different size boxes, and these boxes fit the pallets perfectly. When the parts were moved to the assembly line, the box fit into a holding device that held the box in perfect position for use.

Another example of the systems approach is a TV manufacturer. The TV manufacturer did not make the wooden cabinet but purchased it from a supplier. The supplier built the wooden cabinet, packaged it into a cardboard box that the TV manufacturer provided. The cabinet came into the TV plant, was removed from the carton, and was placed on a conveyor for the assembly of the TV set into the cabinet. The carton was then placed on an overhead belt conveyor that carried it to the packout department. When the TV was completed, it was placed back in the same carton in which it was received. That carton was then moved to the warehouse and shipped to the customers all in the same carton.

In another example, a major oil company purchased plastic bottles from an outside manufacturer. The quart bottles were packaged in a carton of 12 with separators between every bottle. These cartons were placed on a pallet and shipped into the oil company's bottling plant. In the plant, the bottles were dumped onto a filling line and filled with oil. The empty carton was conveyed to the packout end of the filling line and repacked with 12 bottles, closed, stacked on a pallet, and shipped to a customer.

The systems principle integrates as many steps in the process as possible into a single system from the vendor through our plant and out to our customers. An integrated system is where everything seems to fit together.

3. The Material Flow Principle

In the previous chapters, we discussed techniques for creating an optimum material flow layout. The fabrication analysis techniques and the assembly and packout techniques showed us how to place equipment for the shortest flow. The following 10 techniques help us to choose an optimum material handling system.

4. The Work Simplification Principle

Material handling, like every other area of work, should be scrutinized for cost reduction. The work simplification formula tells us to ask four questions:

1. Can this job be eliminated? This is the first question asked because a positive answer will save the maximum amount of cost, namely, everything. Material handling tasks can often be eliminated by combining production operations together.
2. *If we can't eliminate,* can we combine this movement with other movements to reduce that cost? The *unit load concept* (a special section of this chapter) is based on this work simplification principle. If we can move two for the same cost as one, the unit cost of the move will be half. Just think, what if we could move 1,000 instead of one. Many times moves can be effectively eliminated when combined with an automatic material handling system that moves material automatically between workstations. Conveyors are a good example of this.

3. *If we can't eliminate or combine*, can we rearrange the operations around to reduce the travel distances? Rearranging the equipment to make the travel distances less will reduce the material handling costs.
4. *If we can't eliminate, combine, or reroute*, can we simplify? Simplification is making the job easier. Transportation or material handling equipment has taken the drudgery out of work more than any other type of equipment. Some simplification ideas for material handling are:
   a. carts instead of carrying
   b. roller conveyors to move boxes from trucks to the plant floor
   c. two-wheel hand trucks
   d. manipulators can make superpeople out of everyone
   e. slides or chutes
   f. rolltop tables (ball bearings)
   g. mechanization
   h. automation

Cost reduction is a part of every engineer and manager's job. Material handling equipment makes cost reduction easier.

5. Use Gravity

Gravity power is free and there are unlimited ways to use it at workstations in order to bring material into the station and to remove finished parts. Gravity can move material between workstations. A golf club manufacturer moves golf club heads between machines on inclined skate wheel conveyors in boxes of 100. The boxes move themselves into position at the next station. A bar stool manufacturing plant moves the finished stools away from the packout workstation with a conveyor that elevates the stool to 12 feet where it drops off onto a flexible skate wheel conveyor and rolls up 200 feet to a truck awaiting shipment, or to a storage location in the warehouse.

6. Maximize the Building Cube

A goal of material handling is to maximize the *building cube*.* Racks, mezzanines, and overhead conveyors are a few of the material handling devices that promote this goal. The cost of purchasing or leasing land and the additional costs of building plant space are significant costs, which are always on the increase. The better we use our building cube, the less space we need to buy or rent.

*The *building cube* is the cubic feet of the building volume resulting from multiplying the building's length times width times height.

7. Unit Size Principle

A *unit load* is a load of many parts that move as one. The advantages of a unit load is that it is faster and cheaper than moving parts one at a time. the disadvantages are:

1. Cost of making the unit loads and deunitizing
2. Tare weight (the weight of boxes, pallets, and the like)
3. What to do with the empties
4. The need for heavy equipment and its space requirements

Of course, the advantages must outweigh the disadvantages before we would recommend a unit load system.

The most common unit load is the pallet. Almost anything can be stacked on a pallet tied with bonding or plastic wrap and moved around the plant or world as one unit. Pallets are made of a variety of materials with greatly differing costs.

Cardboard pallets @ $1.00 each will make one trip.
Plastic pallets @ $4.00 each will make 20 trips.
Wooden pallets @ $20.00 each will make 100 trips.
Steel skids @ $150.00 each will make 2,000 trips.

