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Instructor's Manual
to accompany

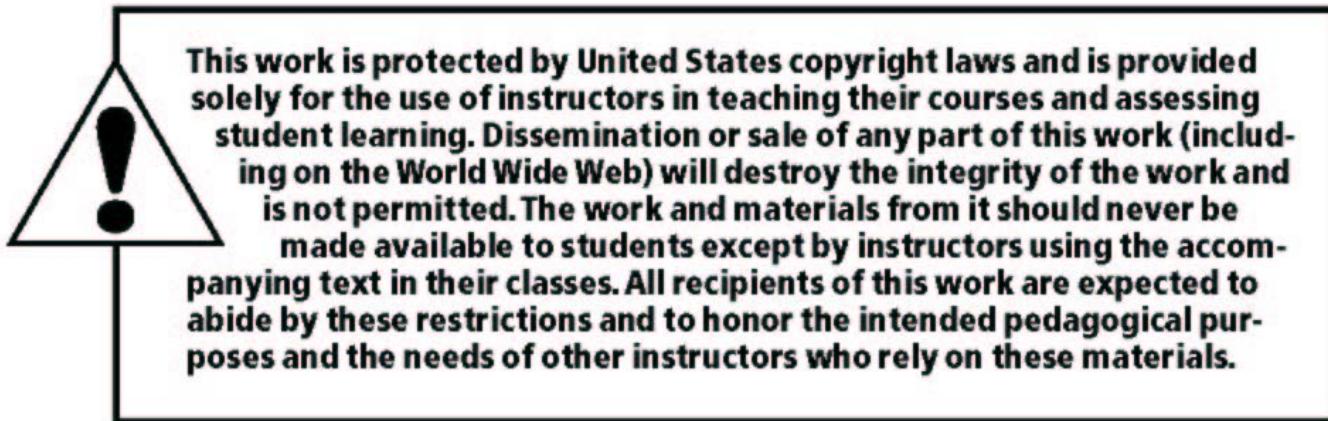
Manufacturing Facilities Design and Material Handling

Third Edition

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Upper Saddle River, New Jersey
Columbus, Ohio



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PREFACE

This instructor's manual has been prepared to accompany the Manufacturing Facilities Design and Material Handling, (3rd ed.), Meyers & Stephens.

The manual has been prepared containing the major points and highlights of each chapter so that it may be used as a lecture guide or simply as a quick reference to the contents of each chapter. Furthermore, from each chapter selected charts and figures have been reproduced in this manual for the convenience of the user in order that they may be used as transparency or any other visual aids masters.

Since the answers to all of the end-of-the-chapter questions have been provided in the textbook, it was not deemed necessary to reproduce the answers in this manual, however, a bank of test questions and problems have been provided in this manual. The answers and the solutions for these test questions have been provided here.

Every effort has been made to ascertain accuracy and to accommodate the instructor. However, as a believer in continuous improvement, I value and look forward to your comments and suggestions.

I would like to express my gratitude to Mr. Isaac S. Slaven for his invaluable assistance in preparing this manual.

Matthew P. Stephens, Ph.D.

Chapter 1

Introduction to Manufacturing Facilities Design And Material Handling

Objectives

In this chapter the students are introduced to the concepts and importance of facilities planning. Objectives of facilities planning are material handling are defined. Design procedures and type of resources are introduced.

THE IMPORTANCE OF MANUFACTURING FACILITIES DESIGN AND MATERIAL HANDLING

Manufacturing facilities design and material handling affect the productivity and profitability of a company more than almost any other major corporate decision. The quality and cost of the product and, therefore, the supply/demand ratio are directly affected by the facility design.

Manufacturing facilities design is the organization of the company's physical facilities to promote the efficient use of the company's resources such as people, equipment, material, and energy. *Facilities design* includes plant location and building design, plant layout, and material handling.

Material handling is defined simply as moving material. ASME defines material handling as the art and science involving the moving, packaging, and storing of substances in any form.

Improvements in **material handling** have affected (positively) working people more than any other area of work design and ergonomics.

Material handling is a part of nearly every step of a facility design process. The material handling equipment choice will affect the layout.

Material handling accounts for about 50 percent of all industrial injuries and from 40 to 80 percent of all operating costs. The cost of equipment is also high, but a proper ROI can be had.

Today, material handling systems can easily be incorporated with cutting edge technologies in automatic data capture equipment and automatic inspection systems for a variety of quality and productivity purposes.

Use the **cost reduction formula** when working with facilities design:

Ask	For Every	So We Can
Why	Operation	Eliminate
Who	Transportation	Combine
What	Inspection	Change sequence
Where	Storage	Simplify
When	Delay	
How		

The five (5) S's are also cost reduction attitudes that will help to reduce costs. The **5 S's principles** are:

1. *Sifting (organization)*. Keeping the minimum of what is required.
2. *Sorting (arrangement)*. Everything has a specific place.
3. *Sweeping (cleaning)*. Promotes safety.
4. *Spick and span (hygiene)*. A safe plant is a result of good layout planning.
5. *Strict (discipline)*. Following the procedures and standardized methods.

LEAN THINKING AND LEAN MANUFACTURING

Lean manufacturing is a concept whereby all production people work together to eliminate waste.

Muda (waste) is defined as any expense that doesn't help to produce value. We want to do only work that will add value.

There are **eight kinds of muda**: overproduction, waiting, transportation, processing, inventory, motion, rework, and poor people utilization.

Kanban is another technique that affects the manufacturing facility design. It is referred to as a "pull" system, differs from the traditional inventory "push" system such as JIT and MRP.

THE GOALS OF MANUFACTURING FACILITIES DESIGN AND MATERIAL HANDLING

A good set of goals will bring us to a successful facility design.

A **mission statement** can best communicate the primary goal of a plant layout and material handling project. For example:

"Build me a plant to produce 1,500 quality swing sets at the lowest possible cost."

Subgoals are added to help us achieve specific goals, and the following is only a small list of potential goals:

1. Minimize unit cost. Minimize project cost.
2. Optimize quality.
3. Promote the effective use of (a) people, (b) equipment, (c) space, and (d) energy.
4. Provide for (a) employee convenience, (b) employee safety, and (c) employee comfort.
5. Control project costs.
6. Achieve the production start date.
7. Build flexibility into the plan.
8. Reduce or eliminate excessive inventory.
9. Achieve miscellaneous goals.

These **goals** should be kept in mind:

1. Facilitate the manufacturing processes
 2. Minimize material handling
 3. Maintain flexibility
 4. Maintain high turnover of work-in-process
 5. Hold down investment in equipment
 6. Make efficient use of building cube
 7. Promote effective utilization of human resources
 8. Provide for employee convenience, safety, and comfort in doing work
-
1. Minimizing unit and project costs are of prime importance.
 2. Quality is critical and difficult to measure.
 3. Promoting the effective use of people, equipment, space, and energy.
- Space is also costly and we want to promote effective use of our space.
Normally, we can do a good job of using floor space, but what about the other spaces?
- a. Under the floor (basements) is a good place for utility tunnels, under the floor conveyors for material delivery or trash removal, and so on.
 - b. Overhead (from 7 feet to rafters) is usable space. We can use this space for overhead conveyors, pallet racks, mezzanines, shelves or bins for storage, balcony offices, pneumatic delivery systems, dryers, ovens, and so on.
 - c. Ceiling space under the roof (in the rafters or trusses) is space that can be used for utilities, heating and cooling, sprinkler systems, catwalks, and some storage.
 - d. On the roof, space can be used for parking, weather testing of a product, utility units, ovens, golf driving range, tennis, and so on.

“Utilizing the building cube.” The idea deals with utilizing the vertical dimensions as well as the horizontal dimensions of the facility.

4. Provide for the convenience, safety, and comfort of our employees. Safety of our employees is a moral and legal responsibility.
5. Control project costs. The cost of the project must be determined before presenting the plan to management for approval.
6. Achieve the production start date. The success of the project will depend on whether we get our product to the market on time.
7. Build flexibility into the plan. It is certain that things will change.
8. Reduce or eliminate excessive inventory. Inventory costs a company about 35 percent a year to hold.
9. Miscellaneous goals include:
 - a. restrict operator lifting to one part.
 - b. use work cells.
 - c. use plug-in-plug-out equipment.
 - d. minimize work in process.
 - e. build kanban.
 - f. build visual management systems.
 - g. design for first-in-first-out inventory for inventory control.

Figure 1-1 New product work progress report to be completed by one engineer.

Engineer	Date: <u>3/11/XX</u>	1670X	1810	1900	1700
1. Obtain product number					
2. Create product name	Wizbang		Gizmo		
3. Select project engineer	Meyers		Stephens		
4. Determine production rate per shift	1,500		1,750		
5. Complete manufacturing plan	3-1X		4-1X		
6. Complete material handling plan	3-1X		4-1X		
7. Set time standards	3-5X		4-5		
8. Determine number of	3-6X		4-6		
a. fabrication machines needed	3-6X		4-6		
b. assembly stations needed	3-6X		4-6		
9. Issue flow chart	3-10X		4-10		
10. Design workstations	3-10		4-10		
11. Select material handling equipment	3-10		4-10		
12. Prepare budget plan	3-12		4-15		
13. Prepare layout plan	3-14		4-15		
14. Present to management	3-15		4-15		
15. Write work orders to build stations	3-25		4-15		
16. Issue purchase orders	3-15		4-15		
17. Develop quality control requirements	4-1		5-1		
18. Try out first workstations	4-1		5-1		
19. Install equipment	4-14		5-14		
20. Write work methods sheets	4-14		5-14		
21. Run production pilot	4-15		5-15		
22. Start production	5-1		5-30		
23. Recheck everything					

Note: X means this step is complete.

THE MANUFACTURING FACILITIES DESIGN PROCEDURE

The following is a systematic way of thinking about the project:

1. Determine what will be produced, for example, a toolbox or lawn mower.
2. Determine how many will be made, for example, 1,500 per 8-hour shift.
3. Determine what parts will be made or purchased.
4. Determine how each part will be fabricated. This is called *process planning*.
5. Determine the sequence of assembly. This is called *assembly line balancing*.
6. Set time standards for each operation.
7. Determine the plant rate (**takt time**).
8. Determine the number of machines needed.
9. Balance assembly lines or work cells.
10. Study the material flow patterns to establish the best flow possible.
 - a. string diagram
 - b. multi-product process chart
 - c. from-to chart
 - d. process chart
 - e. flow process chart
 - f. flow diagram
11. Determine activity relationships.
12. Layout each workstation.
13. Identify needs for personal and plant services, and provide the space needed.
14. Identify office needs and layout as needed.
15. Develop total space requirements from the above information.
16. Select material handling equipment.
17. Allocate the area according to the space needed and the activity relationships.
18. Develop a plot plan and the building shape.
19. Construct a master plan.
20. Seek input and adjust.
21. Seek approvals, take advice, and change as needed.
22. Install the layout.
23. Start production.
24. Adjust as needed and finalize project report and budget performance.

COMPUTERS AND SIMULATION IN MANUFACTURING FACILITIES DESIGN

Simulation can be used to predict the behavior of a manufacturing or service system by actually tracking the movements and interaction of the system.

In the scope of facilities planning and design, computer simulation can be utilized to study and optimize the layout and capacity.

Chapter 2

Sources of Information for Manufacturing Facilities Design

Objectives

Vast arrays of preliminary data from various sources are required for a successful layout. In this chapter the students are introduced to the type of information that is required and the sources from which these data can be obtained.

The facility design depends on basic information that the facility designer must obtain from other departments within the company.

1. Manufacturing engineering establishes the routing and selects the equipment.
2. Tool design department designs the fixtures and specifies the specific tools.
3. Industrial engineering sets the time standards for each operation.
4. The quality department specifies inspection procedures.
5. The safety department wants to input its requirements.
6. Inventory and production control policies affect the space needs and procedures.

The manufacturing facilities designer will also need to obtain data from outside the manufacturing department such as:

1. Marketing
2. Product design
3. Management policy

THE MARKETING DEPARTMENT

The marketing department provides data on what the consumer wants and needs.

- (1) the selling price,
- (2) volume, how many can we sell?
- (3) seasonality, is it a summer or winter product?
- (4) replacement parts that our older product may require.

Volume is used to calculate plant rate. The number of units required per day is a very important number for the facility designer because it determines the number of machines and people for whom we need to provide space.

This data is used to establish the plant rate, or “takt” time

Example: We need 1,000 units per shift out of our plant. Four hundred eighty minutes are available in an 8-hour shift (8 hours times 60 minutes per hour).

Subtract 10 percent for downtime [breaks, etc.]. This leaves 432 minutes of actual work time left to produce 1,000 units. If our plant works at 90 percent efficiency, then 432 minutes times 90 percent equals 389 effective minutes of work.

$$R \text{ (takt time)} = 389 \text{ minutes}/1000 \text{ units} = 0.389 \text{ minute per unit}$$

This is the plant rate.

A finished, packed out unit must come off the assembly and packout line every 0.389 minutes, or just about 2.5 units per minute. This means every workstation and every machine in the plant will need to produce about 2.5 parts per minute.

If we need two parts (like axles on a toy wagon) per finished unit, then we would need 5.14 parts per minute.

Scrap and Rework

Scrap and rework affect the plant rate. If in the preceding example the press operation produces 3 percent scrap, to end up with 2,000 finished wagon bodies we must start with a larger number so that after scraping 3 percent, we will have 2,000 good parts.

If we designate the finished parts with the letter "O," for output, we can calculate our input, "I" as follows:

$$I = 2,000/(1 - 0.03) = 2,062 \text{ units.}$$

If two other steps are performed and one step has a 2.5 percent scrap rate and the other produces .5 percent scrap, then we can calculate our input as follows:

$$I = 2,000/(1 - 0.03)(1 - 0.025)(1 - 0.005) = 2,125 \text{ units}$$

The takt time is now calculated on the basis of 2,125 units.

The general formula is stated as

$$I = \text{Output} / (1 - \% \text{scrap1})(1 - \% \text{scrap2}) \dots (1 - \% \text{scrapn})$$

THE PRODUCT DESIGN DEPARTMENT

Blueprints, sketches, CAD drawings, assembly drawings, bill of materials, and model shop samples inform the facilities designer of what needs to be accomplished.

Either a parts list, a bill of materials or an indented bill of material are needed by the facility designer.

The indented bill of material provides data regarding the composition of the final assembly and a valuable insight into the *order* of the final assembly.

MANAGEMENT POLICY INFORMATION

Management refers to upper-level employees who are responsible for the financial performance of a company. Facility designers must understand the management's policies on:

- (1) inventory policy and lean thinking,
- (2) investment policy (ROI),
- (3) startup schedules,
- (4) make or buy decisions,
- (5) organizational relationships, and
- (6) feasibility studies.

Make or Buy Decisions

Companies themselves do not fabricate every part of their product. The parts that are purchased are called *buyouts*. The parts that we "make" are basic requirements for the fabrication end of our facility.

Organizational Relationships

An organizational chart communicates to the facilities designer the number of employees, therefore, the size of such areas as cafeterias, restrooms, office space, and medical facilities.

Feasibility Studies

Many new product ideas are recommended to management. These ideas need to be evaluated before they are accepted as new manufacturing facilities design projects. At a toy company, for example, one project out of four proposals may be accepted.

Figure 2-1a Sample Blueprint for Toolbox Handle

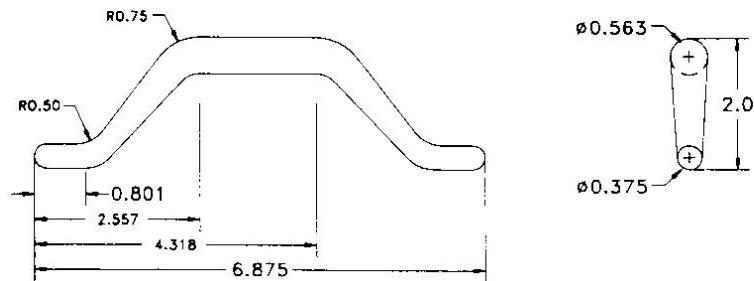


Figure 2-1b Part Drawing—Clamp and Plate

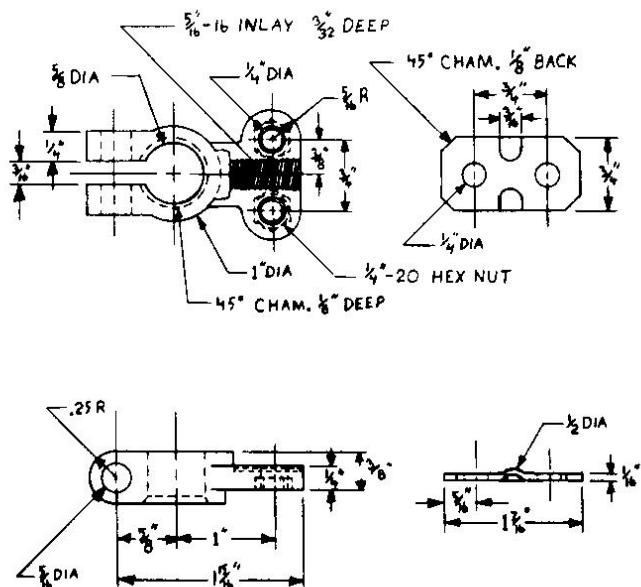


Figure 2-3a Sample Sketch—Exploded View

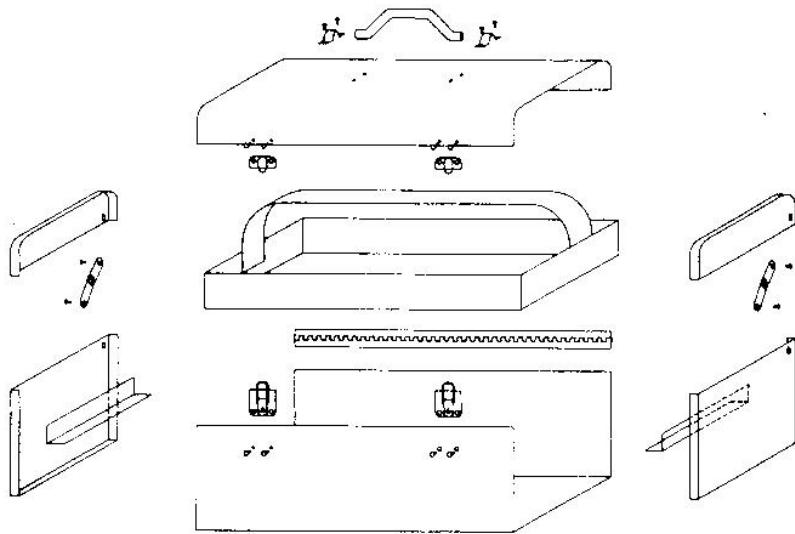


Figure 2-3b Exploded Drawing—Battery Cable Clamp

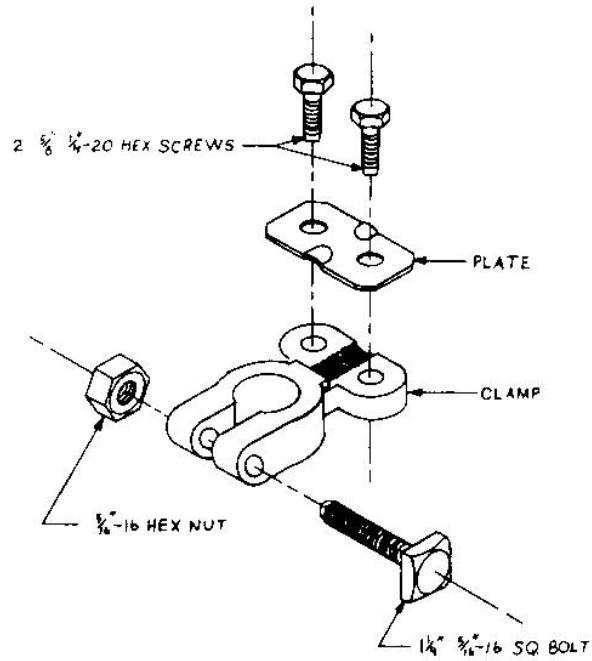


Figure 2-4 Toolbox Parts List

<i>Part No.</i>	<i>Part Name</i>	<i>Quantity Needed per Unit</i>
1	Body ends	2
2	Tray bracket	2
SSSAI	Body end	2
3	Body	1
SSAI	Body assembly	1
4	Cover end	2
5	Cover	1
SSA2	Cover assembly	1
6	Hinge	18"
SA1	Toolbox	1
7	Tray ends	2
8	Tray body	1
9	Tray handle	1
SA2	Tray	1
10	Paint	AR
11	Handle	1
12	Clips	2
I3	Rivet	4
A1	Toolbox	1
14	Catch	2
15	Strike	2
16	Rivets	8
A2	Toolbox	1
17	Hinges	2
18	Rivets	4
A3	Toolbox	1
19	Packing list	1
20	Registration card	1
21	Name tag	1
22	Dividers	4
23	Plastic bag	1
SA3	Parts bag	1
24	Carton	1
25	Tape	24"
Final packout		I

Figure 2-5 Indented Bill of Material

Company: ACME, Inc.		Prepared by: M.P.S.	
Product: Super Gismo		Date:	
Level	Part No.	Part Name	Drug. No.
0	0012	Super gismo	0012
.1	0034	Main frame	0034
.1	0421	4' bracket	0421
.2	0344	Strap ties	0344
.1	0113	1/4" insert	0113
.2	0123	Tube	0123
...3	0014	Clear paint	
.1	0019	Brace	0019
.2	0177	1/4-20 nut	0177
.2	0192	3/16" collar	0192
.1	0330	Cylinder	0330

Figure 2-6 Indented Bill of Material for Toolbox

Level	Part Number	Part Name	Qty. per Unit	Make / Buy
0		Toolbox	1	Make
.1	A1	Exterior Body Assembly	1	Make
.2	SA1	Body Assembly	1	Make
..3		Body End Assembly	2	Make
....4	1	Body End	2	Make
....4	2	Tray Bracket	2	Make
...3	3	Body	1	Make
.2	SA2	Cover Assembly	1	Make
...3	5	Cover	1	Make
...3	4	Cover End	2	Make
....4	18	Rivets	4	Buy
....4	17	Hinge	2	Buy
...3	SA3	Cover Handle Assembly	1	Make
....4	11	Handle	1	Make
....4	12	Clips	2	Buy
....4	13	Rivets	4	Buy
.2	14	Catch	2	Buy
.2	15	Strike	2	Buy
.2	16	Rivets	8	Buy
.2	10	Paint		Buy
.1	A2	Tray Assembly	1	Make
.2	7	Tray End	2	Make
.2	8	Tray Body	1	Make
.2	9	Tray Handle	1	Make
.1	A3	Parts Bag	1	Make
.2	19	Packing List	1	Buy
.2	20	Registration Card	1	Buy
.2	21	Name Tag	1	Buy
.2	22	Dividers	4	Buy
.2	23	Plastic Bag	1	Buy
.1	24	Carton	1	Buy
.1	25	Tape	24"	Buy

Figure 2-7 The assemble chart for the toolbox

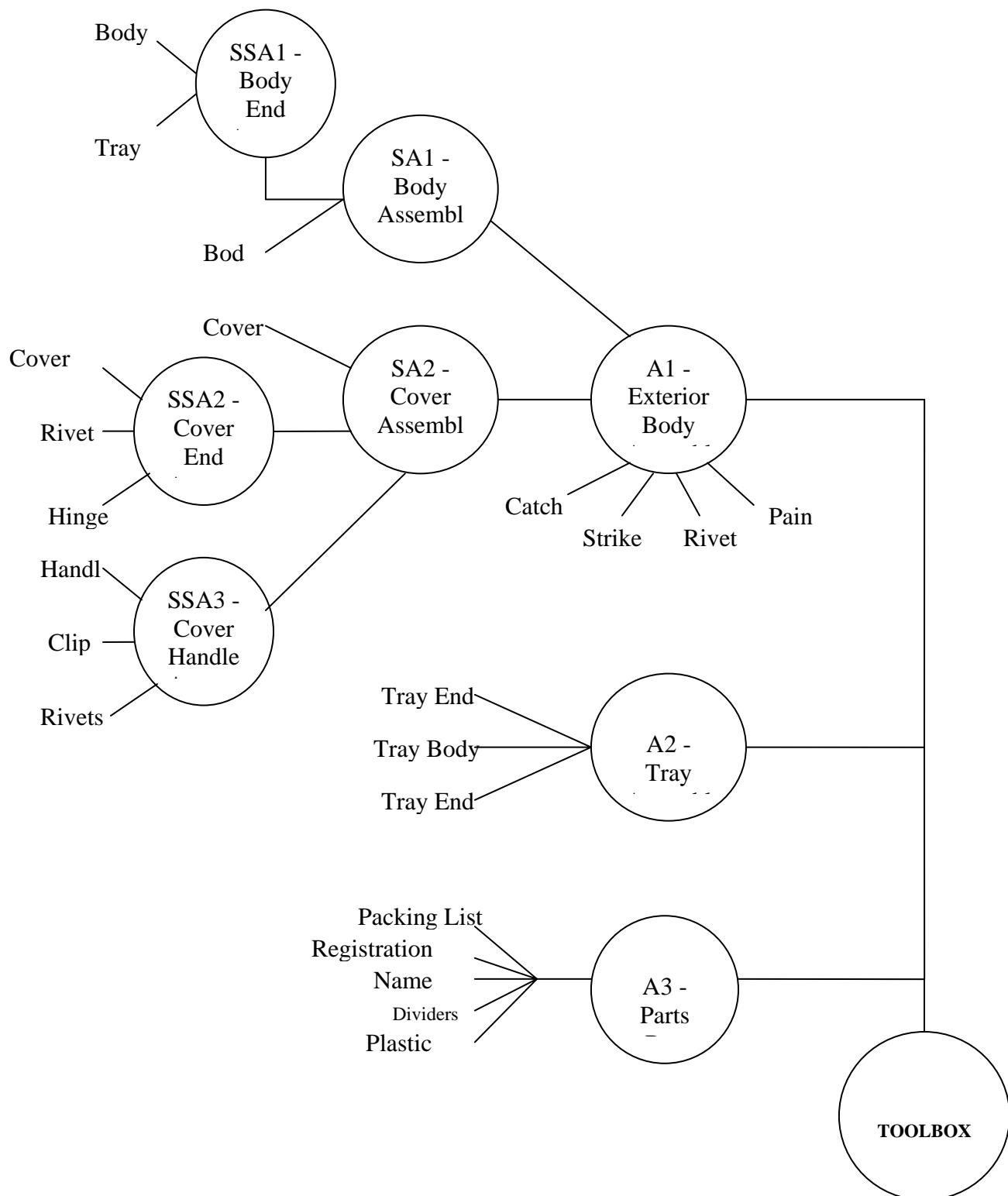


Figure 2-8 Toolbox Make or Buy Decision

<i>Part No.</i>	<i>Part Name</i>	<i>Quantity Needed per Unit</i>	<i>Make or Buy</i>
1	Body ends	2	M
2	Tray bracket	2	M
SSA1	Body end	2	
3	Body	1	M
SSA1	Body assembly	1	
4	Cover end	2	M
5	Cover	1	M
SSA2	Cover assembly	1	
6	Hinge	18"	M
SA1	Toolbox	1	
7	Tray ends	2	M
8	Tray body	1	M
9	Tray handle	1	M
SA2	tray	1	
10	Paint	AR	B
11	Handle	1	B
12	Clips	2	B
13	Rivet	4	B
A1	Toolbox		
14	Catch	2	B
15	Strike	2	B
16	Rivets	8	B
A2	Toolbox		
17	Hinges	2	B
18	Rivets	4	B
A3	Toolbox		
19	Packing list	1	B
20	Registration card	1	B
21	Name tag	1	B
22	Dividers	4	B
23	Plastic bag	1	B
SA3	Parts bag	1	
24	Carton	1	B
25	Tape	24"	B
Final packout		1	

Chapter 3

Time Standards

Objectives

In this chapter the importance and uses of time standards as relate to facilities planning are discussed. Time study and time standards are defined and basic methods for obtaining time standards are explained.

Time standards are among the most basic yet important pieces of information required by the facilities planner. Time or labor standards are used for a variety of purposes in an organization. The uses include:

- 1) cost and budget allocation and control
- 2) production and planning and inventory management
- 3) performance evaluation and incentive pay where applicable
- 4) evaluation of alternative methods of operation
- 5) determining the required number of people and workstations
- 6) calculating the number of machines and work cells
- 7) assembly line balancing and staffing
- 8) calculate the space requirements for all work centers, and
- 9) the overall production facilities space requirements.

WHAT IS A TIME STANDARD?

Time standard is defined as “the time required to produce a product at a workstation with the following three conditions:

- (1) a qualified, well-trained operator;
- (2) working at a normal pace; and
- (3) doing a specific task.”

A *qualified, well-trained operator* is required. Experience is usually what makes a qualified, well-trained operator, and time on the job is our best indication of experience.

Normal pace is the pace at which a trained operator, under normal conditions performs a task with a normal level of effort. Normal level of effort is one in which the operator can maintain a *comfortable* pace, not too fast and not too slow.

1. Walking 264 feet in 1,000 minutes (3 miles per hour)
2. Dealing 52 cards into four equal stacks in 0.500 minute (at a bridge table)
3. Filling a 30-pin board in 0.435 minute (using two hands)

A *specific task* is a detailed description of what must be accomplished and must include:

1. The prescribed work method
2. The material specification
3. The tools and equipment being used
4. The positions of incoming and outgoing material
5. Additional requirements such as safety, quality, housekeeping, and maintenance tasks

THE IMPORTANCE AND USES OF TIME STUDY

The time standard is one of the most important pieces of information produced in the manufacturing department. It is used to develop answers for the following problems:

1. Determine the number of machine tools to buy.
2. Determine the number of production people to employ.
3. Determine manufacturing costs and selling prices.
4. Schedule the machines, operations, and people to do the job.
5. Determine the assembly line balance, conveyor belt speed, load and balance the work cells.
6. Determine individual worker performance and identify bottleneck operations.
7. Pay incentive wages where applicable.
8. Evaluate cost reduction ideas.
9. Evaluate new equipment purchases to justify their expense.
10. Develop operation personnel budgets to measure management performance.

1. How Many Machines Do We Need?

How many machines do we need? The answer depends on two pieces of information:

- a. How many pieces do we need to manufacture per shift?
- b. How much time does it take to make one part? (This is the time standard.)

Example:

1. Make 2,000 wagons per 8-hour shift.
2. It takes us 0.400 minute to form the wagon body on a press.
3. There are 480 minutes per shift (8-hour shift times 60 minutes per hour).
4. Less 50 minutes downtime per shift (breaks, cleanup, etc.).
5. There are 430 minutes per shift available at 100 percent.
6. At 75 percent performance (based on history or expectation)
 $(.75 \times 430 = 322.5)$.
7. There are 322.5 effective minutes left to produce 2,000 units.
8. $322.5/2000 \text{ units} = 0.161 \text{ minute per unit}$

The .161 minute per unit is called the *takt time*, or plant rate.

Time standard (0.400 minute per unit) / Plant rate (0.161 minute per unit) = 2.48 machines.

2. How Many People Should We Hire?

For the data below, assume 75 percent performance during the first year of production.

	Hours Product per 1,000	No. of Units Needed/Day	Actual Hours		
			Hour at 100%	Actual %	Needed
A	150	1,000	150.0	70	214
B	95	1,500	142.5	85	168
C	450	2,000	900.0	120	750
Total 1,132 hours					

1,132 hours of direct labor per day are needed. Each employee will work 8 hours; therefore,

$1,132 \text{ hours} / 8 \text{ hours per employee} = 141.5$ or 142 employees.

3. Determine the Assembly Line Balance, Determine the Conveyor Belt Speed, Load the Work Cells with the Correct Amount of Work, and Balance the Work Cells

The objective of assembly line balancing is to give each operator as close to the same amount of work as possible. Balancing work cells has the same objective.

- 1) Assembly line balancing or work center loading can only be accomplished by breaking the job down into tasks having approximately the same length of time.
- 2) There will always be a workstation or cell that has more work than any other.
- 3) This station is defined as the 100 percent loaded station, or bottleneck station, and will limit the output of the whole plant.
- 4) To improve the assembly line (reduce the unit cost), we will concentrate on improving the 100 percent station.

(Assembly line balancing is discussed in detail in Chapter 4.)

4. How Do We Measure Productivity?

Productivity is a measure of output divided by input.

Example:

Present = Output (1000 units)/ Input 50 people @ 8 hours per day =

$1000/400 = 2.5$ units per manhour

Any increase in output or decrease in input will improve the productivity ratio.

TECHNIQUES OF TIME STUDY

Five techniques of time standard development are studied in this text:

1. Predetermined time standard systems
2. Stopwatch time study
3. Work sampling
4. Standard data
5. Expert opinion standard and historical data

Predetermined Time Standards Systems

When a time standard is needed during the planning phase of a new product development program, the PTSS technique is used .

Frank and Lillian Gilbreth developed the basic philosophy of predetermined time motion systems. They divided work into 17 work elements known as *therbligs*:

- | | | |
|---------------------|------------------|------------------------------|
| 1. Transport empty | 7. Position | 13. Inspect |
| 2. Search | 8. Assemble | 14. Avoidable delay |
| 3. Select | 9. Disassemble | 15. Unavoidable delay |
| 4. Grasp | 10. Release load | 16. Plan |
| 5. Transport loaded | 11. Use | 17. Rest to overcome fatigue |
| 6. Preposition | 12. Hold | |

Stopwatch Time Study

Stopwatch time study is the method that most manufacturing employees think of when talking about time standards.

Time study is defined as the process of determining the time required by a skilled, well-trained operator working at a normal pace doing a specific task.

TIME STUDY PROCEDURE AND THE STEP-BY-STEP FORM

The time study procedure has been reduced to 10 steps.

- Step 1.* Select the job to study.
- Step 2.* Collect information about the job.
- Step 3.* Divide the job into elements.
- Step 4.* Do the actual time study.
- Step 5.* Extend the time study.
- Step 6.* Determine the number of cycles to be timed.
- Step 7.* Rate, level, and normalize the operator's performance.
- Step 8.* Apply allowances.
- Step 9.* Check for logic.
- Step 10.* Publish the time standard.

Figure 3-5a PTSS Example

Fred Meyers & Associates Predetermined Time Standards Analysis							
Operation No.	25	Part No.	2220	Operation Description			
Date	1-21-xx	Time		Assemble brackets to body using 4 bolts			
By I.E.	Meyers		<td data-cs="4" data-kind="parent"></td> <td data-kind="ghost"></td> <td data-kind="ghost"></td> <td data-kind="ghost"></td>				
Description-Left Hand	Freq.	LH	Time	RH	Freq.	Description-Right Hand	Element Time
To next body		R30	18	M30		Aside completed	
Grasp		G2	6	RL		Release	
Move body to fixture		M30	18	R30		To L.H.	
			2	G2		Grasp body in L.H.	
Place in fixture		AP1	5	AP1		Place in fixture	
			49				.049
Get and place 2 brackets on body							
		R12	9	R12		To bracket	
		G2	6				
			4	R2		To bracket	
Same as R.H.			6	G2		Grasp bracket	
		M12	9	M12		To body	
			AP2	10			
				5	AP2(1/2)	On body	
				49			.049
Get and assemble 4 bolts - hand tighten							
		R8	7	R8		To bolt	
		G3	9				
			9	G3		Grasp bolt	
Same as R.H.		M8	7	M8		To body	
			API	5	API	On body	
		10	G4	40	G4	Turn 10 times	
			SF	5	SF		
				82		3rd and 4th bolt	.164
Time	Study	Cycle	Cost:				
25	1.20	2.11	Hours per unit				Total Normal Time in Minutes per Unit .262
50	1.42	2.35					+ 10% Allowance .026
74	1.65		Dollars per hour \$15.00				Standard time .288
97	1.89		Dollars per unit \$0.72				Hours per unit .00480
Total	2.35						Pieces per hour 208
Occ.	10						
Avg. occ.	.235						
Lev. fact	110						
Norm. time	.258						

Step 1. Select the job to study. Request for time study can come from every direction:

1. Unions can question time standards and request a restudy.
2. Supervisors.
3. The job could change, requiring a new standard.
4. New jobs may have been added to the plant.
5. New products can be added, requiring many new time standards.
6. I.Es can improve methods, requiring a new time standard.
7. Cost reduction programs can require new standards.

Once a reason for studying a job has been determined, which person do you time-study? The best answer is two or three, but those people you do *not* want to time study are:

1. *The fastest person on the job.* The other employees may think you are going to require them to keep up.
2. *The slowest person on the job.* No matter how you rate the job and no matter how good the time standard is, the employees will wonder how you came up with that standard.
3. *Employees with negative attitudes that will affect their performance while being studied.* If you can sidestep a potential problem, you should.

Step 2. Collect information about the job.

Now that the job has been identified, collect information for the purpose of understanding what must be accomplished.

Step 3. Divide the job into elements.

Elements. These are units of work that are indivisible. Time study elements should be as small as possible, but not less than .030 minute. The element should be as descriptive as possible.

Principles of Elemental Breakdown

1. It is better to have too many elements than too few.
2. Elements should be as short as possible, but not less than .030 minute.
3. Elements that end in sound are easier to time.
4. Constant elements should be segregated from variable elements.
5. Separate the machine-controlled from the operator-controlled elements.
6. Natural breaking points are best.

7. The element description should describe the complete job.
8. Foreign elements should be listed in the order of occurrence.

The reasons for breaking down a job into elements are as follows:

1. It makes the job easier to describe.
2. Different parts of the job have different tempos.
3. Breaking down the job into elements allows for moving a part of the job.
4. Standard data can be more accurate and more universally applied.

Step 4. Do the actual time study:

This is the main part of the stopwatch time study.

Continuous Example

		1	2	3	4	5
	R	16	.83	1.50	2.17	2.83
Load and clamp	E					
	R	56	1.23	1.90	2.57	3.23
Run machine	E					
	R	66	1.33	2.01	2.67	3.32
Unload and place aside	E					

To calculate each element time (E), subtract the previous reading from each reading.

Snapback Example

		1	2	3	4	5
	R					
Load and clamp	E	.16	.17	.17	.16	.16
	R					
Run machine	E	.40	.40	.40	.40	.40
	R					
Unload and put aside	E	.10	.10	.11	.10	.09

Note that the elemental time (E) is already calculated.

Figure 3-6 Time Study Example: Continuous Form

Meyers & Stephens
*Manufacturing Facilities Design
and Material Handling, 3e*

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Figure 3-7 Time Study Form: The Step-by-Step Form

Fred Meyers & Associates				Time Study Worksheet													
				<input type="checkbox"/> Snapback <input type="checkbox"/> Continuous													
Operation Description		(1)		Drawing No.		(4)		Machine Name		(5)		Machine Number		(6)		Quality ok?	
Part Number		(2)		Operation No.		(3)		Tool Number		(9)		Feeds & Specs		(10)		Safety checked?	
Operator Name		(7)		Department		(8)		Machine Cycle		(12)		Notes		(13)		Setup proper?	
Part Description:		(11)		Material Specifications:													
Element No.	Element Description	Readings										Notes:					
		1	2	3	4	5	6	7	8	9	10						
		R	E	R	E	R	E	R	E	R	E						
		R	E	R	E	R	E	R	E	R	E						
		(14)	(15)	R	E	(16)											
		R	E	R	E	R	E	R	E	R	E						
		R	E	R	E	R	E	R	E	R	E						
		R	E	R	E	R	E	R	E	R	E						
		R	E	R	E	R	E	R	E	R	E						
		R	E	R	E	R	E	R	E	R	E						
Foreign elements		(27)															
Engineer:		(33)		Date:		<u>J. L.</u> (34)		R		No. Cycles		Total normal minutes		(28)			
Approved by:		(35)		Date:		<u>J. L.</u>		X		X		Allowance +		(29)			
								X		X		Standard minutes		(30)			
								X		X		Hours per unit		(31)			
								X		X		Units per hour		(32)			
								X		X		On back station		(33)			
								X		X		Work station allowances		(34)			
								X		X		Product sketch		(35)			
								X		X				(36)			
								X		X				(37)			

Step 5. Extend the time study.

Total/cycles: The total refers to the total time of the appropriate cycles timed.

Average time: Average time is the result of dividing total time by the number of cycles.

Percent R: Percent rating refers to our opinion of how fast the operator was performing.

Normal time: is defined as the amount of time a normal operator working at a comfortable pace would take to produce a part.

Average time X (rating percent/100) = normal time

Unit normal time: is calculated by multiplying the frequency by the normal time.

Examples:

<i>Normal Time</i>		<i>Frequency</i>		<i>Unit</i>
<i>Normal Time</i>				
1.160	X	1/1,000	=	.001
.400	X	1/10	=	.040
.100	X	1/2	=	.050
.050	X	1.1	=	.050

Frequency: indicates how often a task is performed.

Step 6. Determine the number of cycles to be timed.

The accuracy of time study depends on the number of cycles timed. As a rule of thumb, 20 to 25 observations should provide sufficient accuracy for our purposes.

Step 7. Rate, level, and normalize the operator's performance.

Percent rating is the technologist's ***opinion*** of the operator's performance, and is the most challenging aspect of time study.

Step 8. Apply allowances 29 .

Allowances are added to a time study to make the time standard practical.

Total normal time + allowances = standard time

Step 10. Publish the time standard.

Three numbers are required to communicate a time standard:

1. Decimal minutes
2. Hours per unit
3. Pieces per hour

Standard minutes, dividing by 60 minutes per hour equals hours per unit.

Pieces per hour is $1/x$ of hours per unit.

Rating, Leveling, and Normalizing

Rating is the process of adjusting the time taken by an individual operator to what could be expected from a *normal* (100%) operator. Rating an operator includes four factors: (1) skill, (2) consistency, (3) working conditions, and (4) effort (which is most important).

ALLOWANCES

Allowances are extra time added to the normal time to make the time standard practical and attainable.

Types of Allowances

Allowances fall into three categories:

1. Personal
2. Fatigue
3. Delay

Personal allowance. *Personal allowance* is that time an employee is allowed for personal activities such as

1. Talking to friends about nonwork subjects
2. Going to the bathroom
3. Getting a drink
4. Any other operator-controlled reason for not working

Fatigue allowance. *Fatigue allowance* is the time an employee is allowed for recuperation from fatigue. Fatigue allowance time is given to employees in the form of work breaks, commonly known as coffee breaks.

Delay allowances. Delay allowances are called unavoidable because they are out of the operator's control. Examples include:

1. Waiting for instructions or assignments
2. Waiting for material or material handling equipment
3. Machine breakdown or maintenance
4. Instructing others (training new employees)
5. Attending meetings, if authorized
6. Waiting for setup.
7. Injury or assisting with first aid
8. Union work
9. Reworking quality problems (not operator's fault)
10. Nonstandard work—wrong machine or other problem
11. Sharpening tools
12. New jobs that have not been time-studied yet

Work Sampling

Work sampling is the same scientific process used in Neilson ratings, Gallup polls, attitude surveys, and federal unemployment statistics. We observe people working and draw conclusions.

The industrial engineer samples a department and finds the following statistics:

Task	No. of		Hours Worked	Pieces	
	Observations	% Total		Produced	Pieces per Hour ^a
Assemble	2,500	62.5	625	5,000 ^b	8
Idle	1,500	37.5	375	—	
Total	4,000	100.0	1,000 ^c		

^a Pieces per hour = (pieces=5000)/(hours = 625) = 8 pieces per hour

^bFrom supervisor (number of finished products put in the warehouse).

^cFrom payroll (hours paid during our study).

Standard Data

Standard data are the fastest and cheapest technique of setting time standards. Starting with many previously set time standards, the industrial engineer tries to figure out what causes the time to vary from one job to another on a specific machine or class of machine.

Expert Opinion Time Standards and Historical Data

An expert opinion time standard is an estimation of the time required to do a specific job. This estimate is made by a person with a great experience base.

Historical data are an accounting approach to expert opinion time standard systems. A record is kept of how much time was used on each job. When a new job comes along, it is compared to a previous job standard.

TIME STANDARDS FOR MANUFACTURING FACILITIES DESIGN

Time study does not always mean stopwatch time study. The stopwatch method of setting time standards is not very useful in manufacturing facilities design because we need to know the required time for each element of work *before* production begins. For this reason, predetermined time standards or standard data systems are used. Time standards are used for five main purposes in facilities design:

1. Determining the number of workstations and machines
2. Determining the number of people
3. Determining conveyor line speeds
4. Balancing assembly and packout lines
5. Loading work cells

Figure 3-11 Standard Data Worksheet Example

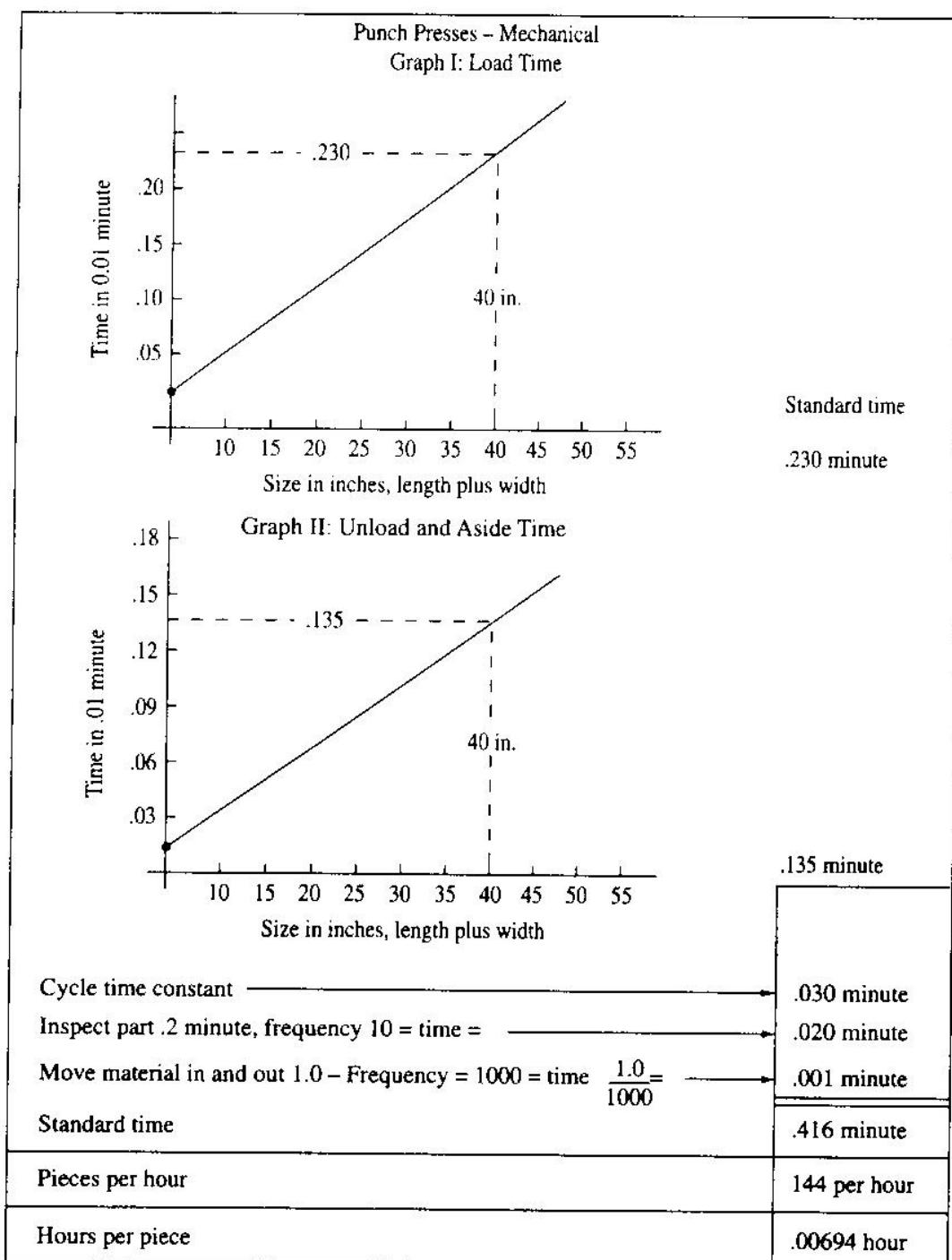


Figure 3-12 Which Time Standards Technique Do We Use?

Cycle Time	Volume of Production		
	High 1,000's	Medium 100's	Low 10's
Long	Work Sampling	Work Sampling Stopwatch	Expert opinion Work sampling History
Medium	Work sampling Stopwatch PTSS	Stopwatch Work sampling	Expert opinion History Stopwatch
Short	PTSS	Stopwatch	Stopwatch Expert opinion

Note: Standard data are the ultimate time standard technique and can be used in all situations.
Standard data should be the goal of all time study departments.

Chapter 4

Process Design

Objectives

The concepts and procedures for process design, or how the product and each component are made, and the impact of these decisions on the layout of the facility is discussed in this chapter.

The process engineer or designer determines how the product and all its components will be made. The information includes the following:

1. The sequence of operations to manufacture every “make” part
2. The machinery, equipment, tools, fixtures, and so on
3. The sequence of operations in assembly and packout
4. The time standard for each element of work
5. The conveyor speed for cells, paint, assembly and packout lines
6. The balance of the work loads of assembly and packout lines
7. The development of a workstation drawing and layout for each operation

Process design can be divided into two broad categories:

fabrication is initially planned on a route sheet

and **assembly and packout** which use the techniques of assembly charts and assembly line balancing.

FABRICATION: MAKING THE INDIVIDUAL PART

The sequence of steps required to produce (manufacture) a single part is referred to as the *routing*. The form used to describe this routing is called the *route sheet*.

Route Sheets

A route (or routing) sheet is required for each individual fabricated part. It lists the operations required to make that part in the proper sequence and accompanies the material from operation to operation.

Figure 4-1 Routing Sheet

Part Name	Box Body		Part Number 1600		Date 10/22/XX		Quantity 1,000	
	A	B	C	D	E	F	G	
Operation number	Operation and tooling	Machine name	Machine number	Pieces per hour	Hours per piece			
2	Description							
3	5	Cut to length	Shear	12	1,200			.00083
4	10	Cut to width	Shear	12	400			.0025
5	15	Noch corners	Press	65	300			.00333
6	20	Punch four holes	Press	65	300			.00333
7	25	Form two short legs	Press break	55	250			.004
8	30	Form two long legs	Press break	55	250			.004
9	35							
10	40							
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

It includes the part number, part name, quantity to produce, operation number, operation description, machine number, machine name, tooling needed, and time standard.

