines on racks</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>106. No formal training for MH equipment operators</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
</tbody>
</table>

### Sheet 5

<table>
<thead>
<tr>
<th>Conditions indicating possible productivity improvement opportunities</th>
<th>Condition exists here ( )</th>
<th>To correct this, we need:</th>
</tr>
</thead>
<tbody>
<tr>
<td>107. No preventive maintenance program</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>108. No equipment replacement program</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>109. No dock levellers</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>110. Unscheduled arrival of outbound and inbound carriers</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>111. Decentralized receiving and shipping</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>112. Inbound material not utilized</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>113. Inadequate number of dock doors</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>114. Receiving numbers not preassigned</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>115. Picking lists not printed in picking sequence</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>116. Orders picked one at a time</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>117. Aisle lengths unplanned</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>118. Excessive handling/conveying in storage</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>119. Poor quality pallets, not standardized</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>120. Manual sorting in order accumulation</td>
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<td>Supervision attention ( )</td>
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<tr>
<td>121. Poor work-in-process control</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>122. Energy inefficient lighting</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>123. Lights, barriers, and fans poorly located</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>124. Fire proof enclosures</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>125. Excessive heating, ventilation, and air conditioning for material stored</td>
<td></td>
<td>Supervision attention ( )</td>
</tr>
<tr>
<td>126. Poorly insulated walls and roof</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>127. Poorly designed enclosures for environmentally controlled areas</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>128. Lack of scheduled energy use to reduce peak loads</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>129. Unclean floors</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>130. Battery charging too frequently</td>
<td></td>
<td>Supervision attention ( )</td>
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<tr>
<td>131. Other</td>
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<td>Supervision attention ( )</td>
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</tbody>
</table>
Once the problem areas have been identified, they must be re-examined for possible improvements. In performing such a study, some basic questions must be asked, such as: Why? What? Where? When? How? Who?

Liberal use of the question “Why?” is essential to separate what must be from what has been; asking what and why defines the correct materials to be handled; asking where, when, and why identifies the necessary moves to be performed; asking how, who, and why establishes the correct methods to be used; and asking which and why yields the preferred design.

Material Handling System Design

- **Why**
  - Is handling required?
  - Are the operations to be performed as they are?
  - Are the operations to be performed in the given sequence?
  - Is material received as it is?
  - Is material shipped as it is?
  - Is material packaged as it is?

- **What**
  - Is to be moved?
  - Data are available and required?
  - Alternatives are available?
  - Are the benefits and disbenefits for each alternative?
  - Is the planning horizon for the system?
  - Should be mechanized/automated?
  - Should be done manually?
  - Shouldn’t be done at all?
  - Other firms have related problems?
  - Criteria will be used to evaluate alternative designs?
  - Exceptions can be anticipated?
Material Handling System Design

- **Where**
  - Is material handling required?
  - Do material handling problems exist?
  - Should material handling equipment be used?
  - Should material handling responsibility exist in the organization?
  - Will future changes occur?
  - Can operations be eliminated, combined, simplified?
  - Can assistance be obtained?
  - Should material be stored?

- **When**
  - Should material be moved?
  - Should I automate?
  - Should I consolidate?
  - Should I eliminate?
  - Should I expand/contract?
  - Should I consult vendors?
  - Should a post audit of the system be performed?

- **How**
  - Should material be moved?
  - Do I analyze the material handling problem?
  - Do I sell everyone involved?
  - Do I learn more about material handling?
  - Do I choose from among the alternatives available?
  - Do I measure material handling performance?
  - Should exceptions be accommodated?

- **Who**
  - Should be handling material?
  - Should be involved in designing the system?
  - Should be involved in evaluating the system?
  - Should be involved in installing the system?
  - Should be involved in auditing the system?
  - Should be invited to submit equipment quotes?
  - Has faced a similar problem in the past?

- **Which**
  - Operations are necessary?
  - Problems should be studied first?
  - Type of equipment should be considered?
  - Materials should have real-time control?
  - Alternative is performed?
Material Handling System Design

- Factors to be considered in analyzing material handling problems include:
  - the types of material,
  - 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, equipment alternatives, and
  - the units to be handled.

- The combination of material characteristics and move or flow requirements is referred to as **material flow**. Hence, to develop material flow system requirements, one should focus on the material to be handled, stored, and controlled and the flow or throughput requirements for the system.

- Material flow is transformed to **material handling** by the method of handling, storing, and controlling the material.

- While it is true that material handling improvements can result in some benefits (*reduced costs and damage, increased throughput, productivity, space and equipment utilization, improved working conditions*), it can also result in some disbenefits (*increased capital requirements, decreased flexibility, reliability, maintainability, and operability*). Hence, one must consider both the short-range and long-range effects of the alternatives.

Material Handling System Design

- Alternatively, the questioning attitude in designing material handling system is:
  \[ \sum_{\text{moves}} [\text{Why} \ (\text{Where} + \text{What} + \text{When})] \]

- The expression within brackets defines the method of performing each move within a facility.

- The moves are considered individually and without reference to other moves within a facility.

- The initial consideration for a particular move is “Why should this move be performed?” The multiplication by “Why” represents the initial consideration and work simplification approach to material handling. For each move;
  - Can the move be eliminated?
  - Can the move be combined with another?
  - Can the move be simplified?
  - Can the sequence of moves be changed to advantage?

- Once it has been determined that a move will take place, the move must be studied by the “where + what + when” expression to **determine the best method of performing the move**.