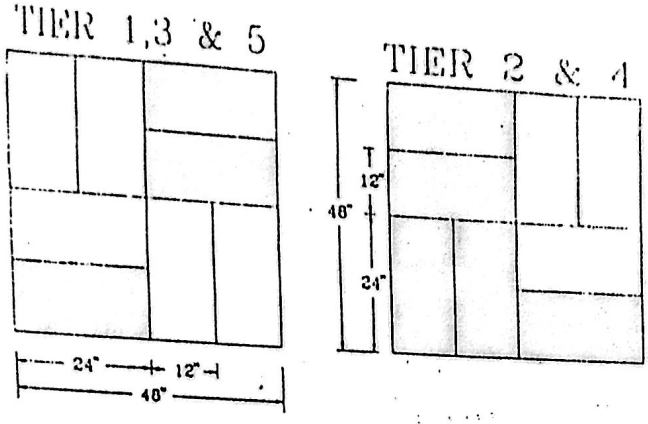
If we had no chance of getting our pallet or the cost of this pallet back, we would use a cardboard pallet. If we used only pallets within our plant, we would choose the steel pallet because its cost per move would be only one-third a wooden or plastic pallet. Strength, durability, versatility, weight, size, cost, and ease of use must all be considered when choosing a unit load technique. Wooden pallets are the most popular because the trucking industry trades pallets. When truckers drop 18 full pallet loads of material, they pick up 18 empties and return them to the supplier. Tens of thousands of dollars per year can be lost without a pallet control system.

The pallet is only one of the under mass techniques of unit loading. Others exclude boxes, tubs, and slip sheets. Still others are *squeezing* and *suspending* methods of handling the unit load.

Squeezing the load is performed by a clamp truck. The product is stacked on the floor into *pallet patterns* just like on pallets (see Figure 10-2). When the stack is complete a fork truck with two vertical plates (about 4 × 4 feet) drives up to the stack with one plate on the right side and the other plate on the left side. The two plates are pulled toward each other squeezing the material between the plates. The load can now be moved. This load can be placed on top of another stack of similar products right up to the rafters. The advantage is no pallet cost or space. Trailers can be loaded and unloaded with no pallets needed.

In the process of suspending unit loads from bridge cranes or jib cranes, a hook suspends from a lifting motor and attaches to chains or cables around the load. Lumber, steel coils, and steel plates are often moved this way. A monorail conveyor can also move many parts at a time.

Figure 10-2 Pallet Pattern



8. Mechanization Principle

The mechanization principle is to add power to eliminate manual moving. Mechanization does not necessarily mean automation. It simply implies the use of mechanical tools to aid in the movement of material. A common hand truck and a dolly are perfect examples of mechanization without automation.

9. Automation Principle

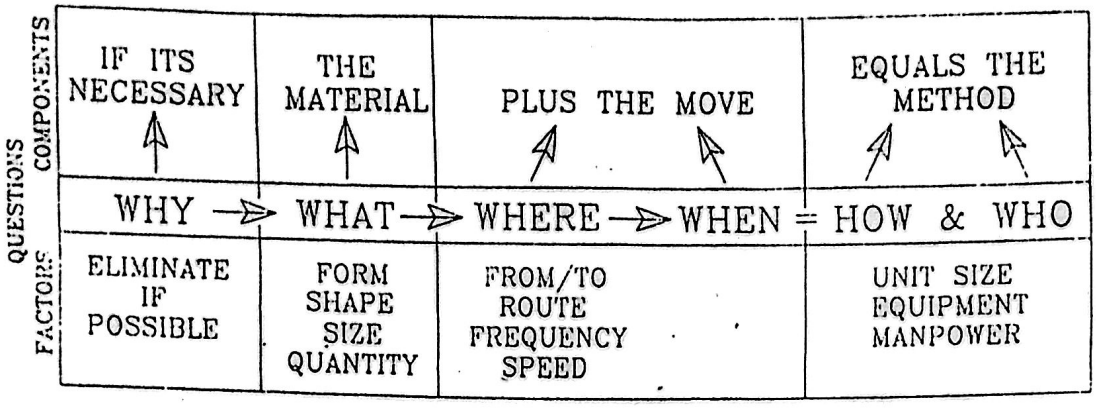
The automation principle makes moves automatic. Many new systems are completely automatic. Automatic storage and retrieval systems place material into storage racks automatically (no people assistance) and remove it when needed. Many machines are automatic because material handling equipment load and unload the machine. Automation is the way of the future and even the manual system must think toward the future when automation will be justified.

An engine block is automatically moved from machine to machine for processing. Machine centers are arranged around an indexing table. When all machines finish their function, the table advances one station and the machines go back to work. The finished parts can be removed by gravity, or a robot can pick up the finished part and place it in a container. This principle is fun to work with because your creative efforts will be well rewarded and personally gratifying.