The route sheet ends with the last operation prior to being assembled with other parts.

There are two ways to change the sequence in order to make the flow through the plant smoother:

1. Change the route sheet, if possible
2. Change the physical layout of the machines

The Number of Machines Needed

This question can be answered when we know:

1. The number of finished units needed per day
2. Which machine runs what parts
3. The time standard for each operation

Example: To build 2,000 toolboxes per 8-hour shift, we calculated the plant rate (*R* value) or takt time as follows:

60 minutes per hour X 8 hours = 480 minutes	
Less downtime 10 percent	48 minutes
Available minutes per shift	432 minutes
Expected efficiency approx.	80 percent
Effective minutes	= 345.6 minutes per 8-hour shift

We have 345.6 minutes to produce 2,000 units.

$$\text{R value} = 345.6 \text{ minutes}/2,000 = 0.173 \text{ minutes per unit}$$

We need the decimal minute time standards to compare with the *R* value or takt time.

Divide the time standard (decimal minute) by the *R* value. The resultant number of machines should be in two decimal places.

Once all the machine requirements for each operation are determined, we total similar machine requirements and round.

WORK CELL LOAD CHART

The work cell load does not have to be for a complete part or product, but it could be for only a few operations.

A *work cell* is a collection of equipment required to make a single part or a family of parts with similar characteristics. This equipment is placed in a circle around an operator or operators.

Advantages of work cells:

1. Significantly reduce setup time
2. Eliminate all storage between operations
3. Eliminate most of the moving time between operations
4. Eliminate delays spent waiting for the next machine
5. Reduce cost
6. Reduce inventory (work-in-process reductions)
7. Reduce manufacturing in process time

ASSEMBLY AND PACKOUT PROCESS ANALYSIS

Once all parts are produced by the fabrication departments or received from the suppliers and available for assembly, new analytical tools are needed. Subassembly, welding, painting final assembly, and packout are all functions included in this area of the plant.

The Assembly Chart

The *assembly chart* shows the sequence of operations in putting the product together. Using the exploded drawing and the parts list, the layout designer will diagram the assembly process.

The sequence of assembly may have several alternatives. Time standards are required to decide which sequence is best. This process is known as *assembly line balancing*.

Figure 4-3 Summary of Route Sheets

Part Name	Body Ends	Tray Brackets	Body	Cover Ends	Cover	Hinge	Tray Ends	Tray	Handle
Time Standards in Pieces per Hour									
Parts per unit Operations	2	2	1	2	1	1	2	1	1
Strip shear	1,850	2,750	1,400	2,100	1,750	—	2,250	1,850	—
Chop shear	950	1,400	1,175	1,050	1,320	935	1,220	1,410	—
Punch	825	—	650	870	759	—	—	—	—
Form	595	841	475	616	528	—	629	567	—
Roll form	—	—	—	—	—	—	—	—	375
Time Standards in Decimal Minutes per Unit*									
(Divide the Above Pieces per Hour into 54 Minutes)									
Strip shear	.029	.020	.039	.026	.031	—	.024	.029	—
Chop shear	.057	.039	.046	.051	.041	.058	.044	.038	—
Punch	.065	—	.083	.062	.071	—	—	—	—
Form	.091	.064	.114	.088	.102	—	.086	.095	—
Roll form	—	—	—	—	—	—	—	—	.144

*The time standards in decimal minutes will be used to determine the number of machines needed.

Figure 4-4 Machine Requirements Spreadsheet

Part Name	2	2	1	1	1	2	1	1	Total
	Body Ends	Tray Brackets	Body	Cover Ends	Cover Body	Hinge	Tray Ends	Body	Machines
Machines									
Strip shear	.34*	.24	.23	.30	.18	—	.28	.17	—
Chop shear	.66	.45	.27	.59	.24	.33	.51	.22	—
Punch press	.75	—	.48	.72	.41	—	—	—	3.27
Press brake	1.05	.74	.65	1.02	.59	—	.99	.55	—
Roll former	—	—	—	—	—	—	—	—	2.36
									5.59
									.83
									.83

* $.029 \div .173 \times 2$ parts per unit = .34 machine.

Figure 4-5 Work Cell Layout

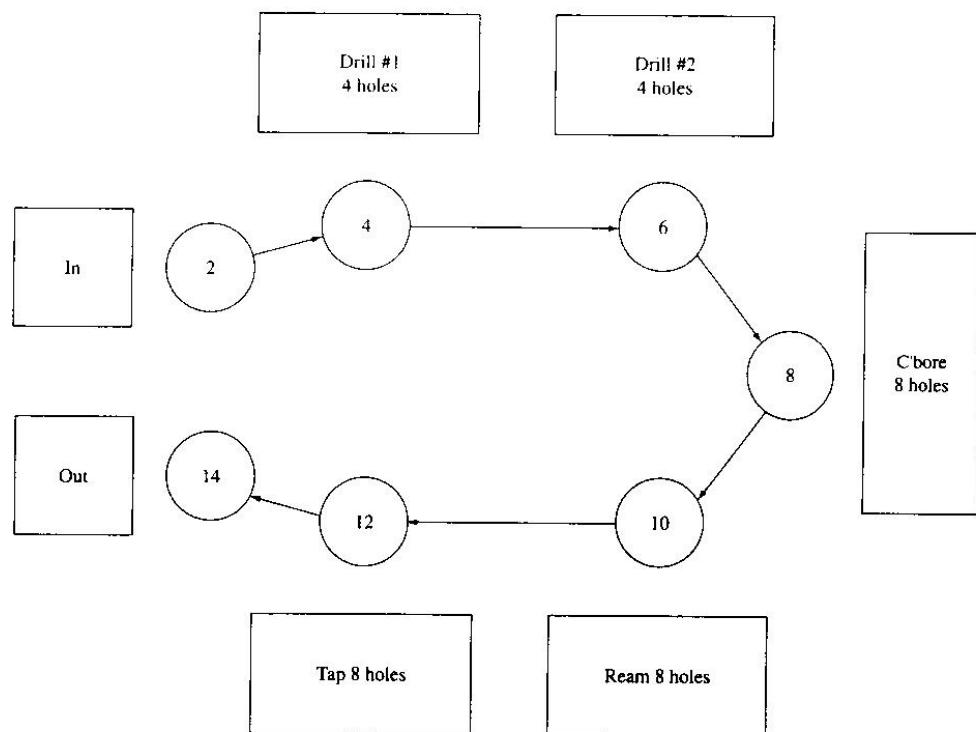
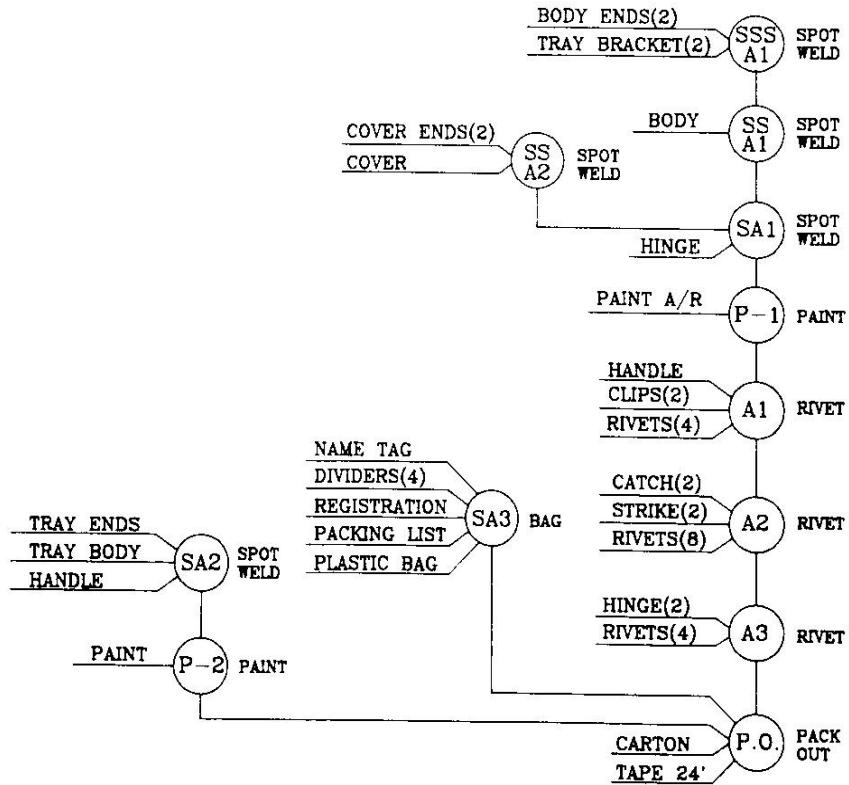


Figure 4-8 Assembly Chart—Toolbox



Plant Rate and Conveyor Speed

Conveyor speed is dependent on the number and units needed per minute, the size of the unit, the space between units, and, sometimes, the hook spacing.

Conveyor belt speed is recorded in feet per minute. Therefore, the size of the part plus the space between parts (measured in feet) times the number of parts needed in one minute equals feet per minute.

Example: Charcoal grills are in cartons 30 X 30 X 24 inches high. A total of 2,400 grills are required every day.

	480	minutes per 8 hour shift
less	50	minutes scheduled down time (breaks, etc.)
	430	available minutes
	80%	anticipated performance
	344	effective minutes of work per day

344 minutes/2,400 grills per day = 0.143 minutes per grill

$$1/0.143 = 7 \text{ grills per minute}$$

$$7 \text{ grills per minute} \times 2\text{-}1/2 \text{ feet per grill (30 inches)} = 17.5 \text{ feet per minute}$$

Paint Conveyor Speed

Example: We are going to paint the following parts on one overhead conveyor system:

Part Number	Parts per Hook	Quantity to Paint (per shift)	Needed Hooks per Day	Hooks per Minute*
15	1	500	500	1.45
263	4	300	75	.22
44	2	1,000	500	1.45
14	8	2,000	250	.73
21	2	100	50	.15
03	1	125	125	.36
				4.36

* Based on 430 minutes @ 80 percent = 344.

A total of 4.36 hooks need to pass any one point in one minute. If the hooks were one foot apart, 4.36 feet per minute would be the conveyor speed.

If the hooks were 1-1/2 feet apart, the conveyor speed would be 6.54 feet per minute (4.36×1.5).

This conveyor speed also determines the size of your drying oven and baking oven. If parts need 10 minutes at 400° to dry, ten minutes at 6.54 feet per minute equals 65.4 feet of conveyor in an oven, so our oven will be about 33 feet long and 4-1/2 feet wide.

Assembly Line Balancing

The purpose of the assembly line balancing technique is:

1. To equalize the work load among the assemblers
2. To identify the bottleneck operation
3. To establish the speed of the assembly line
4. To determine the number of workstations
5. To determine the labor cost of assembly and packout
6. To establish the percentage workload of each operator
7. To assist in plant layout
8. To reduce production cost

Figure 4-10 Paint Hooks

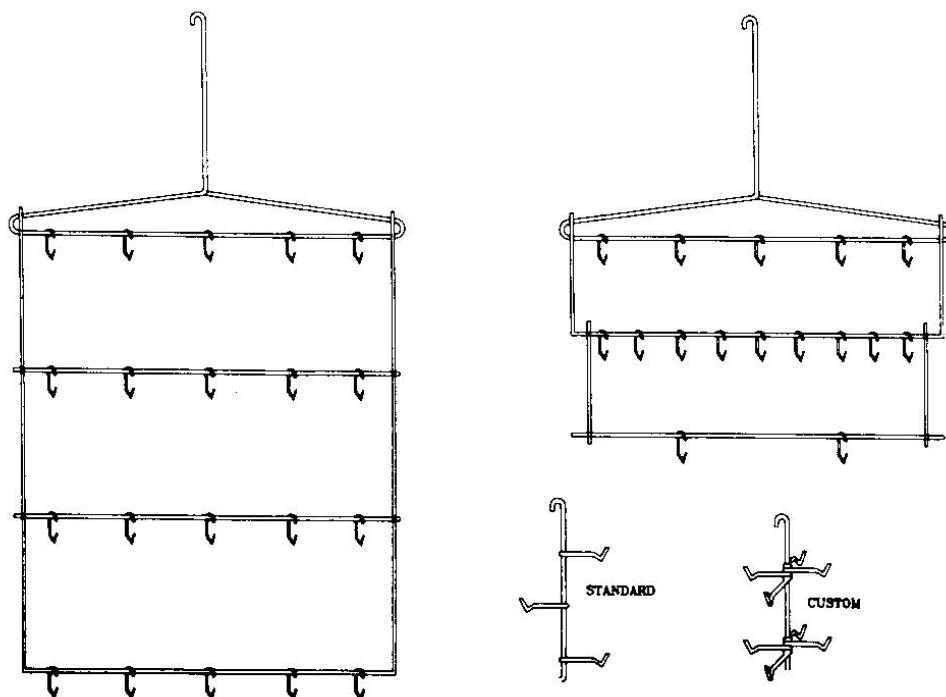
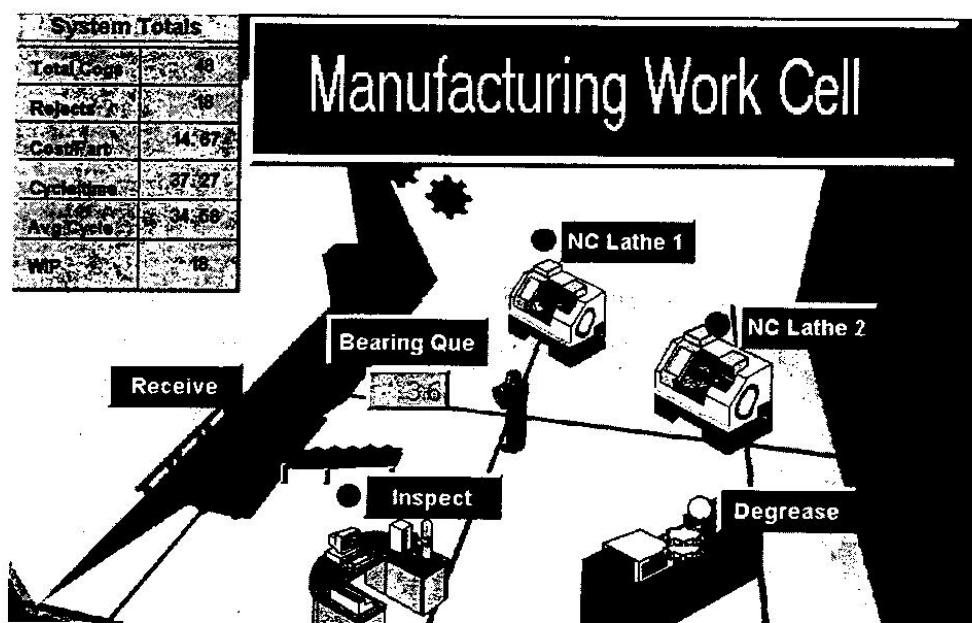


Figure 4-11 Initial Assembly Line Balance

	Time Standard	Number of Stations	Rounded Up	Average Time	Percent Loaded	Hours per Unit	Pieces per Hour
SSSA1	.306	1.77	2	.153	92	.00557	180
SSA1	.291	1.68	2	.146	87	.00557	180
SSA2	.260	1.50	2	.130	78	.00557	180
SA1	.356	2.06	3	.119	71	.00835	120
A1	.310	1.79	2	.155	93	.00557	180
A2	.555	3.20	4	.139	83	.01113	90
A3	.250	1.44	2	.125	75	.00557	180
SA2	.415	2.40	3	.138	83	.00835	120
SA3	.250	1.44	2	.125	75	.00557	180
P.O.	.501	2.90	3	.167	100	.00835	120
Total	3.494		25			.06960	

Figure 4-14 Assembly Line Balancing Step-by-Step Form

Figure 4-19 A Simulated Status of the Manufacturing Cell Utilizing One Operator After a Fixed Period of Time (Courtesy of ProModel Corporation)



Chapter 5

Flow Analysis Techniques

Objectives

Several flow analysis techniques including, string diagram, from-to chart, process chart, operations chart, and multi-column chart are discussed in this chapter.

Flow analysis is the heart of plant layout and the beginning of the material handling plan. The flow of a part is the path that the part takes while moving through the plant.

The purpose is to minimize
(1) distance traveled,
(2) backtracking,
(3) cross traffic, and
(4) cost of production.

Product-oriented vs. process oriented flow

Product-oriented layout considers the overall flow of the product as compared to process-oriented flow layouts that are planned around a group of similar equipment. Advantages of product-oriented flow are:

1. There is simplified coordination and production scheduling
2. Users and makers of parts can see and talk to each other
3. There is less work-in-process inventory
4. This layout eliminates excessive handling of materials
5. Quality problems are easier to identify and quicker to fix
6. Flow of material and operators' work can be standardized
7. Less floor space is required for all the above reasons.
8. This layout provides the foundation for continuous improvement

The following list summarizes the differences between the material flow in a process-oriented layout and a product-oriented layout:

1. Material flow will be much smoother in product-oriented flow plans
2. The distance material has to travel will be much shorter.
3. There is less confusion about which process sequence to use
4. One concern with the product-oriented layout is the restriction of the machine capacity.

Figure 5-1a Process Flow Layout

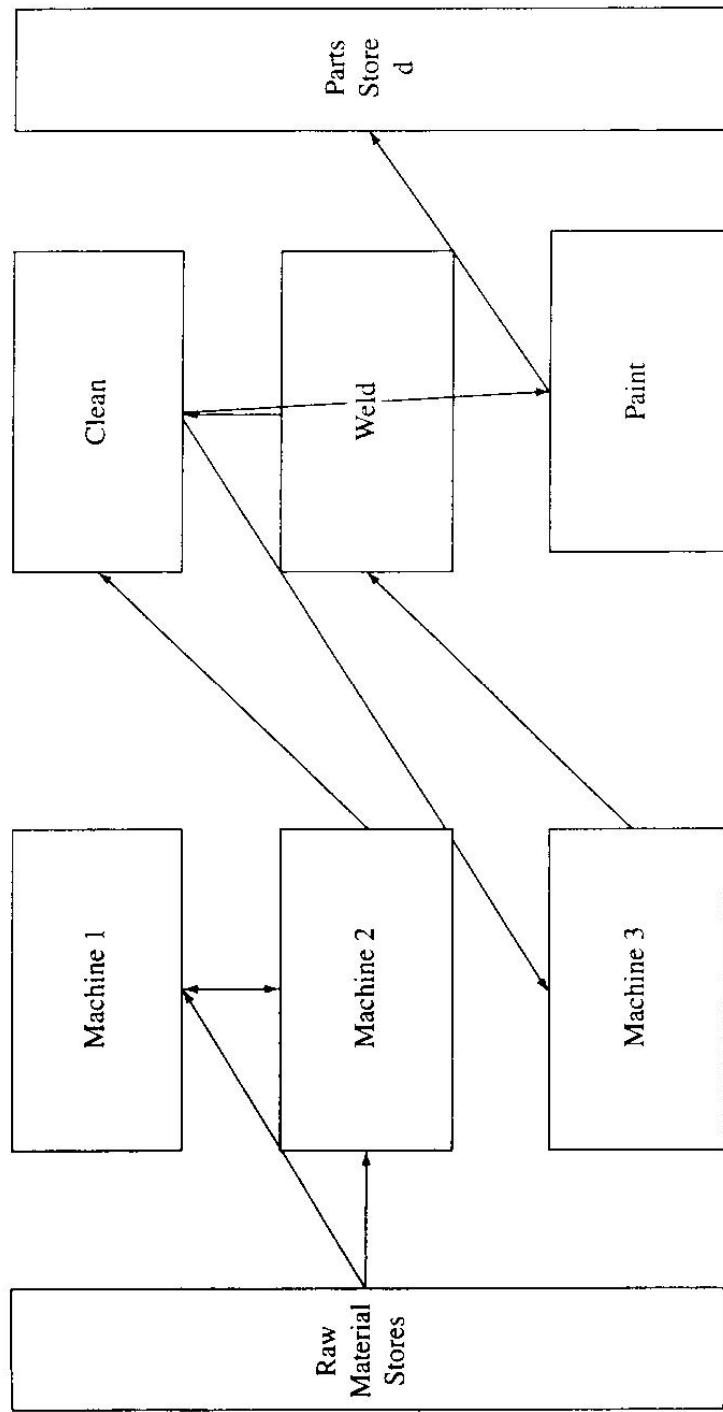
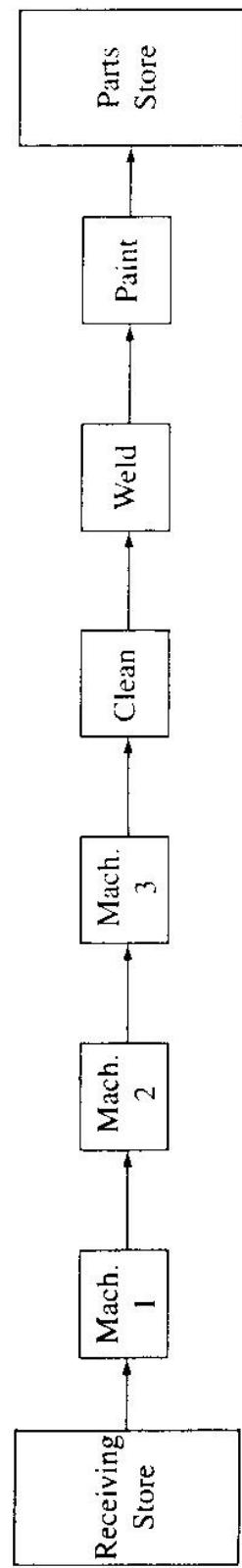


Figure 5-1b Product Flow Layout



FABRICATION OF INDIVIDUAL PARTS

The following techniques are mostly used in process layouts to study the flow of each individual parts.

1. A string diagram
2. A multi-column process chart
3. A from-to chart
4. A process chart

String Diagram

Circles represent equipment and the line between circles will indicate flow.

- (1) Flow lines between adjacent circles will be from middle of circle to middle of circle.
- (2) If we jump a department, we will place the line **above** the circles.
- (3) If the flow is backward, *backtracking*, the flow line is drawn under the circles

<i>Part No.</i>	<i>No. of Steps Traveled</i>
1	9
2	13
3	17
4	17
5	<u>11</u>
Total	67

The second layout produced fewer steps:

<i>Part No.</i>	<i>No. of Steps Traveled</i>
1	19
2	11
3	11
4	7
5	<u>9</u>
Total	57

Figure 5-2 Routing for Five Parts

<i>Part No.</i>	<i>Routing (Operation Sequence)</i>
1	R A B D C F S
2	R B D C A S
3	R E F B A C D S
4	R F A C D S
5	R C A D S

Figure 5-3 String Diagram (Alphabetical Layout—First Try)

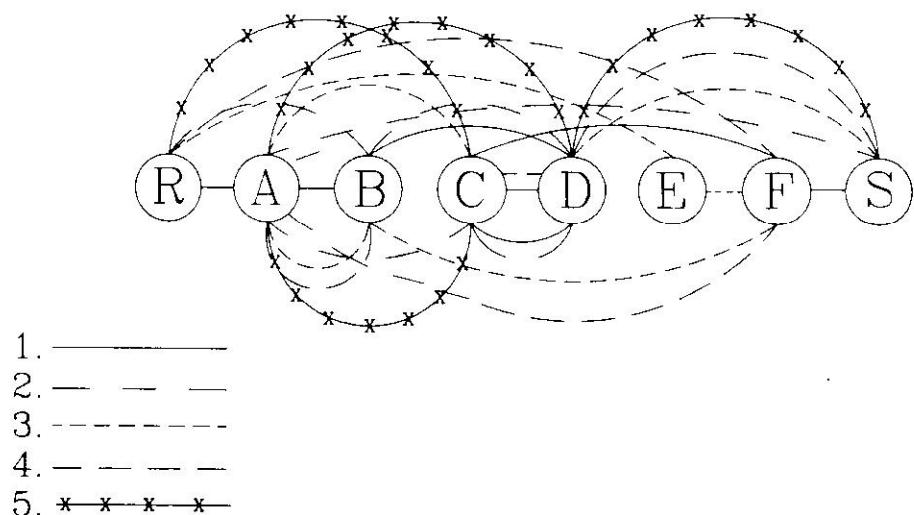


Figure 5-4 String Diagram—Improved Method

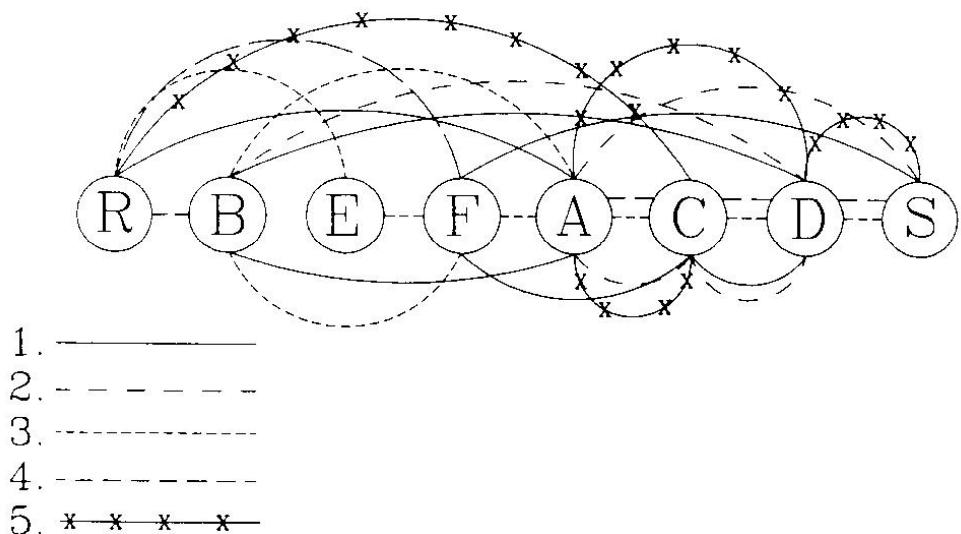


Figure 5-5 Multi-Column Process Chart

MULTI-COLUMN PROCESS CHART						
	PART NUMBERS					
	1	2	3	4	5	
R	○					
A	○					
B	○					
C	○	○				
D	○	○				
E			○			
F			○			
S	○	○	○	○	○	TOTAL
# STEPS	9	13	17	17	11	67
LEAST STEPS	7	7	7	7	7	35

$$\text{EFFICIENCY} - 35/67 = 52\%$$

Multi-Column Process Chart

Using the same routing information used in the string diagram for our five parts, we can show the flow for each part on a multi-column chart.

From-To Chart

The from-to chart is a *quantitative* technique and is the most exact technique of the three.

The quantity and weight for each part is established.

Routing for Five Parts

<i>Part No.</i>	<i>Routing (Operation Sequence)</i>
1	RABDCFS
2	RBDCAS
3	REFBACDS
4	RFACDS
5	RCADS

Figure 5-7 Part Quantity and Weight Data

Part No.	Quantity per Day	Weight in Pounds	Total Weight (lbs)	Relative Importance*
1	2,000	0.5	1,000	1.0
2	2,000	9.0	18,000	18.0
3	2,000	0.5	1,000	1.0
4	2,000	15.0	30,000	30.0
5	2,000	3.75	7,500	7.4

*These numbers and the routing in Figure 5-2 create the weighted value of each move.

Figure 5-8 From-To Chart—Example of Part 1 with a Relative Value of 1

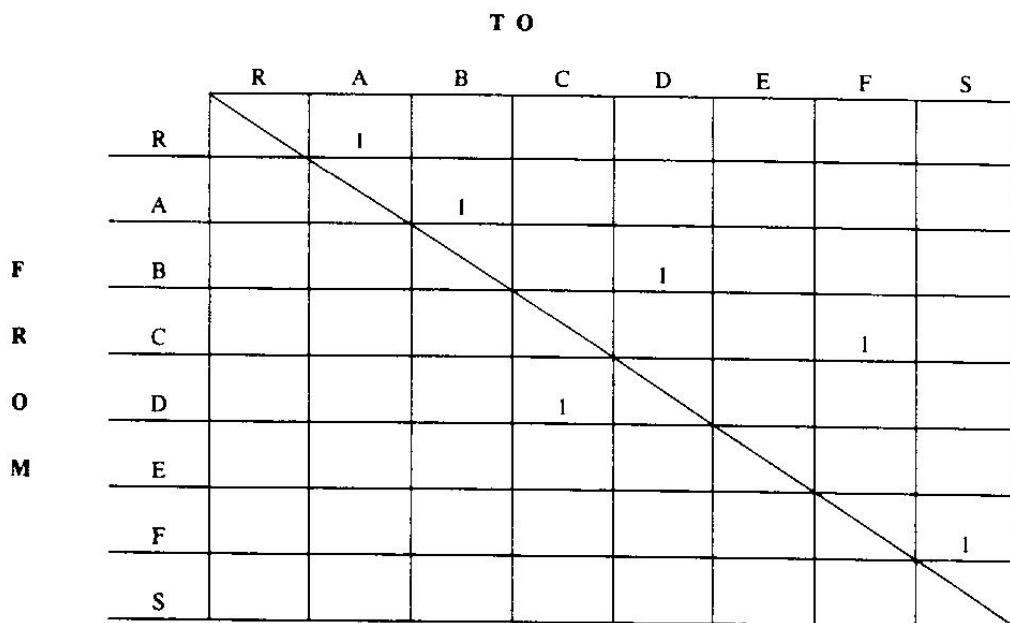


Figure 5-9 From-To Chart—Alphabetical Layout

		T O								
		R	A	B	C	D	E	F	S	Total
R			1	18	7.5		1	30		57.5
A				1	1+30	7.5			18	57.5
F		B		1		1+18				20
R		C		18+7.5		30+1			1	57.5
O		D			18+1				30+1 7.5	57.5
M		E						1		1
F			30	1					1	32
S										
										TOTAL: 283

Figure 5-10 From-To Chart—Alphabetical Layout Analysis

		TO										
		R	A	B	C	D	E	F	S	T	P.P.	
R	R		1 ①	18 (36)	7.5 (22.5)		1 ⑤	30 (180)		57.5	244.5	
	A			1 ①	31 (62)	7.5 (22.5)			18 (108)	57.5	193.5	
F	B		1 ②			19 (38)				20	40	
	C		25.5 (102)			31 (31)		1 ③		57.5	136	
O	D				19 (38)				38.5 (115.5)	57.5	153.5	
	E							1 ①		1	1	
M	F		30 (300)	1 ⑧					1 ①	32	309	
	S									—	—	
T P.P.			57.5	20	57.5	57.5	1	32	57.5	283	1077.5	

P.P. = penalty points

Figure 5-11 From-To Chart—Alphabetical Layout Analysis

		T O									
		R	E	F	B	A	C	D	S	T	P.P.
R	R		1 ①	30 60	18 54	1 ④	7.5 37.5			57.5	156.5
	E			1 ①						1	1
F	F				1 ①	30 60			1 ⑤	32	66
	B					1 ①		1+18 57		20	58
O	A				1 ②		1+30 31	7.5 15	18 54	57.5	102
	C			1 ⑥		18+7.5 51		1+30 31		57.5	88
M	D						1+18 38		1+30+7.5 38.5	57.5	76.5
	S									—	—
T			1	32	20	57.5	57.5	57.5	57.5	283	548.0
P.P.			1	67	57	116	106.5	103	97.5		

Figure 5-12 Sample Process Chart

FRED MEYERS & ASSOCIATES				PROCESS CHART				
<input type="checkbox"/> PRESENT METHOD <input checked="" type="checkbox"/> PROPOSED METHOD 1		DATE: 2		PAGE OF				
PART DESCRIPTION:				3				
OPERATION DESCRIPTION: 4								
SUMMARY <input type="checkbox"/> OPERATIONS <input type="checkbox"/> TRANSPORT <input type="checkbox"/> INSPECTIONS <input type="checkbox"/> DELAYS <input type="checkbox"/> STORAGES		PRESENT NO TIME PROPOSED NO TIME DIFF NO TIME	ANALYSIS: WHY 6 WHAT 6 WHERE 6 WHO 6 HOW 6		FLOW DIAGRAM ATTACHED (IMPORTANT)			
DIST. TRAVELED FT.		FT.	FT.	STUDIED BY:				
STEP	DETAILS OF PROCESS	METHOD	PERMIT	TRANSPORT	INSPECTOR	DELAY		
1								
2								
3	8	9	10	11	12	13	14	15
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
							TIME/COST CALCULATIONS	

Process Chart

A process chart is produced for every fabricated part.

Process chart should invoke these questions:

1. Can I eliminate this step?
2. Can I automate this step?
3. Can I combine this step with another one?
4. Can I change the routing to reduce distances traveled?
5. Can I move workstations closer together?
6. Can I justify production aids to increase effectiveness?
7. How much does this part cost to produce?

Step-by-Step Description for the Process Chart

- 1 Present Method (or) 2 Proposed Method
- 2 Date _____ Page _____ of _____: Get in the documentation habit!
- 3 Part description: most important information on the form.
- 4 Operation description: Also, any miscellaneous information
- 5 Summary: The summary is used only for the proposed solution
- 6 Analysis: how we come up with the proposed method
- 7 Flow diagram attached (IMPORTANT): flow diagram is the picture (worth a1000 words!)
- 8 Details of process: A description of what happens in each step
- 9 Method: how the material was transported—by fork truck, etc.
- 10 Symbols: The process chart symbols
- 11 Distance in feet: is used only with the transportation symbol
- 12 Quantity:
 - a. Operations: The pieces per hour would be recorded here.
 - b. Transportation: How many were moved at a time.
 - c. Inspection: How many pieces per hour or frequency of inspection.
 - d. Delays: How many pieces are in a container
 - e. Storage: How many pieces are there per storage unit.
- 13 Time in hours per unit (.00001): useful for determining cost
- 14 Cost per unit: Hours per unit multiplied by a labor rate per hour
- 15 Time/cost calculations: provide cost formulas

TOTAL PLANT FLOW

The three techniques studied in this section are:

1. The flow diagram
2. The operations chart
3. The flow process chart

Flow Diagrams

The *flow diagrams* show the path traveled by each part from receiving to stores, fabrication, subassembly, final assembly, packout, warehousing, and to shipping.

The flow diagram will point out problems with such factors as cross traffic, backtracking, and distance traveled

The Operations Chart

The *operations chart* has a circle for each operation required to fabricate each part, to assemble each part to the final assembly, and to packout the finished product.

It shows the raw material, the buyouts, the fabrication sequence, the assembly sequence, the equipment needs, the time standards, and a glimpse of the layout.

Flow Process Chart

The *flow process chart* combines the operations chart with the process chart. The operations chart uses only one symbol—the circle or operations symbol.

Computer-Aided Flow Design and Analysis

The use of this technology allows the user to consider and evaluate many configurations without the expense of physically rearranging the facility to achieve an optimum level of efficiency in material flow.

The software produces actual path diagrams showing how materials travel among various activity centers. Line thickness indicates frequency, hence the cost.

Critical paths, bottlenecks, and flow efficiency can be determined. It is an aid:

- To redesign material flow
- To eliminate or significantly reduce nonvalue added handling
- To reduce total part/product travel distance
- To reduce work-in-process inventories
- To evaluate alternate material handling systems

Figure 5-13 Flow Diagram

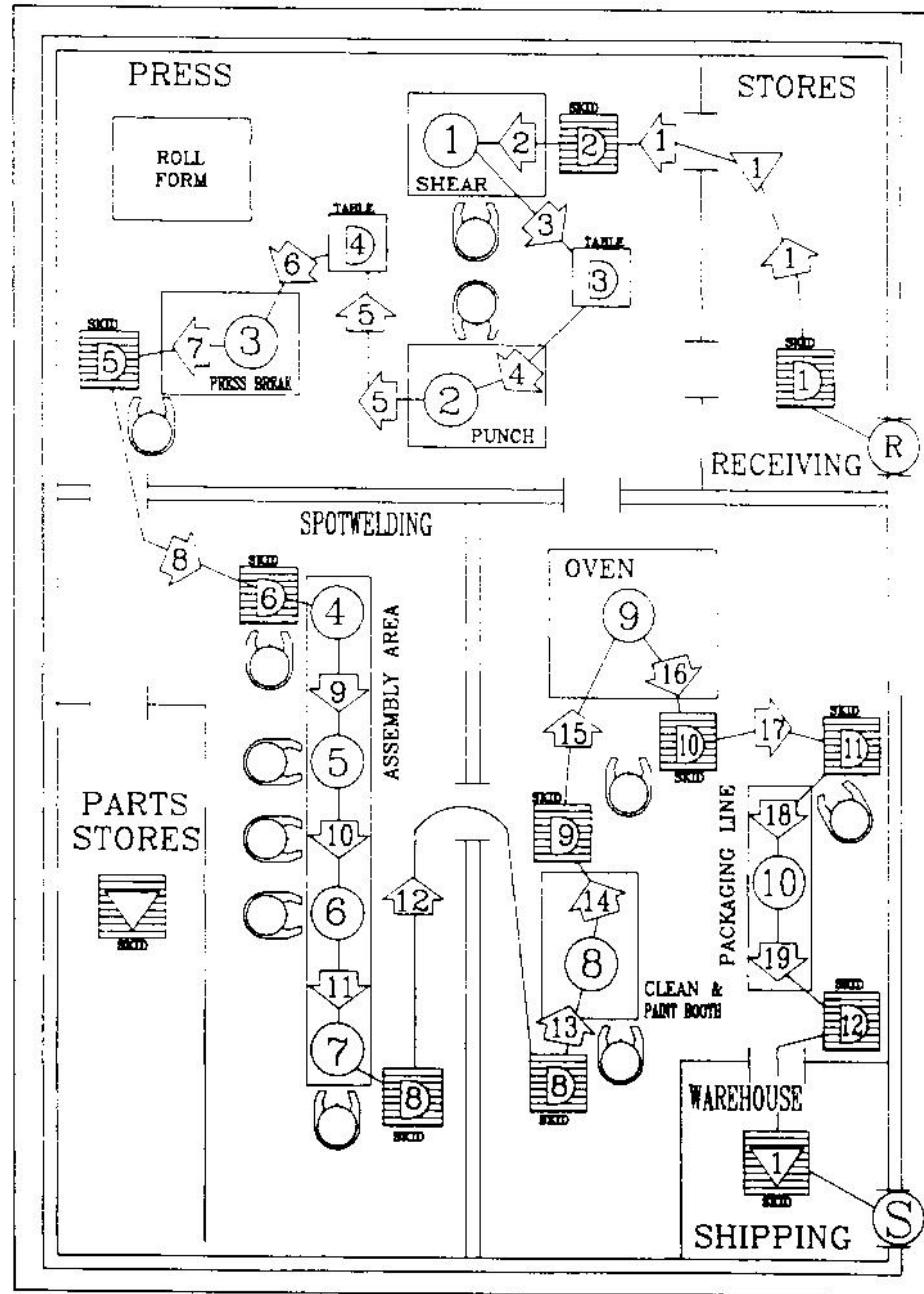


Figure 5-14 Flow Diagram—Toolbox Plant

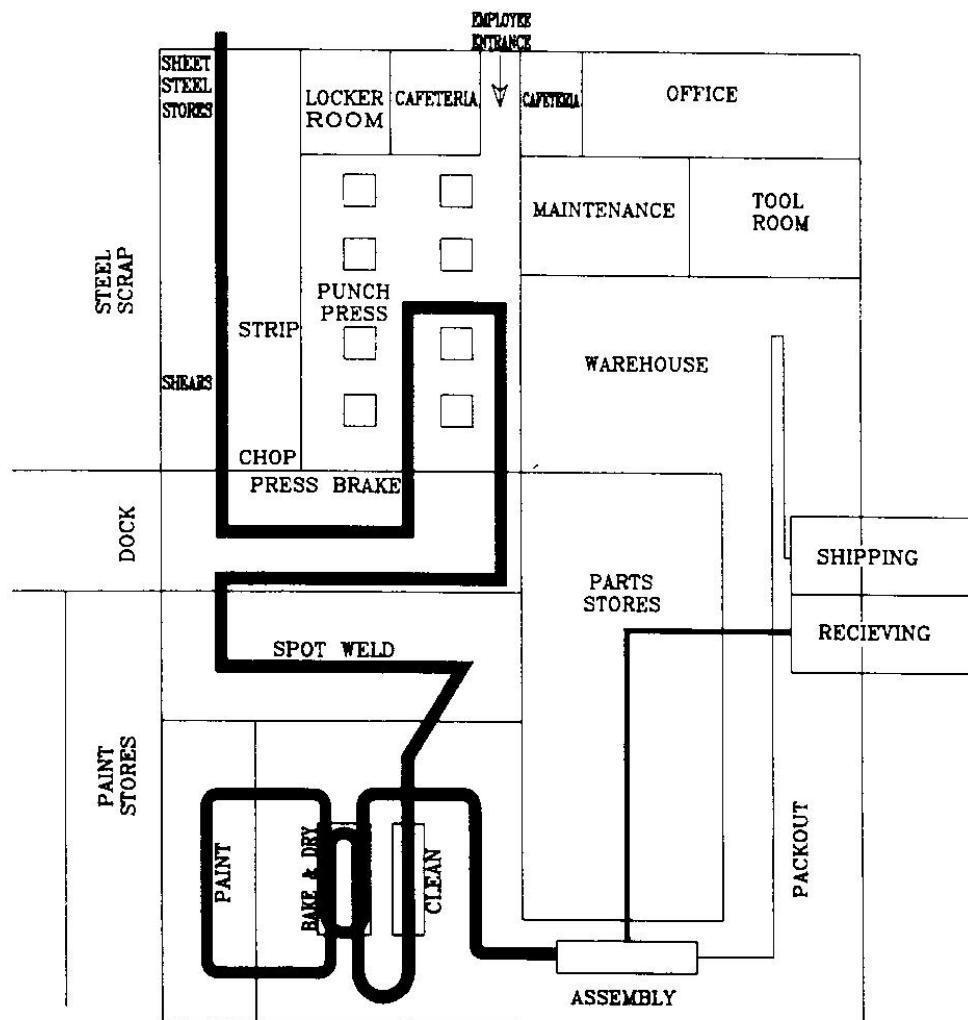


Figure 5-15 Sample Operation Chart

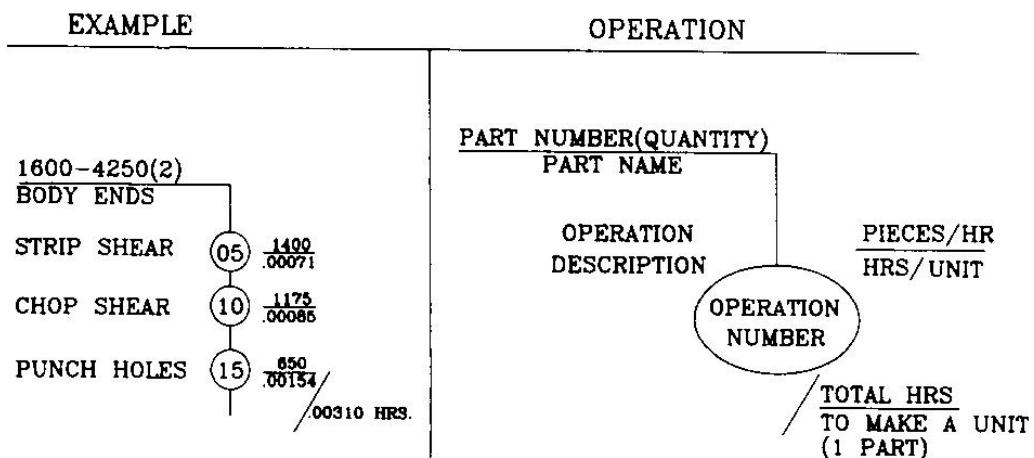


Figure 5-17 Sample Operations Chart

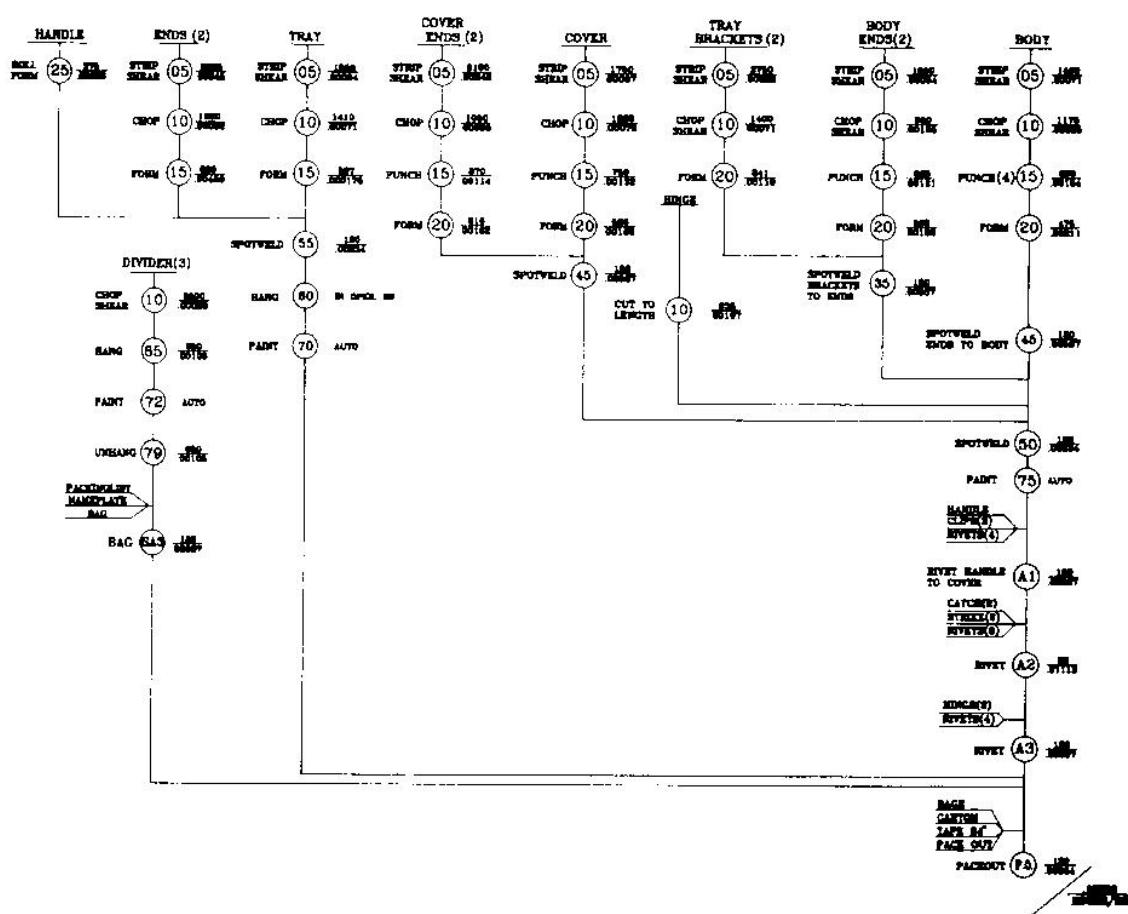


Figure 5-18 Flow Process Chart (Courtesy of Christine M. Stephens, CAD Designer)

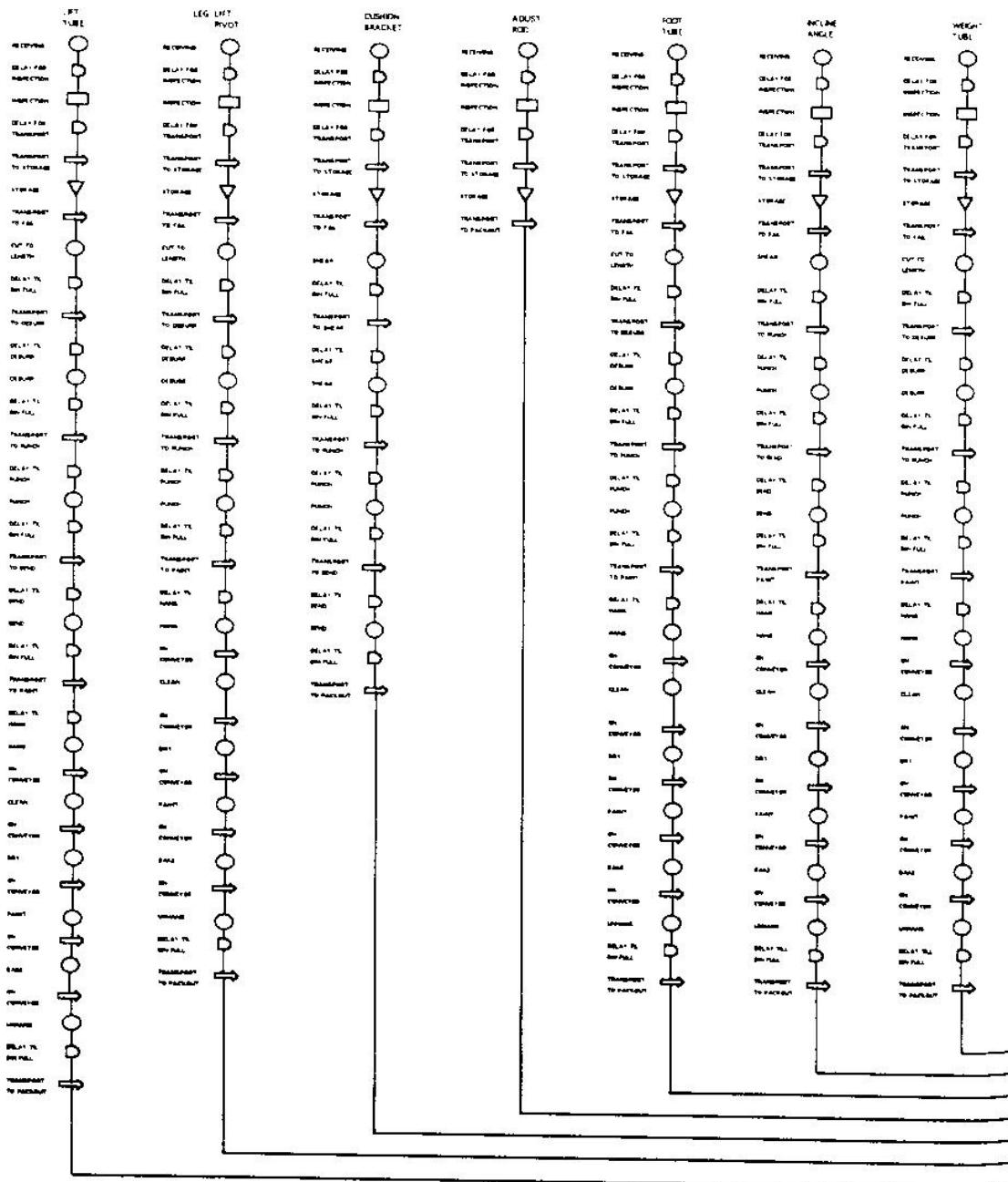


Figure 5-18 (con'd) Flow Process Chart

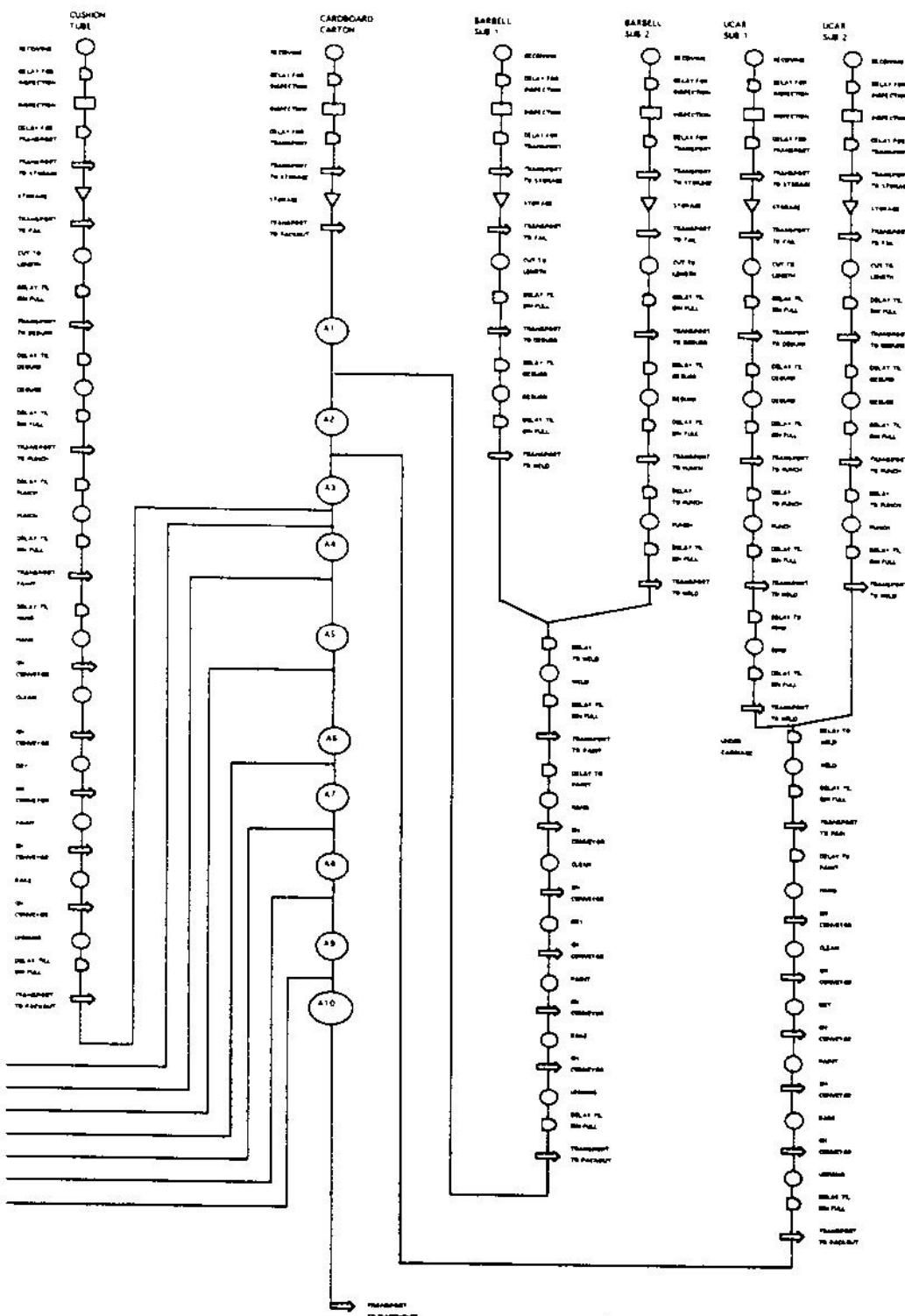


Figure 5-19 Flow Lines Produced by FactoryFLOW (Courtesy of Engineering Animation, Inc.)