- The **material handling planning chart** is a chart that can be extremely useful when investigating each move.
Material Handling System Design

- **Productivity ratios:** used as indicators of the performance of a system.
  - **Material Handling-Labor Ratio.** \[ \text{MHL} = \frac{\text{Personnel assigned to material handling}}{\text{Total operating personnel}} \]
    
    The ratio should be less than 1, and a reasonable value would be less than 0.30 in a plant, while in a warehouse a higher value should be accepted.
  - **Handling Equipment Utilization Ratio.** \[ \text{HEU} = \frac{\text{items moved per hour}}{\text{theoretical capacity}} \]
    
    Ideally, the ratio should be close to 1.0; however, equipment breakdown, poor scheduling, housekeeping, building geography can reduce the load movement.
  - **Storage Space Utilization Ratio.** \[ \text{SSU} = \frac{\text{storage space occupied}}{\text{total available storage space}} \]
    
    If the storage areas (such as bins or racks) are only partially full, then the percent of utilization should be estimated and included in the calculation. A value close to 1 indicates assignment of appropriate space for the storage activities.
  - **Aisle Space Percentage.** \[ \text{ASP} = \frac{\text{space occupied by aisles}}{\text{total space}} \]
    
    It should have a value between 0.10 and 0.15.
  - **Movement/Operation Ratio.** \[ \text{MO} = \frac{\text{number of moves}}{\text{number of productive operations}} \]
    
    It indicates the amount of material handling performed. The moves involved may consist of material moved from receiving, from storage to an operation and back to storage, and so on. A high value indicates room for improvement.
Material Handling Systems Design

- **Manufacturing Cycle Efficiency**,  
  \[ MCE = \frac{\text{time in actual production operations (machine time)}}{\text{time in production department}} \]
  
  Time not spent in production could be caused by delays in material movement, poor scheduling, machine failure, and storage limitation, among others. For increasing machine utilization, the delay should be eliminated or at least minimized. The performance index should be observed over a time period for consistency.

- **Damaged Loads Ratio**,  
  \[ DL = \frac{\text{number of damaged loads}}{\text{total number of loads}} \]
  
  It measures the quality performance of material handling personnel. Damage to the loads during receiving, in-process movement, and shipping should be minimized.

- **Energy Ratio**,  
  \[ ER = \frac{\text{total BTU consumption in the warehouse space}}{\text{warehouse space}} \]
  
  It measures the efficiency of heating and cooling operations. Some of the ways in which it can be improved are reducing heating or cooling of a portion of the warehouse in which there are no workers, turning lights off when not needed, and using lights on moving vehicles rather than permanent lighting.

- Note that: in the design/analysis of MH Systems, the focus should be first on the **material**, second on the **move**, and third on the **method**.

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**Material Handling Systems Design**

- **Unit Load**: It can be defined simply as the unit to be moved or handled at one time or alternatively a number of items arranged such that they can be handled as a single object.

  This can be achieved by **palletization**, **unitization**, and **containerization**.

  In some cases the unit load is one item of production; in other situations the unit load is several cartoons, each containing numerous items of production. The unit load includes the container, carrier, or support that will be used to move the materials.

  The integrity of the unit load can be maintained in a number of ways: tote boxes, cartons, pallets, and pallet boxes, likewise, strapping, shrinkwrapping, and stretchwrapping can be used to “contain”/“enclose” the unit load.

- **Palletization** is the assembling and securing of individual items on a platform that can be moved by a truck or a crane.

  A pallet is most suitable for stacking similar items that have regular shapes.

- **Unitization** is also the assembling of goods, but as one compact load. Unlike palletization, additional materials are used for packaging and wrapping the items as a complete unit.

- **Containerization** is the assembling of items in a box or a bin. It is most suitable for use with conveyors, especially for small items. Items that have different shapes and sizes can be grouped inside a container.
Material Handling Systems Design

The unit load can be handled by trucks, conveyors, or cranes depending on its size and weight.

In general, the factors that influence the selection of the unit load type are:

- the weight, size, and shape of the material,
- the quantity of material to be handled,
- the number of times the unit load is handled before it must be deunitized,
- the environmental conditions to which the unit load is exposed,
- the susceptibility of the material to damage,
- the security aspects of the material being handled,
- the method of receiving, storing, shipping, and handling the unit load,
- compatibility with the material handling equipment,
- compatibility with the other unit loads to be unitized,
- cost of the unit load; and
- the additional functions provided by the unit load such as stacking of material.

• The steps suggested in designing the unit load:
  - Determine the applicability of the unit load concept,
  - Select the type of unit load to be used,
  - Identify the most remote source of a potential unit load,
  - Establish the farthest practicable destination for the unit load,
  - Determine the size of the unit load,
  - Establish the configuration of the unit load,
  - Determine the method of building the unit load.

Material Handling Systems Design

• Unit load can be lifted in a variety of ways:
  - A forklift truck is frequently used to move unit loads placed on pallets; hence, unit loads can be lifted by a support beneath the load,
  - Below-hook lifters are used in conjunction with cranes and hoists to lift or suspend unit loads,
  - Using a clamp truck, to pick up unit load is by squeezing the load,
  - By inserting the lifting element into the unit load, such as a ram used to lift the steel coils.

• In many cases, an existing system is to be improved rather than a new system designed. As a result, unit load specifications may be influenced by the existing building: door widths, column spacing, aisle widths, turning radii of vehicles, and clear stacking heights.

• Advantages of using unit load:
  - It allows for moving large quantities of material that reduces the frequency of movement and therefore reduces the handling cost.
  - The ease of stacking helps achieve better space and cube utilization and promotes good housekeeping.
  - There is greater speed in loading and unloading and a corresponding reduction of handling time.
  - Protection against material damage is provided.

• Disadvantages of using unit load:
  - Costs of the unit load can be high if a large number are required, especially if the containers are not reusable.
  - Loading and unloading equipment that is different from what is available might be required.
  - When used in shipping to customers, there is the problem of returning the empty pallets and containers if they are reusable.