10. Equipment Selection Principle

Which piece of material handling equipment should we use? Which problems should be studied first? Should I do an overview before studying the individual material handling problems? These are typical questions asked by a new project engineer. Where to start is easy—just start collecting information about the product (material) and the move (job). A series of questions has been developed that has been used for generations by reporters and these questions will serve the material handling project engineer well: Why? Who? What?

Figure 10-3 The Material Handling Equation



Where? When? How? If we answer these questions about each move, the solution will become evident.

The material handling equation is a plan for a systematic approach to equipment solution (see Figure 10-3).

Understand the material plus the move and the proper piece of equipment will develop.

Here is a list of the specific questions to ask!

1. *Why are we making this move?* (Why?) This question is asked first because if a good answer is not forthcoming, we can eliminate this move. By combining operations, the move between operations can be eliminated. We can combine machines together (called *work cells*) and eliminate moves.
2. *What are we moving?* (What?) Understanding what is being moved requires a knowledge of the size, shape, weight, and the number being moved and the kind of material. With the knowledge of what needs to be moved, we have half the information required to make an equipment selection.
3. *Where are we moving the material from and to?* (Where?) If the move is the same every time, a fixed path technique is warranted (conveyor). If the move changes from part to part, a variable path technique is used (industrial truck). If the path is short, maybe gravity can be used (e.g., slides, rollers, skatewheel).
4. *When is the move needed?* (When?) Is this move once or twice a day? If so, an industrial truck is warranted. If this is several times a minute, a conveyor is used. A few examples of analyzing the material + move = method follow item 5 below.
5. *How will the move be made?* (How?) Will we move it by hand, or by conveyor, or by fork truck. Many options are available to us and the most cost-efficient method is our goal.

Here are a few examples of ways to put these questions into action.

Example 1: Oil from a tanker truck to a tank farm for a bottling company.

Why = we need oil to put into quart cans

What = oil

Where = from tank truck to tank farm

Who = receiving clerk
When = four times a day as they arrive
How = pump—meter and hose

Example 2: Unload 20,000 pounds of flat steel stock from a flatbed trailer into our plant.
Why = we need steel in our plant (maybe coil would be better)
What = 20,000-pound loads of steel (3-1/2 feet × 10 feet × 20 inches)
Where = from flatbed trailer into our storage area
Who = receiving clerk
When = 40,000 pounds per day (one truck)
How = bridge crane

Example 3: Move parts one at a time from spot weld through paint to assembly.
Why = moving a major amount of our product automatically
What = toolboxes and tote trays
Where = from spot weld to paint to assembly
Who = automatically
When = 11 parts per minute, 432 minutes per shift
How = overhead conveyor belt

Example 4: Move all the product (except sheet metal) from the receiving dock to stores and/or to manufacturing.
Why = to keep a bank of material so that we do not run out of raw material and parts
What = all raw material and purchased parts
Where = from receiving to stores to manufacturing
Who = store clerk
When = as material arrives and as production requests material
How = narrow aisle reach truck

As information is collected, the picture becomes clearer and the plan takes shape. The more you know about the material and the move, the better the job of equipment selection you will do.

11. The Standardization Principle

There are many types of material handling equipment—shop boxes, bins, pallets, shelves, racks, conveyors, trucks, and the like—and in every area, we want to standardize on one (or as few as possible) size, type, and even brand name. The reasons are many, and they change with the type of equipment, but if we have a special piece of equipment for every move or storage, we will have too many different types and sizes to inventory and control. Material handling moving equipment (like fork trucks) are manufactured by many compa-

nies. We need to choose just one and then stay with that brand, type, and size because spare parts inventory, maintenance, and operation of this equipment will be most cost efficient. Equipment selection and standardization should not be based on the initial purchase cost alone. Costs of material handling systems can be grouped into two categories—the cost of the ownership of the system, which includes the initial purchase price and the subsequent maintenance costs, and the cost of the operation of the system. This latter cost includes the cost of training personnel to use the system safely, energy cost, and other direct or indirect costs associated with the use of the system.

Having only a few sizes of cartons will simplify the storage area. We may put these few sizes of cartons onto a single sized pallet and into a uniform sized rack, which is serviced by one type of lift truck.

12. The Adaptability Principle

Use equipment that can do many different jobs without excessive changeover time or costs. If special purpose equipment can be justified in a reasonable amount of time, then go ahead, but remember that change is inevitable, and your special purpose equipment will become obsolete and useless. The adaptability principle is the best reason to buy a fork truck, which is very versatile. With any amount of production volume, there is almost always a better way to move material other than by fork truck.

Buy standard size pallets, buy shop containers that will handle a variety of parts, and buy storage equipment that can store a wide variety of products. In this way, change will be less costly.