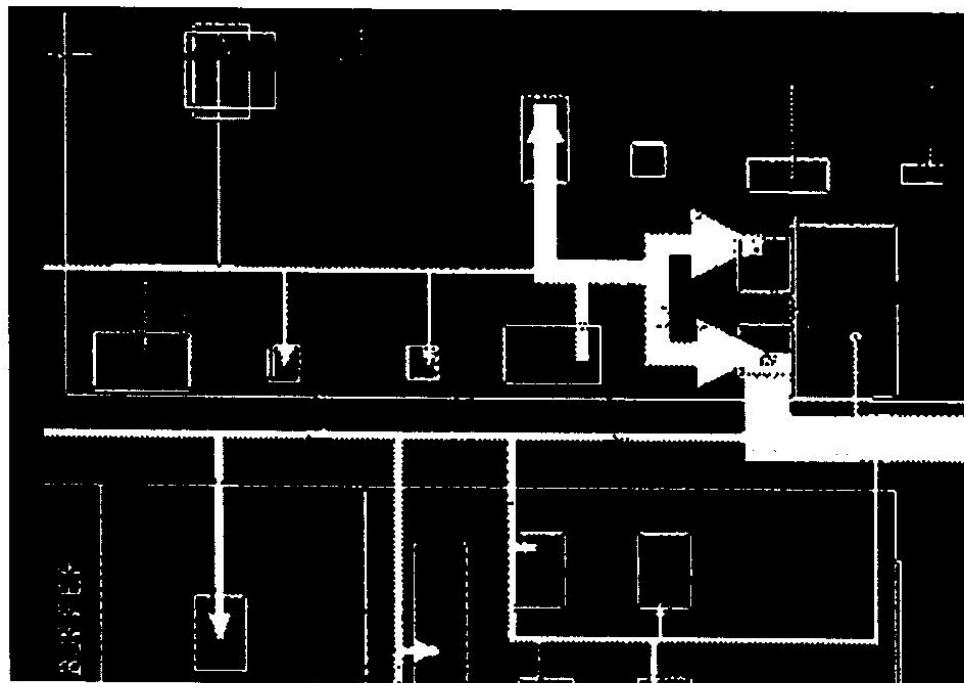
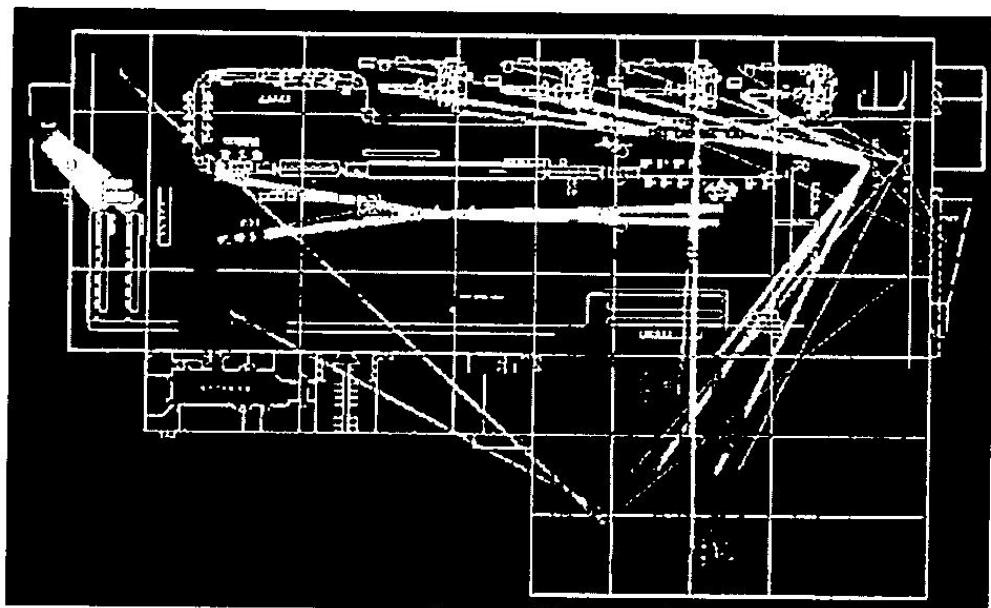


Figure 5-20 Proposed Layout for an Automotive Plant Using FactoryFLOW (Courtesy of Engineering Animation, Inc.)



Chapter 6

Activity Relationship Analysis

Objectives

In this chapter the activity relation chart, its uses, construction, and analysis along with the related worksheet and the dimensionless block diagram are discussed.

In addition to manufacturing flow, other departments, services, and facilities must be included to establish good overall flow.

The techniques in this chapter will help us to establish the optimum placement of everything that needs space and include:

1. The activity relationship diagram
2. The worksheet
3. The dimensionless block diagram
4. The flow analysis

THE ACTIVITY RELATIONSHIP DIAGRAM

The *activity relationship diagram*, also called an *affinity analysis diagram*, shows the relationship of every department, office, or service area with every other department and area.

It helps with the analysis of the relationship among all activity centers, the need for their closeness, and hence, the arrangement of the facility.

<i>Code</i>	<i>Definition</i>
“A”	Absolutely necessary that these two departments be next to each other
“E”	Especially important
“I”	Important
“O”	Ordinary importance
“U”	Unimportant
“X”	Closeness undesirable

Figure 6-1 Activity Relationship Diagram

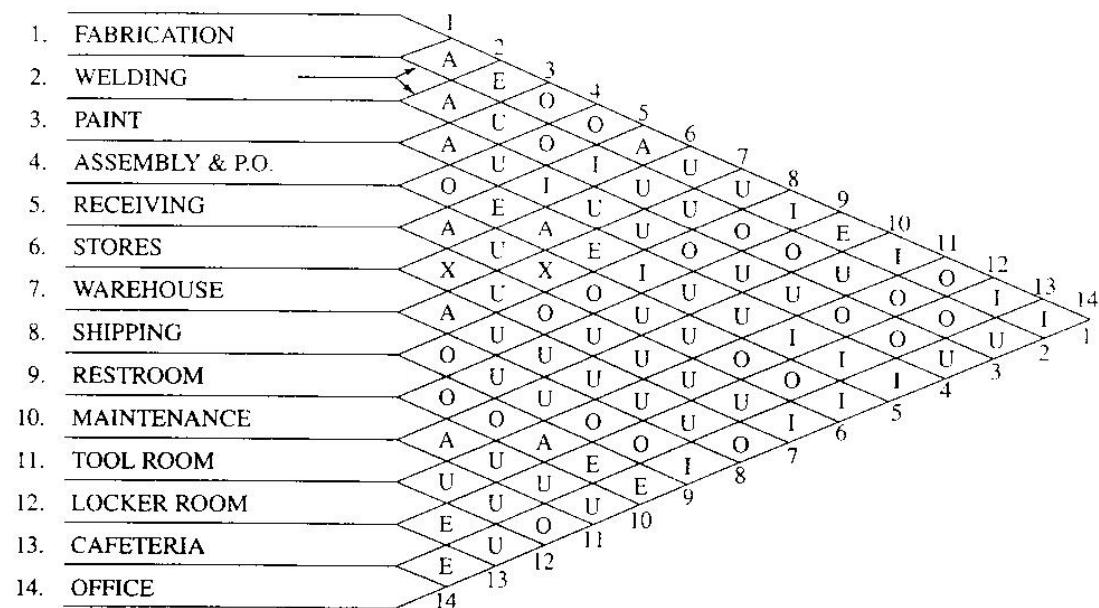


Figure 6-2 Activity Relationship Worksheet

Activities	A	E	I	O	U	X
1. Fabrication	2, 6	3, 10	9, 11, 13, 14	4, 5, 12	7, 8	
2. Welding	1, 3	6	9, 10, 12, 13, 5	9, 12, 13, 9	7, 8, 4, 11, 14	
3. Paint	2, 4	1	6	1, 5	5, 7, 8, 10, 11, 14	
4. Assembly and P.O.	3, 7	6, 8	9, 12, 13, 14	4, 2, 1, 9, 12, 13	2, 10, 11	
5. Receiving	6		14	3, 7, 10, 11	3, 7, 10, 11	
6. Stores	5, 1	4	3, 2, 14	9	8, 10, 11, 12, 13	8
7. Warehouse	4, 8			14	5, 3, 2, 1, 9, 10, 11, 12, 13	7
8. Shipping	7	4	14	9, 12, 13	6, 3, 2, 1, 10, 11	6
9. Restrooms	12	13, 14	4, 1	8, 6, 5, 11, 3, 2, 10	7	
10. Maintenance	11	1		9, 2	8, 7, 6, 5, 4, 3, 12, 13, 14	
11. Tool room	10		1	9, 14	8, 7, 6, 5, 4, 3, 2, 12, 13	
12. Locker room	9	13	4	8, 5, 3, 2, 1	11, 10, 7, 6, 14	
13. Cafeteria	14, 12, 9	4, 1		8, 5, 3, 2	10, 11, 7, 6	
14. Office	13, 9	8, 6, 5, 4, 1		11, 7	12, 10, 2, 3	

Figure 6-3 One Square Representing the Fabrication Department

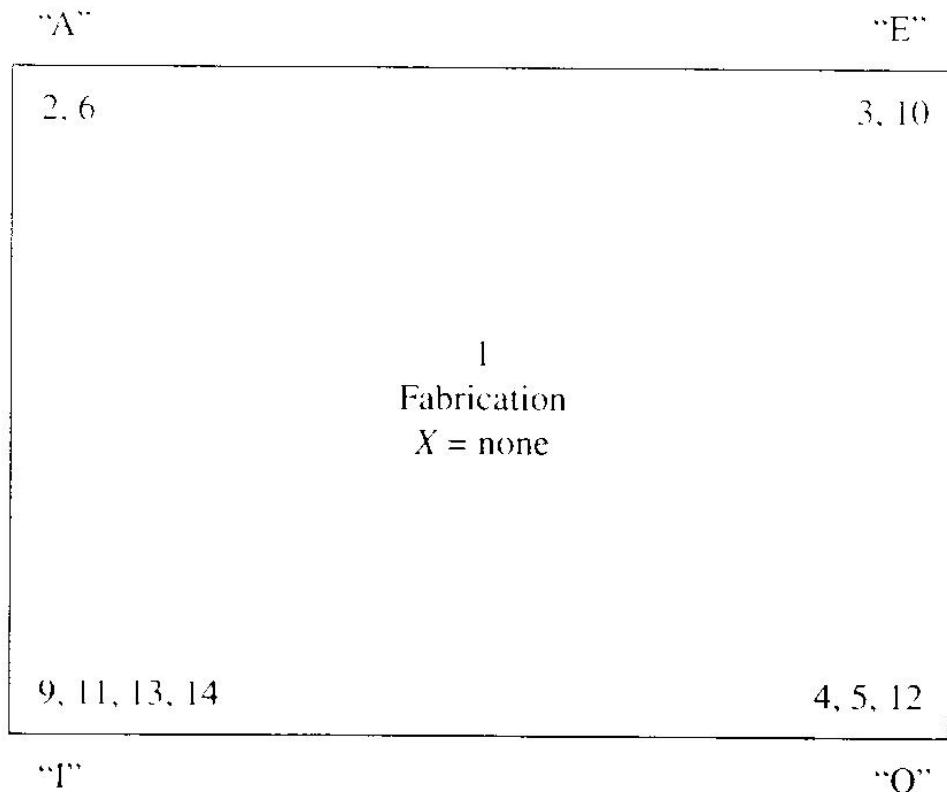


Figure 6-4 Dimensionless Block Diagram

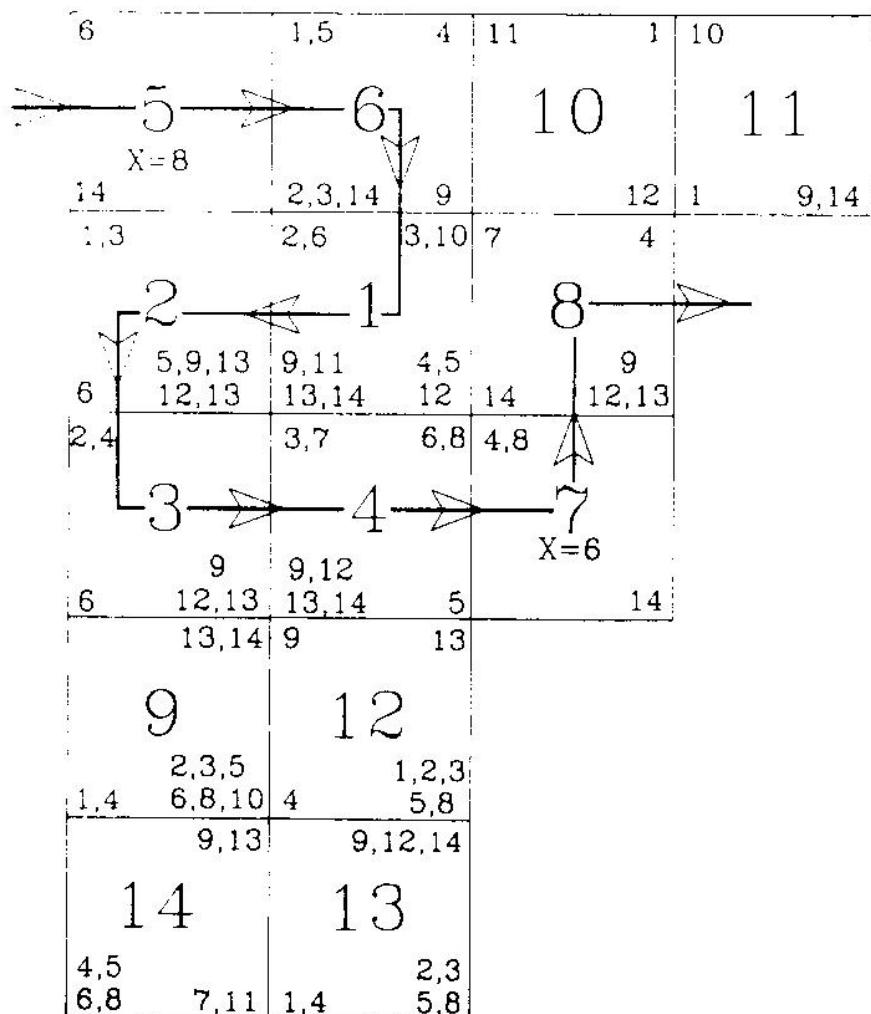
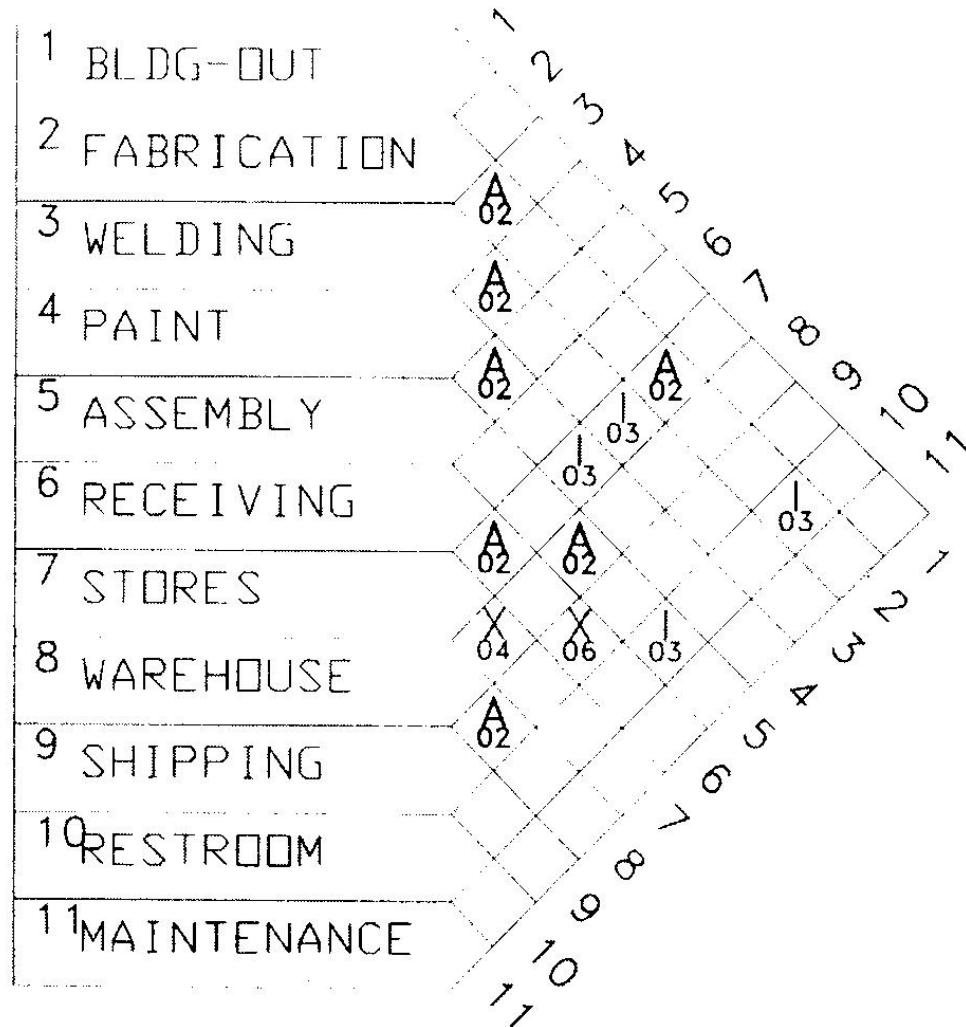


Figure 6-9 FactoryPLAN-Generated Activity Relationship Chart (Courtesy of Engineering Animation, Inc.)



Step-by-step procedure for developing an activity relationship diagram:

1. List all departments in a vertical column on the left-hand side of the form
2. Starting with line 1, establish the relationship code for each department.
Establishing these relationship codes requires an understanding of all the
3. Reason codes can be for clarification

<i>Reason Code</i>	<i>Reason</i>
1	For better flow
2	All material moves between these two departments
3	People movement
and so on	and so on

Determining the Relationship Code

Do not overstate the relationship between the work centers.

Follow the rule-of thumb :

<i>Code</i>	<i>Percentage</i>
“A”	5
“E”	10
“I”	15
“O”	25

The total number of relationships, N , between all possible pairs of work centers in any facility can be determined as follows ($n = \# \text{ of departments}$):

$$N = n(n - 1) / 2$$

For example, for a facility with 25 different departments or work centers:

$$N = 25(25 - 1) / 2 = 300 \text{ possible relationships.}$$

WORKSHEET

The *worksheet* is an interim step between the activity relationship diagram and the dimensionless block diagram.

1. List all the activities down the left-hand side of a sheet of paper.
2. Make six columns to the right of the activity column and title these six columns, “A,” “E,” “I,” “O,” “U,” and “X”.
3. Taking one activity at a time, list the activity number(s) under the proper relationship code.

DIMENSIONLESS BLOCK DIAGRAM

The *dimensionless block diagram* is the first layout attempt

Even though this layout is dimensionless, it will be the basis for the master layout and plot plan.

1. Cut up a sheet of paper into about 2-inch 3 2-inch squares.
2. Place an activity number in the center of each square.
3. Taking one square at a time, make a template for that activity by placing the relationship codes in the following positions
 - a. “A” relationship in the top left-hand corner
 - b. “E” relationship in the top right corner
 - c. “I” relationship in the bottom left corner
 - d. “O” relationships in the bottom right corner
 - e. “U” relationships omitted
 - f. “X” relationships in the center under the activity number.
4. Each activity center is represented by one square.
5. Arrange the templates so as to satisfy as many activity codes as possible.

FLOW ANALYSIS

Perform flow analyses on the dimensionless block diagram.

Starting with receiving, show the movement of material to stores, to fabrication, to welding, to paint, to assembly and packout, to the warehouse, and to shipping.

Chapter 7

Ergonomics and Workstation Design Space Requirements

Objectives

In this chapter the basic concepts of ergonomics as it relates to workstation design are discussed. Considerations for operator space needs are introduced.

WORKSTATION DESIGN

The result of ergonomics and workstation design is a workstation layout, and the workstation layout determines the space requirements.

The manufacturing department's total space requirements are just a total of individual space requirements.

Ergonomics is the science of preventing muscular/skeletal injuries in the workplace. It is the study of workplace design and the integration of workers with their environment.

The following information must be included in any workstation design:

1. Worktable, machines, and facilities
2. Incoming materials (materials packaging and quantity must be considered)
3. Outgoing material
4. Operators space and access to equipment
5. Location of waste and rejects
6. Fixture and tools
7. Scale of drawing

Figure 7-2 Workplace Layout—Old Method

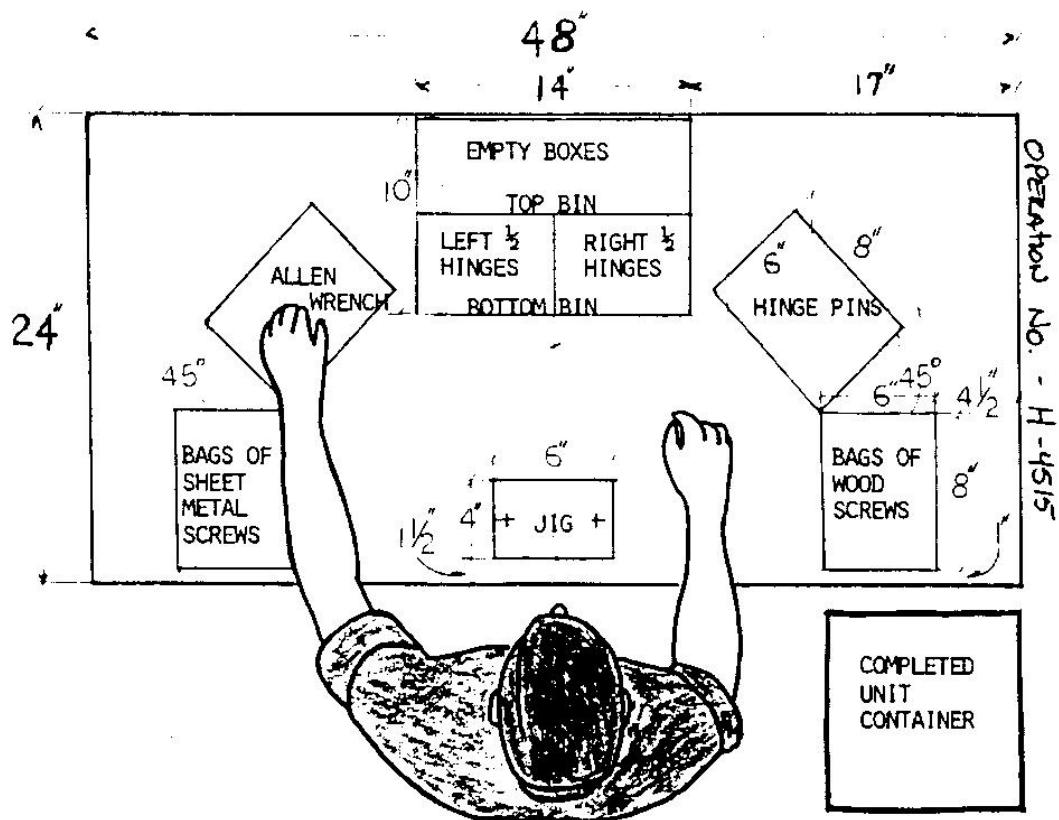


Figure 7-3 Workbench (Courtesy of American Seating Co.)

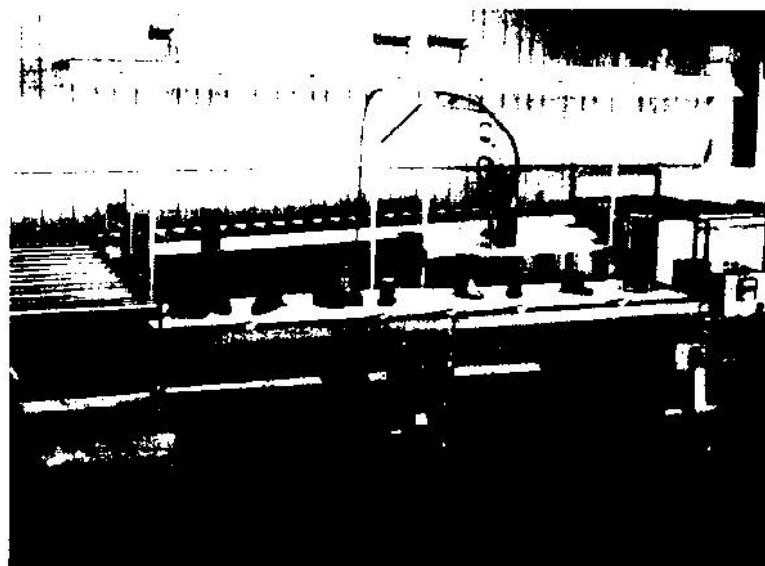


Figure 7-4 Workstation Layout

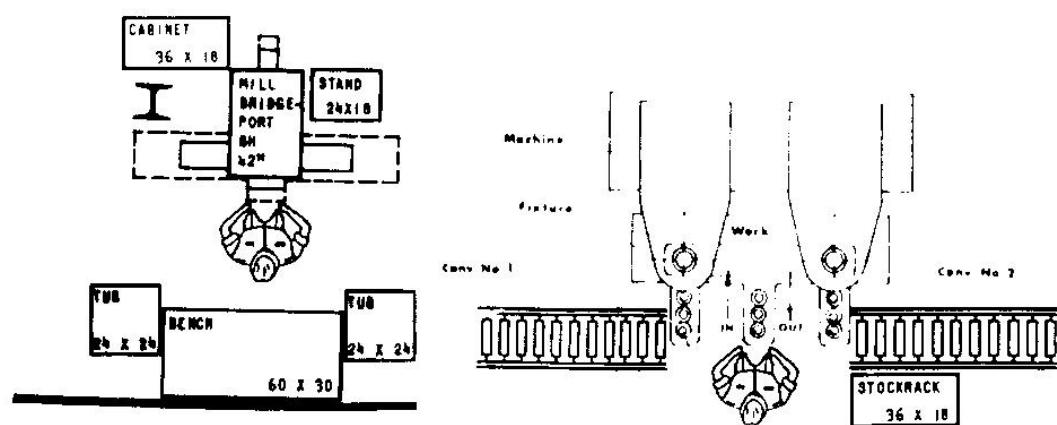


Figure 7-5 Strip Shear—Total Square Feet: 96

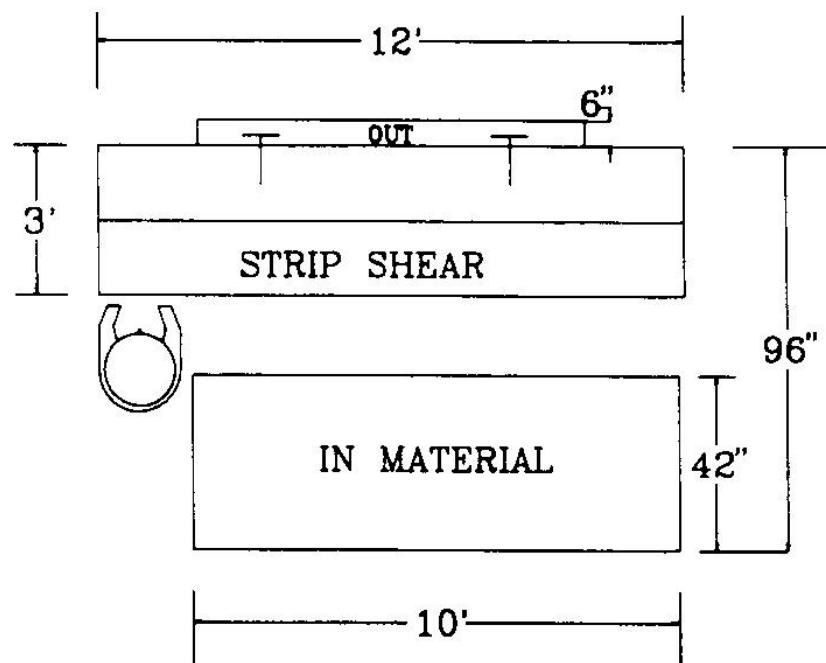


Figure 7-6 Punch Press—Total Square Feet: 88

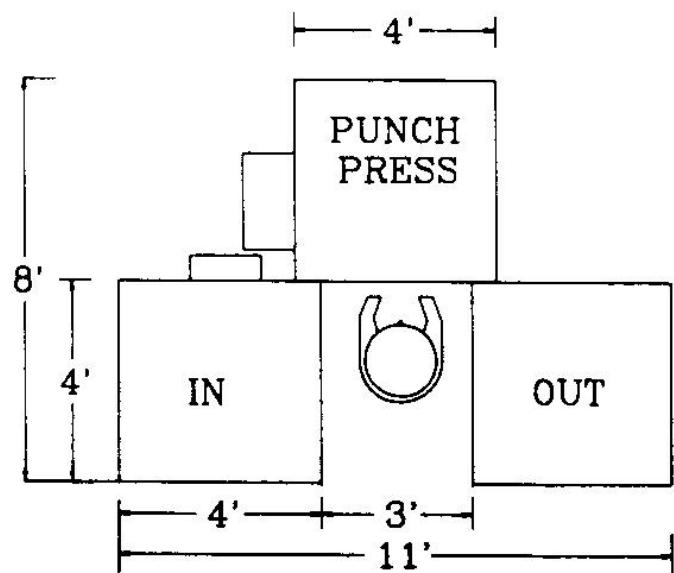


Figure 7-8 Press Brake—Total Square Feet: 88

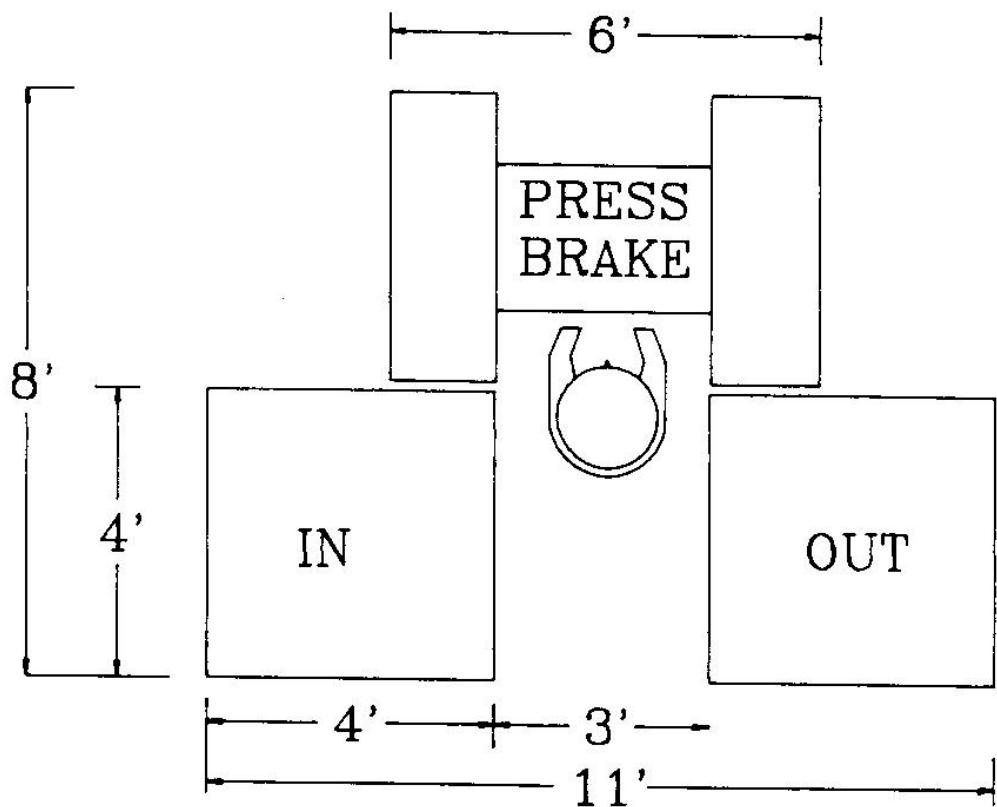


Figure 7-10 Fabrication Department Layout

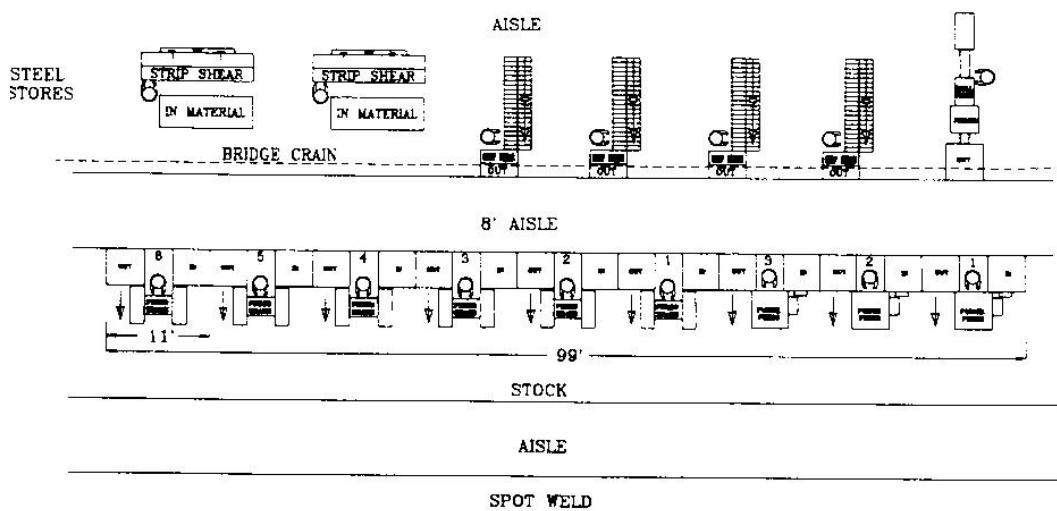


Figure 7-15 Operator Considerations (Courtesy of Alden Systems Co., Inc.)

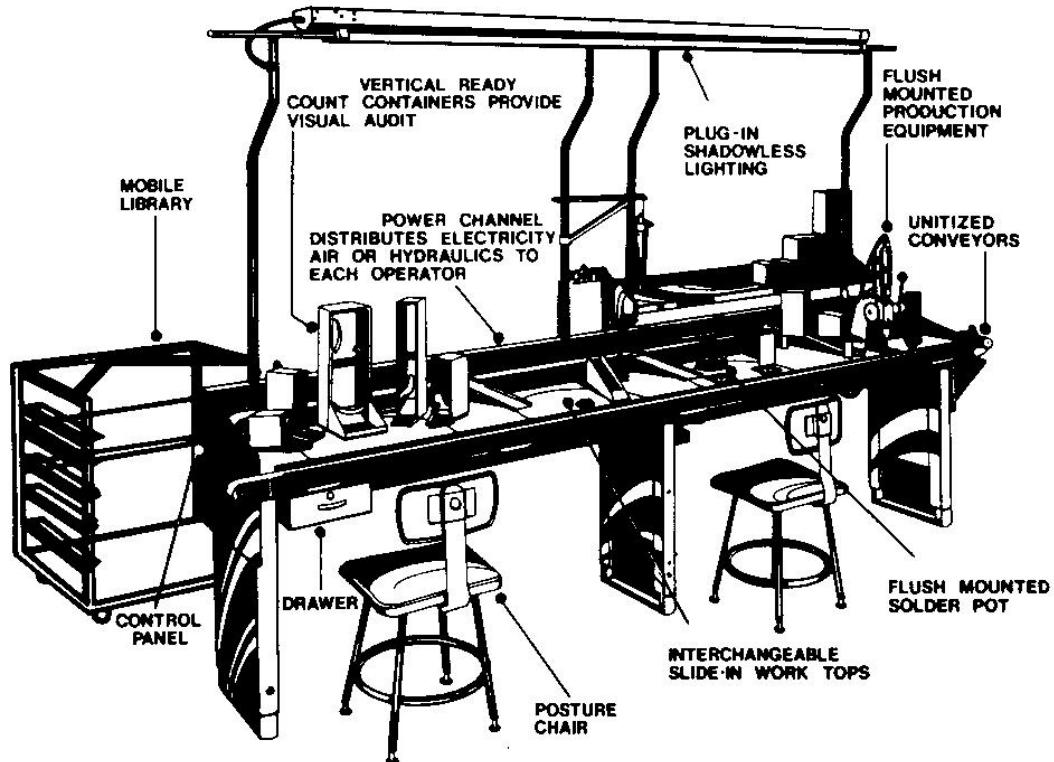


Figure 7-16 Machinery and Equipment Layout Data Sheet—Blank Form

FRED MEYERS & ASSOCIATES		MACHINERY & EQUIPMENT LAYOUT DATA SHEET	
DESCRIPTION OF MACHINERY & EQUIPMENT:		DATE:	
DESCRIPTION OF OPERATION:			
DESIGNED BY:	COMPANY NAME	LOCATION:	
PHOTO		LAYOUT DRAWING	
SCALE =			
Reference Notations/Changes			
MACHINE SPECIFICATIONS			

ERGONOMICS AND THE PRINCIPLES OF MOTION ECONOMY

Effectiveness is doing the right job. *Efficiency* is using the job right.

These principles enable the workstation designer to achieve these goals.

Principle 1: Hand Motions

1. Eliminate as many hand motions as possible.
2. Combine motions together to eliminate other motions.
3. Make motions as short as possible, discourage leaning (excessive reaching)
4. Reduce the force required as much as possible.
5. Keep both hands equally busy.
6. Use mirror image moves.
7. Do not use the hand as a holding device.
8. Locate frequently used tools and materials closer to the point of use.

Principle 2: Basic Motion Types

Ballistic motions are fast motions created by putting one set of muscles in motion and **not** trying to stop those motions by using other muscles. Ballistic motions should be encouraged.

Controlled or restricted motions are the opposite of ballistic motions and require more control especially at the end of the motion. They should be eliminated when possible—they are costly, fatiguing, and unsafe.

Continuous motions are curved motions and are more **natural** than straight-line motions.

Principle 3: Location of Parts and Tools

1. Have a fixed location for everything.
2. Place everything as close to the point of use as possible.

Principle 4: Free the Hands from as Much Work as Possible

Keep in mind: Operator's hands are the most expensive fixture that a designer could use.

1. Fixtures and jigs are designed to hold parts.
2. Foot-operated control devices can be designed to activate equipment.
3. Conveyors or powered round tables can move parts.
4. Fixtures can be electric, air, hydraulic, and manually activated.

Principle 5: Use Gravity

Gravity is free power. Use it!

Gravity can move parts closer to the operator by putting an incline in the bottom of parts hoppers.

Gravity can also be used to remove finished parts from the workstation by using chutes or slides.

Principle 6: Operator Safety and Health Considerations

Keep safety hazards in mind and anticipate emergency action requirements while designing the workstation.

Design the workstation to eliminate straining the neck to look at things, to eliminate stooping or bending, to eliminate turning sideways or turning around, and to eliminate excessive reaches and moves.

Adequate lighting may not be available in the normal lighting of a manufacturing department, so additional lighting should be added—much like a desk lamp.

Operator space should be 3 3 3 feet, which is normal unless the workstation is wider.

SPACE DETERMINATION

The *space determination procedure* for most production departments starts with the workstation design.

	<i>Length</i>	<i>X</i>	<i>Width</i>	<i>X</i>	<i>Sq. Ft.</i>	<i>No. of stations</i>	<i>Total Square Feet</i>
Strip shear	12	X	8.5		102	2	204
Chop shear	15	X	5		75	4	300
Punch press	11	X	8		88	3	264
Press brake	11	X	8		88	6	528
Roll former	17	X	6		102	1	102
paint system	100	X	28		2,800	1	2,800
Spot welding assembly	34	X	28		952	1	952
	38	X	16		608	1	608
Total square feet							5,758

X 150 percent = 8,637 square feet are required

Chapter 8

Auxiliary Services Requirement Space

Objectives

In this chapter the need for the auxiliary or support services in a manufacturing facility is introduced and space determinations for these departments are discussed.

Manufacturing departments need support services, and these services need space.

1. Receiving and shipping
2. Storage
3. Warehousing
4. Maintenance and tool room
5. Utilities, heating, and air conditioning

RECEIVING AND SHIPPING

Receiving and shipping are two separate departments, but they have very similar people, equipment, and space requirements.

The receiving department is the start of the material flow, whereas the shipping department is the end of the material flow.

The Advantages and Disadvantages of Centralized Receiving and Shipping

1. Common equipment
2. Common personnel
3. Improved space utilization
4. Reduced facility cost.

The disadvantages of centralized shipping and receiving are space congestion and material flow. It would be a costly mistake to ship out some of the newly received parts.

Multiple receiving locations is also a possibility.

The Trucking Industry's Effect on Shipping and Receiving

The trucking industry is organized nationally to deliver raw materials and parts to industry in the morning and pick up shipments in the afternoon. This is known as ***less than truck load quantities*** (LTL).

The Functions of a Receiving Department

The functions of a receiving department are:

1. To assist in locating a trailer at the receiving dock door
2. To assist in the unloading of the material
3. To record the receipt of the number of containers
4. To open, separate, inspect, and count the material being received
5. To develop an overage, shortage, or damage reports as needed
6. To develop a receiving report
7. To send material to raw material stores or straight to production if needed.

Record receipt. When material is unloaded, it is checked in on a log. This log is often called a *Bates log*.

Over shortage and damage reports (OS&D). If the count is either over or under, an OS&D report is prepared and sent to purchasing for resolution. Damage suffered in shipment and quality problems are also reported on this form.

Receiving reports. The receiving report is the notice to the rest of our company that a product has been received and contains the following information:

- (1) the P.O. number (purchase order number),
- (2) the vendor's name and address,
- (3) the date,
- (4) the part number(s),
- (5) the part name(s),
- (6) the quantity,
- (7) the Bates log number, and
- (8) the packing list number.

Send to stores or production.

A significant portion of the problems associated with these manual operations of identification, counting, sorting, routing, and inventory management, and the resulting human errors can be alleviated through the use of **automatic identification and data capture (AIDC) technologies**.

Facilities Required for Receiving Departments

Dock doors. The number of dock doors needed is dependent on the arrival rate at peak time, and the service rate.

Dock plates, dock levelers, and dock boards. These tools are used to bridge the gap between the floors of buildings and the floors of trailers so that material can be moved on and off the trailer easily.

Aisles. Aisles leading from the trailers into the plant must be sized for the material handling equipment, the material being moved, and the frequency of trips.

Outside areas. Space considerations should be given to the following:

1. Trailer parking alone can take up 65 feet out from the plant wall.
2. Maneuvering space is the space between the road and parking area and is usually about 45 feet.
3. Roadways are 11 feet one way or 22 feet for two-way traffic.

Offices. Space for a desk, files for purchase orders, Bates logs, receiving reports, and over shortage and damage reports are needed. Usually 100 square feet per clerk are necessary.

Space Requirements for the Receiving Department

- 1) Visualization of the receiving job based on the number of finished products produced per day and the weight of those units.
- 2) The second method is the *facility approach*. It is based on the following data:
 - (1) dock doors;
 - (2) aisles;
 - (3) unloading hold area;
 - (4) working area to open, separate, count, and check quality;
 - (5) office area; and
 - (6) holding area for stores.

The Functions of a Shipping Department

1. Packaging finished goods for shipping
2. Addressing cartons or containers
3. Weighing each container
4. Collecting orders for shipping (stage)
5. Spotting trailers
6. Loading trailers
7. Creating bills of lading

Figure 8-1 Receiving Area

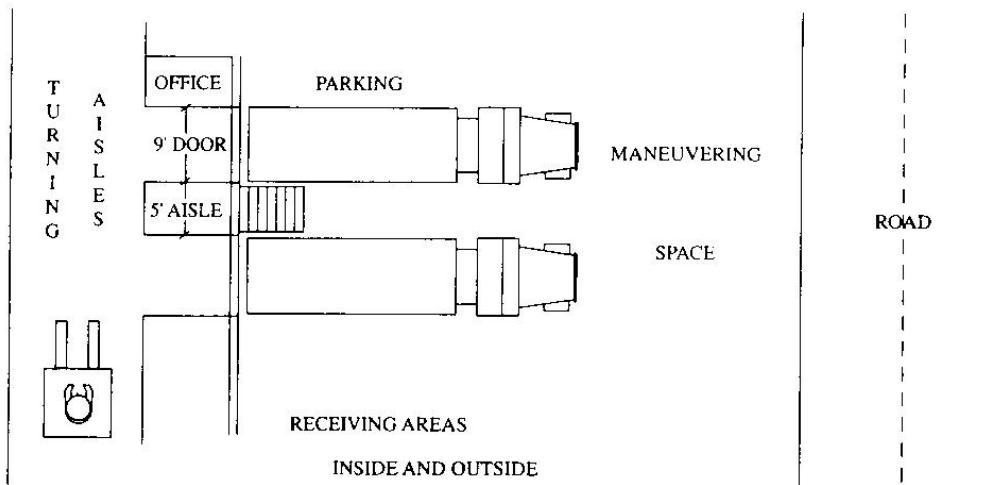


Figure 8-2 Receiving Dock for Steel

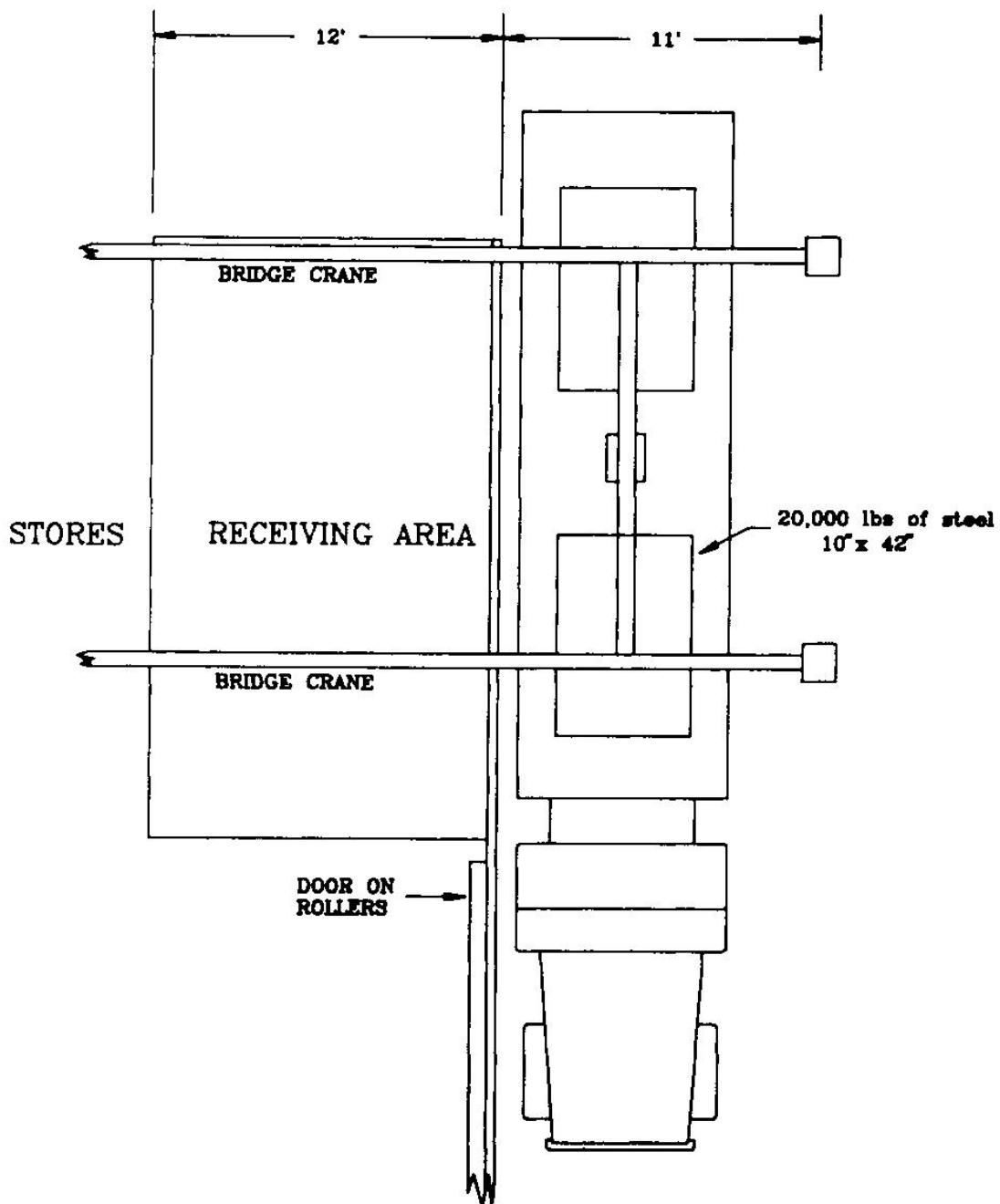


Figure 8-3 The Exterior of the Receiving Dock

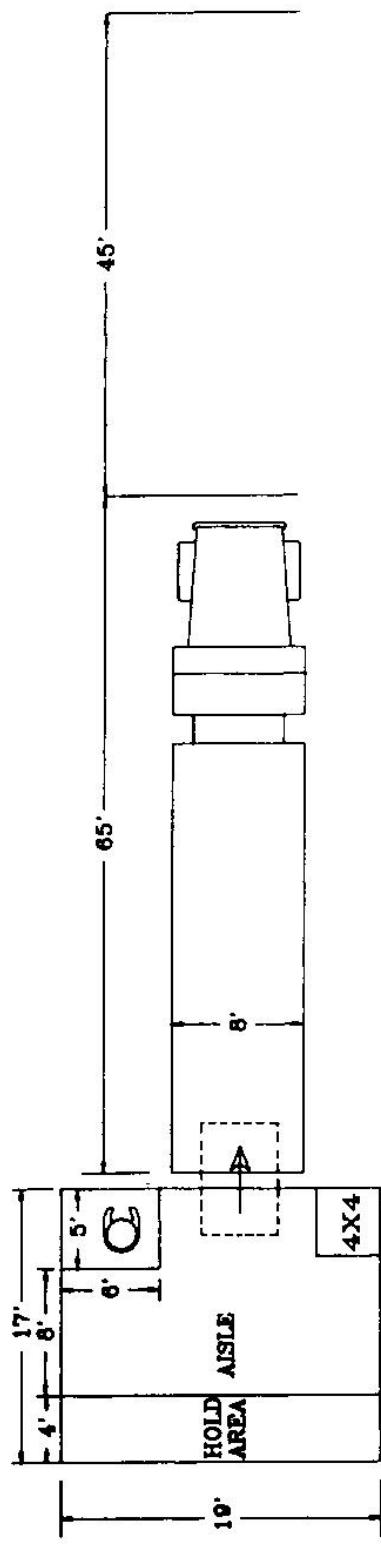
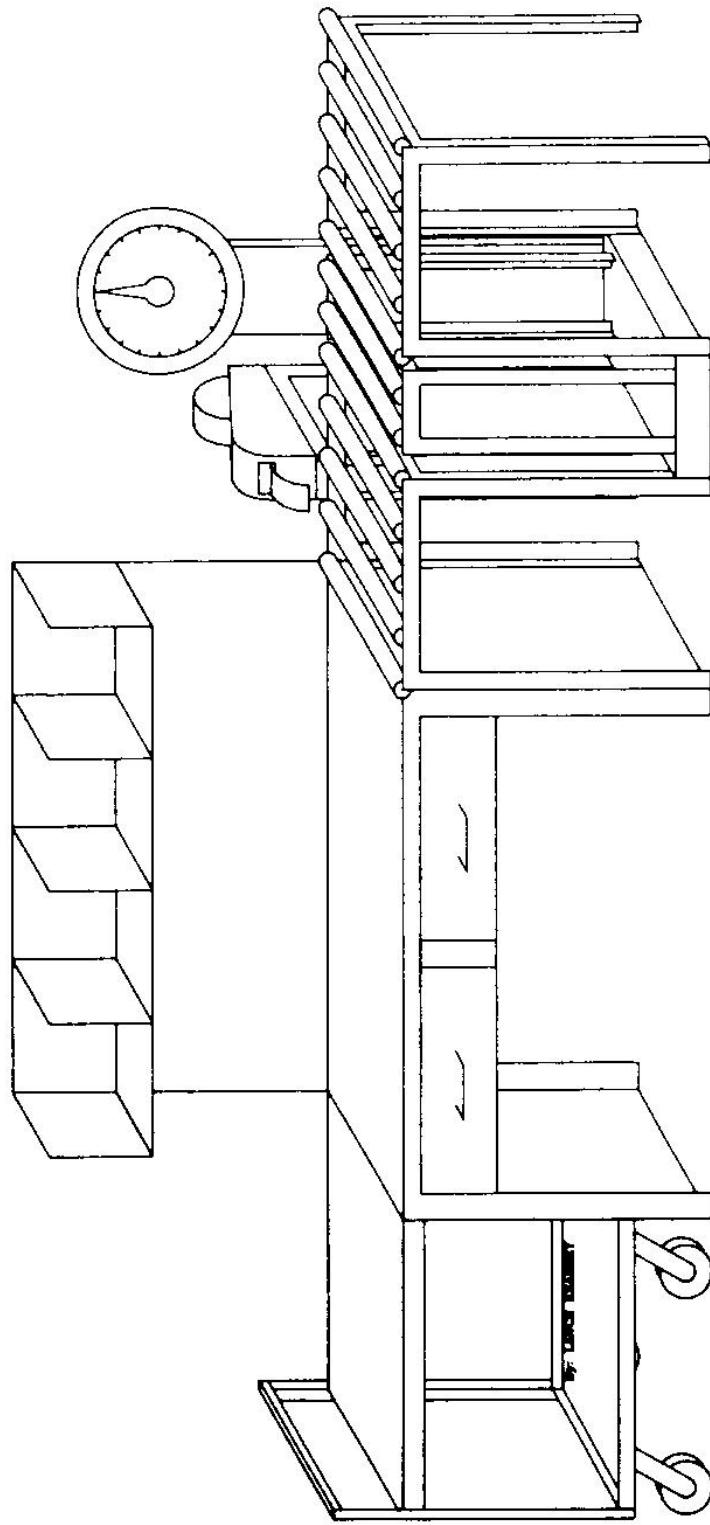


Figure 8-4 Packaging Workstation



Packaging finished goods for shipping. This process varies with the product and the kind of company. Keep in mind that the weight of the container must be compatible with our customer's ability to unload the shipment.

Packaging workstation design must also consider the principles of motion economy. Proper work height, good lighting, and all tools and materials located conveniently are only a few of the principles of motion economy that must be considered.

Bills of lading. The bill of lading lists every order and the weight of that product.

SPACE REQUIREMENTS FOR SHIPPING DEPARTMENTS

The shipping department and subsequently our customers can significantly enhance their operations and reduce human error as the result of the application of automatic identification and data capture (AIDC) technologies.

Space for shipping must include areas for packaging, staging, aisles, trailer parking, roadways, and offices. Sometimes, lounges for truckers and restrooms are included.

Example:

Two thousand toolboxes per day times 5 pounds per toolbox equals 10,000 pounds per day. How many cubic feet do 2,000 toolboxes take up?

$$(8 \times 8 \times 8 \text{ inches}) / 1,728 \text{ cubic inches per foot} = 0.66 \text{ cubic feet} \times 2,000$$

$$= 1,333 \text{ cubic feet per day}$$

A trailer is 8 feet wide times 40 feet long times 7 feet high, or 2,240 cubic feet.

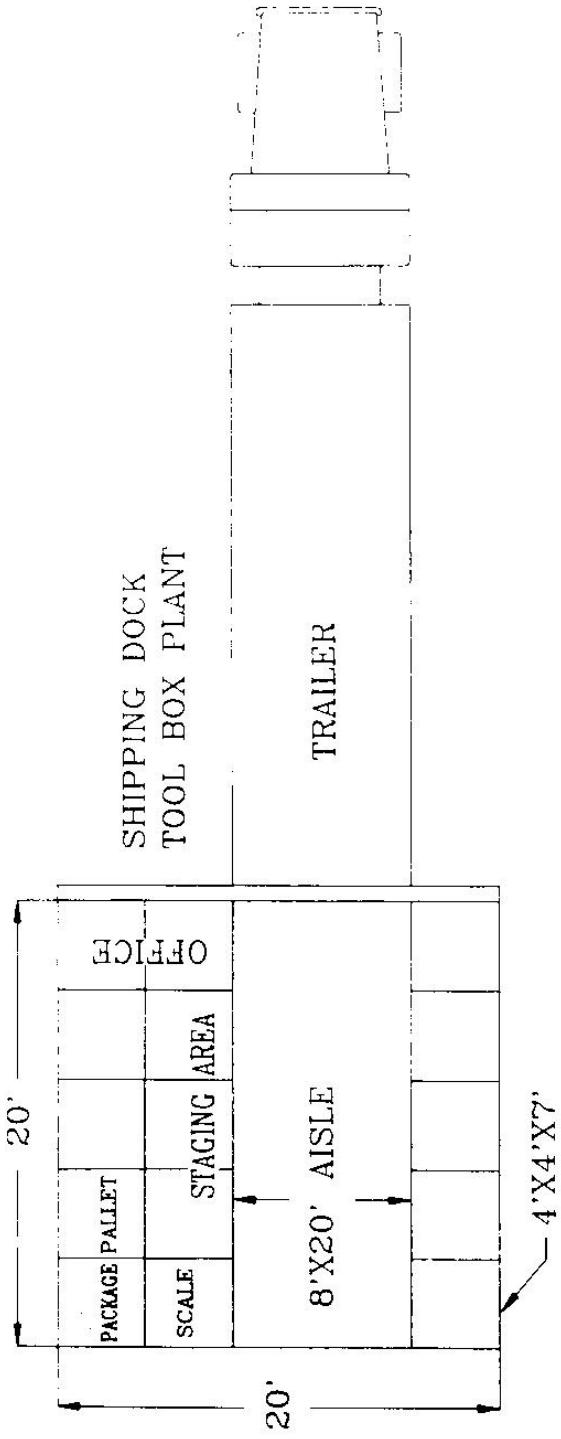
$$(1,333 \text{ cubic feet}) / 2,240 \text{ cubic feet per trailer} = 0.6 \text{ trailers per day}$$

Therefore, one dock door is required.

Space to store (stage) a day's supply of shipments (1,333 cubic feet) is required.

A space of 8 feet times 40 feet times 60 percent equals 192 square feet for staging. [The total trailer capacity is 8 feet times 40 feet equals 320 square feet. Only 60 percent (.6) of the total capacity is utilized; therefore, we multiply the total capacity by 60 percent in this case.]

Figure 8-7 Square Footage of Shipping Department



STORAGE

Stores is a term used to denote an area set aside to hold raw materials, parts, and supplies. There are many different types:

- Raw material stores
- Finished parts stores
- Office supplies stores
- Maintenance supplies stores
- Janitorial supply stores

The space requirements is dependent on the stated inventory policy. For example: “Provide space to store a one-month supply of raw material,” or “Provide an area to store a one-week supply of “A” items, 2 weeks of “B” items, and a one-month supply of “C” items.”

Just-in-Time Inventories

This is a very special inventory subject that takes total corporate commitment and very special relationships with vendors. JIT will affect the plant layout in many ways:

1. Adjust or eliminate receiving, receiving reports, and so on.
2. Eliminate incoming quality control checks.
3. Eliminate or greatly reduce stores area requirements.

The goals of any stores department should be:

1. To maximize the use of the cubic space
2. To provide immediate access to everything (selectivity)
3. To provide for the safekeeping of the inventory including, (a) damage and (b) count control

Figure 8-8 Inventory Curve—One Curve per Part Number

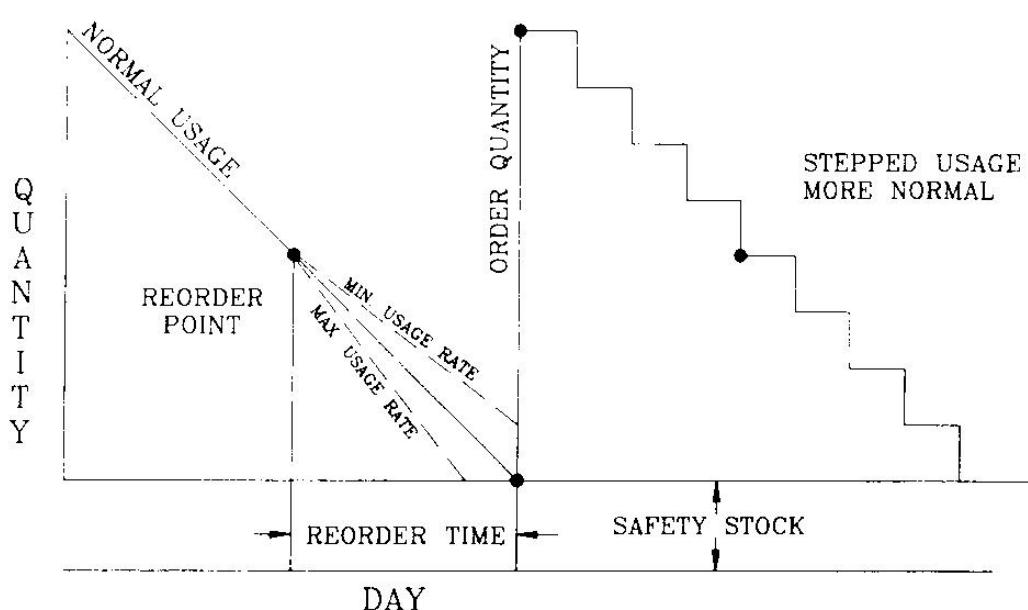


Figure 8-9 Storeroom Layout–Location System

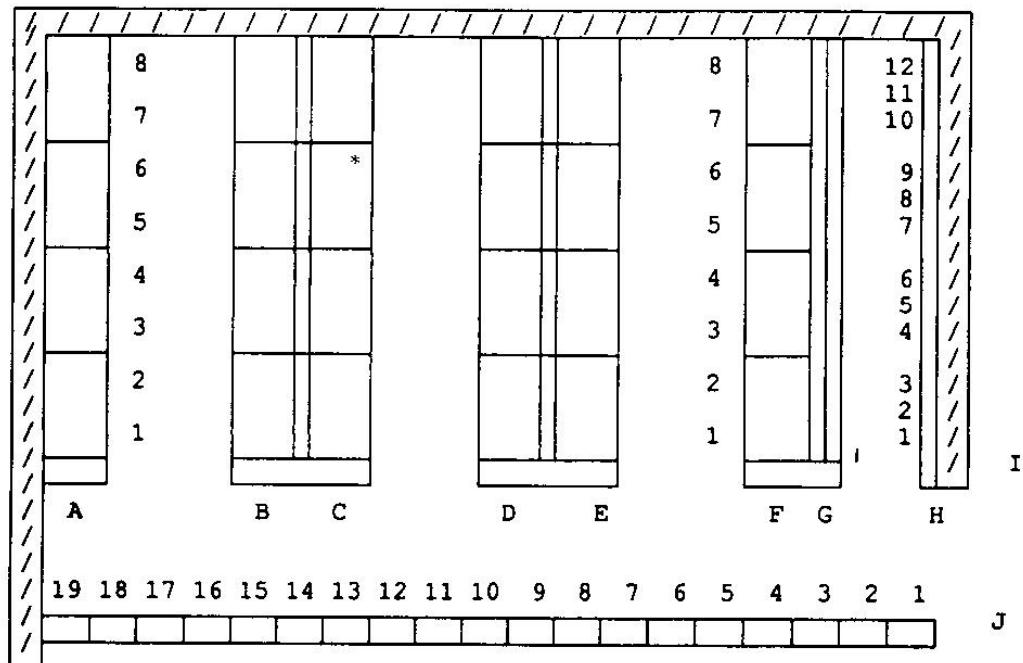


Figure 8-10b Storage Rack (Courtesy of White Storage & Retrieval System, Inc.)



Storage facilities requirement spreadsheet. Every part must be measured for cubic size, multiplied by the number of parts to be stored, and converted to cubic feet.

1. List all the raw materials and buyout parts.
2. For each part, list the length, width, height, and cubic inches.
3. State required quantity divided by 2 (allow room for average inventory).
4. Calculate cubic feet required.
5. Determine the number of storage units required for each part.

For example:

Shelves are 3 cubic feet each (1 X 1 X 3 feet).

A pallet is 4 X 4 X 4 feet high or 64 cubic feet per unit load.

6. Determine number of shelves or racks needed

Example:

1,200 shelves divided by 6 shelves per unit equals 200 shelving units.

To store 1,000 pallets, 100 pallet racks are required (10 pallets per rack)

Aisle feet. The concept of aisle feet is very useful. *Aisle feet* will help to determine the space needed.

Determine the **linear feet** of space needed to store the racks, shelving units, etc.

Example:

How many aisle feet of pallet racks do we need?

100 pallet racks times 9 feet wide each equals 900 aisle feet.

In our example:

600 aisle feet of shelving, 900 aisle feet of racking, 80 aisle feet of floor storage, and 4 and 8-foot aisles.

Laying out the storage area

Step 1. Start with a wall, placing the floor storage against the wall

Step 2. Place 900 aisle feet of pallet rack with 8-foot service aisles.

Step 3. Place 600 aisle feet of shelving serviced by 4-foot aisles.

Figure 8-13 Storage Facilities Requirement Spreadsheet

Part No.	Name	L	W	H – in. ³	Q/2	ft ³	Shelf 3 ft ³	Pallet 64 ft ³	Floor 576 ft ³
1	Bracket	18	6	2		10,000			
2	Body	12	6	2		5,000			
3	Washer	12	DA.	2		20,000			
4	Nut	12	DA.	2		20,000			
5	Bolt	12	DA.	2		20,000			
6	Lid	12	6	1		5,000			
7	Hinge	6	1	1		10,000			
8	Handle	7	1	3		10,000			
9	Rivet	14	DA.	2		100,000			
10	Carton	24	16	4		10,000			
	etc. 990 other parts					20,000			
1,000	Booklet	8 1/2	11	.020					
					Total Storage Units				
							1,200	1,000	20

Figure 8-14a Floor Storage—Three Pallets High X Three Pallets Deep
($4 \times 12 \times 12 = 576$ cubic feet)

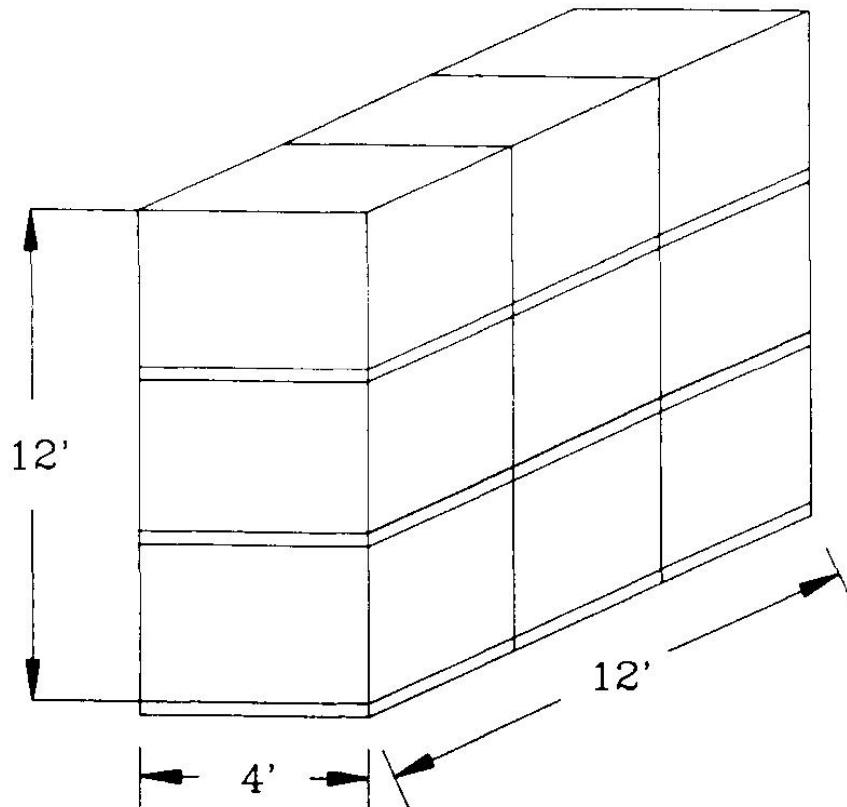


Figure 8-15 Storage Space Requirement—22-Day Supply, 2,000 Toolboxes per Day

Part No. Box No.	Part Name	L	W	H	= in. ³	Q/2	ff ⁱ Needed	Floor 1 Shelf 1 x l x 3 ft			Pallet 4 x 4 ft Floor 10 x 3.5 x 3 ft High
								Shelf 1 x l x 3 ft	Pallet 4 x 4 ft	Pallet 4 x 4 ft	
1	Handle	6	1	1	= 6,000	22,000	.76				2
2	Handle clip	1	1	1/2	= .5	44,000	12.7				5
4	Rivet	6	6	6	(10,000)	88,000	1.1				1
2	Catch	1/2	1/2	1/2	= .094	44,000	2.3				1
2	Strike	1	1	1/2	= .188	44,000	5				2
8	Rivet	6	6	6	(10,000)	176,000	2.2				1
2	Hinge	6	1/2	1/2	= .375	44,000	9.5				4
4	Rivet	6	6	6	(10,000)	88,000	1.1				1
1	Name tag	3	1	.02	= .06	22,000	.7				1
1	Packing list	8 1/2	5 1/2	.005	= .234	22,000	3				1
1	Booklet	8 1/2	5 1/2	.05	= 2.34	22,000	30				1
1	Carton	36	24	1/2	= 216	22,000	2,750				43
1	Plastic bag	10	6	.03	= 1.8	22,000	23				1
#5	Steel*	5 lbs	22 gal			110,000	220				2
	Total							17			45

Our toolbox warehouse needs only:

Three shelving units = 9 aisle feet

Five pallet racks = 45 aisle feet

Two floor storage areas = 20 aisle feet

A very simple layout, but steel will be received and stored in different areas.

*Steel weighs 500 pounds per cubic foot and comes in 42 x 120 x 18 inches high.

Figure 8-17 Storage Space Design

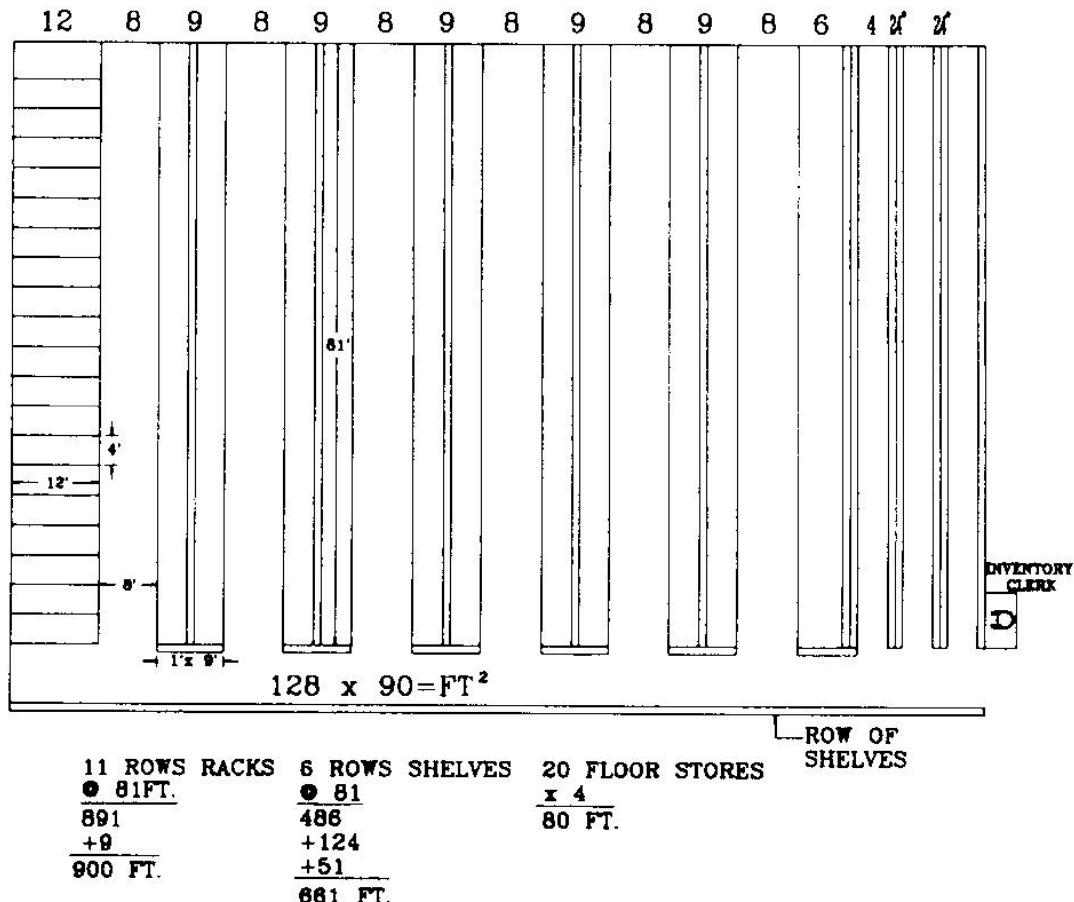
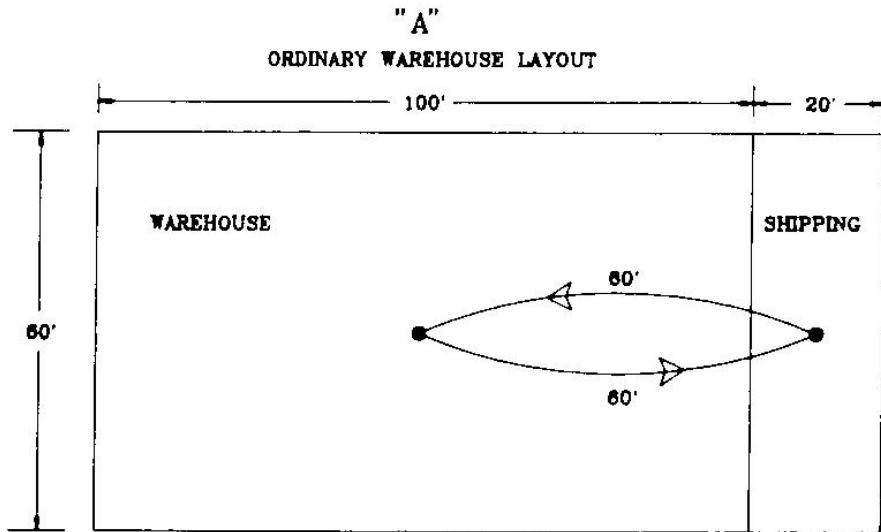


Figure 8-18 ABC Layout Cost Savings



The average trip in the ordinary warehouse would be from the middle of the warehouse to the middle of shipping (60 feet each way) 120 ft.
The average distance of an ABC layout is 28 feet one way and 56 feet round trip

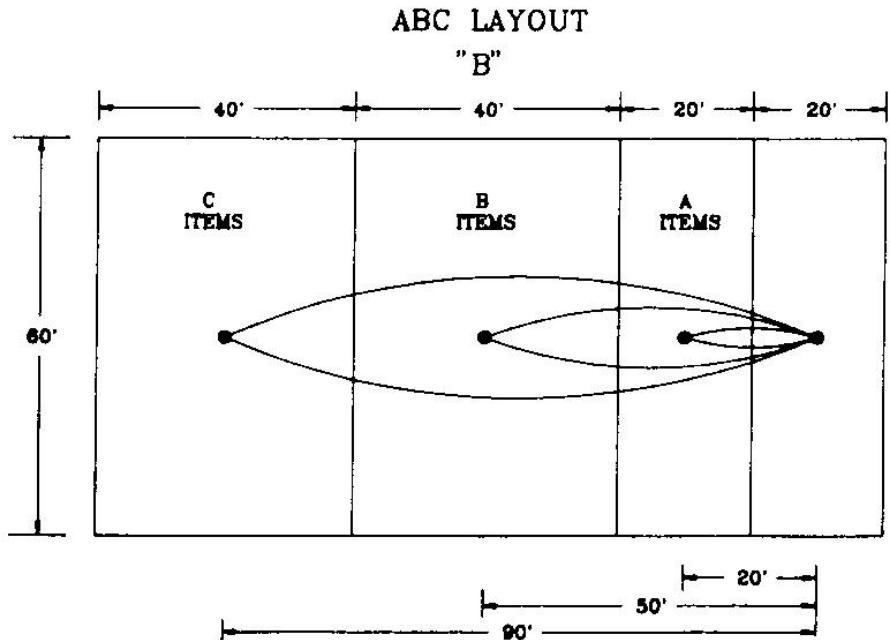
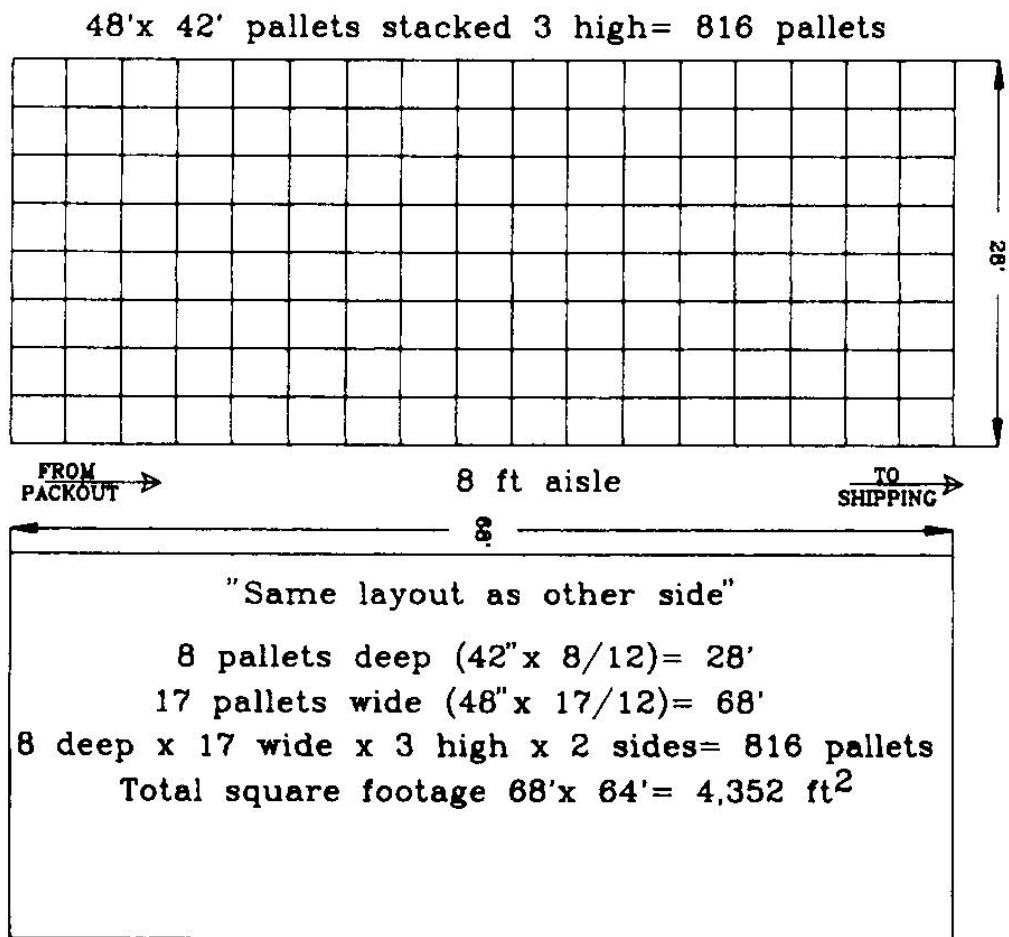


Figure 8-24 Warehouse Layout—Toolbox Plant



WAREHOUSING

Warehousing is the storage of finished products. As in the storeroom, the area requirement will depend on management policy.

Seasonality could require us to stockpile our finished product for months in order to meet market demands.

Warehouse Design Criteria

Two requirements may affect the layout of a warehouse:

1. Fixed locations
2. Small amount of everything

ABC Analysis to reduce travel distance

- “A” items: 20 percent of the inventory items account for 80 percent of the sales
- “B” items: 40 percent of the inventory items account for 15 percent of the sales
- “C” items account for only 5 percent of the sales dollars but 40 percent of the part number.

$$\text{“A” items} = 20 \text{ feet} @ 80\% = 16.0 \text{ feet}$$

$$\text{“B” items} = 50 \text{ feet} @ 15\% = 7.5 \text{ feet}$$

$$\text{“C” items} = 90 \text{ feet} @ 5\% = 4.5 \text{ feet}$$

$$\begin{array}{l} \text{Total Distance for} \\ \text{Average Part} \end{array} = 28.0 \text{ feet (56 feet round trip)}$$

The Functions of a Warehouse

The three basic functions of a warehouse are:

1. To safekeep the finished product
2. To maintain some stock of every product sold by our company
3. To prepare customer orders for shipment

Warehouse Space Determination

The size of the finished/packaged product multiplied by the quantity manufactured each day times the number of days supply will equal the cubic footage of warehouse space required.

Example: Provide a warehouse to store a 30-day supply of toolboxes at the rate of 2,000 units per day.

(18 X 8 X 8 inches)/ 1,728 inches per cubic feet = 0.666 cubic feet

0.666 X 2,000 X 30 days =
40,000 cubic feet + pallets

(42 X 42 X 54 inches)/ 1,728 = 55.125 cubic feet per pallet
72 toolboxes per pallet
2,000 per day X 30 days = 60,000 toolboxes
60,000/72 = 833 pallets

Chapter 9

Employee Services—Space Requirements

Objectives

In this chapter the students are sensitized to the needs of the employees as relate to facilities planning. Employees space requirements for doing work and personal needs are discussed.

Employee services include, but are not limited to:

1. Parking lots
2. Employee entrance
3. Locker room
4. Toilets
5. Cafeteria
6. Recreation areas
7. Drinking fountains
8. Aisles
9. Medical services
10. Break areas and lounges

The location and quality of these services affect the efficiency and productivity of our employees, the quality of work life, and employees' relationship with the company's management.

PARKING LOTS

1. Manufacturing employee parking
2. Office employee parking
3. Visitor parking

Convenience and the efficient use of space are very important considerations when determining the parking lot design. The entrances to the plant will determine where the parking lots are located.

The size of the parking lot is directly proportional to the number of employees, location of the company, and availability of public transportation.

<i>Employees</i>	<i>Parking Space</i>	<i>Spaces per 100 Employees</i>
1.25	to	1 80
1.5	to	1 67
1.75	to	1 57
2.0	to	1 50

Office parking may be incorporated with the visitor parking spaces and a ratio of 1 to 1 may be appropriate.

The facilities planner must comply with the requirements of the Americans with Disabilities Act (ADA) of 1989 in all aspects of planning and design. Providing special and properly designed parking spaces and creating a barrier-free environment in all aspects of the facility in a matter of law.

The size and shape of the available space may be the deciding factor, but some general statistics follow:

<i>Parking Stalls</i>	<i>Width*</i>	<i>Length*</i>
Small cars	8	15
Medium cars	9	17.5
Large cars	10	20

*In feet.

Width of Driveways

Single lane—11 feet

Double land—22 feet

1. As the angle, A , of the parking spots increases, the required width of the aisle increases
2. As the width of the parking spots increases, the required width of the aisle decreases.
3. The wider the parking spots (to 10 feet) are, the less door damage there is in your parking lot.
4. Local building codes often dictate parking spot size.
5. Local building codes often dictate the number and location of handicapped spots.
6. As a general rule of thumb, a parking lot will be 250 square feet per number of parking spots needed.

Figure 9-1 Perpendicular Parking (Most Space Consumed)

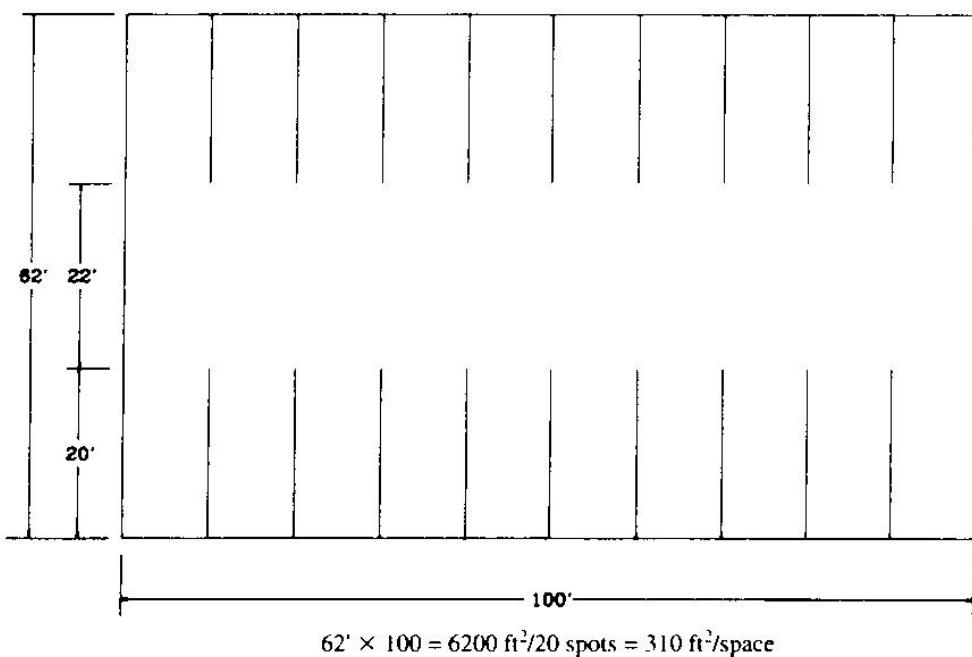
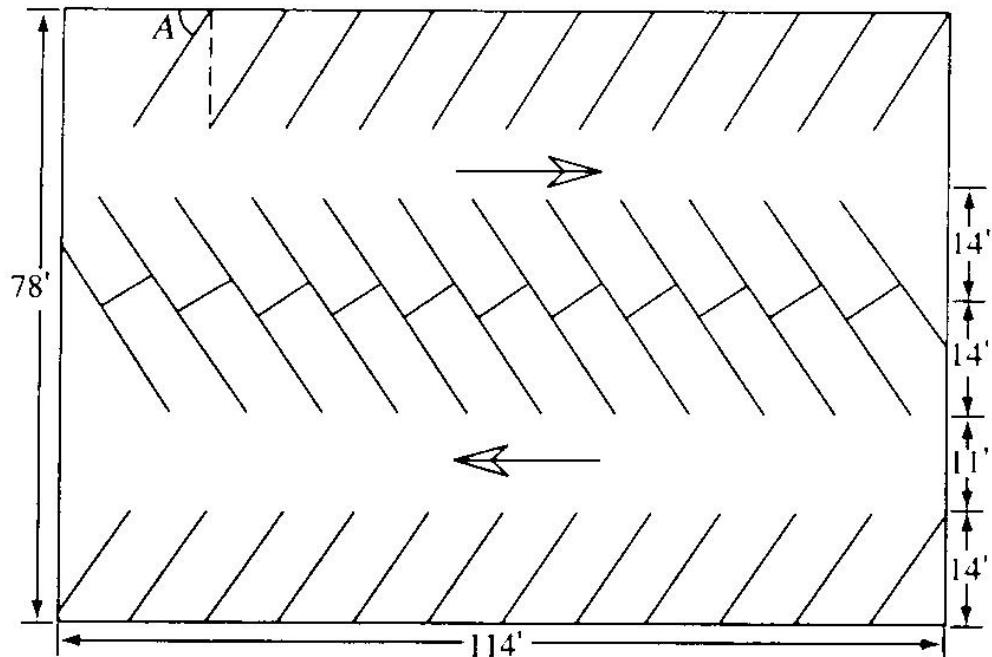
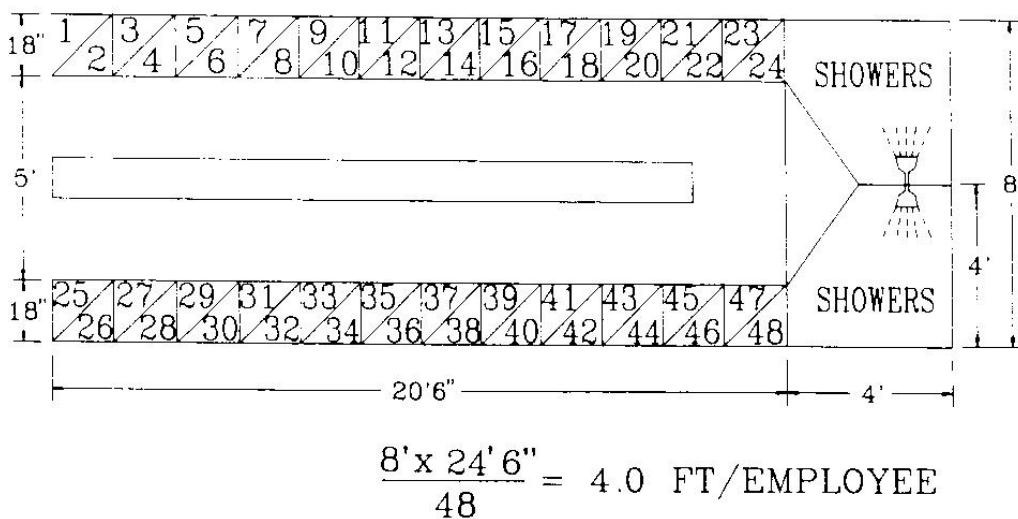


Figure 9-2 Angular Parking Lot



$$\frac{78' \times 114'}{44 \text{ spaces}} = 202 \text{ ft}^2/\text{space}$$

Figure 9-5 Locker Room



EMPLOYEE ENTRANCES

Employee entrance affects the placement of parking, the locker room, time card racks, restrooms, and cafeterias.

The size depends on the number of persons using the door at any given time. The door could measure from 3 feet to 6 feet with an aisle leading into the plant.

Personnel and security offices will be sized at 200 square feet per office person. About one personnel person per 100 employees and one security person per 300 employees are normal.

LOCKER ROOMS

Staggered shift starting could reduce congestion in the locker room. For example:

7:00–11:00	Lunch	11:30–3:30
7:30–11:30	Lunch	12:00–4:00
8:00–12:00	Lunch	12:30–4:30
3:30–7:30	Lunch	8:00–12:00
4:00–8:00	Lunch	8:30–12:30
4:30–8:30	Lunch	9:00–1:00

TOILETS AND RESTROOMS

The number of toilets depends on the number of employees. The local codes may dictate the number. The number of washbasins is usually equal to the number of toilets. Also ADA. requires that at least one men's restroom and one women's restroom in the office and in the factory meeting ADA standards be provided.

The size of a restroom is 15 square feet per toilet, washbasin, and entry way, and 9 square feet for urinals.

	<i>50 Men</i>	<i>50 Women</i>
Toilets	2 @ 15 = 30	3 @ 15 = 45
Washbasins	3 @ 15 = 45	3 @ 15 = 45
Urinals	1 @ 9 = 9	
Reclining area		1 @ 15 = 15
Door	1 @ 15 = 15	1 @ 15 = 15
Total	99	120
X 150 percent	149	180

Figure 9-7 Men's Restroom

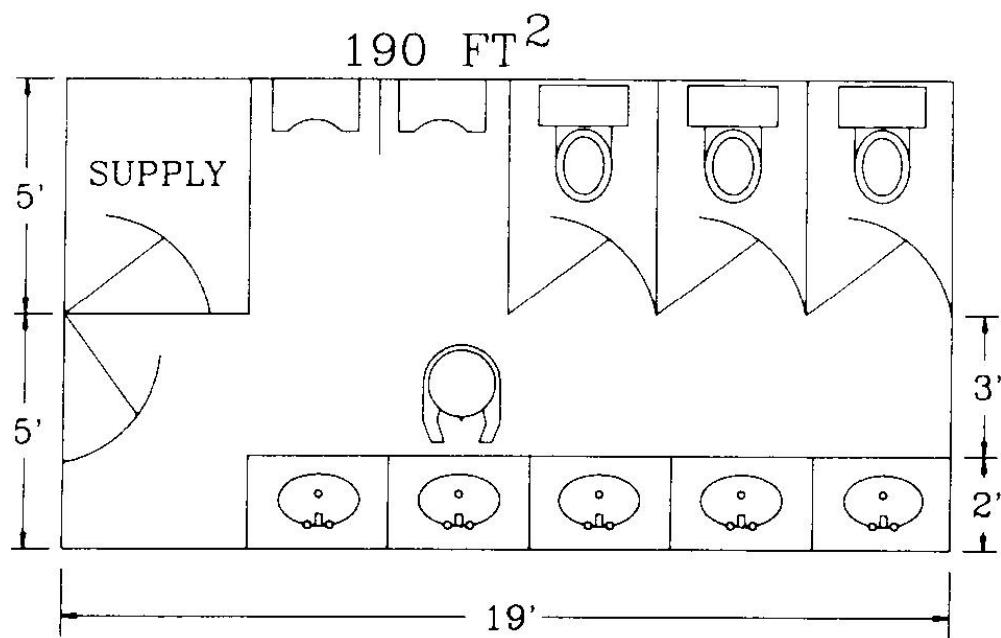


Figure 9-8 Lunch Room Space Determination

Per Person or Unit	3 Periods 100 people		5 Periods 500 people		7 Periods 1,000 people	
Cafeteria serving line (300 ft.)	—		300		600	
Waiting line (4 ft ²)	120		180		320	
Vending machines (20 ft ²)	100		—		—	
Eating area	495		1,995		3,000	
Waste (½ ft ²)	50		250		500	
Food storage (½ to 1 ft ²)	50		500		1,000	
Food prep. (2 ft/meal)	—		Catered		2,000	
Dish washing (½ to 1 ft ²)	—		500		750	
Total	815		3,725		8,170	
Aisles and misc. + 25 percent	204		931		2,043	
Grand total	<u><u>1,019 ft²</u></u>		<u><u>4,656 ft²</u></u>		<u><u>10,213 ft²</u></u>	
Square ft per person	10.2 ft ²		9.3 ft ²		10.2 ft ²	
Size	22 × 46		48 × 96		71 × 143	

Figure 9-9 A Staggered Lunch Room

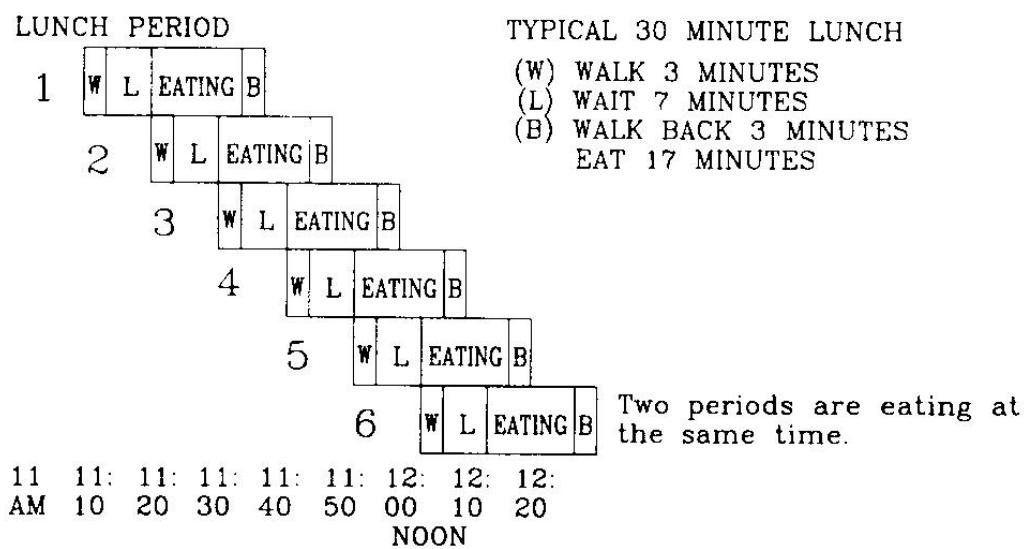
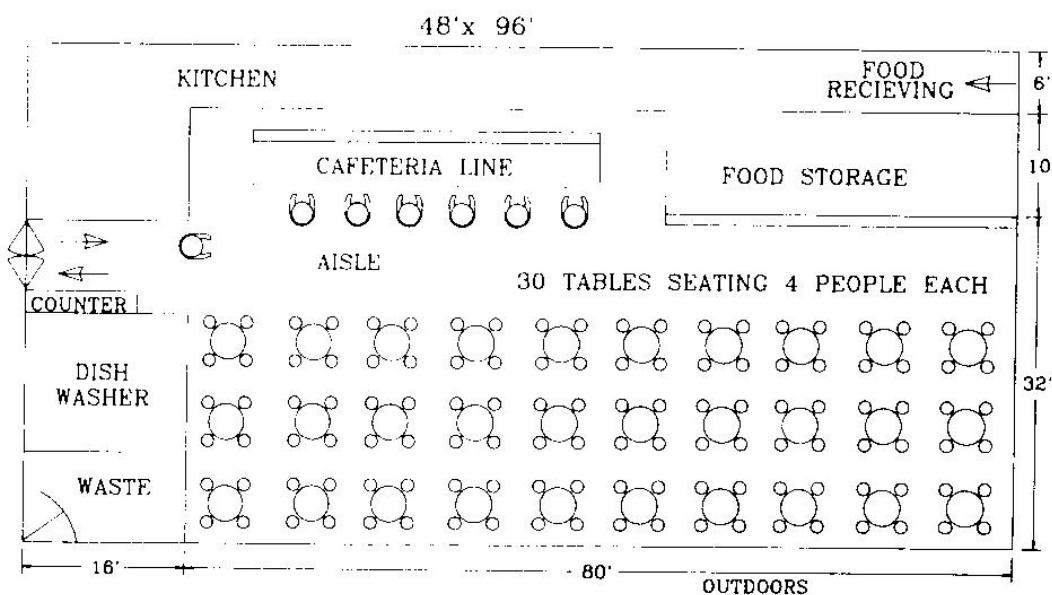


Figure 9-10 Cafeteria Layout for 500 People



LUNCH ROOMS

There are five types of eating facilities:

1. Cafeterias with serving lines
2. Vending machines
3. Mobile vendors
4. Dining rooms (executive)
5. Off-site diners (lunch counters)

A cafeteria feeds a lot of people in a short time. One serving line can service 9 employees per minute. One line is 30 feet long and 10 feet wide. If lunch periods were staggered, 540 people per hour could be served. Cafeterias are generally used in big plants.