13. The Dead Weight Principle

"Don't use a 20-pound sledge hammer to drive a tack." Try to reduce the ratio of equipment weight to product weight. Don't buy equipment that is bigger than necessary.

Tare weight is a term used to describe the weight of packaging material. When we move a product, we place the product into a container; we may place packaging materials around the product to prevent damage while moving. These containers may be placed on pallets as well. The container, the stuffing, and the pallet all add up to the tare weight. If we ship this packaging, the tare weight costs as much to ship as does our product. This packaging is also expensive to buy. So, the goal is to reduce this tare weight and save money.

14. The Utilization Principle

Material handling equipment and operators should be used fully. Knowing what work is required, the number of times per day, and the time required per move will help us to manage the work load of our people and the equipment.

15. The Maintenance Principle

Material handling equipment must be maintained. Preventive maintenance (periodic, planned maintenance) is cheaper than emergency maintenance, so a preventive

maintenance program including schedules must be developed for each piece of material handling equipment.

Pallets, shop boxes, and storage facilities need repair too. Missing slats on pallets can cause product damage and safety problems. Wooden pallets cost about $20 each, so we do not want to throw them away because one slat is broken. Set up a pallet repair area to store and repair broken pallets.

16. The Obsolescence Principle

As equipment wears out or a better, more efficient method becomes available, let's replace that equipment and improve our operation. Good maintenance records will help us to identify worn out equipment. Good system planners are always looking for better ways to improve the operations.

17. The Control Principle

Materials are costly and material handling systems can be a part of the inventory control system. Conveyors can move material past a scanner to count, identify, and reroute. Automatic identification and data capture (AIDC) systems today are a major aspect of material handling systems. With the aid of this technology, quality inspection, inventory control, and item tracking can be incorporated into the material handling systems. Bar codes can be generated that will accompany the product from supplier, through all stages of production and assembly, to its final destination. The bar code can contain such data as the part number, routing, order quantity, and engineering change order, to name a few. Incorporating this technology into a material handling system can significantly reduce or eliminate the need to count or track the material physically. The information can be entered only once into the computer and is automatically updated as the material passes through the system and the bar code is scanned. This can eliminate the old paper packing slips and the required manual operations, which followed. Not only do the systems offer a tremendous savings in operation time, but also the cost, the accuracy, and the reliability are significantly improved.

18. The Capacity Principle

We want to get as much out of our production equipment and our employees as possible. Material handling equipment can help to maximize production equipment utilization.

A punch press can cycle every .030 minute or 33 times per minute, but our time standard for manually loading and unloading this press is only 300 pieces per hour. This is only 15 percent of the machine's capability.

$$\frac{60 \text{ minutes per hour}}{.030 \text{ minute per unit}} = 2{,}000 \text{ pieces per hour potential}$$

$$\frac{300 \text{ pieces per hour present}}{2{,}000 \text{ pieces per hour potential}} = 15 \text{ percent}$$

If we purchased a coil-feeding material handling system, we would approach 100 percent machine utilization.

Material handling equipment can assist our production equipment in achieving its potential. Don't buy a new machine, just get the capacity available in our present machine.

19. The Performance Principle

Know what your material handling costs are and work at reducing them. The process chart, discussed earlier in this book, gives us a form to calculate the unit cost of every move. This is a starting point for cost reduction. Material handling labor moves material, and a measurement of output could be pounds moved. Input is labor hours. Anything we can do to increase pounds moved or to reduce labor hours will increase productivity.

Performance of material handling can also be calculated by ratios:

$$\text{Percent of material handling} = \frac{\text{material handling hours}}{\text{total labor hours}}$$

Tracking this percentage can show the improvements in performance.

Performance includes a lot more than labor. Segregating material handling cost from total operation costs would result in a better ratio. Again, improvement in the ratio would indicate improved performance.

20. The Safety Principle

Manual handling is probably the most dangerous method of material handling, and as stated earlier, material handling equipment has improved the world of work more than any other area of industry. Material handling equipment can also be a source of safety problems, so safety methods, procedures, and training must be a part of any material handling plan. It is management's responsibility to provide a safe work environment. Tens of billions of dollars are spent on injured workers. This human cost is also reflected in the cost of our product. Safety considerations must be a major factor in selecting material handling equipment, considering that material handling activities are the leading cause of workers' injuries and compensation payments in the United States.

According to the U.S. Census of Fatal Occupational Injuries, between 6,000 to 6,600 workers have been fatally injured each year since 1992. The National Safety Council estimates that each fatal work injury, in monetary terms, costs approximately $790,000. This figure includes lost wages, medical insurance, and administrative and indirect costs such as production downtime. Furthermore, based on the data from the Social Security Administration published for 1993, a total of $42.9 billion was paid for all workers' compensation claims. These costs are significant in both social terms and lost productivity to the business sector.