Vending machines can serve very complete meals. A vending machine with a microwave oven for special foods can provide employees with many meal choices.

Mobile vendors are outside vendors who drive their wares to the plant.

Executive dining rooms are very special and are used to entertain special customers, vendors, and stockholders. They usually provide a limited selection from a menu with the meal being cooked on site.

Off-site dining at local diners is attractive to many employees. It allows them to get away from the job. Most factory people are not given enough time to leave the plant for lunch. Companies also discourage people from leaving the plant at lunch time because the companies lose control.

The size of the lunch room depends on

- (1) the number of employees,
- (2) the type of service provided, and
- (3) the facilities included.

RECREATION

Health conscious employees are better employees and companies are recognizing this fact. Health clubs, tracks, locker rooms, as well as Ping-Pong tables, card games, and social clubs are becoming a part of our plants.

DRINKING FOUNTAINS

They should be located within 200 feet of every employee and on an aisle for easy access. (3 X 5 feet) should be allowed for each drinking fountain.

AISLES

Aisles can be the greatest consumers of plant space.

Aisles are for movement of people, equipment, and material. The aisles must be sized for that use.

Aisles should be long and straight. Side aisles may be smaller but perpendicular to the main aisle.

A couple of ideas used to reduce aisles are:

1. Use stand-up reach trucks instead of fork trucks.
2. Use double deep pallet racks or drive-in pallet racks.

MEDICAL FACILITIES

May vary from 6-foot 3 6-foot first aid rooms to full-fledged hospitals. When a plant approaches 500 people, a registered nurse is usually justified.

Nurses require facilities such as waiting rooms, examining room, medical supplies, and record and reclining areas. One nurse would require a 400-square-foot area.

Office	100 ft ² /nurse
	200 ft ² /doctor
Examining rooms	200 ft ² /room
Waiting area	25 ft ² /nurse and doctor
Supply room	25 ft ² nurse or doctor
Basic first aid room	36 ft ²

BREAK AREAS AND LOUNGES

If the lunch room is too far away from groups of employees, a break area should be provided. "Too far" is defined as over 500 feet.

Lounges are usually found in shipping and receiving areas for visiting truck drivers to wait for their loads.

MISCELLANEOUS EMPLOYEE SERVICES

Some other employee service areas may include:

- (1) training facilities,
- (2) babysitting,
- (3) barbers and hairdressers, and
- (4) libraries.

Chapter 10

Material Handling

Objectives

In this chapter material handling is defined. The goals and the 20 principles of material handling are discussed. Material handling problem-solving procedures are presented.

Material handling is the function of moving the right material to the right place, at the right time, in the right amount, in sequence, and in the right position or condition to minimize production costs.

Material control systems such as part numbering, location, inventory control, standardization, lot size, order quantities, safety stocks, labeling, automatic identification techniques are an integral part of modern material handling systems.

Definition: Material handling can be broadly defined as all movement of materials in a manufacturing environment.

ASME defines *material handling* as the art and science involving the moving, packaging, and storing of substances in any form.

Material handling has five distinct dimensions: movement, quantity, time, space, and control.

Movement involves the actual transportation or transfer of material. Efficiency and safety are of prime concerns.

Quantity dictates the type and nature of the material handling equipment. Cost per unit must be considered.

Time determines how quickly the material can move through the facility. It affects work in process, excessive inventories, repeated handling of the material, and order delivery lead times.

Space is concerned with the required space for the storage of the material handling equipment and their movement, as well as the queuing or staging space for the material itself.

Control deals with tracking of the material, identification, and inventory management.

Material handling equipment has reduced the drudgery of work and production cost.

The handling of material is attributed to more than one-half of all industrial accidents. Material handling equipment can eliminate manual lifting.

Material handling equipment (like all equipment) can cause injury, so safety is an important factor when selecting material handling equipment.

Material handling also accounts for, on the average, 50 percent of the total operation cost.

COST JUSTIFICATION

Material handling equipment can be very expensive, so all investments should be cost-justified.

Nonpowered equipment can be very cost efficient. Gravity chute, rollers, hand carts, and hand jacks are examples.

Safety, quality, labor, power, and equipment costs must all be included in the unit costs.

Sample Material Handling Cost Problem

What? 80 pound bags of clay equals a 160,000 pound boxcar load; no other size bags are available.

Where? From the boxcar to the storeroom, 300 feet.

Who? Two temporary workers.

When? One week, twice a year.

How? Present method. Manually unload the pallets, move pallets into the storeroom with the fork truck.

How much could you spend to this job?

One week, twice a year, two employees @ \$7.50 per hour.

4 weeks X 40 hours per week X \$7.50 per hour = \$1,200

Currently we are spending \$1,200 per year on this job. Should the current method stay the same or are there other alternatives that can be employed?

But consider the following:

Cumulative trauma disorders and work-related injuries are costing business real dollars and productivity.

According to BLS the rate of incidents has increased steadily since 1986.

In 1996, 25 million workers reported lower back pain and 25 percent of all workers missed an average of one day of work per year due to the same problem.

The compensations cost the U.S. business approximately 20 billion dollars and 12 million lost workdays annually.

The cost of an “average” lower back case is over \$5,500 in direct cost. Indirect costs may raise the total U.S. loss to well over \$30 billion annually.

According to the Bureau of Labor Statistics, the following tabulation on incident rates for injuries shows the rates per 100 full-time workers since 1992:

	1992	1993	1994	1995	1996
Private industry	8.9	8.5	8.4	8.1	7.4
Goods-producing	12.4	11.9	11.9	11.2	10.2
Service-producing	7.3	7.1	6.9	6.7	6.2

Among the good-producing industries, manufacturing had the highest incidence rate in 1996.

GOALS OF MATERIAL HANDLING

1. Maintain/improve quality, reduce damage, provide for protection of materials.
2. Promote safety and improve working conditions.
3. Promote productivity:
 - a. Material should flow in a straight line.
 - b. Material should move as short a distance as possible.
 - c. Use gravity! It is free power.
 - d. Move more material at one time.
 - e. Mechanize material handling.
 - f. Automate material handling.
 - g. Maintain or improve material handling/production ratios.
 - h. Increase throughput by using automatic material handling equipment.
4. Promote increased use of facilities:
 - a. Promote the use of the building cube.
 - b. Purchase versatile equipment.
 - c. Standardize material handling equipment.
 - d. Maximize production equipment utilization using material handling feeders.
 - e. Maintain, and replace as needed, develop a preventive maintenance program.
 - f. Integrate all material handling equipment into a system.
5. Reduce tare weight (dead weight).
6. Control inventory.

THE 20 PRINCIPLES OF MATERIAL HANDLING

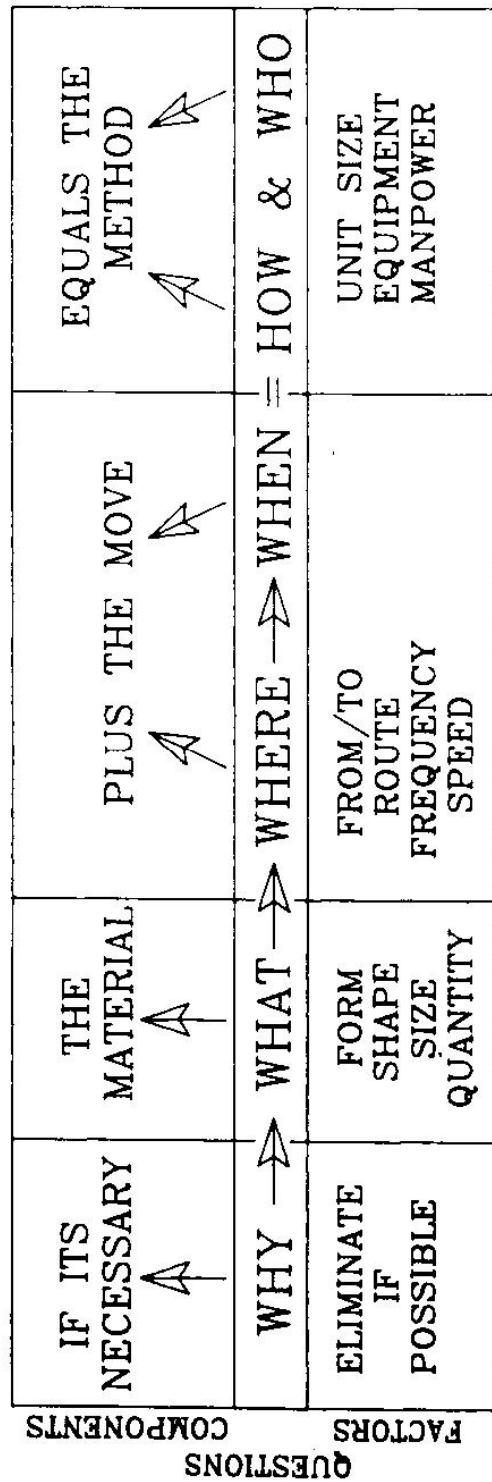
The College Industrial Committee on Material Handling Education, sponsored by The Material Handling Institute, Inc. and the International Material Management Society has adapted the 20 principles of material handling.

Figure 10-1 The Principles of Material Handling*

-
1. *Planning principle*. Plan all material handling and storage activities to obtain maximum overall operating efficiency.
 2. *System principle*. Integrate as many handling activities as is practical into a coordinated system of operations, covering vendor, receiving, storage, production, inspection, packaging, warehousing, shipping, transportation, and customer.
 3. *Material flow principle*. Provide an operation sequence and equipment layout optimizing material flow.
 4. *Simplification principle*. Simplify handling by reducing, eliminating, or combining unnecessary movement and/or equipment.
 5. *Gravity principle*. Utilize gravity to move material wherever practical.
 6. *Space utilization principle*. Make optimum utilization of building cube.
 7. *Unit size principle*. Increase the quantity, size, or weight of unit loads or flow rate.
 8. *Mechanization principle*. Mechanize handling operations.
 9. *Automation principle*. Provide automation to include production, handling, and storage functions.
 10. *Equipment selection principle*. In selecting handling equipment, consider all aspects of the material being handled—the movement and the method to be used.
 11. *Standardization principle*. Standardize handling methods as well as types and sizes of handling equipment.
 12. *Adaptability principle*. Use methods and equipment that can best perform a variety of tasks and applications where special purpose equipment is not justified.
 13. *Dead weight principle*. Reduce ratio of dead weight of mobile handling equipment to load carried.
 14. *Utilization principle*. Plan for optimum utilization of handling equipment and manpower.
 15. *Maintenance principle*. Plan for preventive maintenance and scheduled repairs of all handling equipment.
 16. *Obsolescence principle*. Replace obsolete handling methods and equipment when more efficient methods or equipment will improve operations.
 17. *Control principle*. Use material handling activities to improve control of production inventory and order handling.
 18. *Capacity principle*. Use handling equipment to help achieve desired production capacity.
 19. *Performance principle*. Determine effectiveness of handling performance in terms of expense per unit handled.
 20. *Safety principle*. Provide suitable methods and equipment for safe handling.
-

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Figure 10-3 The Material Handling Equation



The Unit Load Concept

A *unit load* is a load of many parts that move as one.

Advantages of a unit load:

- 1) faster
- 2) cheaper

Disadvantages:

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

Mateewrial Handling Equation

The material handling equation is a plan for a systematic approach to equipment solution.

1. *Why are we making this move?* (Why?) Can we eliminate this move?
2. *What are we moving?* (What?) Understand the size, shape, weight, and the number being moved and the kind of material.
3. *Where are we moving the material from and to?* (Where?) If the same every time, a fixed path technique is warranted (conveyor). If it changes, a variable path technique is used (industrial truck).
4. *When is the move needed?* (When?) How often? If several times a minute, a conveyor is used.
5. *How will the move be made?* (How?) By hand, by conveyor, by fork truck?

THE MATERIAL HANDLING PROBLEM-SOLVING PROCEDURE

- Step 1.* Analyze the requirements to define the problem. Be sure the move is required.
- Step 2.* Determine the magnitude of the problem. Cost analysis is best.
- Step 3.* Collect as much information as possible—why, who, what, where, when, and how.
- Step 4.* Search for vendors. Suppliers often provide outstanding assistance.
- Step 5.* Develop viable alternatives.
- Step 6.* Collect costs and savings data on all alternatives.
- Step 7.* Select the best method.
- Step 8.* Select a supplier.
- Step 9.* Prepare the cost justification.
- Step 10.* Prepare a formal report.
- Step 11.* Make a presentation to management.
- Step 12.* Obtain approvals (adjust as needed).
- Step 13.* Place an order.
- Step 14.* Receive and install equipment.
- Step 15.* Train employees.
- Step 16.* Debug (make it work) and revise as necessary.
- Step 17.* Place into production.
- Step 18.* Follow up to see that it is working as planned.
- Step 19.* Audit performance to see that payback was realized.

Chapter 11

Material Handling Equipment

Objectives

In this chapter various types of material handling equipment are presented.

Material handling equipment may be grouped into four general categories.

Fixed-path or *point-to-point* equipment. This class of equipment serves the material handling need along a predetermined, or a fixed path such as the train and the railroad track, conveyor systems.

Fixed-area material handling system serve any point within a three-dimensional area or cube such as a jib crane or a bridge crane or an ASRS system.

The material handling equipment that can move to any area of the facility is referred to as *variable-path variable-area* equipment. All manual carts, motorized vehicles, and fork trucks can be pushed, dragged, or driven throughout the plant.

The forth category consists of all *auxiliary tools and equipment* such as pallets, skids, automatic data collection systems, and containers.

In this text, the organization follows the flow of material from the receipt of material to the warehousing of that material as follows:

1. Receiving and shipping (because they are similar)
2. Stores
3. Fabrication
4. Assembly
5. Packaging
6. Warehousing

Two additional areas of material handling are:

7. Bulk material handling
8. Automatic storage and retrieval systems

RECEIVING AND SHIPPING

Receiving and Shipping Docks

The most common type of dock is known as a ***flush dock***.

Drive-in docks are similar to flush docks except that when the door opens, the truck and trailer can back into the plant and the door can be closed. This type of dock is very expensive and quite desirable in bad weather.

Drive-through docks are a pair of doors across the plant from each other. The truck drives into the plant, unloaded or loaded, the other door is opened, and the truck drives out.

Finger docks are extensions to the plant and can handle many trailers at one time.

Dock Equipment

A **door** is a part of a dock. A dock door is typically a 9 X 9-foot rollup. A **seal** is built of compressible material that will seal off the outside weather from the plant environment. **Bumpers** are placed outside the dock door below the floor level to stop the trailer and to protect both the building. An **automatic dock leveler** can be built into the dock door floor to make placing the dock plate automatic.

Moving Equipment

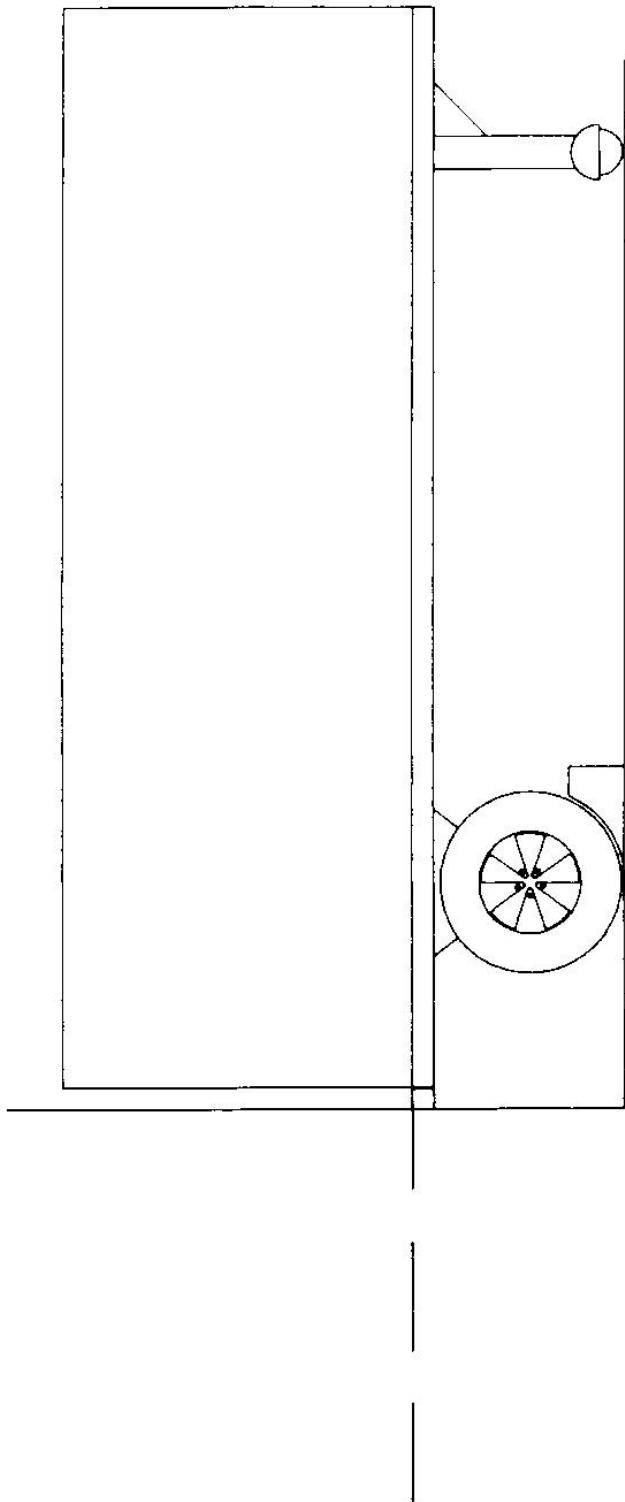
Hand carts.

1. *Two-wheel hand truck.* Up to 500 pounds can be moved by a single person.
2. *Pallet hand jack or pallet truck-hydraulic lift* are rolled under a pallet, the handle is pumped, the pallet is lifted. Up to 2,000 pounds can be moved by hand.
3. *Four-wheel hand carts*
4. *Pallets*

Fork Trucks

Fork trucks are by far the most popular piece of material handling equipment and are versatile.

Figure 11-1a Flush Dock-Side View



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Figure 11-2a Finger Dock–Top View

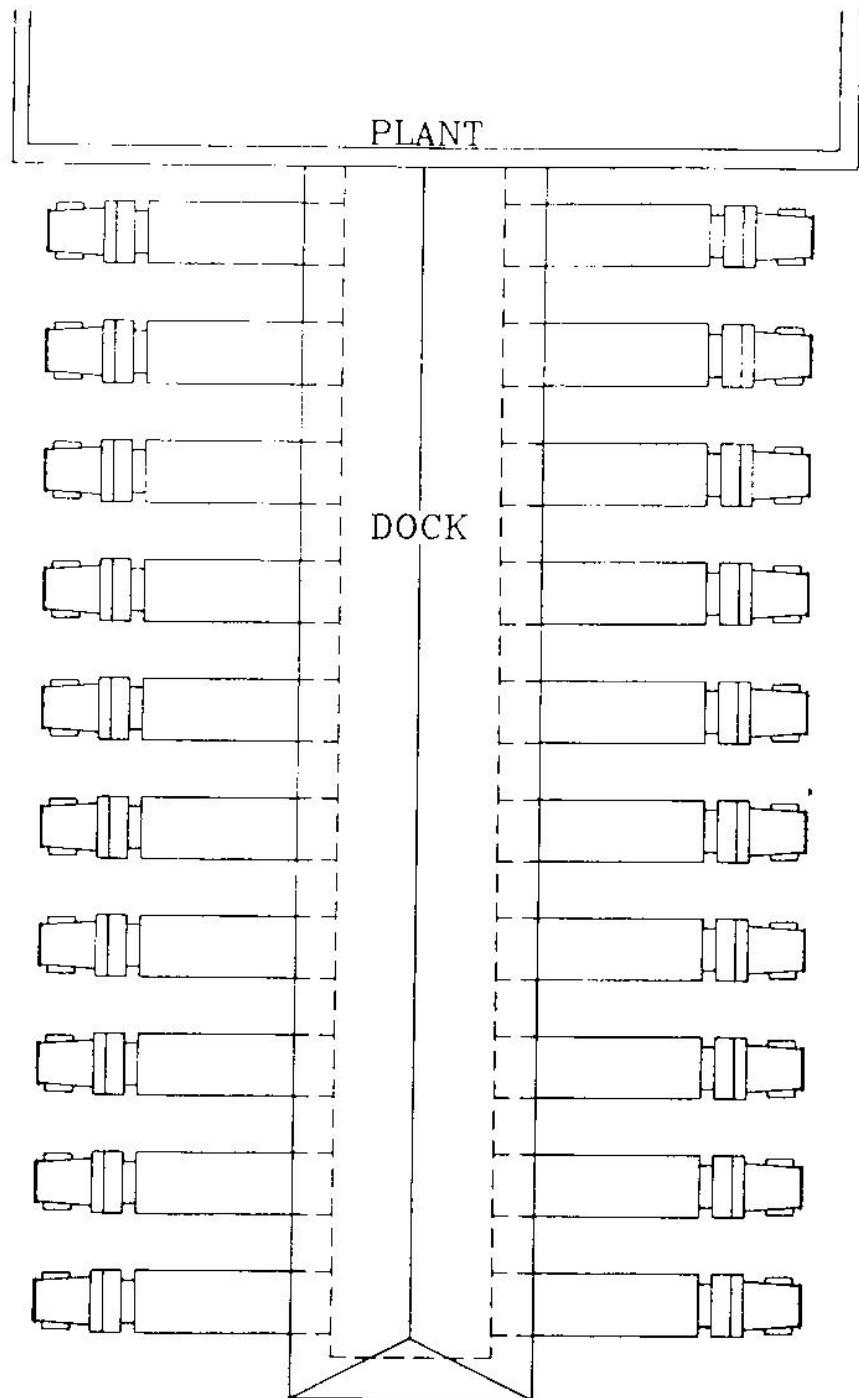


Figure 11-9a Industrial Trucks (Courtesy of Yale Materials Handling Corp.)

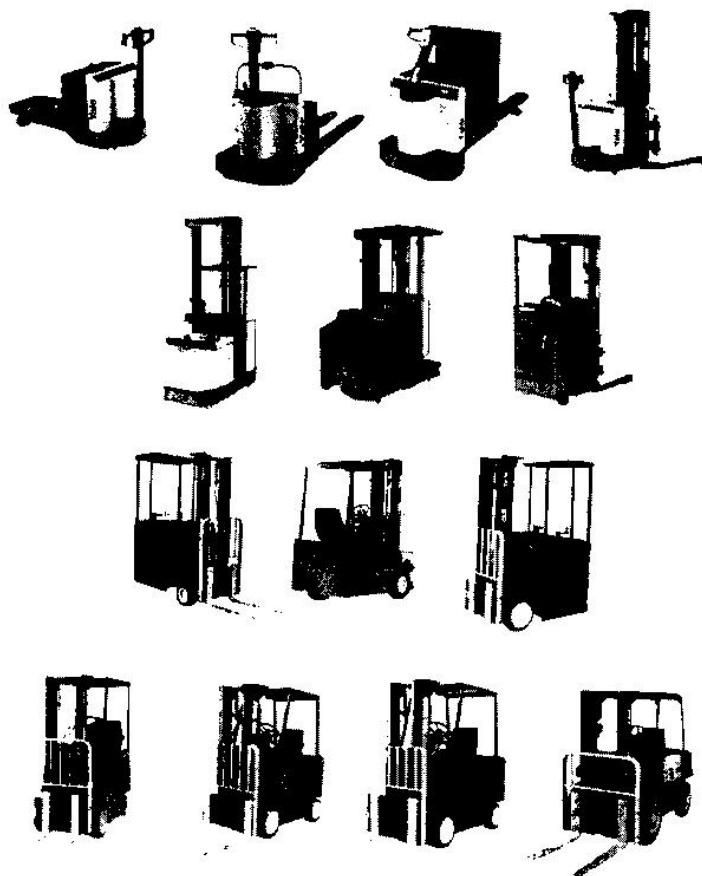


Figure 11-10a A Universal Lift System (Courtesy of Air Technical Industries)

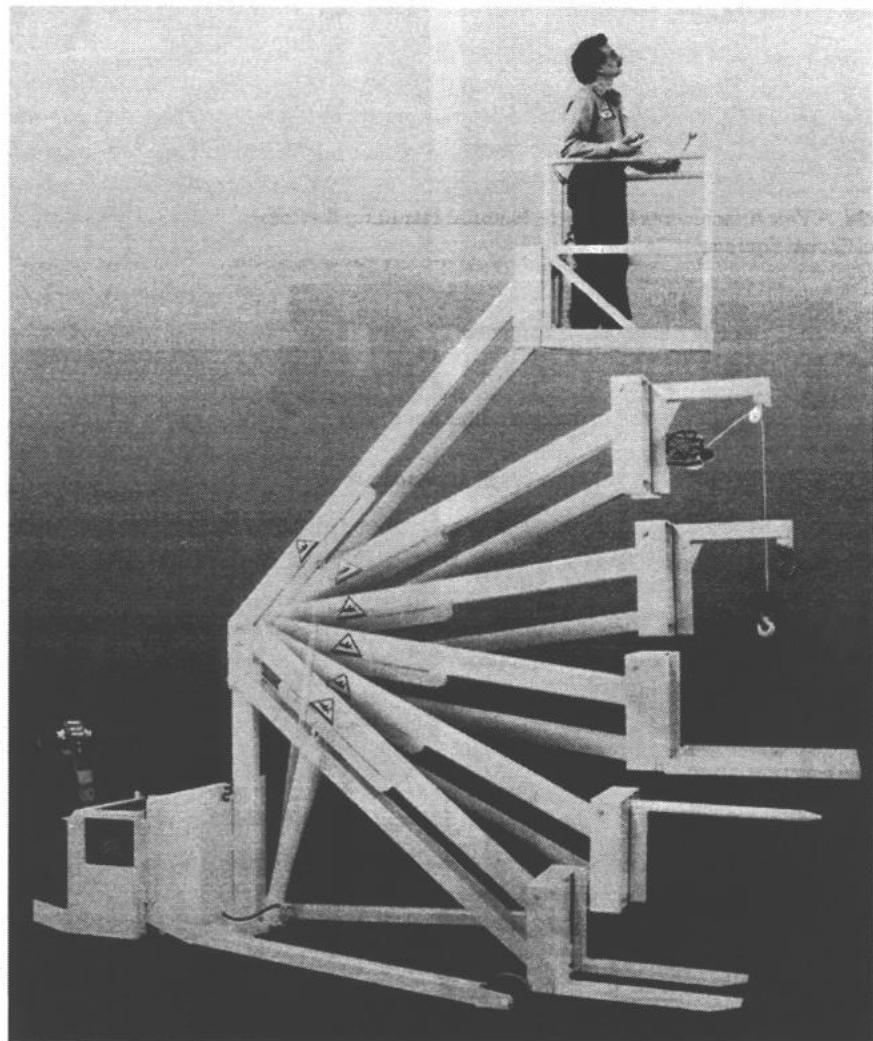


Figure 11-10b A Universal Lift System Performing Various Functions
(Courtesy of Air Technical Industries)

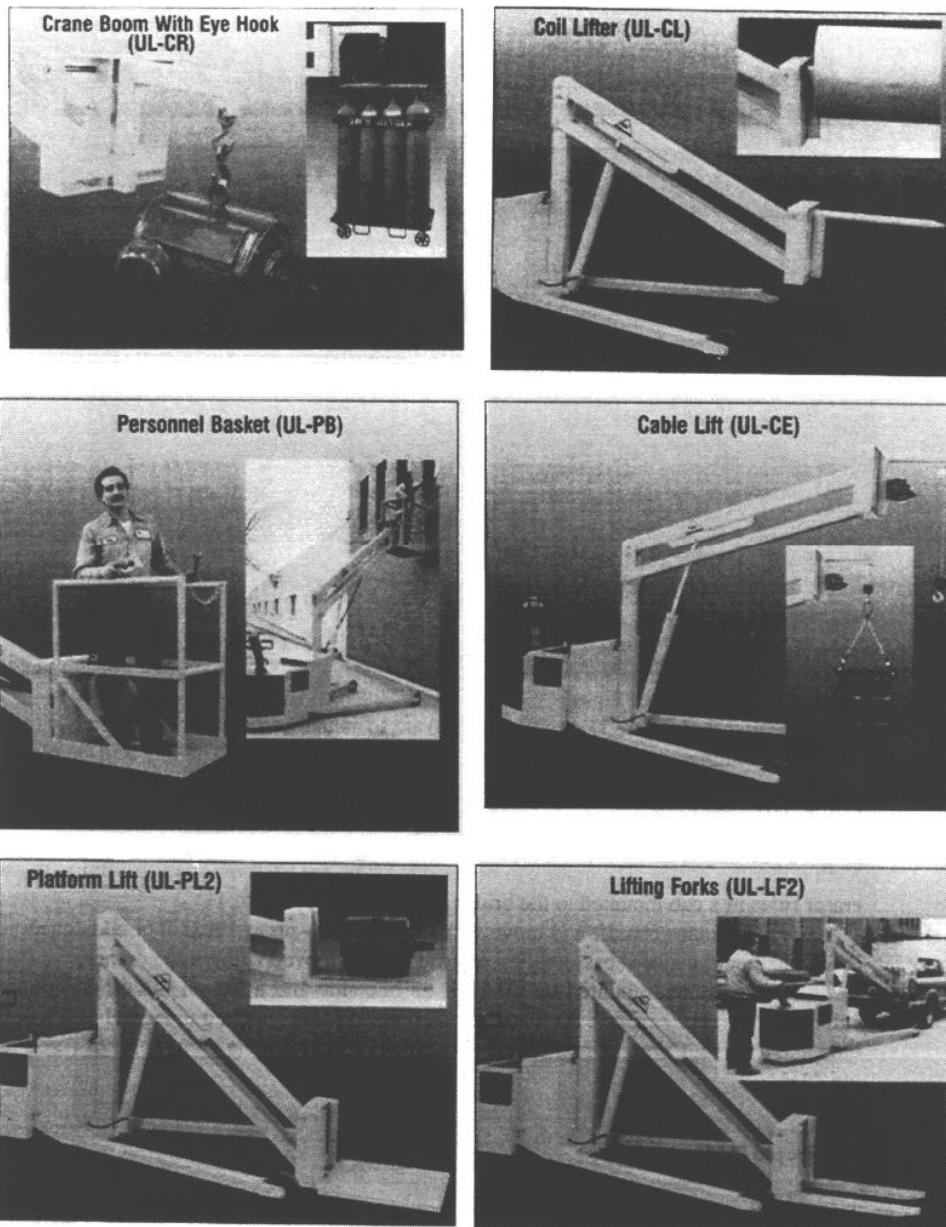


Figure 11-14c Double Deep Pallet Racks

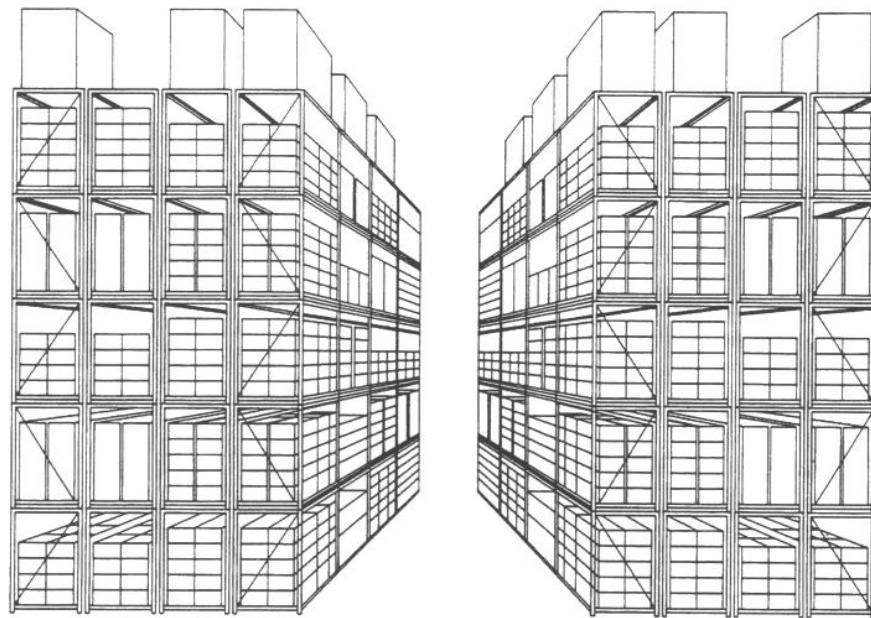
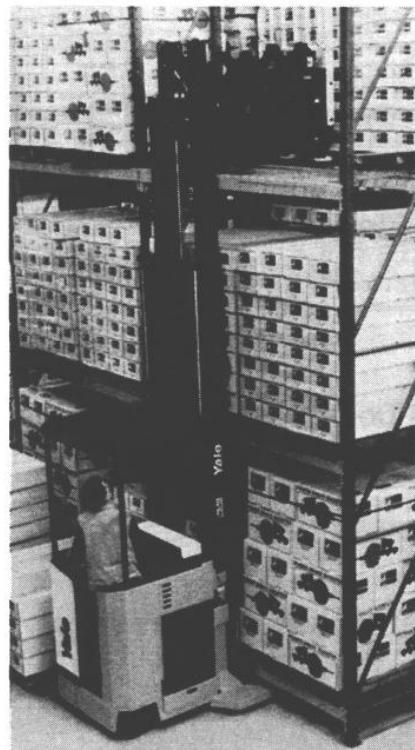


Figure 11-14c (cont'd) Double Deep Pallet Racks (Courtesy of Ridge Rak, Inc.)



Figure 11-15 A Reach Truck (Courtesy of Yale Materials Handling Corp.)



Multipurpose equipment. In an attempt to standardize material handling equipment, diversified multipurpose equipment must be given special consideration.

Bridge cranes can lift and move very heavy loads—up to 100,000 pounds or more.

Telescopic Conveyor

Telescopic conveyors have several sections of conveyor that extend as needed.

Weight Scale

Weight scales are valuable receiving and shipping tools that can be built into the material handling system.

Systems Required on Shipping and Receiving Docks

1. Part numbering systems which allows for identification of inventory.
2. Purchase order system authorizes the receiving of material.
3. Customer order system authorizes the shipment of material.
4. Bill of lading authorizes a trucking company to move material and to bill for services.

STORES

Storage Units

Storage units can include:

1. *Shelves*
2. *Racks*: Palletized material is stored on pallet racks, usually 10 pallets per rack
3. *Double deep pallet racks* allow for stacking 20 pallets on both sides of the aisle instead of 10 pallets.
4. *Portable racks* fit over a pallet load of soft material. Another pallet is then set on top of this portable rack.
5. *Mezzanines* can be built over shelving areas to use the space over the shelves.
6. *Rolling shelves* allow for only one aisle in maybe 10 rows of shelves.

7. *Drawer storage units* are popular maintenance storage unit because many small parts can be stored in a small area.

Stores Mobile Equipment

Narrow aisle trucks are better than fork truck because: 1) can turn in narrow aisles, 2) the operator stands up.

1. Narrow aisles save space.
2. Standing up saves operator time
1. *Reach truck*. Has a scissor attachment allowing to be extended over 4 feet
2. *Straddle truck*. Has the ability to straddle a pallet on the floor
3. *Side shifting lift trucks*. Are the most space-conserving mobile equipment
4. *Maintenance carts*. Portable oil and grease carts, portable welders, portable toolboxes and portable benches are all possible.
5. *Dollies and casters*.
6. *Maintenance tool crib*. Used for safekeeping of maintenance tools and supplies.
7. *Carousel storage and retrieval systems*.

FABRICATION

Shop Containers

Shop containers are used to move parts in unit loads.

Tubs and Baskets

Tubs and baskets are larger shop containers

Drop bottom tubs. A rack holds the tub over an inclined slide, the bottom is dropped and parts flow out.

Tilt stands. Tilt stands holds parts on an angle to make retrieving easier.

“V” stands. “V” Allow for easy access to parts.

Scissor lifts or hydraulic lifts. A scissor lift material to a comfortable height.

Dump hoppers. Dump hoppers can make the handling of material at a workstation almost effortless.

Figure 11-27 Drop Bottom Tub

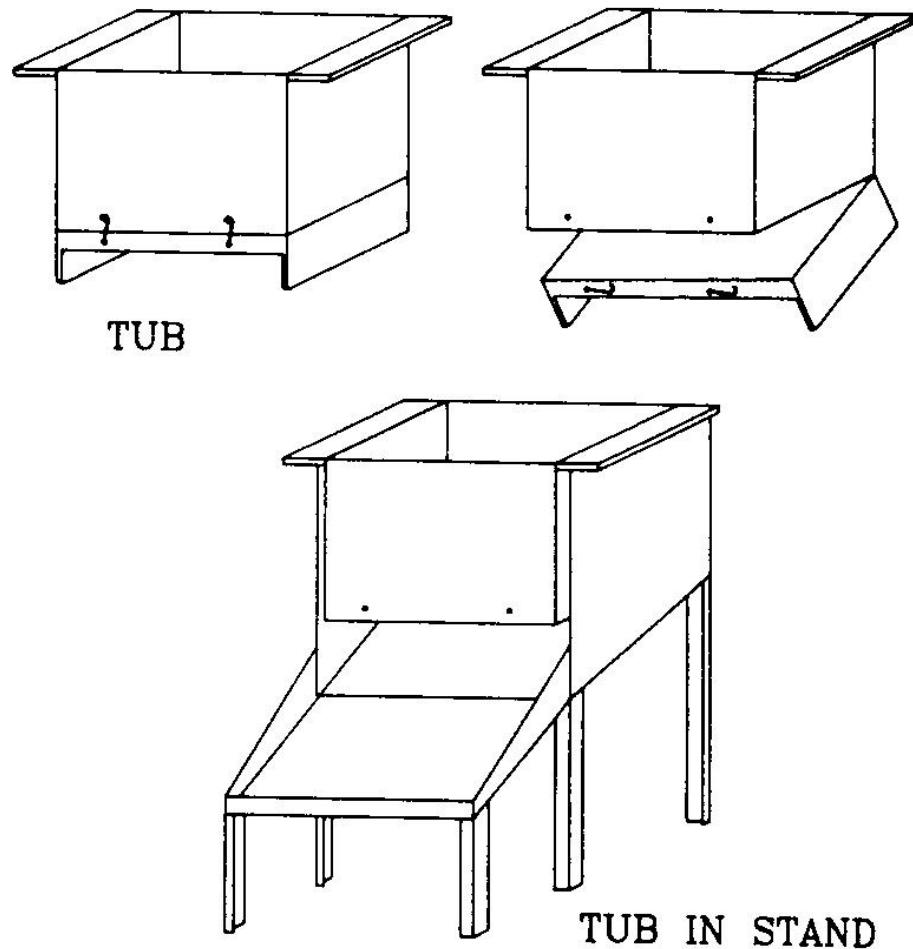


Figure 11-28 Drop Side Basket (Courtesy of Steel King Industrial Containers)

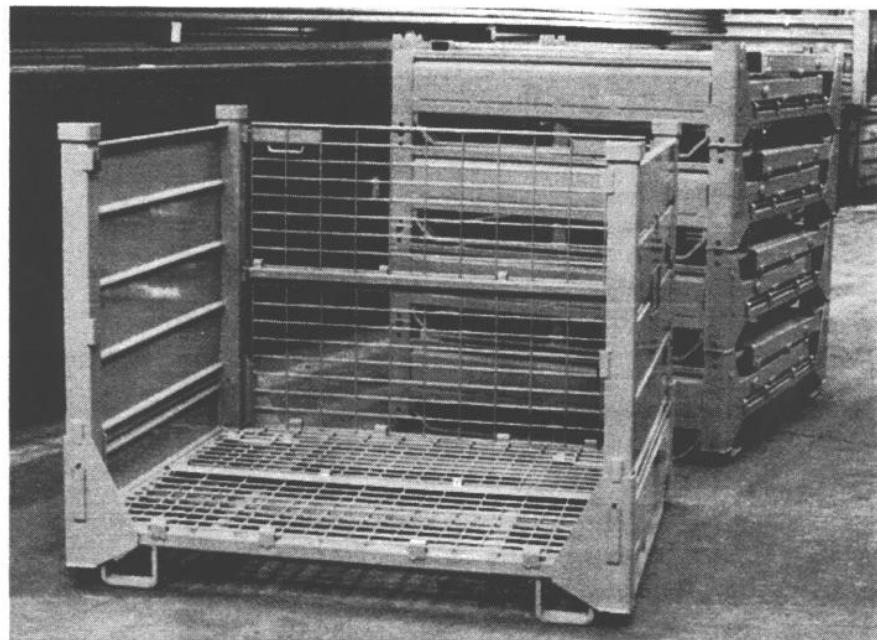


Figure 11-29 Tilt Tables and Stands (Courtesy of Air Technical Industries)

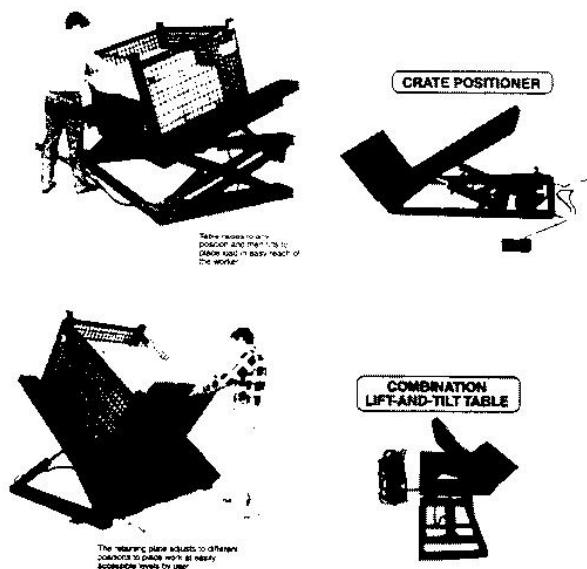


Figure 11-31 "V" Stand

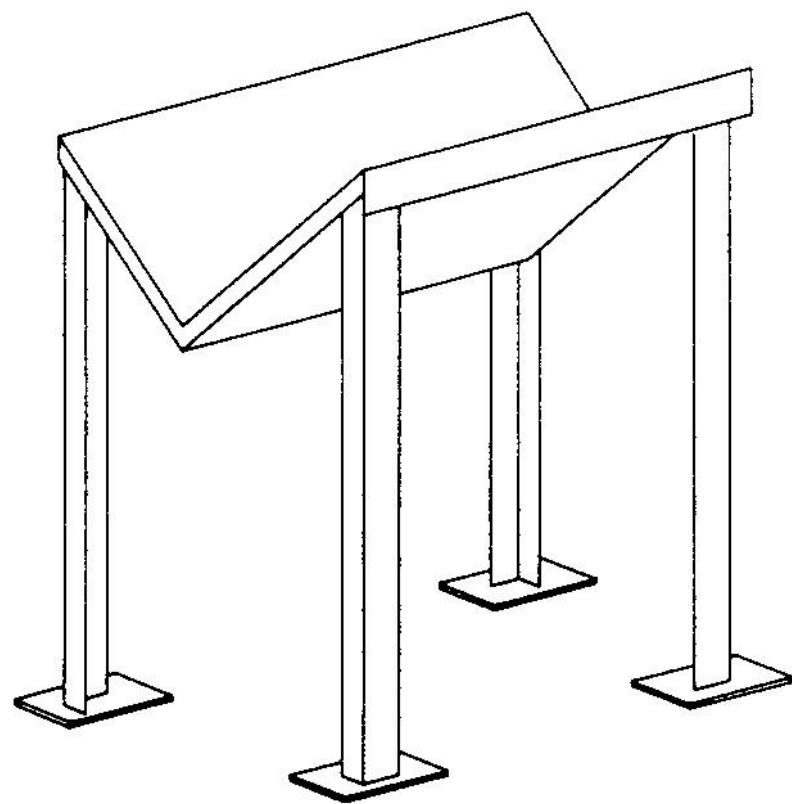


Figure 11-32 Scissor Lifts (Courtesy of W.W. Monroe Equipment Co.)

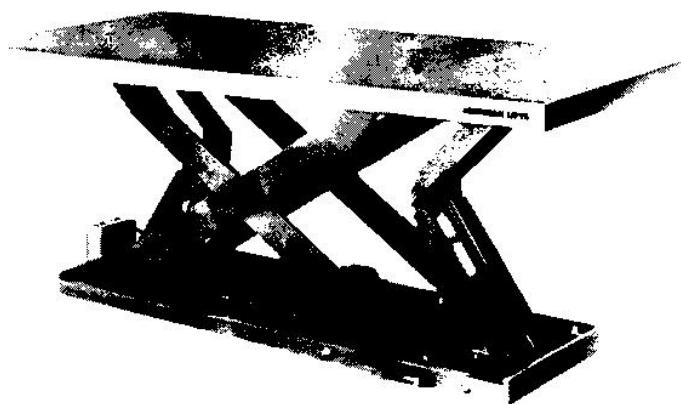
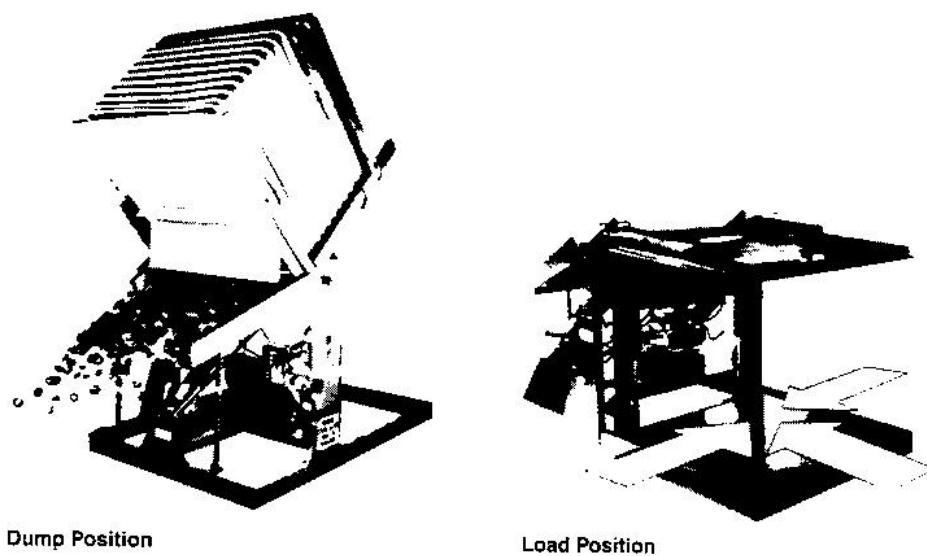


Figure 11-33 Dump Hoppers (Courtesy of Wilde Mfg., Inc.)



Workstation Material Handling Devices

Counterbalances. Counterbalances hold tools where they are needed and nearly eliminate the weight of the tool.

Manipulators and Lifting Devices

Manipulators are positioning devices with almost human flexibility and dexterity with superhuman strengths.

Vibratory feeders. Vibratory feeders orient, feed, count, and present a part to the next operator.

Waste disposal. Removing waste from workstations requires special material handling equipment.

Walking beams. Walking beams can continually load and unload machines, eliminating the need for an operator doing any material handling.

Ball tables. Allow for easy movement of heavy material.

Powered round tables. A workstation can be built on a round table and indexed automatically.

Jib cranes. Jib cranes are a lifting device attached to a boom.

Vacuum or magnetic lifts. A vacuum, or magnetic lift hoists long heavy sheets of material.

Robots. Can be used to perform a variety of dangerous tasks in a hostile environment.

Mobile Fabrication Equipment

Slides and chutes.

Skatewheel and roller conveyor (nonpowered). Skatewheel and roller conveyors come in 10-foot sections and can be combined to make any length. They can be easily moved for a change of direction.

Lift conveyors. Lift conveyors can move parts from near the floor to any elevated position.

Figure 11-34c Manipulators at Work (Courtesy of Positech, A Division of Columbus McKinnon Corporation)

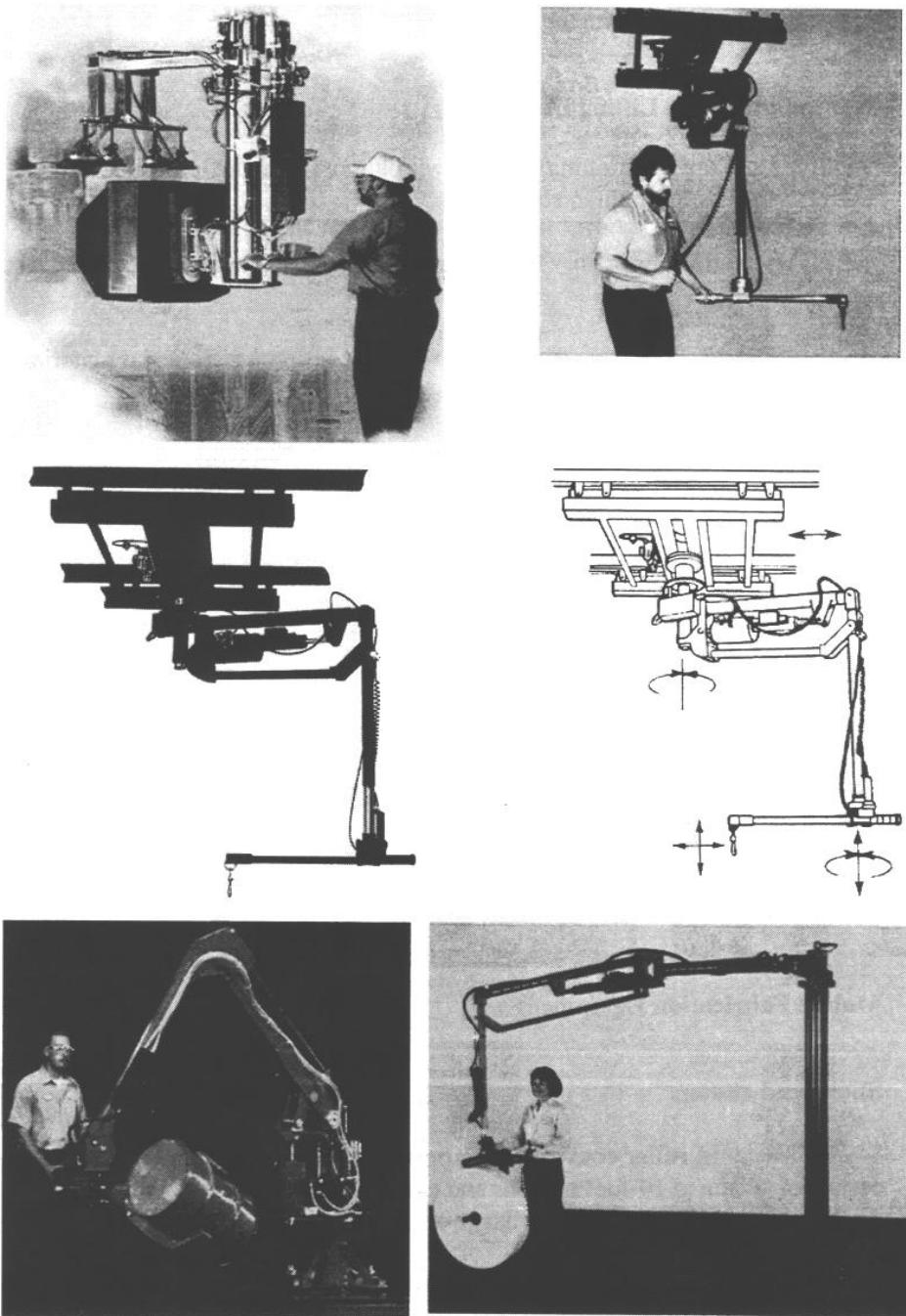


Figure 11-34d Lifting Devices in Action (Courtesy of Palamatic Handling Systems)



Figure 11-36b Automatic Chip Removal System (Courtesy of Turbo Conveyor)

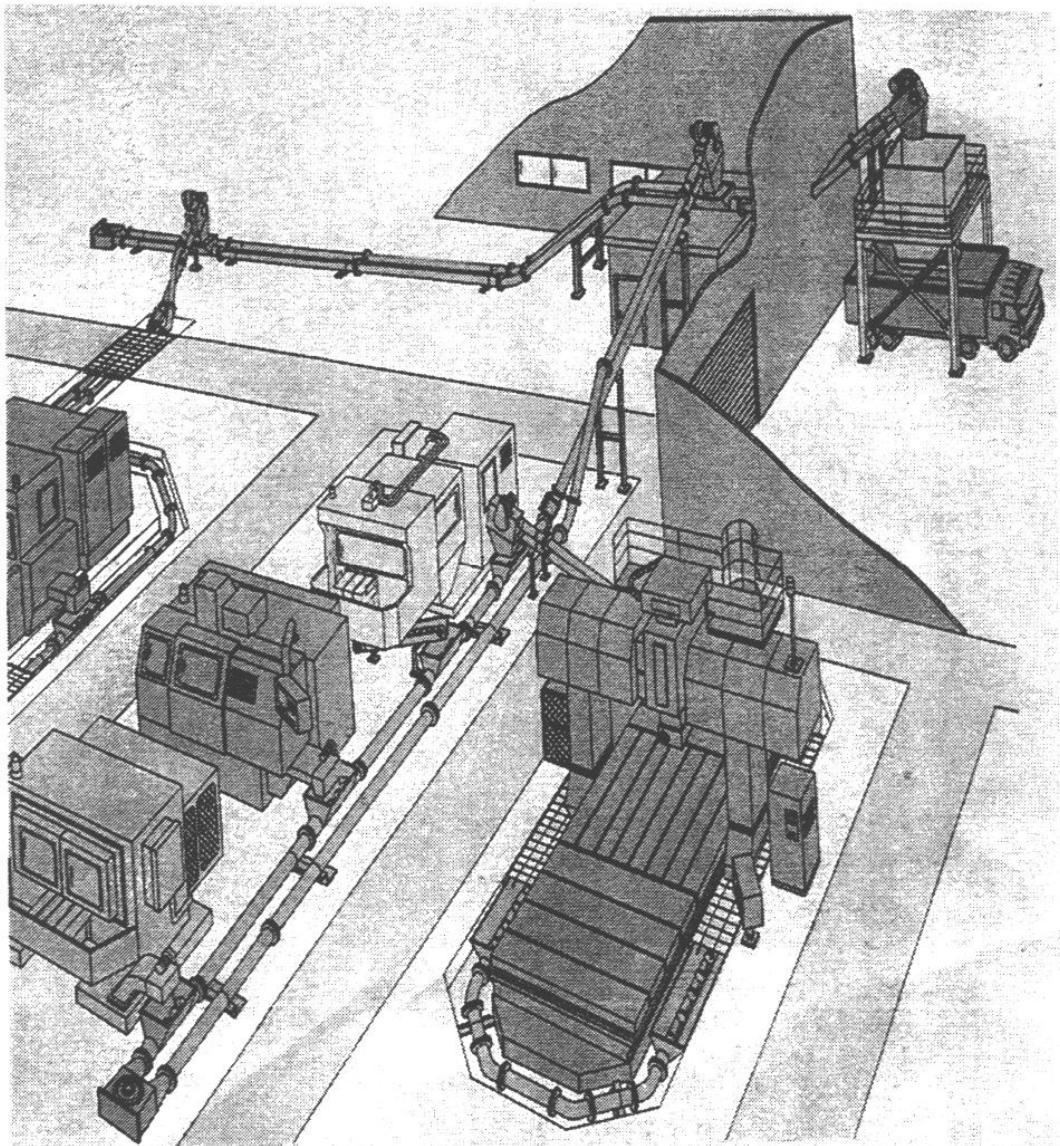


Figure 11-39 Powered Round Table

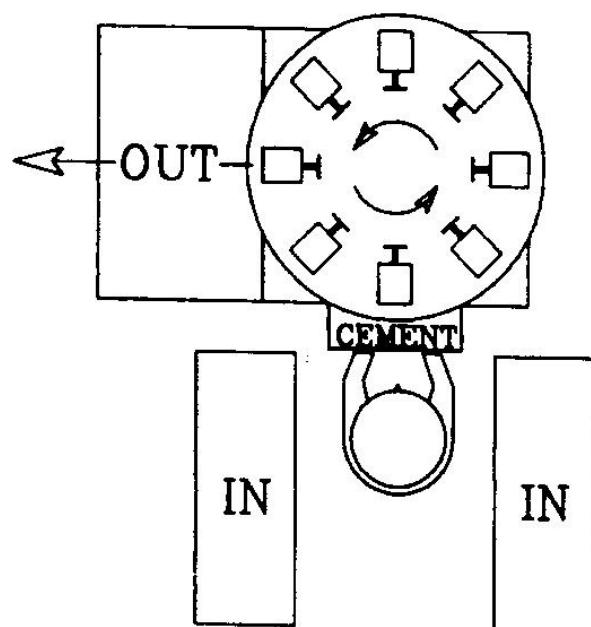


Figure 11-41 Manipulator (Courtesy of TDA Buddy Systems)

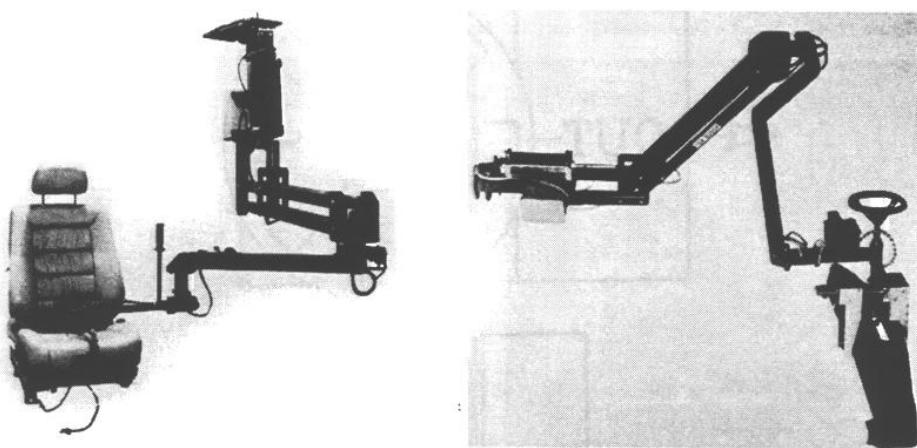


Figure 11-44 Skatewheel and Roller Conveyor (Courtesy of Hytrol Conveyor Co.)



■ Six-Way Skatewheel Switch

This special "Six-Way" Skatewheel Switch is designed to transfer products from two diverging lines to a main line. This unit can also be provided with special removable guard rails.

Figure 11-45b Adjustable Angle Conveyor (Courtesy of Dorner Mfg. Corp.)

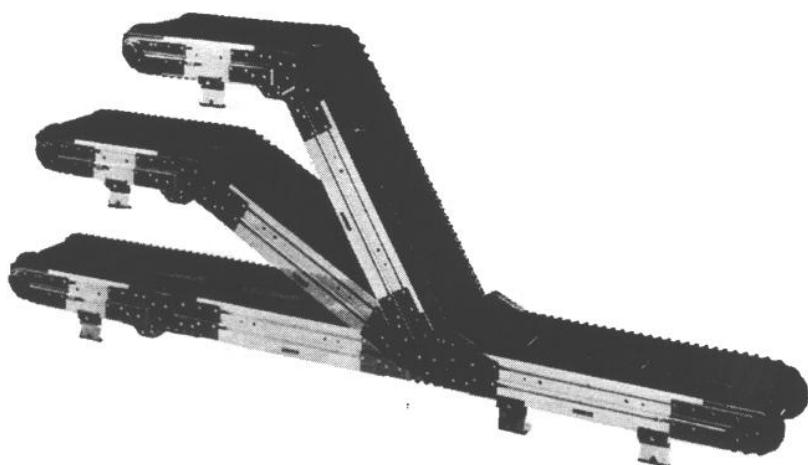


Figure 11-45c Magnetic and Vacuum Conveyors (Courtesy of Dorner Mfg. Corp.)

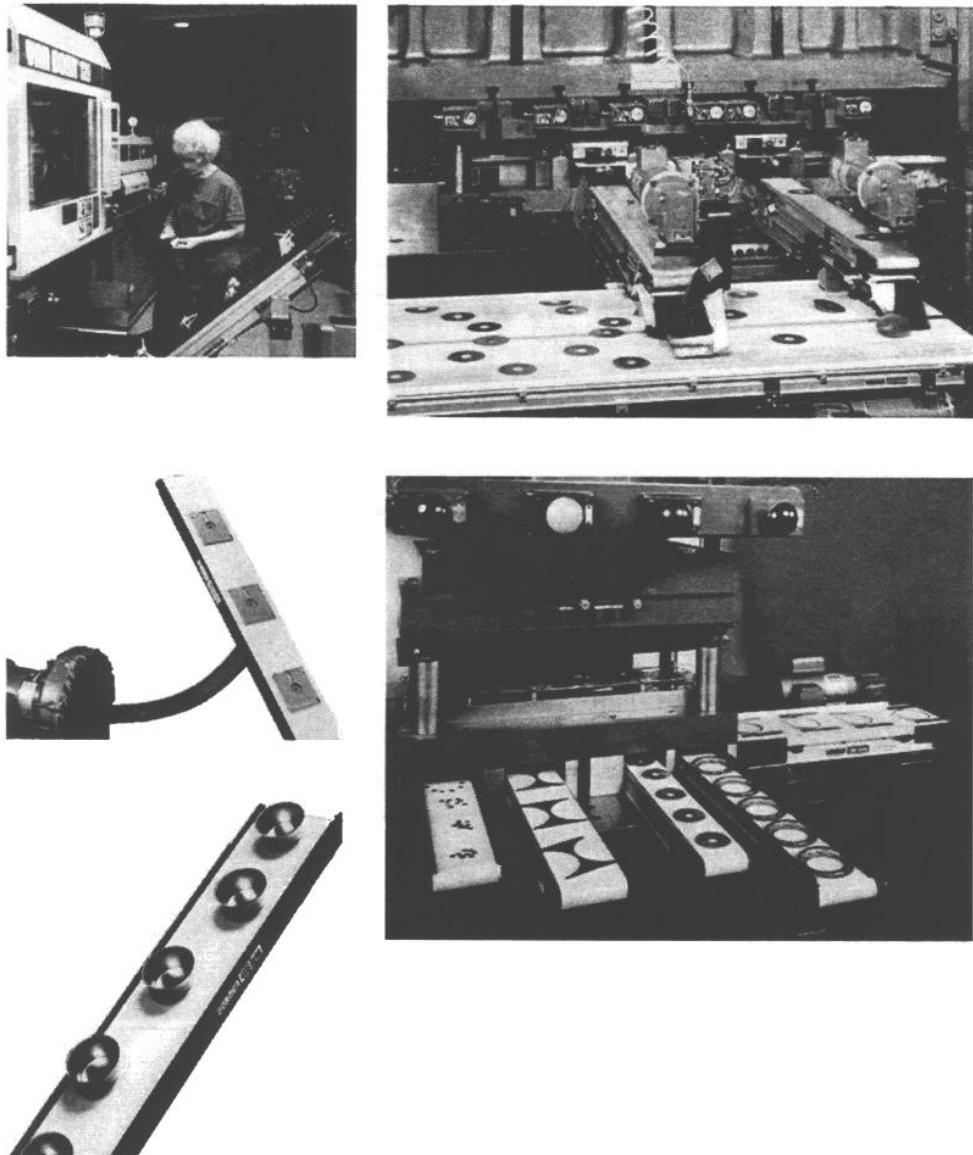


Figure 11-51 Belt Conveyor (Courtesy of Hytrol Conveyor Co.)



Figure 11-53 Car-Type Conveyors (Courtesy of Webb-Stiles Company)

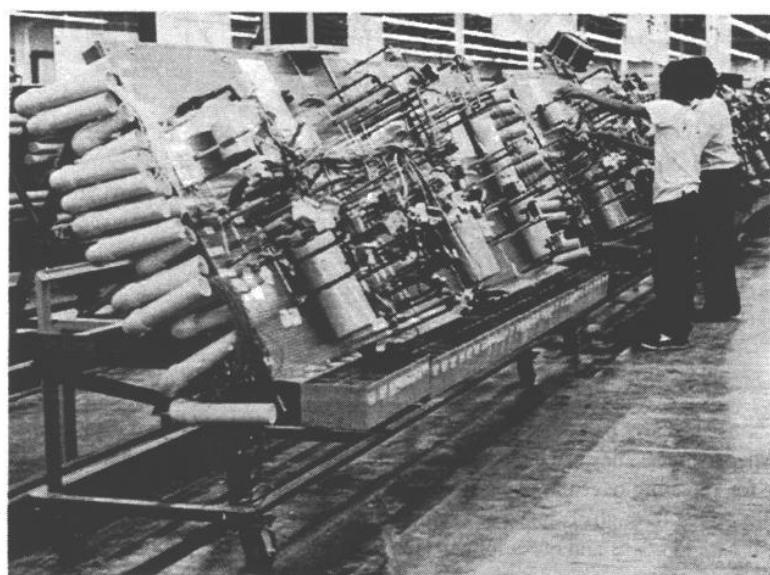
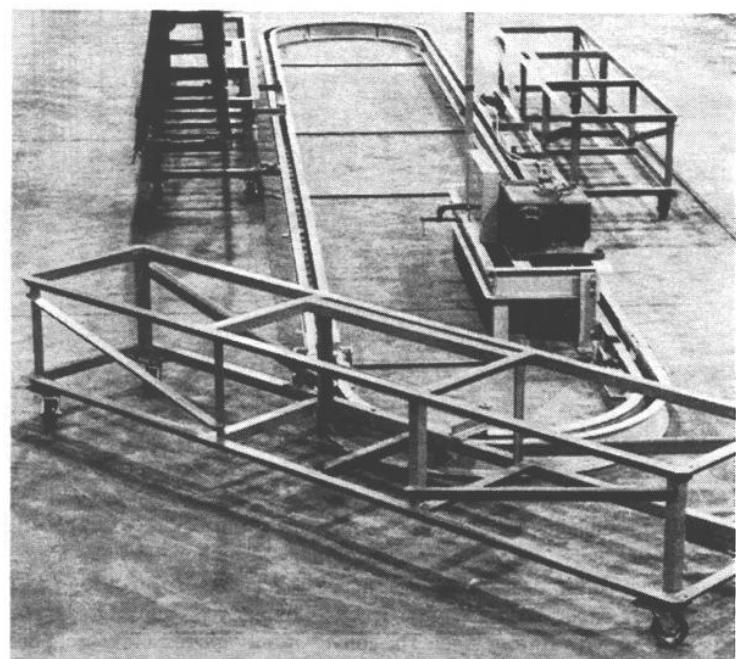


Figure 11-55a Towline (Courtesy of S.I. Handling Systems, Inc.)

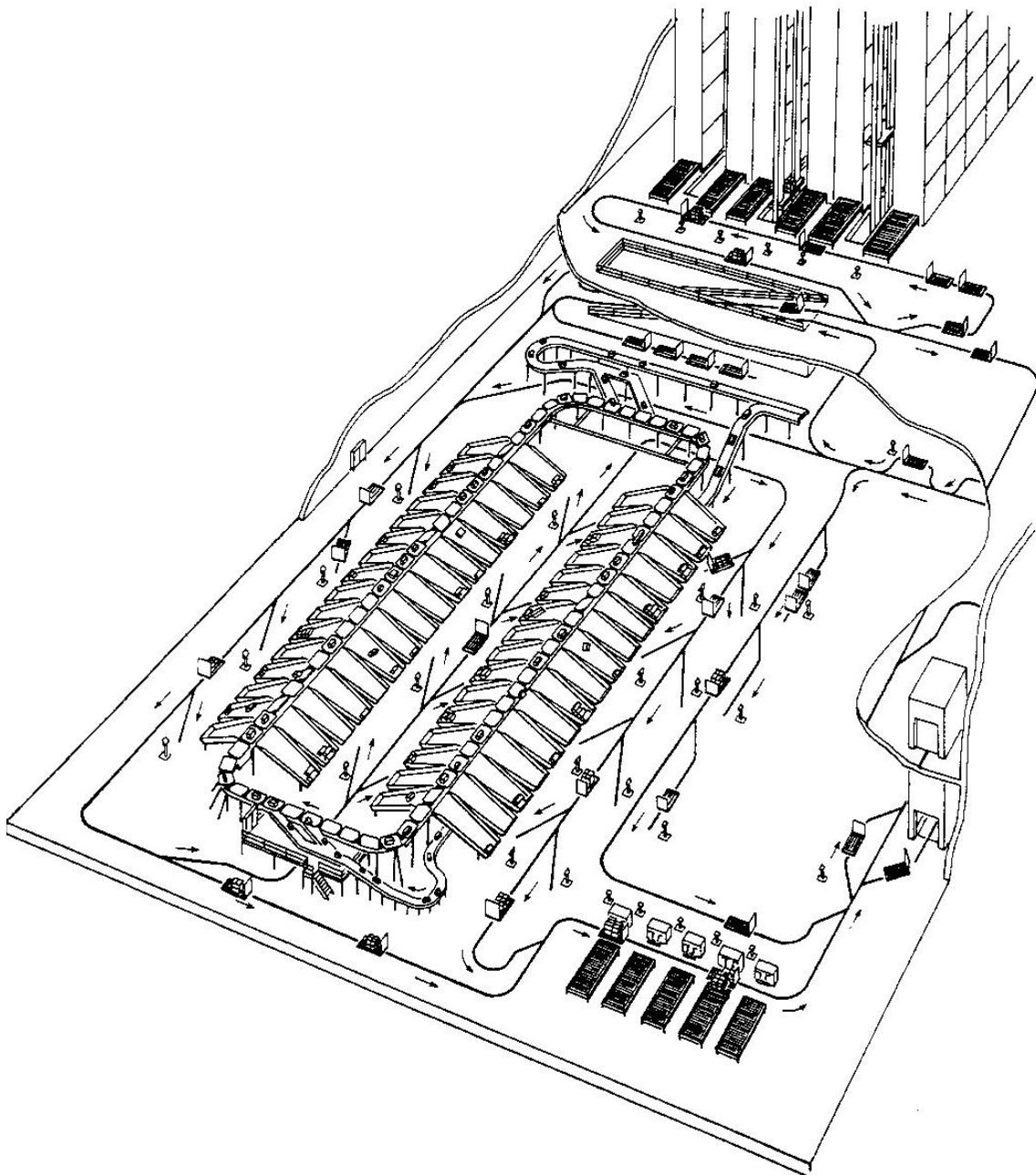


Figure 11-56a Overhead Trolley Conveyor (Courtesy of Richards-Wilcox)

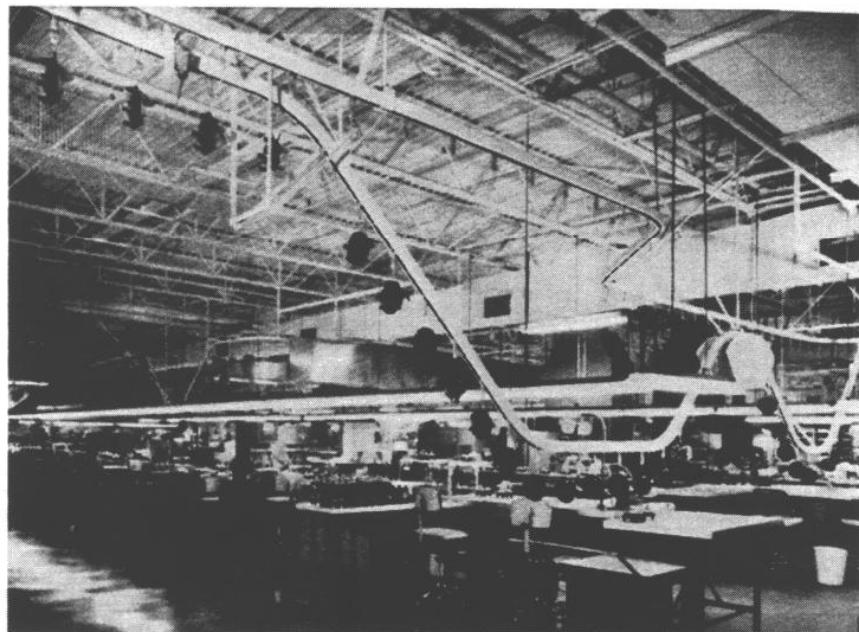
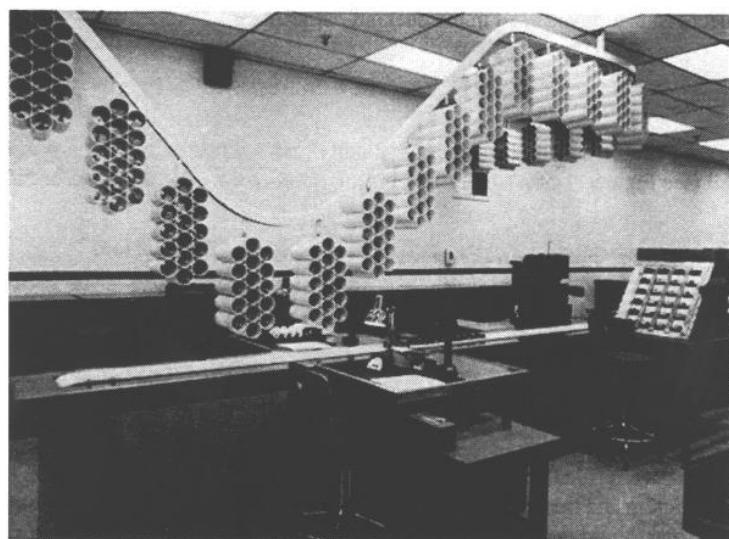


Figure 11-56b Trolley Conveyors (Courtesy of the Buschman Company)



Adjustable angle conveyors. They can be set up and easily reconfigured to meet a variety of manufacturing, assembly, and bulk handling needs.

Magnetic conveyors. Can be used for lifting ferrous parts and components on an inclined angle cheaply and efficiently.

Auger conveyor. Grain and wood chips are moved this way.

Vibratory conveyor. Move parts down a chute or slide by vibration.

Monorail trolley. Can move a heavy tool anywhere along a 20-foot path.

Powered hand trucks. Can lift and move great weights and are easy to control.

ASSEMBLY AND PAINT

Belt Conveyors

Belt conveyors are endless loops of fabric that can be any width by any length.

Powered Roller Conveyor

The powered roller conveyor performs similarly to a belt conveyor.

Car-Type Conveyor

Fixtures are attached onto a cable and pulled along a fixed path.

Slat Conveyor

Slat conveyors are narrow slates of wood or metal attached to chains.

Tow Conveyor

Tow conveyors pull carts around a fixed path.

Overhead Trolley Conveyor

Overhead trolley conveyors can go anywhere.

Power and Free Conveyor

Power and free conveyors are dual track trolley conveyors with one track for the power line and the other track for carrying the trollies.

PACKOUT

Box Formers

Box forming can be accomplished automatically and wrapped around the product being packaged. Soft drink bottling plants are a good example of this.

Palletizers

Boxes are automatically stacked on pallets per a prearranged program.

Pick and Place Robots

The robot can handle a number of different packages at the same time, but the function is the same as a palletizer.

Banding

Banding boxes closed can be accomplished automatically by placing a bander around the packout

Stretch Wrap

Stretch wrap is like banding in that it holds packages together on a pallet.

WAREHOUSING

Picking Carts

Customer's orders can be picked from shelves and placed on picking carts. Tool, drug, audio tape, and book warehouses use this kind of equipment.

Gravity Flow Bins

Good for small, high volume product.

Tractor-Trailer Picking Cart

Suitable when picking larger orders.

Clamp Trucks: are a special fork truck that eliminated the use of pallets.

Rotary Conveyor Bins: bring small product to picker—save walking

Vertical Warehouse and Picking Cars

The vertical warehouse could have 40 shelves high that are 300 feet long on both sides of a 4 foot aisle.

BULK MATERIAL HANDLING

Bulk Material Conveyors

Troughed belt conveyor. Belt troughed conveyors are concave and resemble a long feed through. The coal and logging industries use troughed conveyors.

Screw conveyor. Use of screw conveyors in processing plants such as paper mills, bakeries, and feed mills is common.

Vacuum delivery systems. A vacuum system is a system of tubes moving pellets or powders from tank cars to storage towers to equipment.

Pumps and tanks. Oil, drinks, most liquids, and semiliquids are moved from tankers to tanks to filling stations pumps.

Conveyor systems. If the products are cartons, a system of diverted conveyors may be used. UPS and other distribution systems are examples.

Cross-Docking and Flow-Through

Integration of computers with material handling systems has facilitated the concept of cross-docking. When the ultimate destination of a part which enters the facility is specified, the flow can be virtually uninterrupted through the facility by intervals of storage. The benefits include:

- Reduced warehousing and inventory costs
- Reduced processing costs
- Reduced handling and labor costs
- Reduced storage and warehouse space
- Improved productivity
- More efficient flow of material

Figure 11-59 Taping (Courtesy of Durable Packaging Corp., 3139 West Chicago Avenue, Chicago, IL)

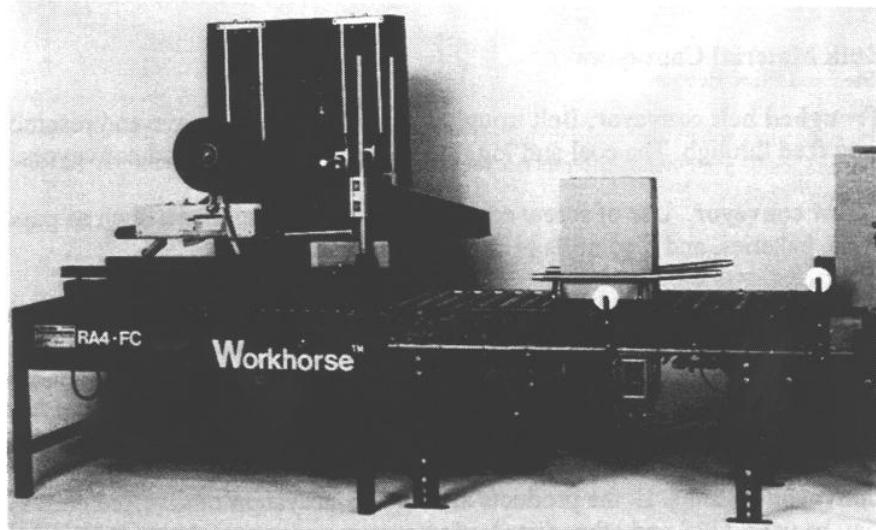


Figure 11-60 Robotic Palletizer (Courtesy of GM Fanuc Robotics Corporation)



Figure 11-74 Troughed Bed Belt Conveyor (Roller Bed) (Courtesy of Hytrol Conveyor Co.)

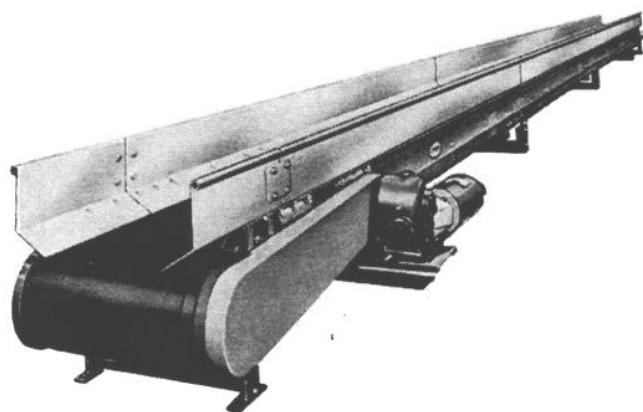
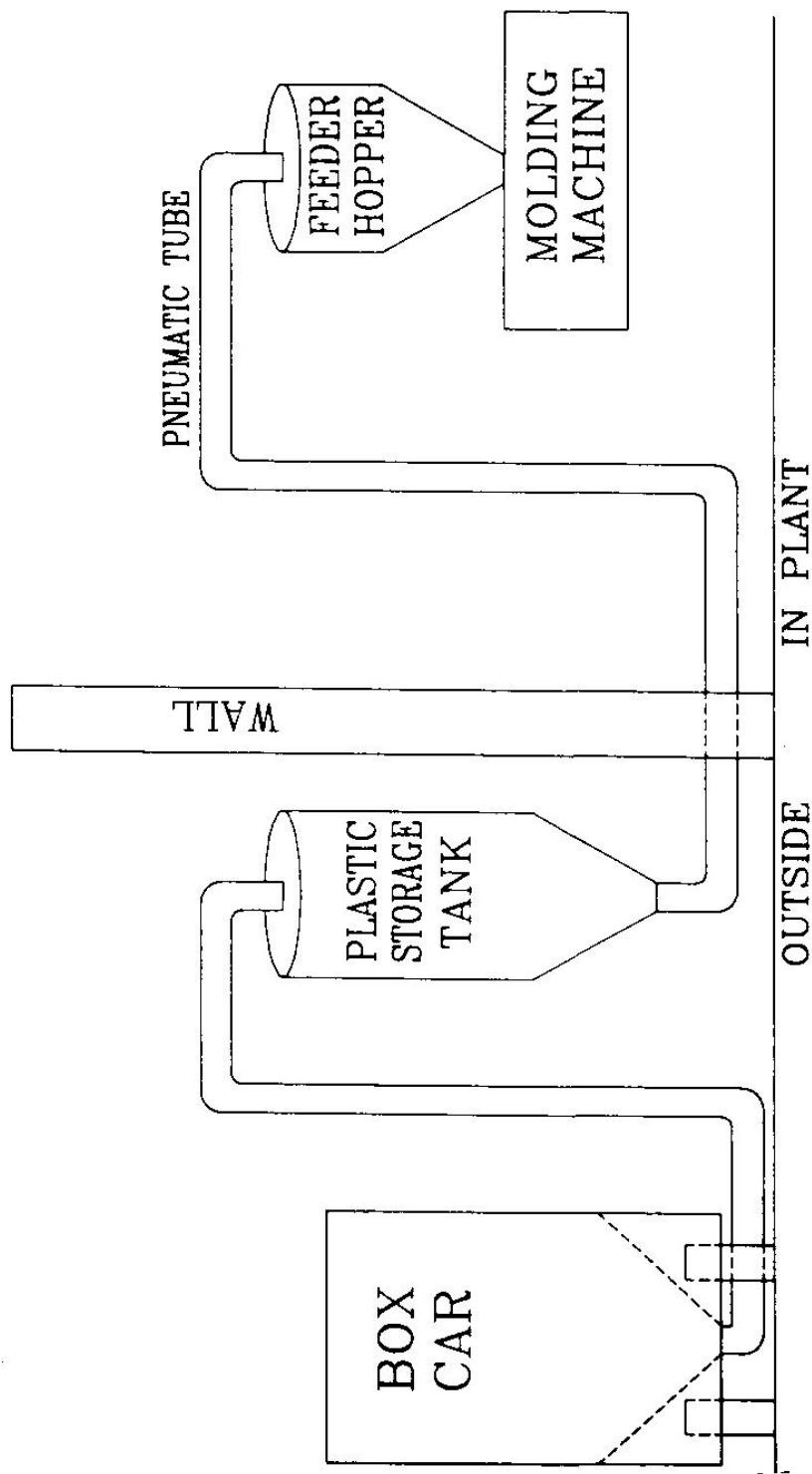


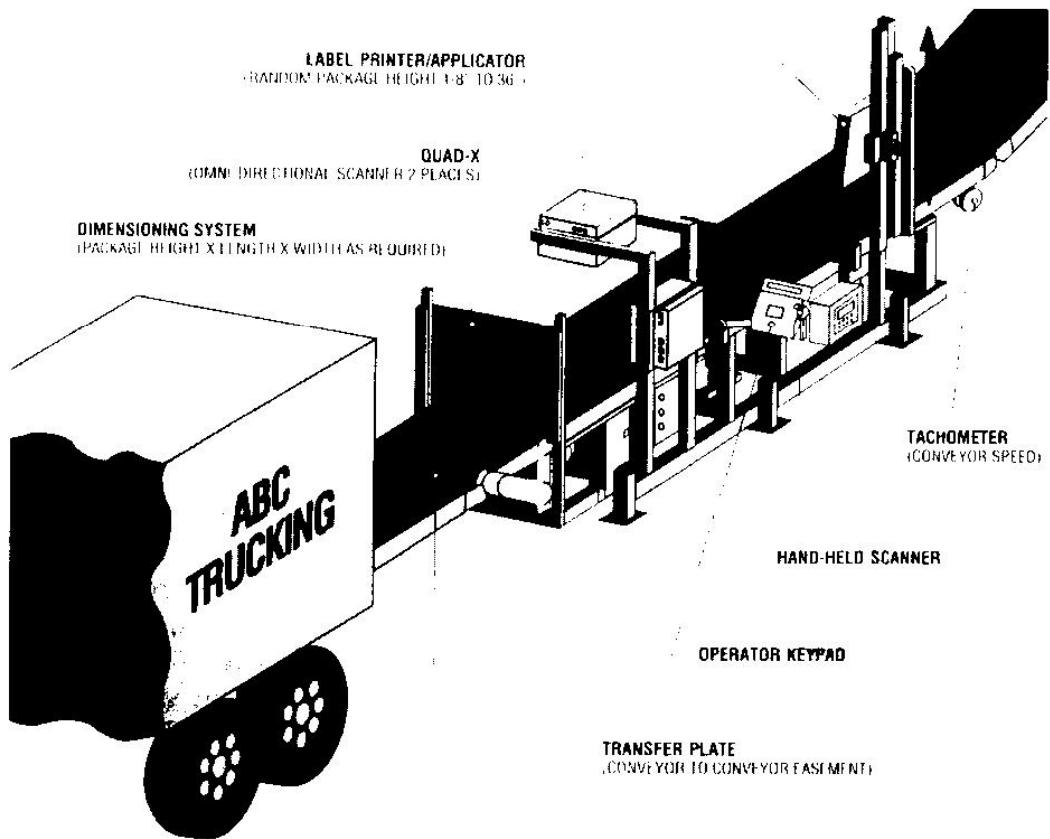
Figure 11-75 Vacuum Delivery System



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Figure 11-81 Computer-Integrated Cross-Docking System (Courtesy of Accu-Sort Systems, Inc.)



Chapter 12

Office Layout Techniques and Space Requirements

Objectives

In this chapter parallels between plant layout and office layout are drawn. It is brought to the attention that flow of information and people is as critical as that of material. Methods for office space allocation and layout are discussed.

GOALS OF OFFICE LAYOUT DESIGN

1. Minimize *project cost*. Strive for cost effectiveness not cheap.
2. Improve *productivity*. Reduce walking distances and useless work.
3. Increase *flexibility*. Office layouts will change.
4. *Cleaning and maintaining* office space is costly. Enhance this process.
5. Minimize *Noise*. Fabrics on the walls, floors, and ceilings can help.
6. Expedite *Material flow*. Distances must be held to a minimum.
7. Create a *pleasing atmosphere* in order to promote pride and productivity.
8. Minimize *visual distractions*. Panels and furniture can be used.
9. Create a *pleasing reception area*. First impressions of our company.
10. *Energy costs* can be affected by the layout.
11. Provide adequate *workspace*. Layouts must address every worker's needs.
12. Provide for the *convenience*. Restrooms, lockers (or coat racks), lunch rooms.
13. Be *safety* conscious. Be aware of aisle sizes, stairways, machines, and clutter.

TYPES OF OFFICE SPACE

Office space costs more per square foot than does manufacturing or distribution space, so space use is very important. Our discussions are focused on manufacturing plant office layouts instead of corporate offices, but the techniques and processes are the same.

Supervisors' Offices

A 10 X 10-foot portable office located in the middle of a production department.

Shipping, receiving, maintenance, as well as production supervisors could use this type of office construction.

Supervisors should be located where they are immediately accessible to their employees and have a line-of-sight view for improved communication.

Open Office Space

Open office space or *bull pens*) is large rooms that house many people.

Advantages:

1. Improved *Communications*.
2. Common *equipment* is accessible to more people.
3. Less *space* is required, as compared to private offices.
4. *Heating, cooling and ventilation* costs and problems are minimized.
5. *Supervision* of the people in an open office is easier.
6. *Layout changes* are quicker and less costly.
7. *Files and literature* are accessible to all.
8. *Cleaning, vacuuming, and sweeping* work is reduced.

Disadvantages:

1. The *lack of privacy* is probably the biggest problem with open offices.
2. *Noise* can be a problem with open offices.
3. Does not offer *status* that a private office carries.
4. *Confidentiality* of some work may require private space.

Figure 12-1 Supervisor's Office (Courtesy of Global Equipment Co.)

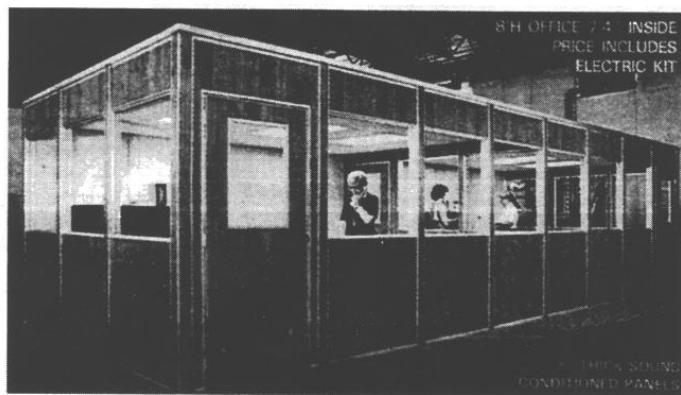
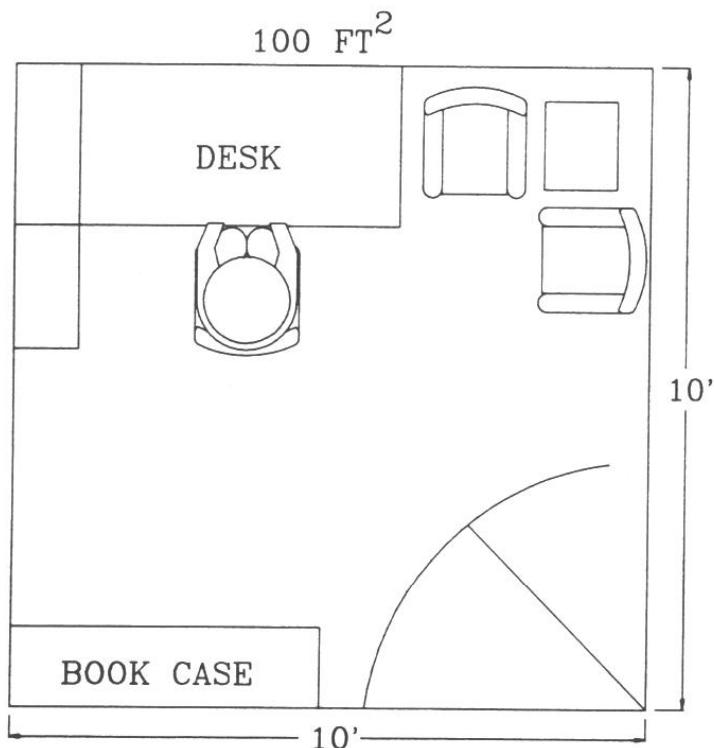


Figure 12-3 Open Office (Bull Pens)

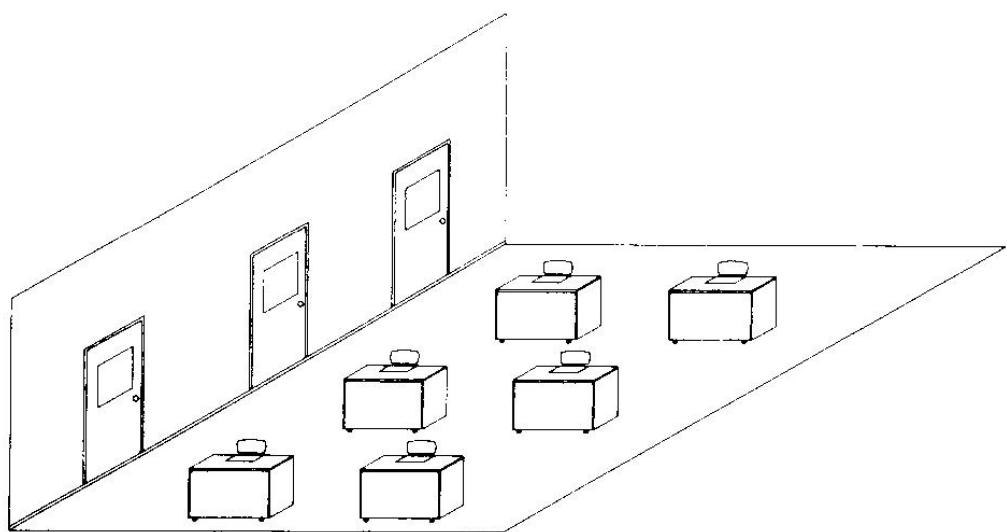


Figure 12-4 Conventional Offices (Courtesy of Global Equipment Co.)

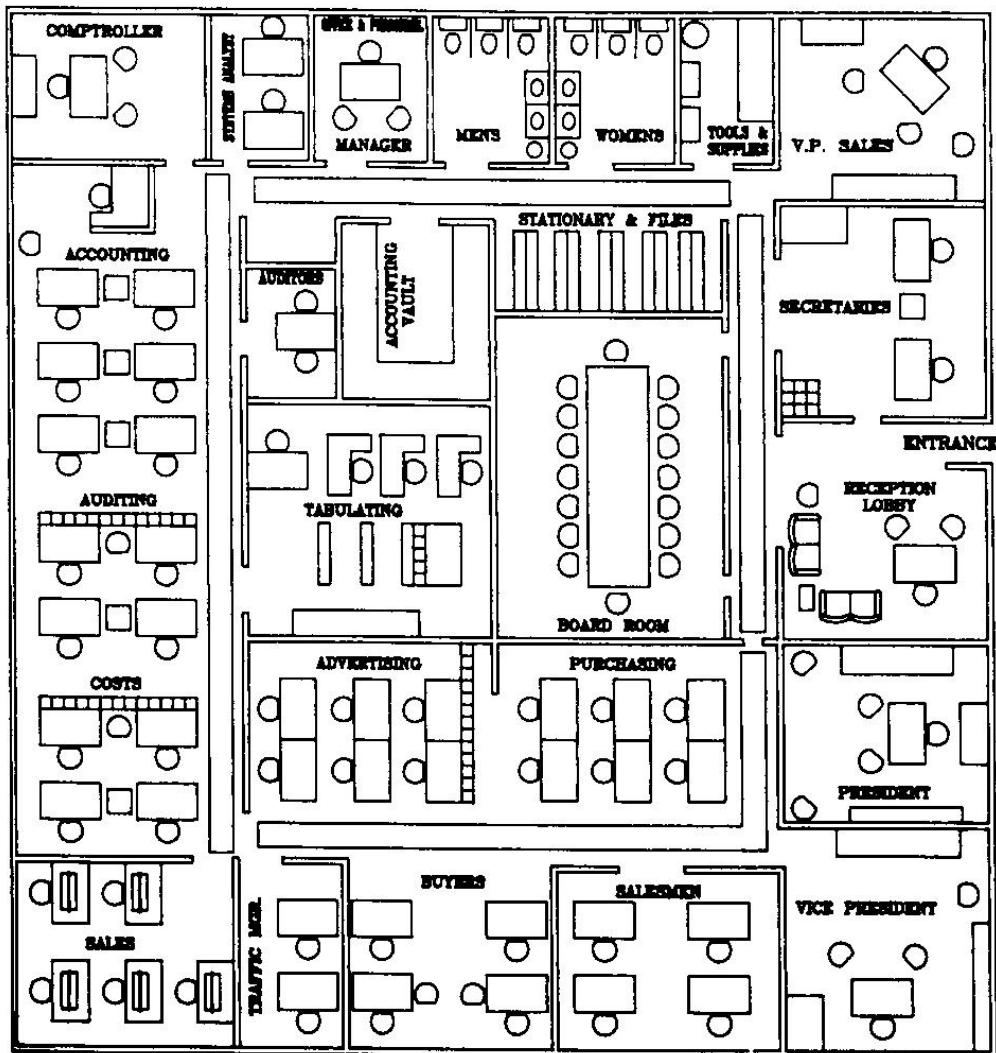


Figure 12-6 Modern Office Layout

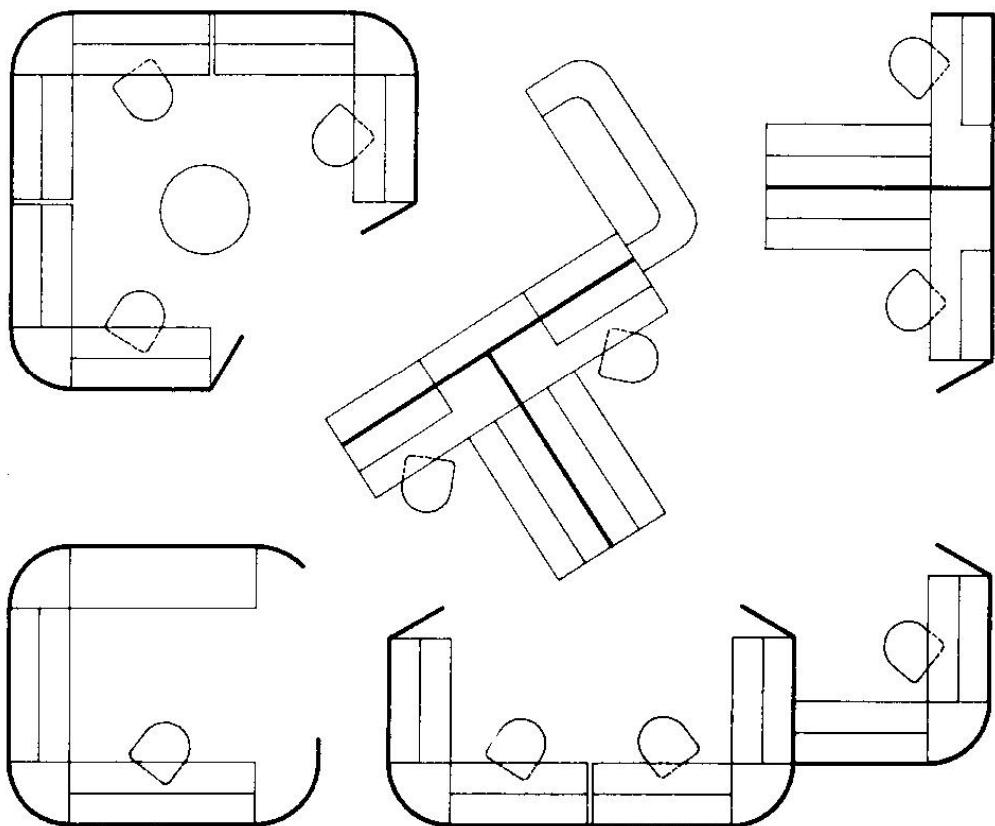
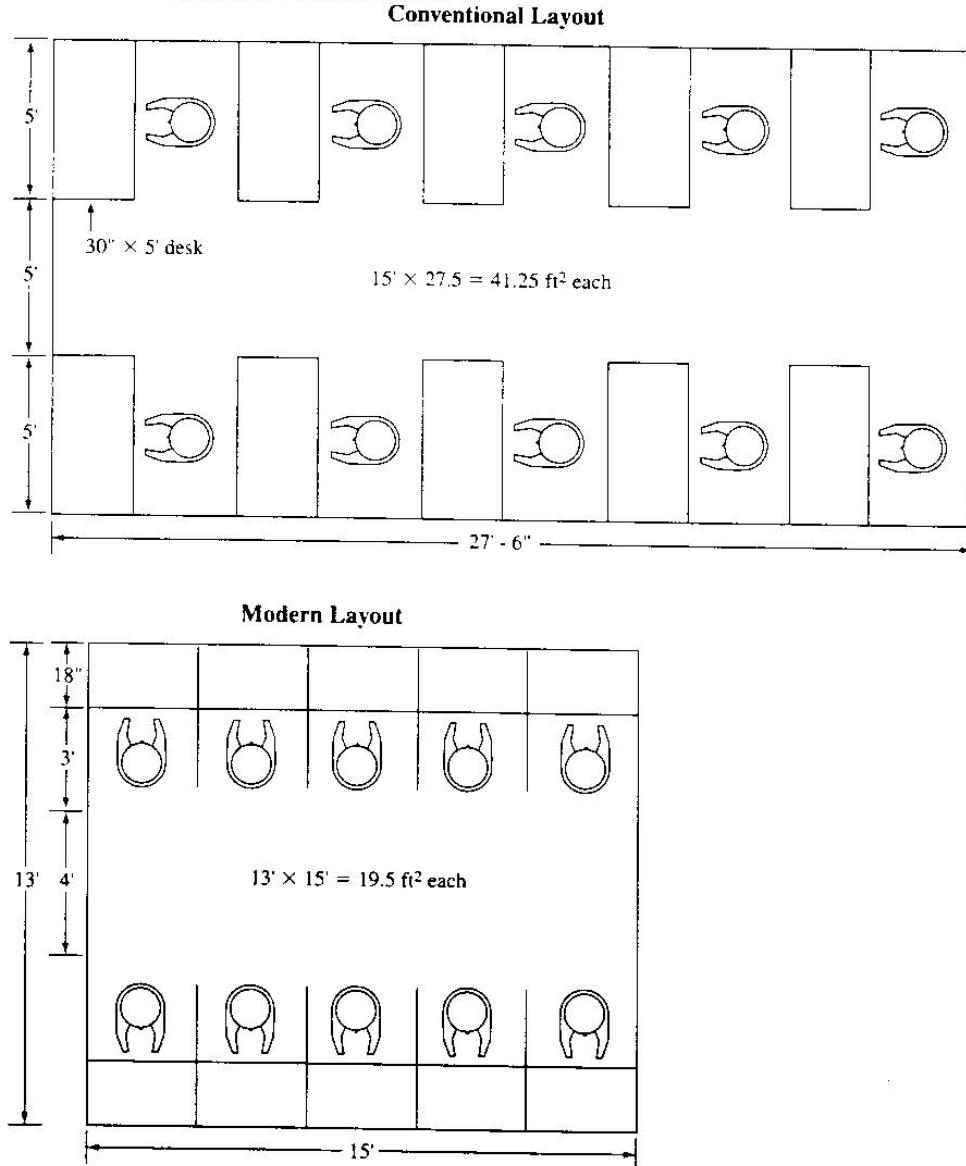
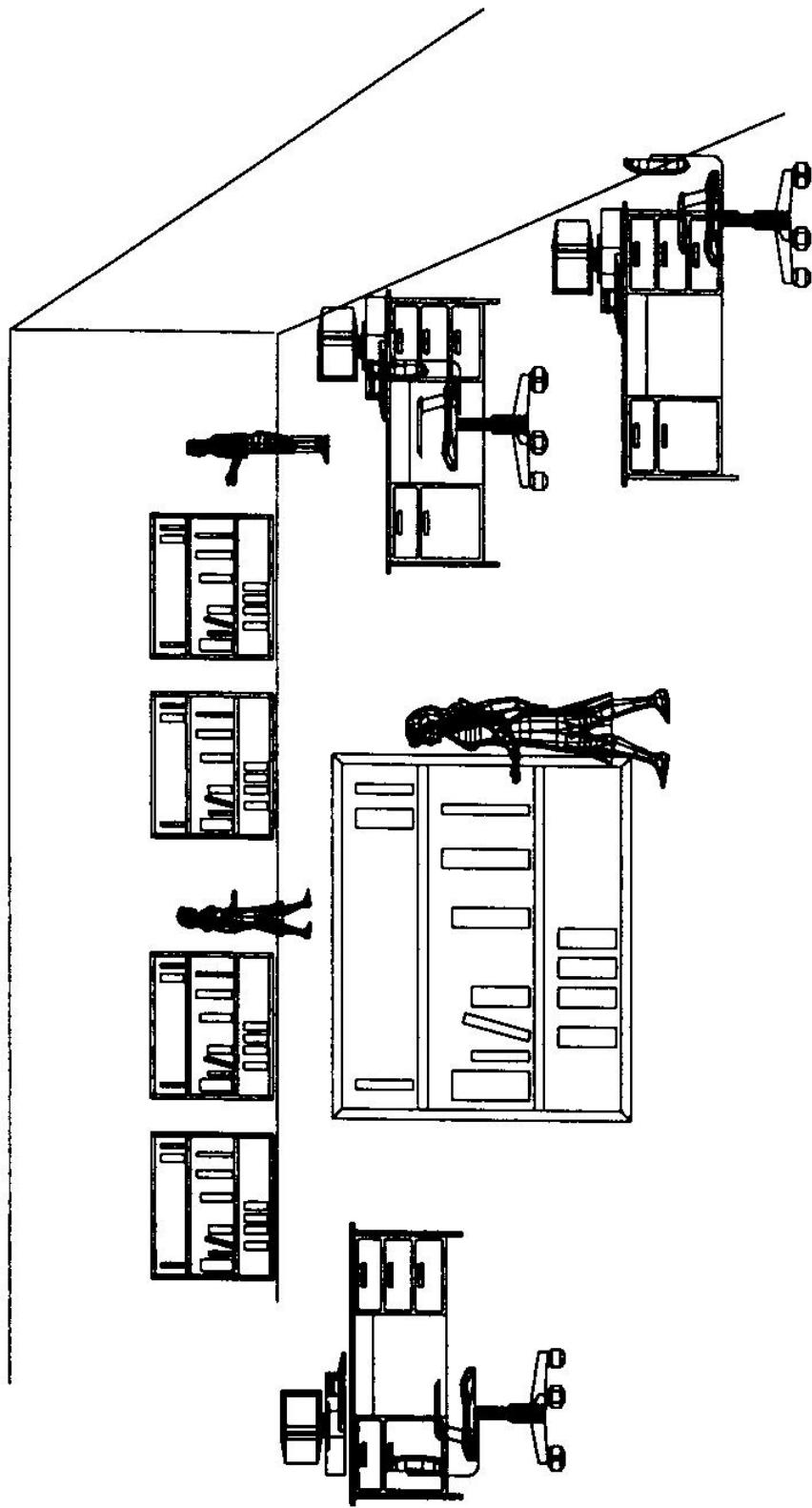


Figure 12-7 Conventional Space vs. Modern Space—10 Data Entry Clerks' Workstations



Note: At a rental rate of \$25.00 per square foot per year,
the conventional space would cost \$5,625.00 per year, a savings of
\$4,687.50 per year.

Figure 12-8 Point of Use Storage



Conventional Offices

Conventional offices, also known as *fixed walled offices*, are the opposite of open offices.

More than one person can be assigned to an office, and at what point it becomes an open office is a little fuzzy.

A combination of open office concept and conventional office advantages would allow for the best of both techniques. We will call this the *modern office concept*.

The Modern Office

The modern office will provide private office space where needed without negatively affecting the cost of utilities, maintenance, and accessibility.

1. Panels do not go to either the ceiling or the floor. Air can circulate.
2. Cabinets are built into the panels to make a better use of the space.
3. Tables are built into the panels to save space and costs.
4. Drawers under the tables allow for storage of supplies just as a desk would.
5. Utilities (electrical, computer, and phone) lines can be carried in the panel.

6. Modern offices can be easily rearranged to meet the changing needs.
7. The modern office is very flexible.

They are also called *clustered offices*, *landscaped offices*, and *free-standing office*.

SPECIAL REQUIREMENTS AND CONSIDERATIONS OF SOME OFFICES

1. *Privacy* may be required by some office employees.
2. *Point of use storage* store supplies close to the point of use.
3. Offices in manufacturing plants often have a *second floor*.
4. *Centralized* or *decentralized*? Place where they are needed.

The advantages to a centralized office are:

- a. single office area construction, including all common utilities.
- b. the convenience of having all office people in one area
- c. the convenience to outside visitors without disturbing production
- d. common files and equipment

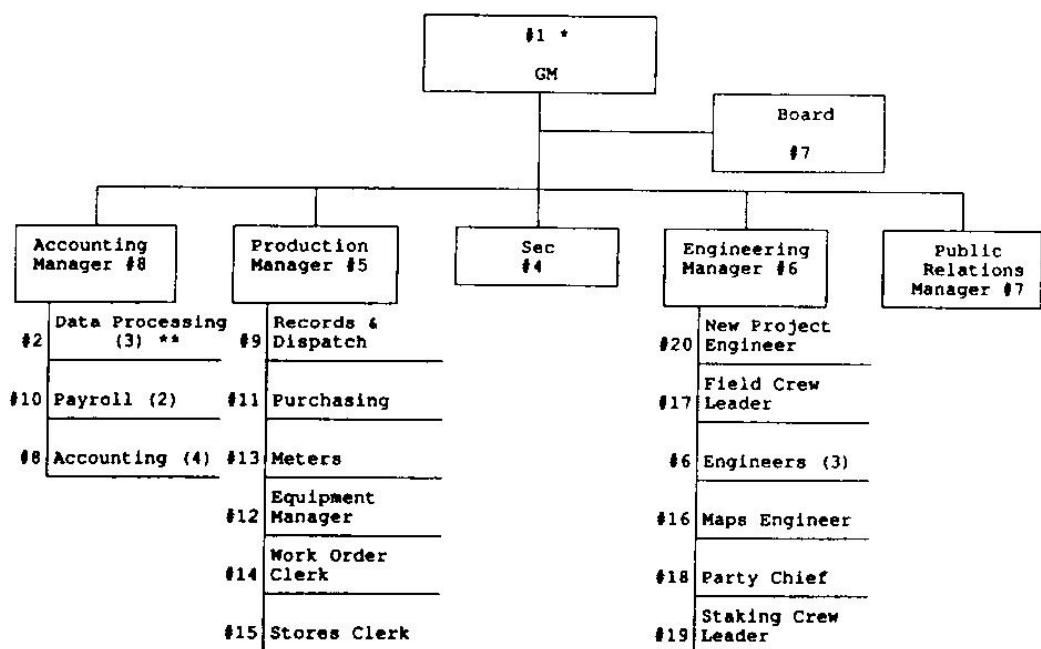
The disadvantage: Location may not be convenient for all operations.

5. *Flexibility* is an important consideration from the very early stages of planning.
 - a. use *floors* for running of electricity, cables, telephone lines, etc.
 - b. *Drop ceilings* and hollow panel can also be used as above.
6. *Conference rooms* can be used to provide privacy when required.
7. *Libraries* are special needs areas where reference books and magazines are kept.
8. A *reception area* is the visitors' center.
9. *Telephone systems* are becoming automatic, but some personal attention is always necessary.
10. *Copy and fax machines* can be major pieces of equipment.
11. Incoming and outgoing mail can be big business.
12. *Files and storage areas*. Legal requirements force companies to keep many of these documents for years.
13. A *word processing or secretarial pool*.
14. *Aisles* are big users of space. 3 to 5 feet for smaller, 6 to 8 feet for larger.
15. *Computer mainframes*.
16. Other areas and considerations to keep in mind are (a) lighting, (b) vaults, (c) standardization, and (d) expansion.

THE TECHNIQUES OF OFFICE LAYOUT

1. The organizational chart
2. The flowchart (systems and procedures analysis)
3. Communications force diagram
4. Activity relationship diagram
5. Worksheet
6. Dimensionless block diagram
7. Size development
8. Detailed master plan

Figure 12-10 Organizational Chart—Electrical Power Co-Op



* Position Numbers (#1)

** Number of People in This Office (3)

Figure 12-11 Flowchart Symbols

Operation	=		Perform some function such as match, review, fill orders, input data, and so on.
Form	=		Generate a form or a document. A special operation. If more than one copy is used, another page is shown behind the first page for each copy.
File	=		File documents. A "T" could be placed inside the triangle to indicate a temporary file or a follow-up file and a "P" could be used for permanent file or completed file.
Transportation	=		Physically moving something such as material (not paperwork).
Decision	=		Yes/No, Go/No Go at any point where the direction of flow might change.
Approval	=		Used when management approval is required.
Paperwork Flow	=		Shows flow of information.
Telephone	=		Shows flow of information by telephone or computer.
Processing	=		Used for computer processing.
Delay	=		Indicates delay in the process, such as waiting for approval.

Figure 12-12 Purchase Order Payment System

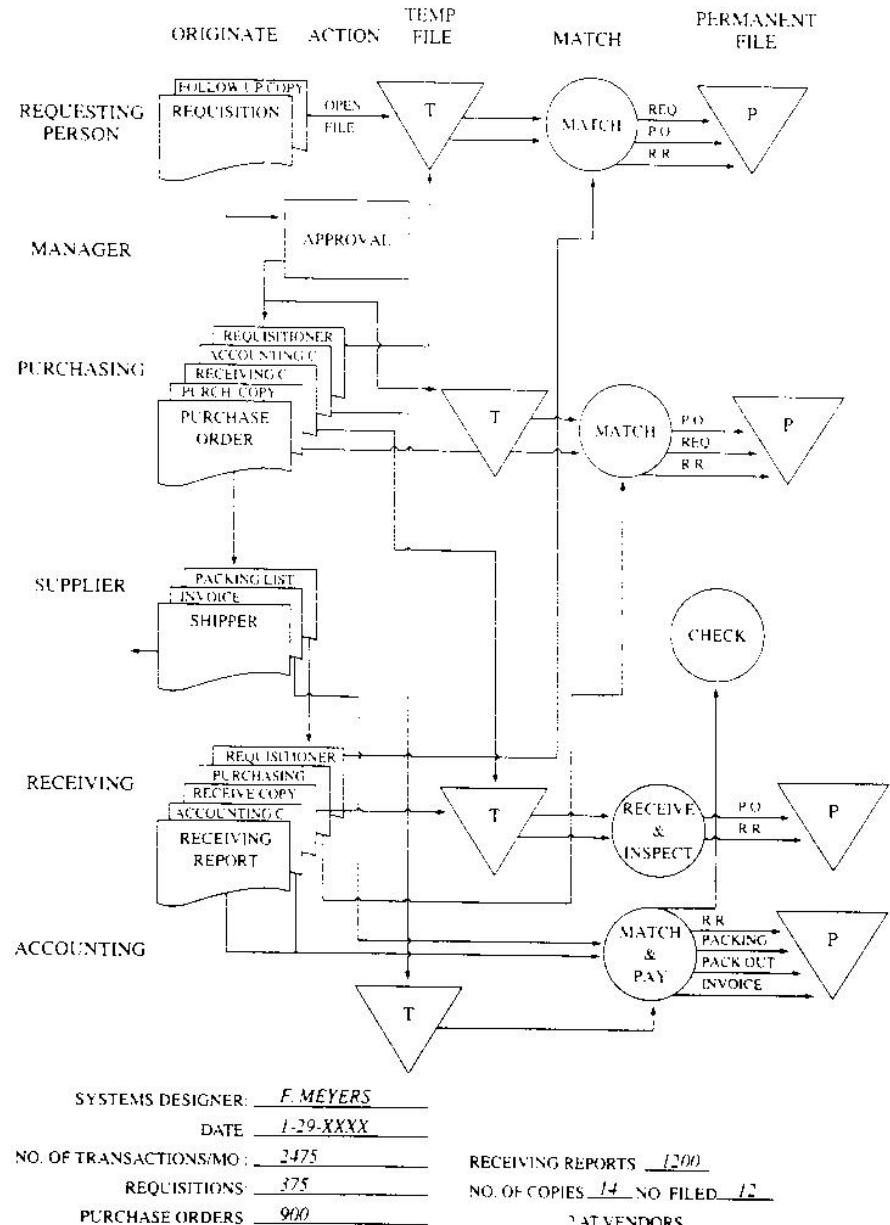


Figure 12-13 Communication Force Diagram—General Manager

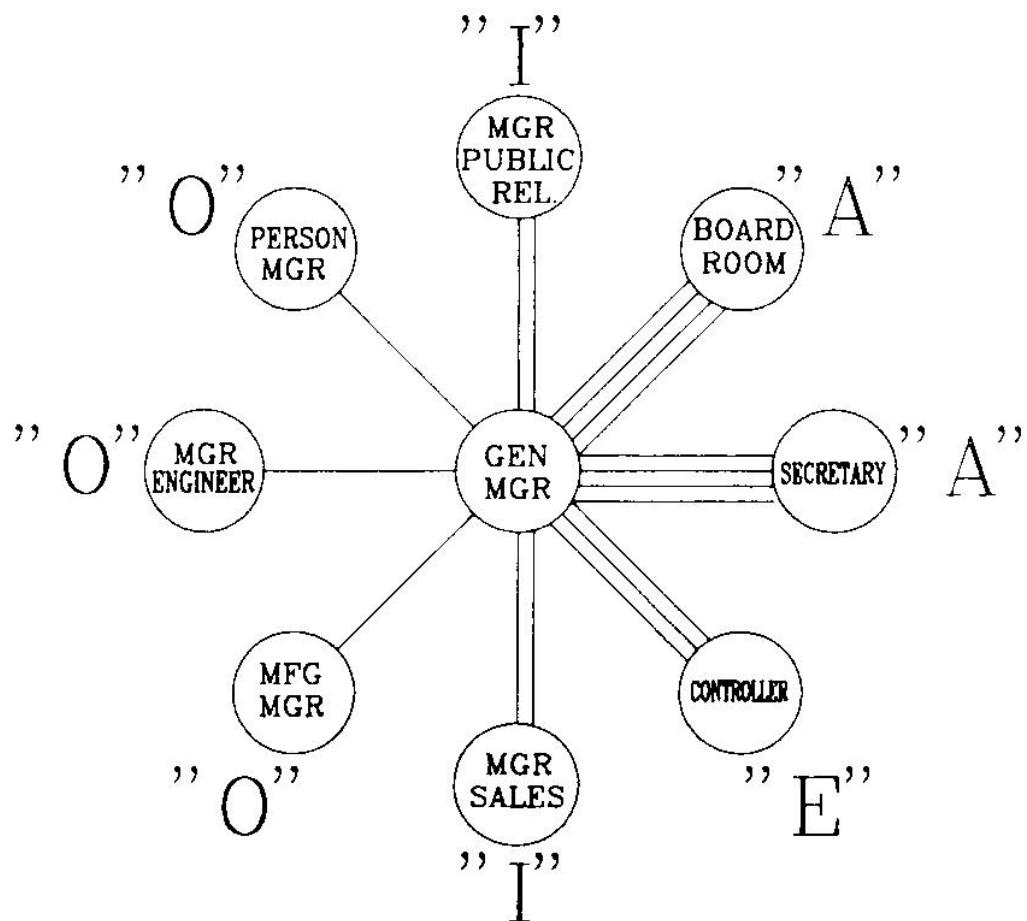
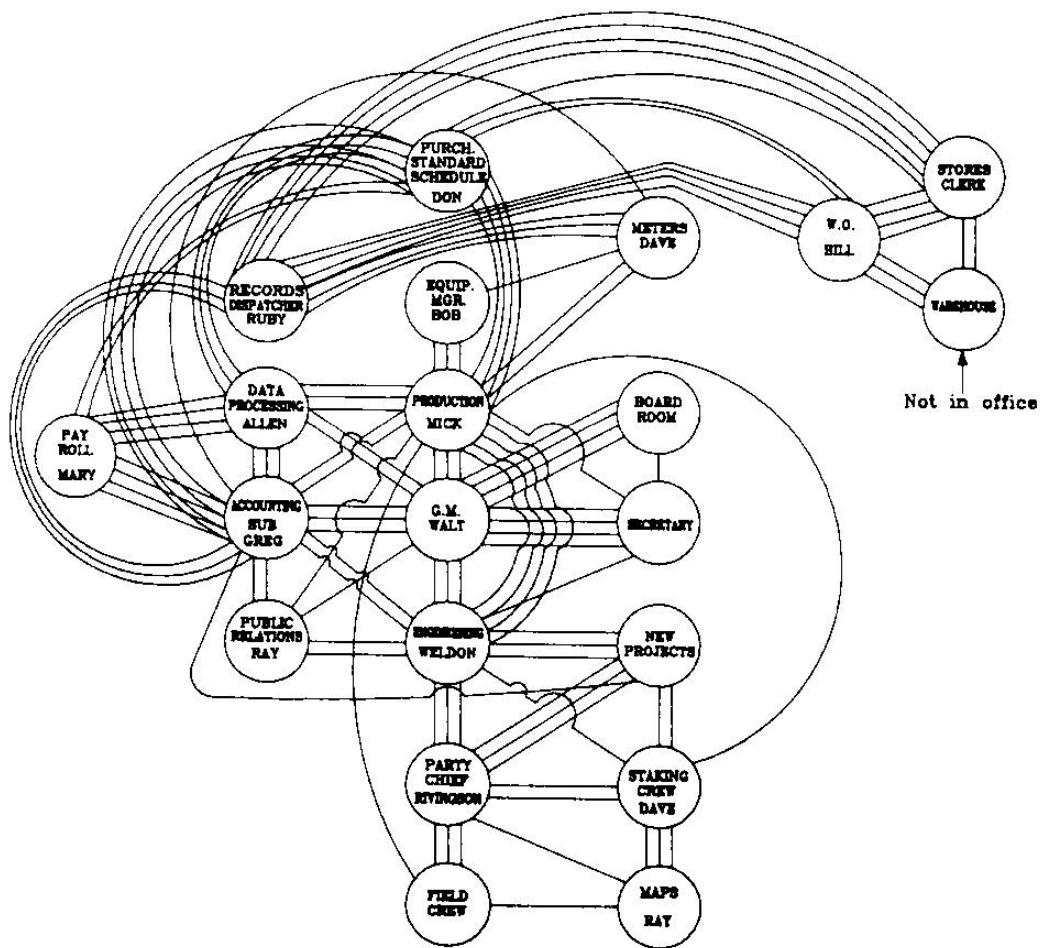


Figure 12-14 Communication Force Diagram—Electric Power Co-Op



Office Space Determination

1. *The 200 square feet per person technique.*

For 36 people, $36 \times 200 = 7,200$ square feet.

2. *The level of the organization technique.*

<i>No. of People</i>	<i>Positions</i>	<i>Sq Ft Each</i>	<i>Total Sq Ft</i>
1	Senior Executive	250	250
4	Managers	200	800
4	Clerical	100	400
9	Accounting	100	900
5	Engineers	125	625
6	Supervisors	150	750
100 percent extra space allowance			3,725

Total			7,450 ft ²

3. *The workstation technique.* The workstation layout approach is the most detailed and will include restrooms, lockers, cafeterias, reception areas, boardrooms, conference rooms, and anything else that takes up space.

Chapter 13

Area Allocation

Objectives

Determining the overall space requirements and allocating space for each specific areas of the facility are discussed in this chapter.

Area allocation is a process of dividing up the building's space or allocating space among the departments.

SPACE REQUIREMENTS PLANNING: STEP ONE

The space requirement for the fabrication area is a total of all machines and workstations. The area for one machine is the maximum length times the maximum width.

The size and shape of a department may change to fit into our final building shape.

Consider the following areas.

Under the floor. Almost anything can be placed in a basement area.

Overhead. Overhead areas can be used in many different ways.

Clear space. 8 feet above the floor to the ceiling (also called the *truss*). A mezzanine, racks, overhead conveyors, cafeterias and offices?

Truss level. Walkways are built in the trusses of steel mills. Utilities, heaters, blowers, sprinklers, ovens, and the like can be placed in the trusses.

Roof. Can be used for recreation, air conditioning, water towers, cooling towers, parking, and the like.

Anything we can get off the floor will reduce our building size.

Figure 13-1 Total Space Requirements Worksheet for Toolbox Plant

	<i>Stations</i>	<i>W</i>	<i>L</i>	<i>(Figure No.) = Square Feet</i>
I. Manufacturing				
A. Fabrication				
Strip shear	2	× 9.5	× 12	(7-5) 228
Chop shear	4	× 7	× 13	(7-7) 364
Punch press	3	× 8	× 11	(7-6) 264
Press break	6	× 8	× 11	(7-8) 528
Roll former	1	× 6	× 18	(7-9) 108
Fabrication Total:				1,492
B. Spot weld	1	× 26	× 30	(4-12) 780
C. Paint	1	× 28	× 100	(7-11) 2,800
D. Assembly & P.O.	1	× 16	× 38	(4-13) 608
Subtotal				5,680
50 percent allowance (mostly aisles)				2,840
Manufacturing Total:				8,520
II. Production Services				
Receiving—steel	13	× 25		(8-2) 325
Receiving—cartons	17	× 19		(8-3) 323
Stores	18	× 25		(8-16) 450
Warehouse	64	× 68		(8-24) 4,352
Shipping	20	× 20		(8-7) 400
Maintenance & tool room	(two people @ 400 ft each)			800
Utilities (estimate only)*			100	
Production Services Area Total:				6,750
(aisles are included in each layout in this area)				
III. Employee Services				
Employee entrance	10	× 20		(9-3) 200
Locker room	(3.5 ft ² /employee × 50 employees)			175
Toilets	10	× 20		(9-7) 200
Cafeteria	(10 ft ² /employee × 50 employees)			500
Drinking fountain	(6 fountains × 15 ft ² each)			90
Medical services	(first aid room only 10 × 10 feet)			(9-12) 100
Services Area Required Total:				1,265
IV. Office Area (11 people from organizational chart) (11 people × 200 ft ² each)				2,200
Total Building Space				18,735
V. Outside Areas				
Receiving, parking, and maneuvering area				
Shipping, parking, and maneuvering area				
Employee parking (50 employees)				
1.5 employees per parking space				
250 ft ² /parking place (9-2)				
<u>50 employees</u>				
<u>1.5 employees/spaces</u>				= 34 spaces
<u>34 spaces × 250 ft²/space = 8,500 ft²</u>				

*I didn't size it properly, but the error will be minimized by an educated guess. This is a very minor use of area.

BUILDING SIZE DETERMINATION

Standard building increments are 100 X 100 feet, 50 X 50 feet, 40 X 40 feet, and even 25 X 50 feet.

This refers to column spacing. A 25 X 50-foot building would come in multiples of 25 feet in width and 50-foot increments in length.

A 2-to-1 length to width ratio is a very desirable building shape.

Figure 13-2 Dimensionless Block Diagram

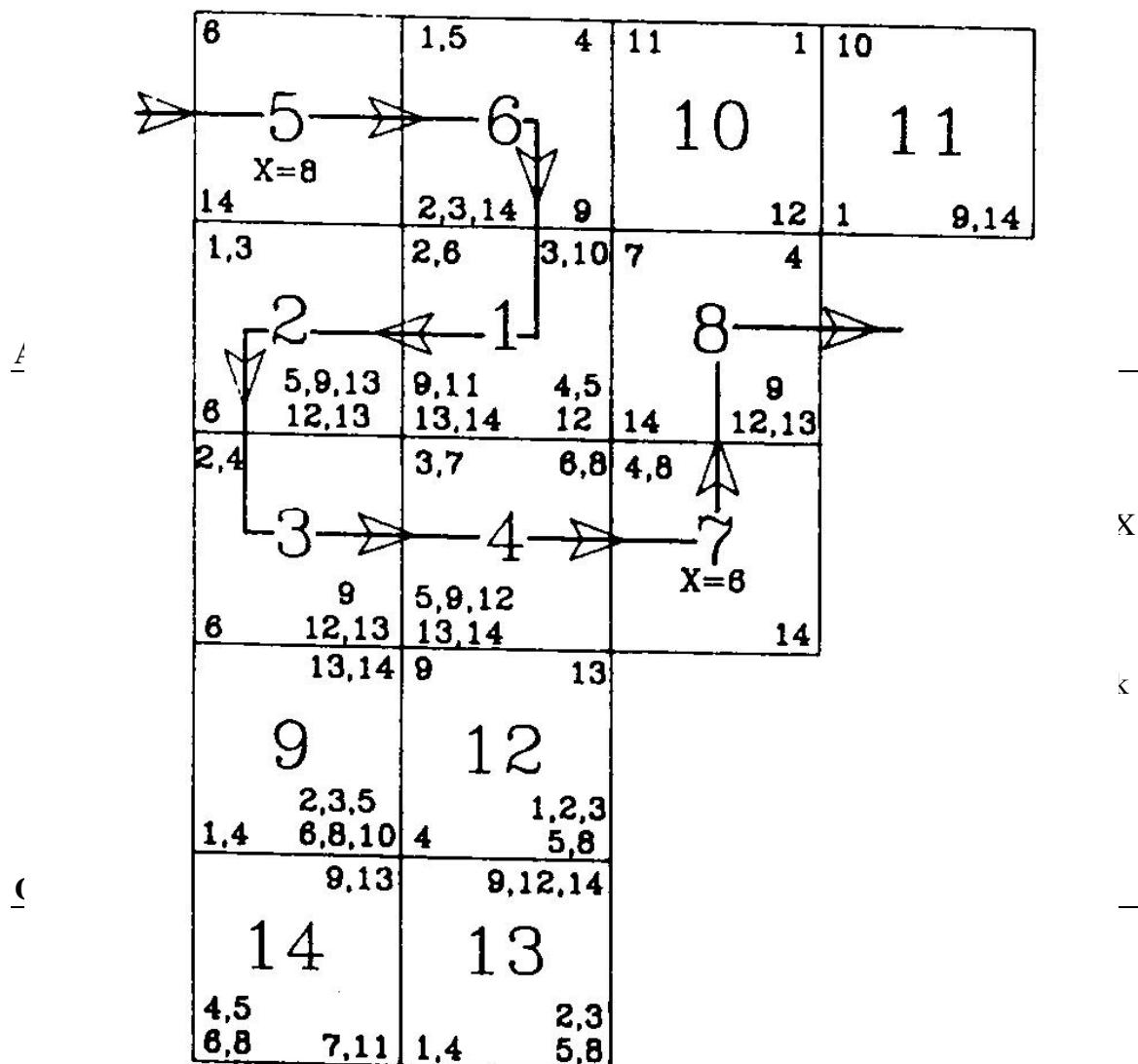


Figure 13-3a 100 X 200-Foot Grid (2.5 X 5 inch) Scale 1/2 Inch = 20 Feet

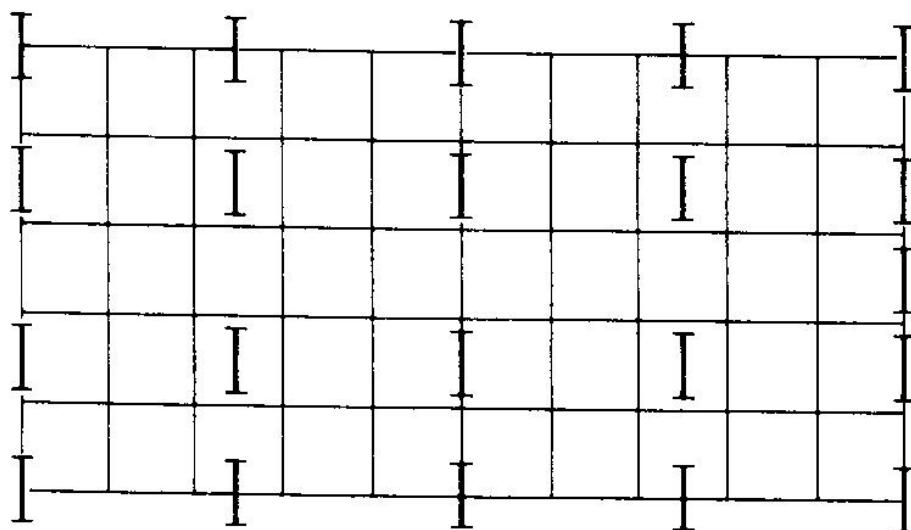
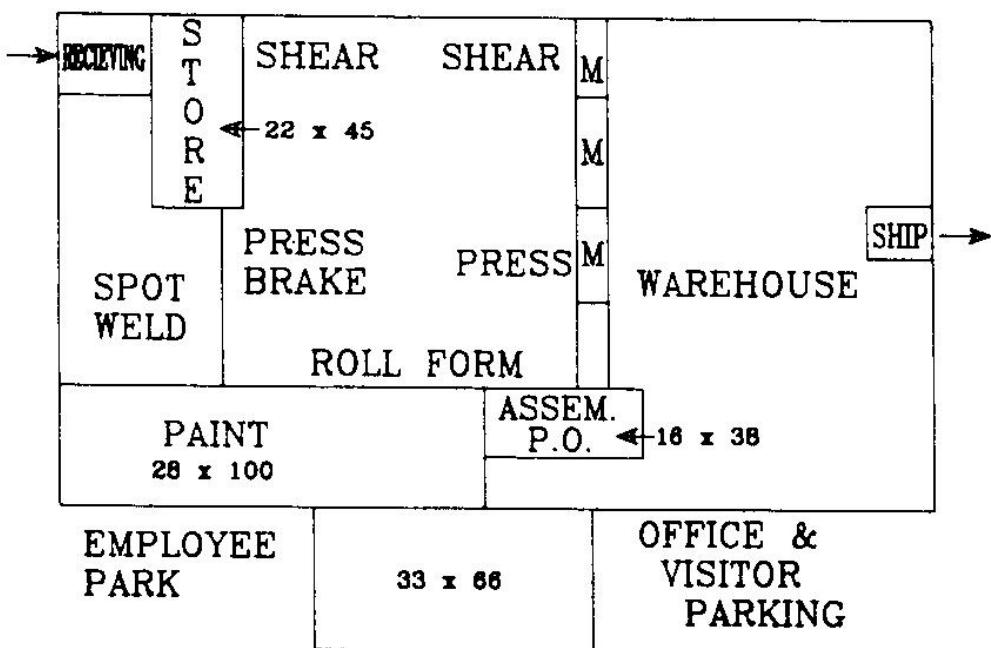


Figure 13-3b Square Allocation

R	S	F	F	F	F	UTL	W	W	W
S.W.	F	F	F	F	F	TR	W	W	W
S.W.	F	F	F	F	F	TR	W	W	SHIP
P	F	F	F	F	ASSY.	P.O.	W	W	W
RR LR	C	O	O	O	O	O	O		

Figure 13-3c Area Allocation Layout



<i>Department</i>	<i>Square Feet</i>	<i>#400 ft² Blocks</i>
Fabrication	2,238	6
Spot weld	1,170	3
Paint	4,200	11
Assembly & P.O.	912	3
Receiving	648	2
Stores	450	1
Warehouse	4,352	11
Shipping	400	1
Maintenance & tool room	800	2
Utilities	100	1/4
Employee entrance	200	1/2
		1
Locker room	175	
Toilets	200	1/2
Cafeteria	500	1 1/2
Drinking fountain	—	—
Medical	100	1/4
Office	2,200	6
		50

Chapter 14

Facilities Design—The Layout

Objectives

Developing the final layout is discussed in this chapter. Different tools and topics such as plot plan, master plan, layout procedures, and evaluation are presented.

The term “layout” is applied to plot plans and master plans.

PLOT PLAN

A *plot plan* shows how the building(s), parking lots, and driveways fit on the property. The main highways, utilities, drains, and the like are also as important to the construction project.

The plot plan communicates how the plant will fit on the lot and what external facilities are required.

- Step 1.* Start with a layout of the property showing the lot lines.
- Step 2.* Place the main/access roads that border the property.
- Step 3.* Show sources of water, power, gas, and phones.
- Step 4.* Place building with front facing the road. Expansions go to the rear of the building.
- Step 5.* Show receiving and shipping.
- Step 6.* Connect receiving and shipping to the main road.
- Step 7.* Show employee and public entrances.
- Step 8.* Provide parking for visitors and employees.

A plot plan must also show expansion possibilities.

As a general rule of thumb acquire 10 times more property than the building size.

An economic factor is the cost of frontage. The property gets cheaper as we move back from the road.

MASTER PLAN

The *master plan* is the finished product of the facilities design project. The term “plant layout,” often refers to the master plan.

The master plan shows where every machine, workstation, department, desk, and all other important items are located.

Figure 14-1 Plot Plan

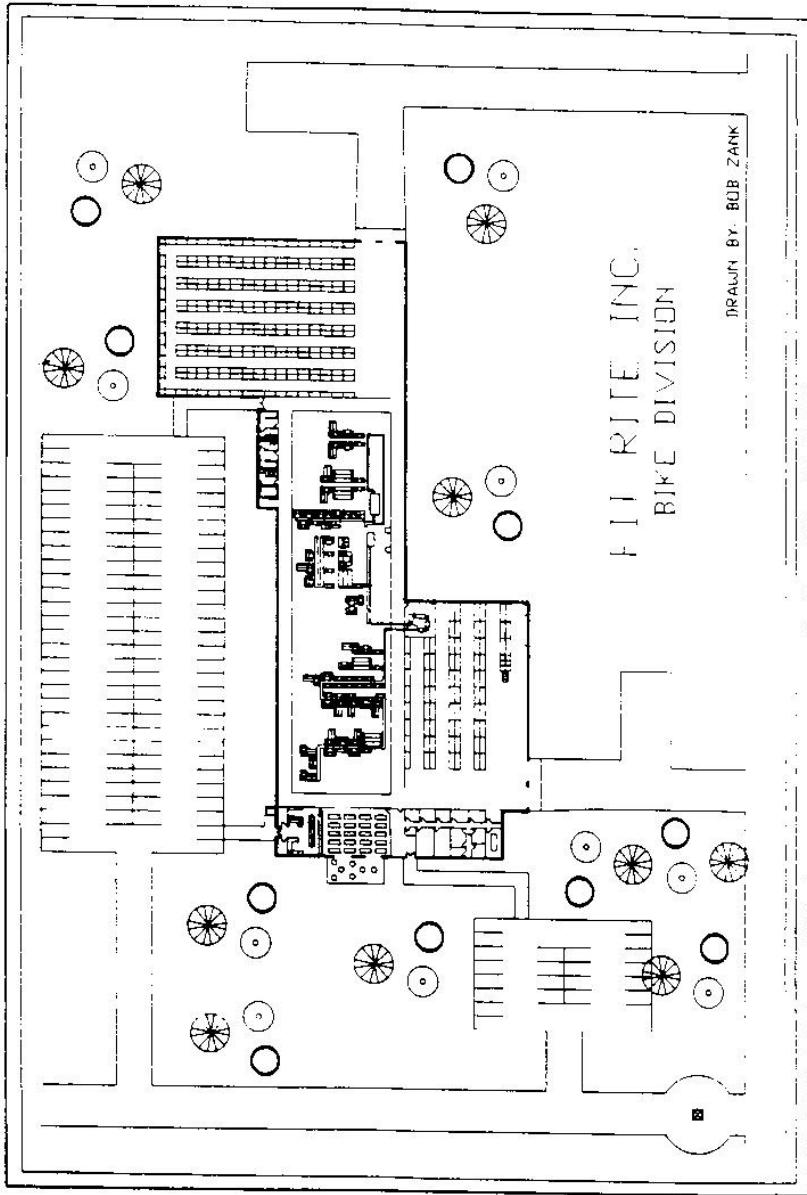


Figure 14-2 Toolbox Plant Plot Plan

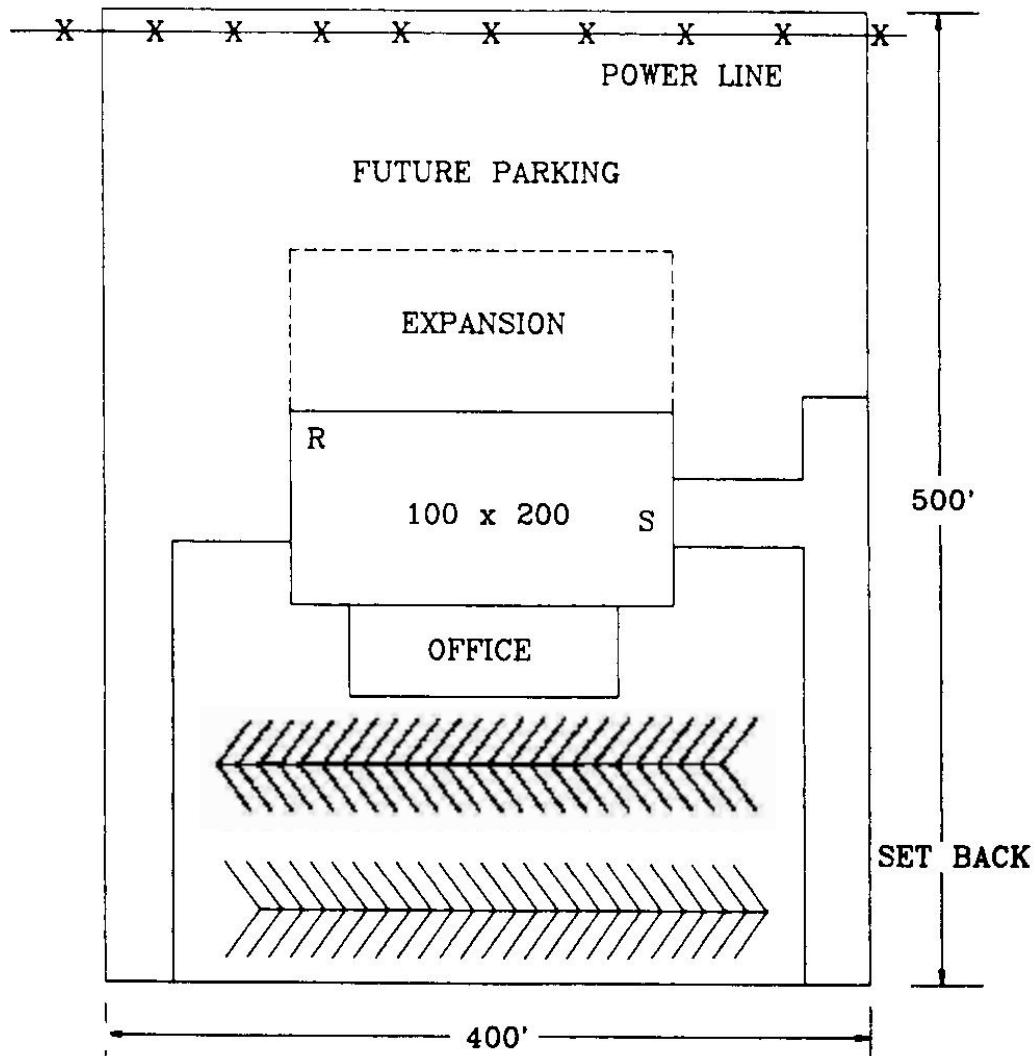


Figure 14-3 Plant and Office Layout Tape (Courtesy of Chartpak Co.)

Catalog Number	Tape Surface	Price Code	Catalog Number	Tape Surface	Price Code
TL382A	Clear	00	TL382A	Clear	00
TL383A	Clear	00	TL393A	Clear	00
TL384A	Clear	00	TL394A	Clear	00
TL385A	Clear	00	TL395A	Clear	00
TL386A	Clear	00	TL396A	Clear	00
TL387A	Clear	00	TL397A	Clear	00
				24° Door Swing	
TL388A	Clear	00	TL398A	Clear	00
				36° Door Swing	
TL389A	Clear	00	TL399A	Clear	00
TL390A	Clear	00	TL400A	Clear	00
TL391A	Clear	00	TL815A	Clear	00
			TL817A	Clear	00

Figure 14-3 (con'd) Plant and Office Layout Tape

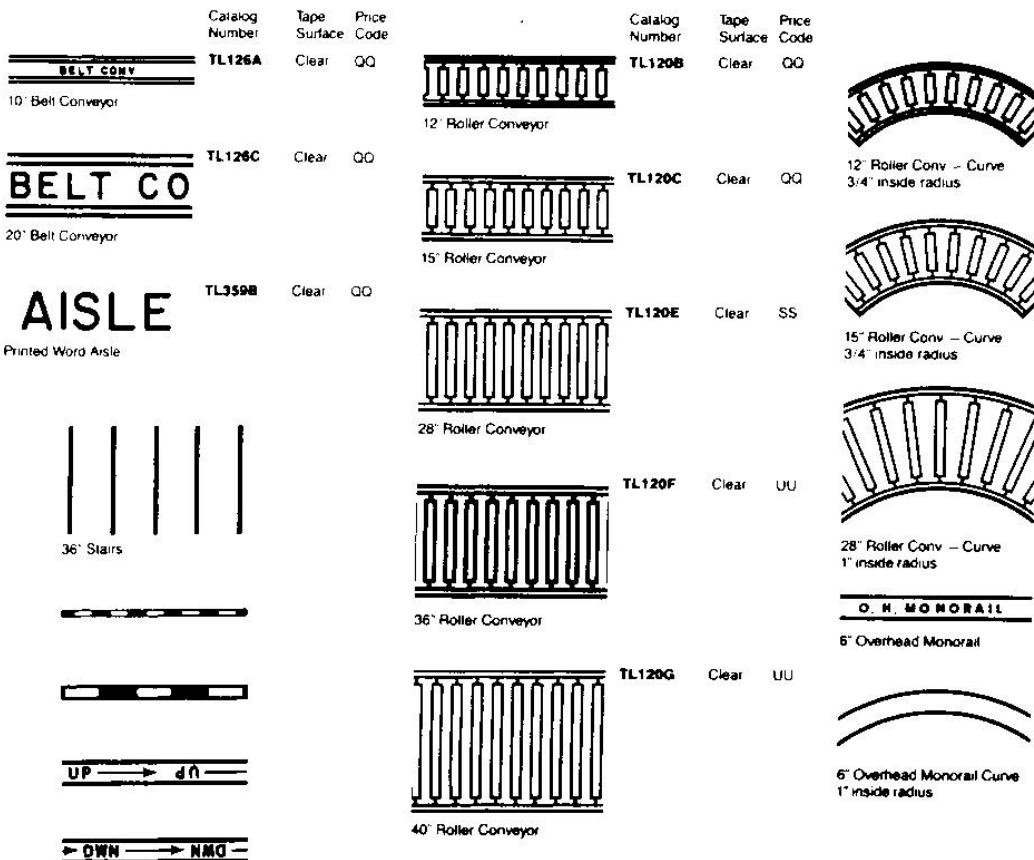


Figure 14-4 Sample Plastic Templates (Courtesy of Plan Print Corp.)

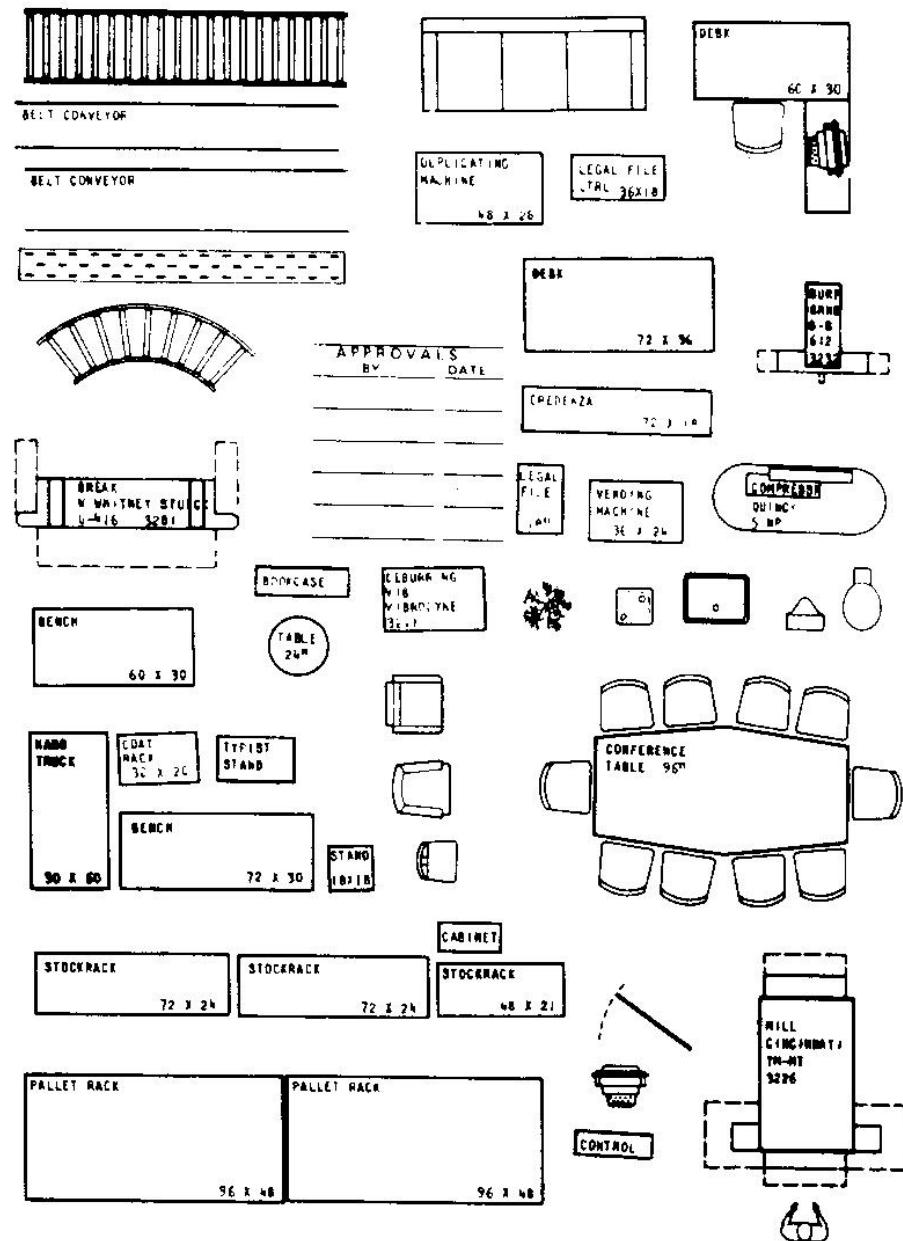


Figure 14-8 Three-Dimensional Plant Layout (Courtesy of Clark A. Cory,
Purdue University)

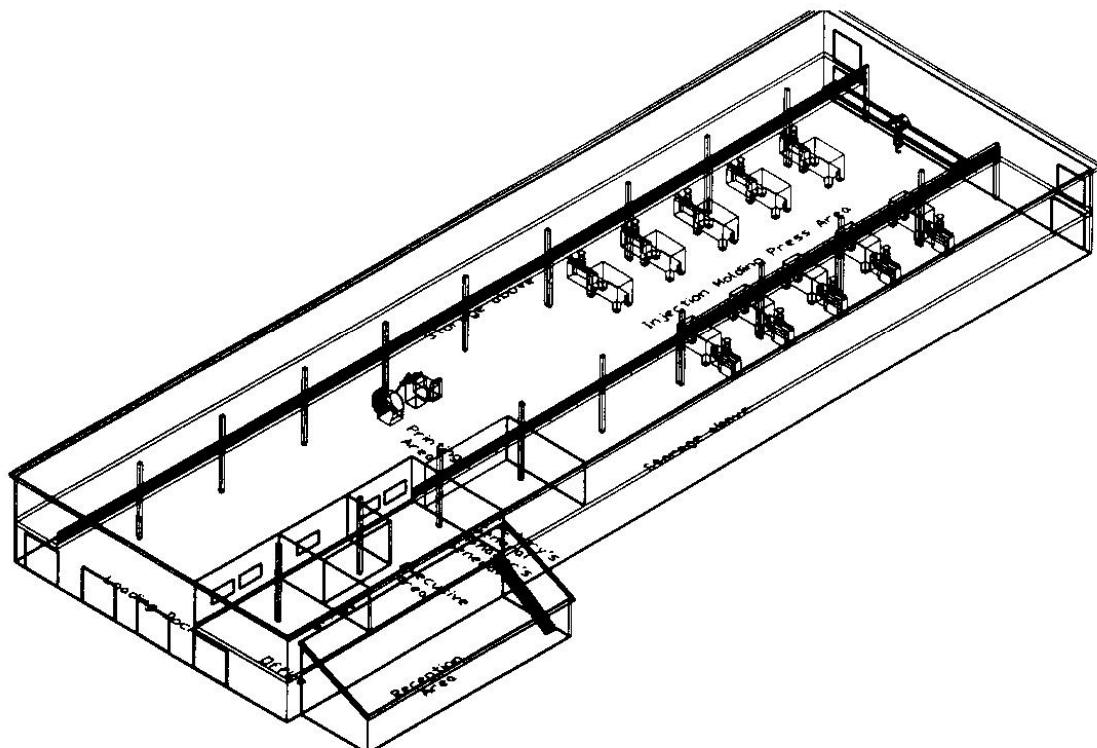
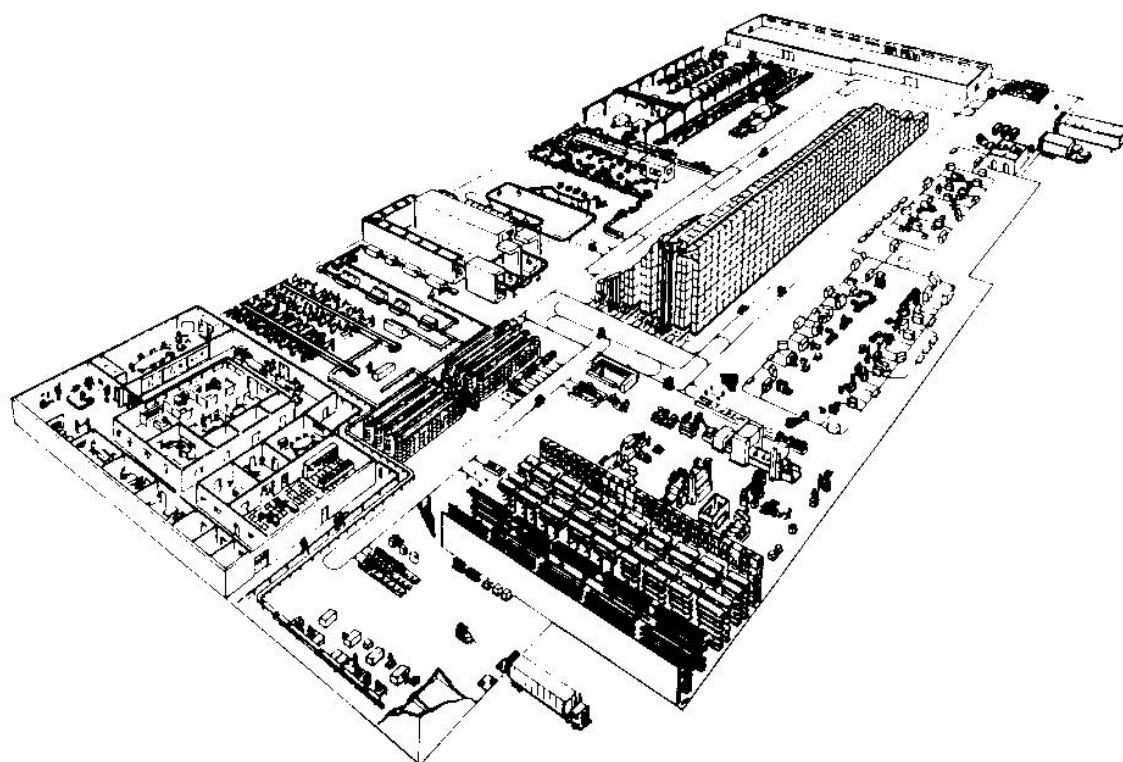


Figure 14-9 CAD Plant Layout—Three-Dimensional (Courtesy of S.I. Handling Systems, Inc.)



Plant Layout Methods

There are three methods of depicting the plant layout:

1. The template and tape technique
2. The three-dimensional models technique
3. The computer-aided design (CAD) technique

The template and tape method of facilities design.

The template and tape technique is a layout made of transparent templates and rolls of various tapes placed on a mylar grid base.

Templates are transparent or translucent plastic outlines of very specific pieces of equipment.

Computer-aided plant layout packages, and most computer-aided drafting or design (CAD) software systems contain a wealth of three-dimensional (3-D) as well as flat templates to aid the facilities planner.

1. Place the mylar base on a table
2. Lay out the external walls
3. Cut out the doors
4. Place the I beam
5. Place aisles
6. Place internal walls (minimize internal walls, they interfere with good flow)
7. Place equipment per flow analysis and activity relationship analysis
8. Use clear plastic overlay, show the flow of material
9. Seek advice from your peers

Three-dimensional (3-D) models. Three-dimensional model layouts have the big advantage of illustrating and highlighting any height problems. They are also a great help in visualizing the layout.

Computer-aided design technique (CAD). Computer-aided plant layout design is the state-of-the-art technique. The advantages of all the previous techniques are improved with CAD and the disadvantages have been minimized.

Initial cost of a computer-aided facilities planning software may be considered a disadvantage, less costly CAD packages are quite capable of producing great results of a highly professional caliber.

Advanced Computer Systems

In addition to aid from computers, from CAD to flow analysis and simulation, the next generation technology to aid the facilities planner is the virtual reality technology.

This technology will allow the planner to “walk through” the facilities before the facility ever existed.

EVALUATION

1. *Minimize distance traveled.* The shorter, the better. Some travel is not as bad as other methods.

a. How many feet are traveled automatically?

Automatic travel ratio = automatic feet/total feet

b. Gravity movement is free power.

Gravity ratio = Gravity feet/total feet

2. *Maximize space utilization.*

a. Aisle space can be calculated by the square footage of aisle space and divided by the total space available.

Percent aisle space = square aisle feet/square feet of plant

(the lower, the better)

b. Stores and warehouse cube utilization is total storage available.

Percent cube utilization = Storage cubic feet/total cubic feet

(the higher, the better)

c. Machine space utilization

Machine space utilization = machine space required/total plant space

(the higher, the better)

3. Machine utilization ratio. Operator loading, unloading reduces machine utilization.

4. Control material handling costs.

a. Percent material handlers = # of material handlers/production people

or

Material handling ratio = # of material handling hours/total hours worked

b. Manual move/operations ratio equals the number of moves divided by the number of operations. This will promote the combining of operations or the mechanization of moves to eliminate manual moves.

5. Just-in-time manufacturing ratios measure how long a product is in process (in the plant).

In-process ratio time = cycle time/total time in process

6. The from-to chart is an evaluation technique that is quantitative and results in usable measurable efficiency.

7. The cost evaluation technique is the most complete and most used evaluation technique.

Chapter 15

Application of Computer Simulation and Modeling

Objectives

Basic concepts of computer simulation and modeling are defined in this chapter. Students are introduced to some user-friendly, state-of-the-art simulation packages.

INTRODUCTION

The advent of faster and more powerful computers and the development of user-friendly, menu-driven software packages have made the use of the simulation and modeling much more appealing and, therefore, more commonplace.

Even the most carefully planned, highly automated, sophisticated manufacturing systems are not always immune from costly design blunders or unanticipated failures. Among the common examples of these costly mistakes are insufficient space to hold in-process inventory, mismatches in machine capacities, inefficient material flow and unexpected bottlenecks, congested paths for automatic guided vehicles (AGVs), and the list goes on.

A number of user-friendly advanced simulation packages are available that allow the user to simulate either the working of a factory, performance of various material handling equipment, a just-in-time inventory environment, a warehousing and logistics problem, or the behavior of a group technology system.

DEFINING COMPUTER SIMULATION

Simulation is defined as an experimental technique, usually performed on a computer, to analyze the behavior of any real-world operating system.

The simulation software generates reports and detailed statistics describing the behavior of the system under study.

Simulation has two important characteristics.

- 1) It is dynamic; the behavior of the model is tracked over simulated time.
- 2) It is a stochastic (random) rather than a deterministic model.

ADVANTAGES AND DISADVANTAGES OF SIMULATION

Advantages of simulation are:

1. Simulation is relatively flexible and straightforward.
2. Simulation allows the study of the interactive effects of many components in a dynamic and stochastic environment.
3. Simulation's basic concepts are easily comprehended. Thus, a simulation model is often easier to justify to management and customers.

The main **disadvantage** of simulation is that development of some very complex models may be quite expensive and time-consuming. An analyst may, therefore, settle for a quick and dirty estimate.

SIMULATION IN FACILITIES PLANNING

Facilities planners can use simulation to study various aspects of facilities design, capacity planning, inventory policies, office and parking lot layouts, warehousing and logistics planning, and maintenance scheduling, to name a few possibilities.

Currently a number of user-friendly advanced simulation and layout planning packages are available to facilities planners at affordable costs.

Machine utilization ratios, space requirements, inventory policies, material handling systems, and manufacturing cell capacities can be evaluated in virtual reality before costly implementation and blunders.

HOW SIMULATION WORKS

The purpose of simulation is to help the decision maker to solve a particular problem.

1. *Problem definition.* Clearly define the problem and state the goals of the study so that the purpose is known.
2. *System definition.* Define the boundaries and the restrictions of the system in terms of resource availability.
3. *Conceptual model.* Develop a graphical model to define system components, variables, and their interactions that constitute the system.
4. *Preliminary design.* Decide on and select those factors that you think are critical in the performance of the system. Do not obscure critical data with trivia.
5. *Input data preparation.* Remember the cliché, “garbage-in, garbage-out.”
6. *Model translation.* Develop a working knowledge of the simulation package.
7. *Verification and validation.* Confirm that the model represents the system.

8. *Experimentation.* Now we can truly learn the power of experimentation and investigation.

9. *Analysis and interpretation.* Draw inferences from the data generated by the simulation.

10. *Implementation and documentation.* The results can now be recorded, documented, and implemented along with its uses and limitations.

Simulation practices can be performed for a variety of reasons, among which are:

1. *Evaluation.* Determine how well a proposed system design performs.

2. *Comparison.* Compare alternative designs to carry out a specific function.

3. *Prediction.* Investigate the performance of a proposed system.

4. *Sensitivity analysis.* Helps to determine which of the many factors have the greatest effect on the overall operations of the system.

5. *Optimization.* Establish what factors or which combination of factors produces the best overall system response.

6. *Bottleneck analysis.* Discover the nature and location of bottlenecks.

COMPUTER-AIDED LAYOUT DESIGN

FactoryCAD is a powerful drawing tool. By customizing AutoCAD, FactoryCAD makes it easy to create, refine, improve, and edit either new or existing drawings. The package contains a tutorial, which introduces you to FactoryCAD using hands-on exercises.

The planner may also find the “animate” command of particular interest. Used with various materials handling equipment, the animate command tracks the path of the equipment to assure that sufficient clearances have been allowed.

FactorCAD allows the drawing of objects in either two-dimensional (2D) or three-dimensional (3D).

FactoryPLAN is a tool for designing and analyzing layouts based on the desirability of closeness of different departments, work areas, offices, storage areas, or manufacturing cells.

Whereas FactoryCAD can aid in the drawing of the plant layout, FactoryPLAN is a planning tool, which can be used to analyze and optimize the layout.

FactoryOPT, working with FactoryPLAN, determines the optimum locations of the activity centers, hence the optimum plant layout.

Computer-Assisted Layout Performance Analysis

FactoryFLOW provides the planner with the ability to view and manipulate spatial problems in a spatial medium.

The planner can, in real time, easily make changes to the model, routings, production volumes, material handling equipment, and other system variables in order to examine various alternatives.

FactoryFLOW creates graphs using “intelligent” flow lines that are ideal for flow problem analyses and can help to illustrate total move distances, intensities, and costs.

ProModel is a user-friendly simulation and analysis tool. The software can aid the planner to analyze an existing facility or to develop a new plant.

ProModel helps in the design and simulation of the model with realistic animation.

By playing various “what-if” scenarios and running the simulation, one can determine whether the proposed changes indeed have a positive effect on the facility before implementing such changes on the factory floor.

Figure 15-1 A Three-Dimensional (3-D) Conveyor System Drawn with the Aid of FactoryCAD (Courtesy of Engineering Annomation, Inc.)

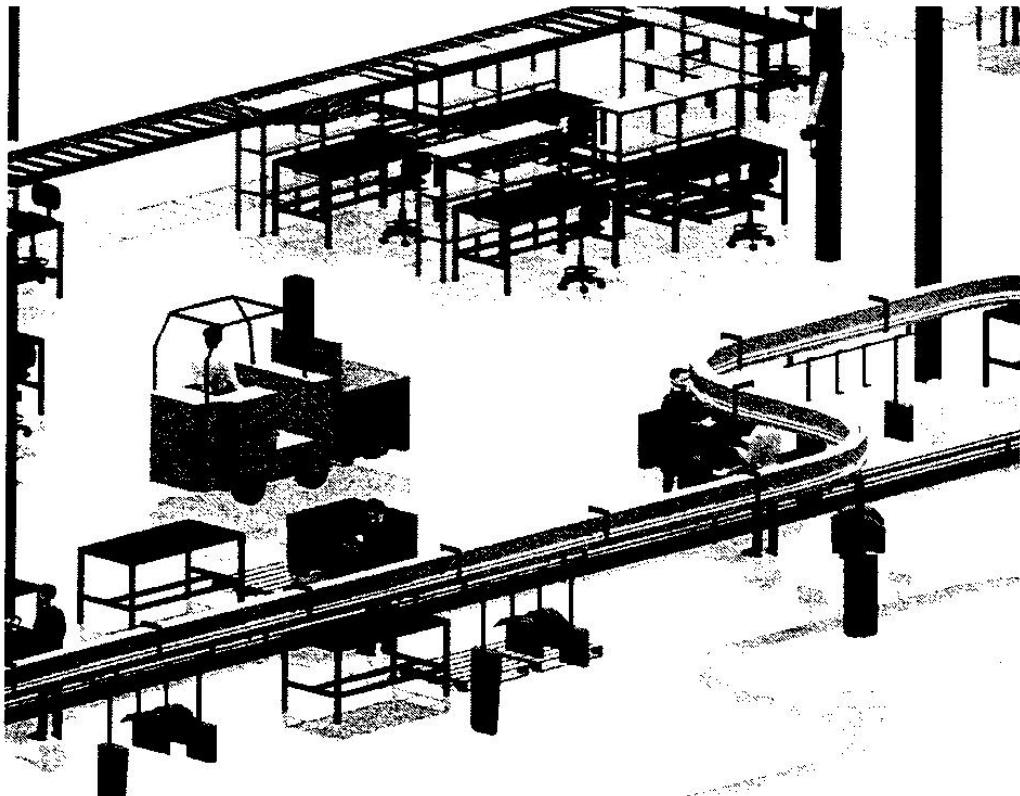


Figure 15-3 Flow Lines Generated by FactoryFLOW Based on Relationship Codes Supplied by Planner (Courtesy of Engineering Annomation, Inc.)

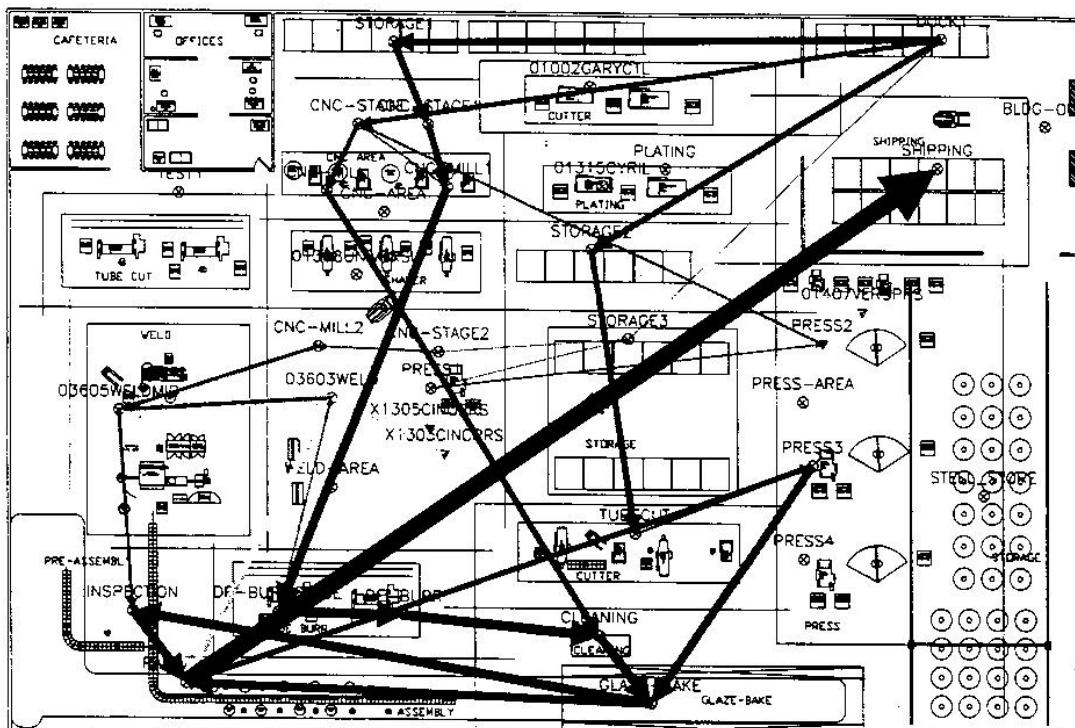


Figure 15-4 Flow Lines after the Analysis by FactoryFLOW (Courtesy of Engineering Annomation, Inc.)

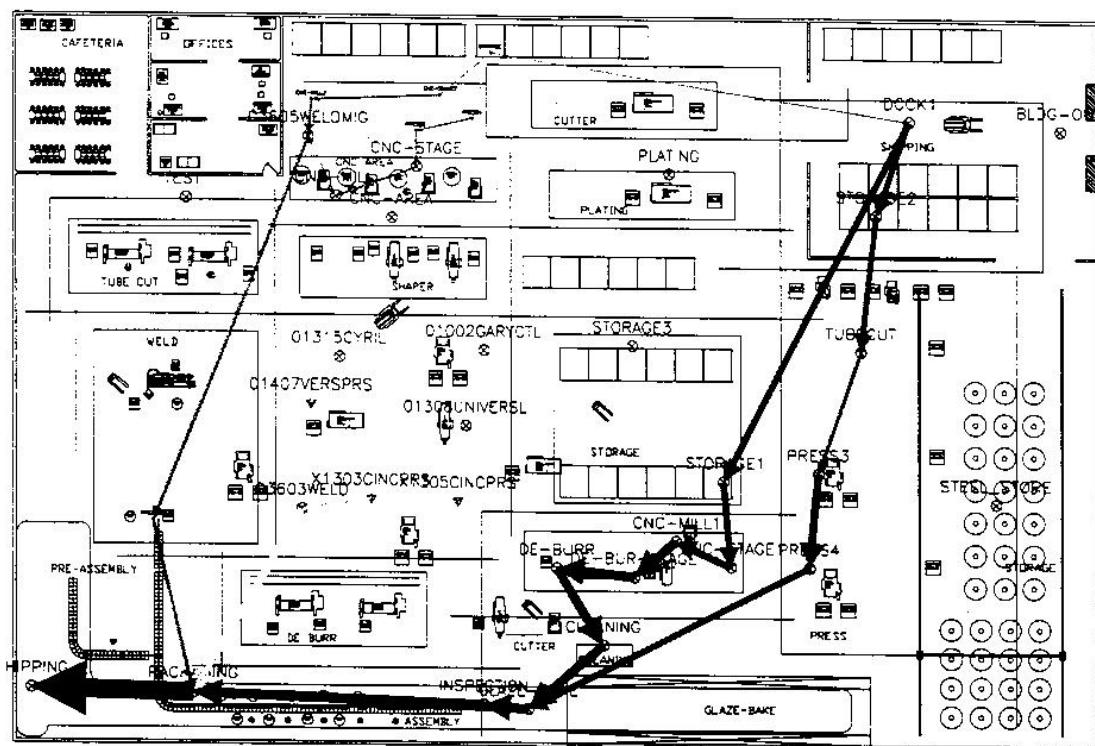


Figure 15-5 A Sample of Icons Available to Modeler (Courtesy of ProModel Corporation)

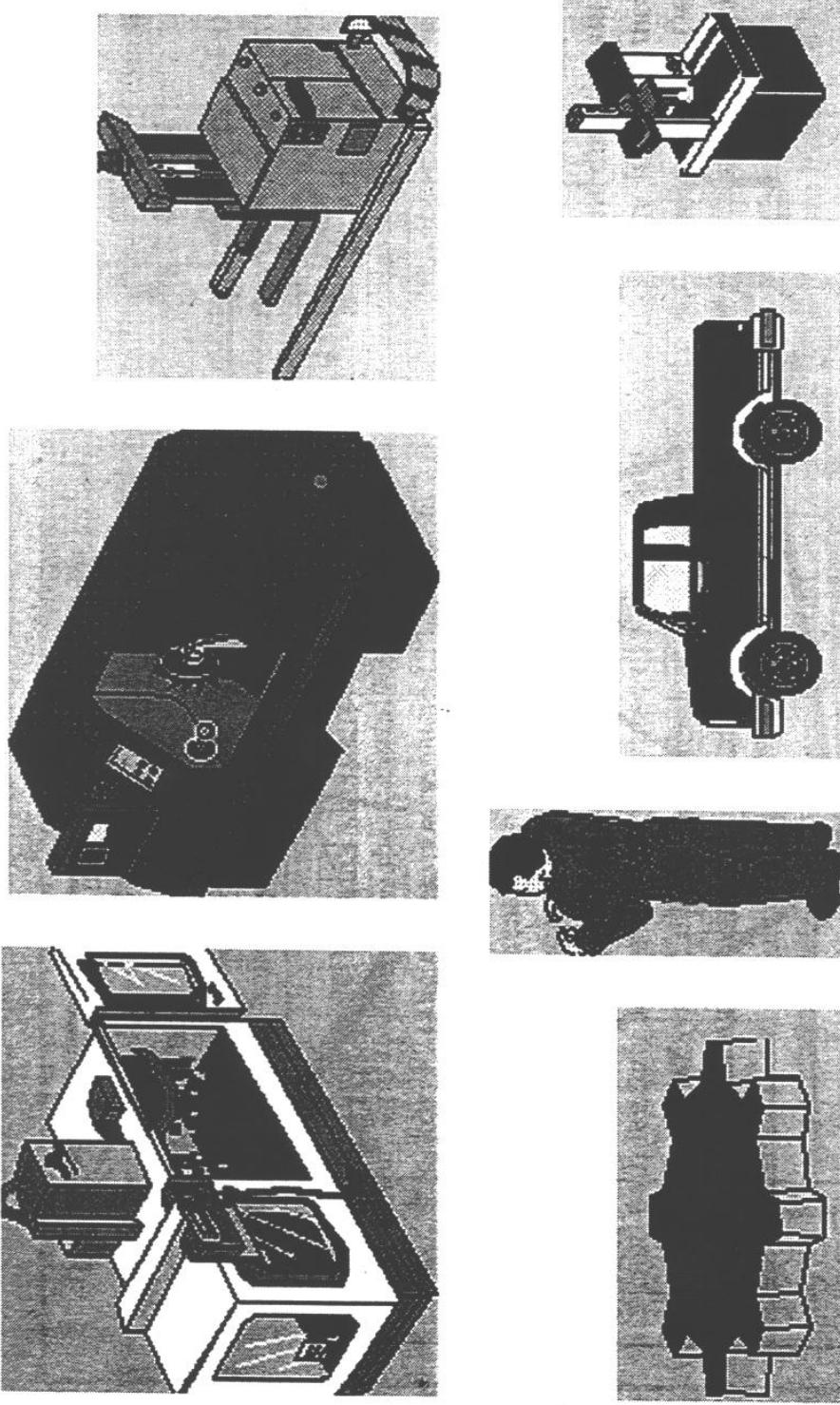
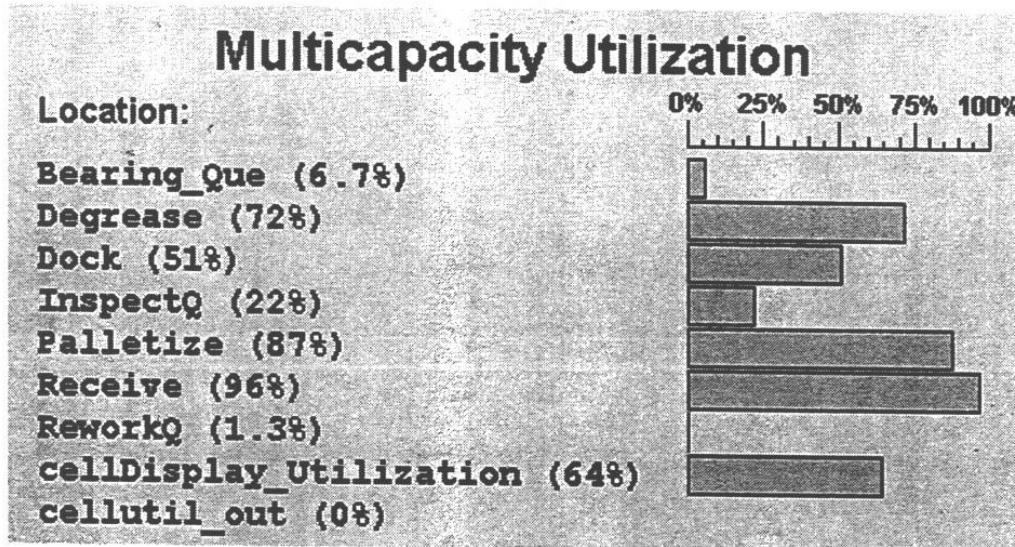
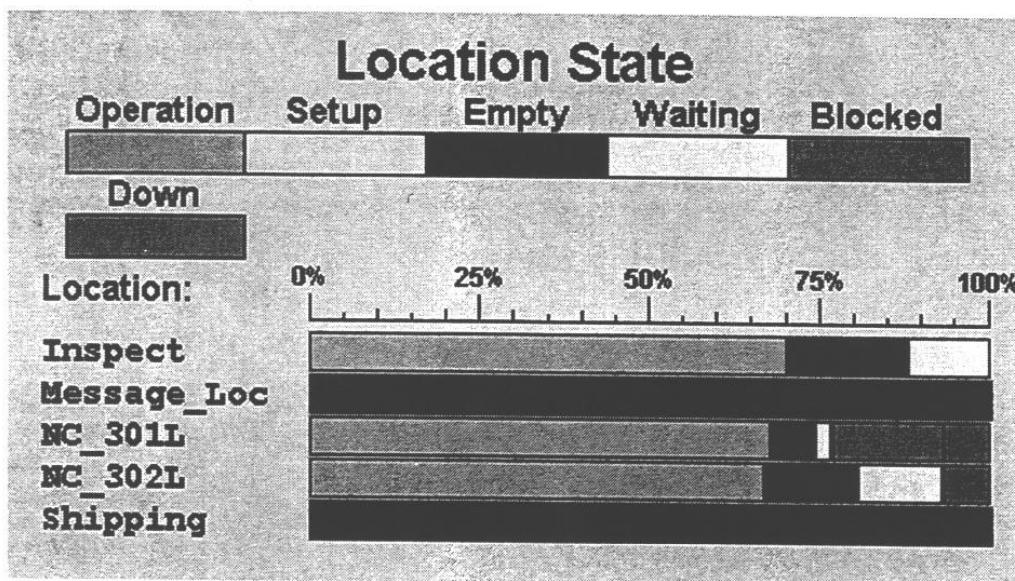


Figure 15-8 Some of Statistics Provided by Simulation Regarding the Machining Center (Courtesy of ProModel Corporation)



Chapter 16

Selling the Layout

Objectives

This is the wrap-up chapter. The students are sensitized to the importance of presentation and “selling” of the layout project.

THE PROJECT REPORT

The following is a specific outline for the project report:

1. The goal is to layout a manufacturing plant in order to produce 2,000 toolboxes per 8-hour shift and to achieve the subgoals of:
 - a. minimizing unit cost
 - b. optimizing quality
 - c. promoting the effective use of our resources
 - d. providing for the employees’ convenience, safety, and comfort
 - e. controlling project cost
 - f. achieving the expected production start date
 - g. minimizing work-in-process inventory
2. Set a volume and plant rate (R value or takt time):
 - a. 2,000 units per day
 - b. 10 percent personal fatigue and delay allowance
 - c. 80 percent historical performance
 - d. an R value of .173 or 5.8 sets of parts per minute
3. Drawings of the product should include:
 - a. blueprints
 - b. an assembly drawing
 - c. an exploded drawing
 - d. a parts list
4. Set a management policy. It should include:
 - a. an inventory policy—maintain a 30-day supply
 - b. an investment policy—50 percent ROI
 - c. a startup schedule—date
 - d. a make or buy decision
 - e. an organizational chart

5. The process design should include:
 - a. a route sheet for each “make” part, including time standards
 - b. the number of machines required
 - c. the assembly chart
 - d. assembly time standards
 - e. conveyor speeds (paint line, assembly line)
 - f. assembly line balance
 - g. the subassembly line layout
 - h. the assembly and P.O. layout
 - i. the process chart
 - j. the flow diagram
 - k. the operations chart
 - l. the flow process chart
6. The activity relationship should include:
 - a. the activity relationship diagram
 - b. the worksheet
 - c. the dimensionless block diagram
 - d. the flow analysis
7. The workstation design should include:
 - a. machine layouts
 - b. area determination
 - c. paint layout
 - d. aisles
8. Auxiliary services should include:
 - a. receiving
 - b. shipping
 - c. stores
 - d. warehouse
 - e. maintenance
9. Employee services should include:
 - a. parking lots
 - b. employee entrances
 - c. locker rooms
 - d. toilets
 - e. the cafeteria
 - f. medical services
10. The office should include:
 - a. an organizational chart

11. Area allocation should include:
 - a. the total space requirements worksheet
 - b. the building size
 - c. the dimensionless block diagram
 - d. the area allocation diagram
12. Material handling systems and requirement:
 - a. state types and the number of material handling units
 - b. calculate all conveyor speeds (feet per minute)
13. The layout should include:
 - a. the plot plan
 - b. the master plan

THE PRESENTATION

The presentation of the project occurs at a management meeting where the project engineer (or engineers) present their project plan. The presentation should be **visual**.

Using the product model, the presenter can cover:

1. The goal and subgoals
2. The volume and plant rate
3. The product
4. The make or buy decisions
5. The process design

With the layout, the presenter can cover:

1. The process design (further description on flow of each part)
2. Assembly and packout
3. The operations chart or flow process chart
4. The activity relationships and dimensionless block diagrams
5. The auxiliary services
6. The employee services
7. The office
8. The area allocation diagram

ADJUSTMENTS

The facilities planner should present the layout to every person who will listen. With every presentation, you will adjust the layout making it better.

APPROVAL

More major changes may require a second presentation. Most companies will require many levels of approval depending on the amount of money being requested.

The approval process is important, and the top managers' input is valuable and will only serve to make a better project.

What management is approving most of all is an expenditure budget (limit). Successful project engineers and managers will make every effort not to exceed the budget.

Test Questions

with

Solutions

1. The disadvantages of a process-oriented layout stem from
 - a. the use of special purpose equipment.
 - b. the breakdown of any one machine tends to seriously degrade the capacity of the entire system.
 - c. the dependence on general purpose machines and equipment.
 - d. the dependence on specialized material handling equipment.

Answer: c

2. A good layout requires the determination of
 - a. capacity and space requirements.
 - b. material handling requirements.
 - c. flows of information.
 - d. all of the above

Answer: d

3. Which industrial form includes specifications regarding materials, description of operations, type of machine, and tool used?
 - a. activity chart
 - b. job card
 - c. master production schedule
 - d. operation sheet

Answer: d

4. Labor standards are necessary to determine which of the following?
 - a. the steps necessary to perform a task
 - b. cost and time estimates prior to production
 - c. the amount of raw materials to be consumed in the process
 - d. the type of machines required by the process

Answer: d

5. All of the following are major components in the decision to locate a manufacturing firm **except**
 - a. the prevailing wage rates.
 - b. the proximity of raw materials or suppliers.
 - c. the center for the geographic area being served.
 - d. the parking/access to the plant.

Answer: d

6. Ergonomics involves human reaction to
- monotony.
 - fatigue.
 - repeated motion.
 - all of the above.

Answer: d

7. Given that racks are 14' (W) and each rack can store 3 pallets side by side, and 4 pallets high. If all the following items are stored on pallets and in *random* locations,
- Calculate the required number of pallets for each item, b) determine the total required aisle-feet in the raw material storeroom for an *average* inventory level.
Pallet capacity is 4' x 4' x 4'.

L x W x H	Q	# OF PALLETS
16" 10" 4"	5200	
12" 36" 8"	6000	
36" 4" 3"	4000	
36" 24" 1/2"	6000	

Solution:

$$\frac{16'' \times 10'' \times 4''}{1728} \times \left(\frac{5200}{2} \right) = 962.96 \text{ FT}^3 (\text{AVG}) \div 64 = 16 \text{ PALLETS}$$

$$\frac{12'' \times 36'' \times 8''}{1728} \times \left(\frac{6000}{2} \right) = 6,000 \text{ FT}^3 (\text{AVG}) \div 64 = 94 \text{ PALLETS}$$

$$\frac{(36'' \times 4'' \times 3'')}{1728} \times \left(\frac{4000}{2} \right) = 500 \text{ FT}^3 (\text{AVG}) \div 64 = 8 \text{ PALLETS}$$

$$\left(\frac{36'' \times 24'' \times .5''}{1728} \right) \times \left(\frac{6000}{2} \right) = 750 \text{ FT}^3 (\text{AVG}) \div 64 = \frac{12 \text{ PALLETS}}{130 \text{ PALLETS}}$$

$$130 \text{ PALLETS} \div 12 \text{ PALLETS/RACK} = 11 \text{ RACKS} \times 14 \text{ FEET} = 154 \text{ Aisle-Feet}$$

8. Calculate the required number of storage units (racks, etc.) and the required aisle-feet.

a) 740 pallets each 4' x 4' x 4'. Use 3-wide, 5-high racks. Racks are 15' wide.

Solution:

$$740 \div 15 = 50 \text{ units}$$

$$50 \times 15 = 750 \text{ Aisle-Feet}$$

b) 1800 shelf spaces, 1 1/2' (deep) x 1 1/2' (high) x 3' (wide). Use 7-high shelves.

Solution:

$$1800 \text{ shelves} \div 7 \text{ shelves per unit} = 257.1 \approx 258 \text{ units}$$

$$258 \times 3 = 774 \text{ Aisle-Feet}$$

9. Construct a FROM-TO chart for the following data. What is the efficiency of the layout?

The proposed layout is as follows: **B D R F C S P W**

PART NO. WT. FACTOR OPERATION SEQUENCE

A	4	R F D C S
B	3	R C B F S
C	1	R B F C W S
D	2	R D C F B S

Solution:

F	T	B	D	R	F	C	S	P	W	Points	PENALTY
B					3+1 ⑫		2 ⑩			6	22
D						4+2 ⑯				6	18
R	1 ④	2 ④		4 ④	3 ⑥					10	18
F	2 ⑫	4 ⑯			1 ①	3 ⑥				10	35
C	3 ⑯		2 ④		4 ④		1 ③			10	35
S											
P											
W					1 ④					1	4

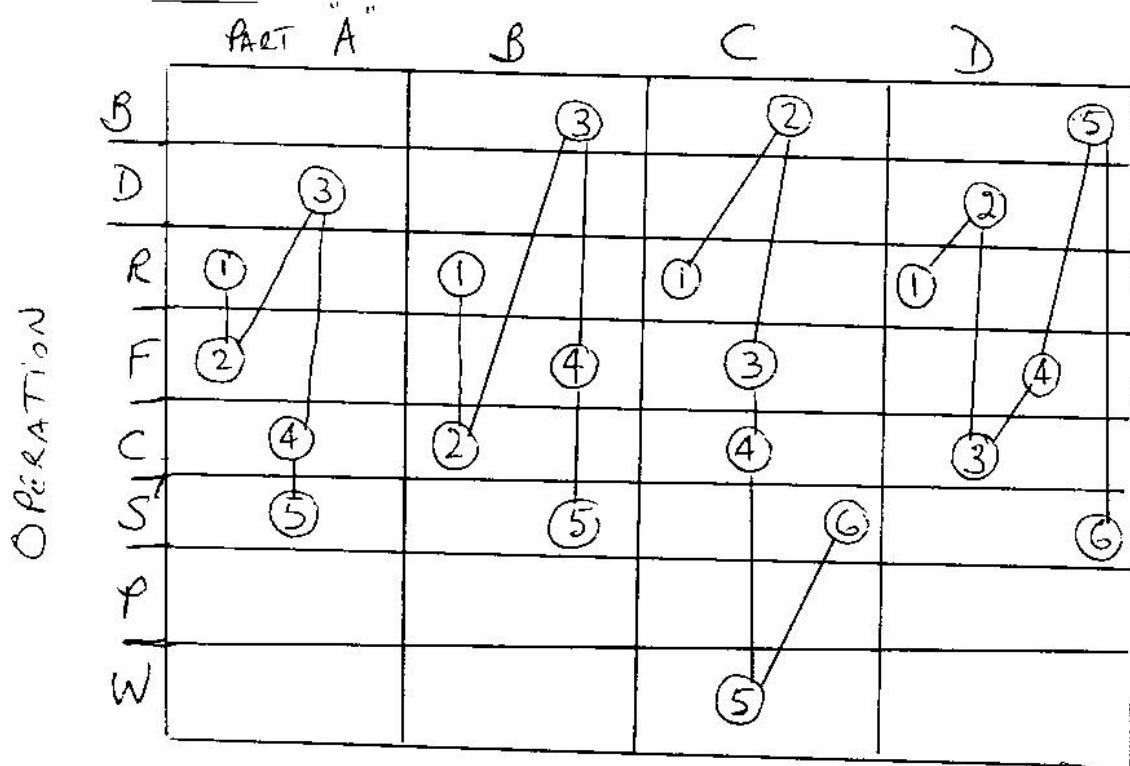
TOTAL Points = 43

43 132

$$\text{EFFICIENCY} = \frac{43}{132} = 32.58\%$$

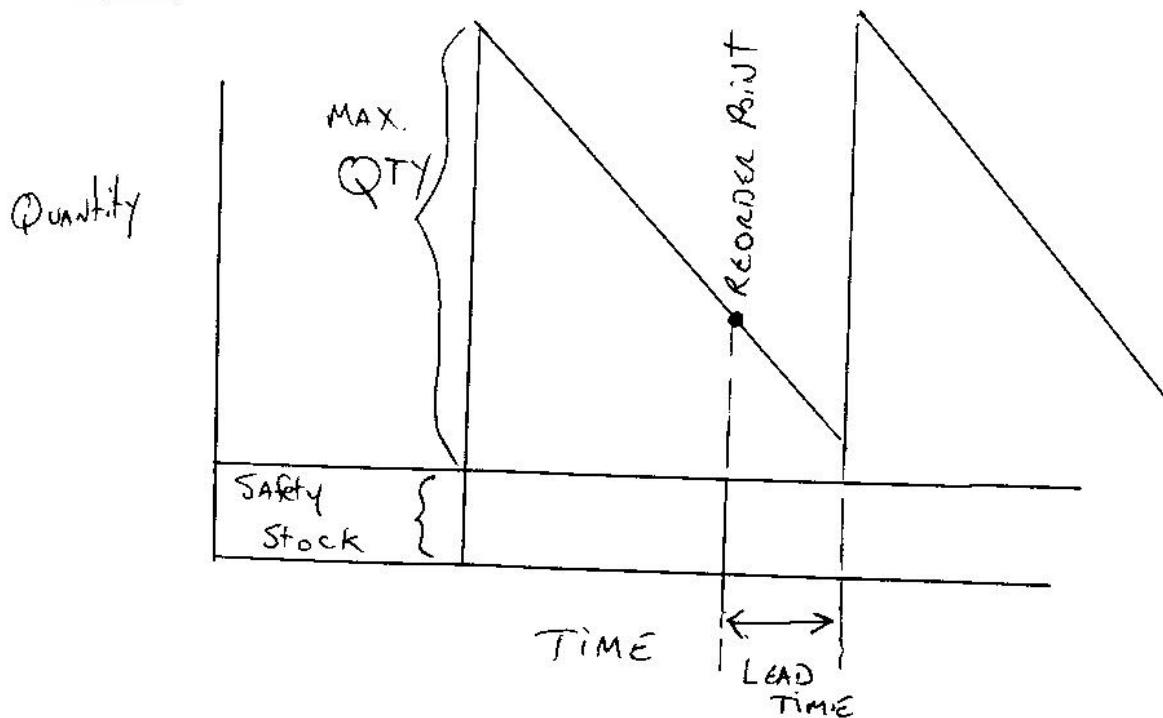
10. From the data given in problem 9, construct a multi-product flow diagram.

Solution:



11. Sketch a CLEAR inventory re-ordering and consumption cycle. Clearly identify your axis and all relevant data on the graph.

Solution:



12. Four operations are performed on an assembly line. Time standards are given below in minutes. Balance this assembly line to produce 3,500 units in an 8-hour shift. Allow (2) 10-minute breaks. Assume 85% performance. What is the efficiency of this line? (Do not attempt to optimize your solution – your initial solution is sufficient)

Operation Standard time

1	0.052
2	0.446
3	0.218
4	0.290

Solution:

$$\begin{aligned} 8 \text{ hours} \times 60 \text{ minutes per hour} &= 480 \text{ minutes per shift} \\ &\quad - 20 \text{ " for breaks} \\ &= 460 \text{ minutes per shift} \end{aligned}$$

$$460 \times 85\% \text{ performance} = 391 \text{ minutes productive time}$$

$$391 \div 3,500 \text{ units} = 0.112 \text{ minutes per unit}$$

TAKT time (or "R" value)

Solutions to Problem #12 (Cont'd)

LINE TIME	OPERATION STANDARD TIME	# OF STATIONS	Avg. Sta. Time	% LOAD	PSC/HOUR LINE	HOURS/1000 LINE
•112	1 0.052	.46=1	.052	46	536	1.86
.446	2 0.446	3.98=4	.112	100	134.5	7.4
.224	3 0.218	1.95=2	.109	97	267.8	3.7
.1336	4 0.290	2.56=3	.097	87	178.5	5.6

Total operation time = 1.006 minutes per unit

Total line time = 1.118 min. per unit

$$\frac{1.006}{1.118} = 90\% \text{ line eff.}$$

13. Four operations are performed to produce a part. The scrap rate for these operations are as follows: Op1: 0.5%, Op2: 2.05%, Op3: 2.0%, and Op4: 3.50%. If 3500 finished parts are required how many parts do we start with?

Solution:

$$I = \frac{O}{(1-P_1)(1-P_2) \dots}$$

$$I = \frac{3500}{(1 - .005)(1 - .0205)(1 - .02)(1 - .035)} = 3798$$

14. In order to obtain an accurate estimate, an operation has been observed five times and the measurements are as follows:

0.055, 0.050, 0.065, 0.060, 0.060 (in minutes). The operator has been rated at 115%. Assuming 12% for allowances, calculate the following.

a) Normal time

Solution: $\frac{.055 + .050 + .065 + .060 + .060}{5} = .058 \times 1.15 = .067$ minute

b) Standard time

Solution:

$$(.067 \text{ minute normal time}) \div (1 - .12) = .085 \text{ min/ac std time}$$

c) Pieces per hour

Solution: $.085 \text{ min/ac} \div 60 \frac{\text{min}}{\text{hr}} = .0014 \frac{\text{hr}}{\text{pc}} \quad \frac{1}{x} = 705.88 \frac{\text{pcs}}{\text{hr}}$

d) If the direct labor cost is estimated at \$13.50/hr, determine direct labor cost per piece.

Solution:

$$.0014 \frac{\text{hr}}{\text{unit}} \times 13.50 \frac{\$}{\text{hr}} = .0191 \frac{\$}{\text{unit}}$$

or 1.91 $\frac{\$}{\text{unit}}$

15. For the following data calculate the takt time. Length of shift: 8.5 hours, production requirements: 3300 units, overall efficiency 85%, non-production time: breaks, 20 minutes; clean-up 10 minutes; meeting, 10 minutes; lunch, 30 minutes.

Solution:

$$8.5 \text{ HRS} \times 60 \text{ min./hr} = 510 \text{ minutes/shift}$$

$$510 \text{ min} - (20 \text{ min. BRK}, 10 \text{ min. meetings}, 30 \text{ min. Lunch}) = 440 \text{ min}$$

$$440 \times 85\% \text{ performance} = 374 \text{ min. per shift}$$

$$374 \div 3300 \text{ units} = 0.113 \text{ min/unit TAKT time}$$

16. Complete the routing sheet below. Use "R" = 0.252.

OPERATION	STD TIME (min.)	HOURS/1000 PCS/HOUR	FRACTION EQUIPMENT
1	0.042		
2	0.125		
3	0.050		
4	0.600		
5	0.240		

Solution:

OPERATION	STD TIME (min.)	HOURS/1000 PCS/HOUR	FRACTION EQUIPMENT
1	0.042	.70	1428
2	0.125	2.08	480
3	0.050	.833	1200
4	0.600	10.0	100
5	0.240	4	250

17. Various parts are placed on an overhead conveyor and are spray painted. Depending on the part, one or more parts can be placed on the same hook as indicated in the data below. The hooks are 24 inches apart and the "R" value = 0.322. Keep in mind that the hooks and the parts are a matched set.

Part Number	Quantity to Paint	Quantity per Hook	Required No. of Hooks
xb-13	550	3	—
12-45	640	4	—
zz-12	755	3	—
qy-97	1200	7	—
tr-x7	1540	6	—
qw-65	951	5	—

a) Calculate the required number of hook for each part and complete the column.

Solution: Example: $550 \div 3 = 184$; For the other parts: 160, 252, 172, 257, & 191

b) Calculate the speed of this conveyor belt.

Solution: $24'' \div 12 \text{ INCHES PER FOOT} = 2' \text{ SPACE between Hooks}$

$$\frac{2 \text{ FEET}}{\cdot 322 \text{ min. TAKT TIME}} = 6.21 \text{ FEET PER MIN.}$$

18. The average observed time for an operation is given as 0.125 min/unit. The operator has been rated at 90%. Assuming 15% for allowances, calculate the standard time.

Solution:

$$.125 \text{ min} \times .90 = .1125 \text{ min. NORMAL TIME}$$

$$\frac{.1125}{(1 - .15)} = .132 \text{ min. STANDARD TIME}$$

19. Calculate the "R" value to produce 3000 units in a 10-hour shift. Allow a total of 30 minutes for breaks and 10 minutes for clean-up. Assume 90% efficiency.

Solution:

$$\begin{aligned} 10 \text{ HRS} \times 60 \text{ min. PER HOUR} &= 600 \text{ min.} \\ &\quad - 30 \text{ min. BREAKS} \\ &\quad - 10 \text{ min. CLN UP} \\ \hline 560 \text{ min.} \times .90 &= 504 \text{ min.} \end{aligned}$$

$$504 \div 3000 = .168 \text{ min/unit. TAKT TIME}$$

20. If the total part length and the spacing is 15 inches, using "R" = 0.320,
 conveyor speed = _____ ft/min.

Solution:

$$15 \text{ INCHES} \div 12 = 1.25 \text{ FT. PART SPACING}$$

$$1.25 \text{ FT} \div 0.320 \text{ min/part} = 3.91 \text{ FT PER MIN.}$$

21. Complete the production routing below. "R" = 0.420.

OPERATION	STD TIME MIN.	HOURS/1000 PCS/HOUR	FRACTION EQUIPMENT REQUIRED
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1	.085
2	.072
3	.250
4	.750

Solution:

OPERATION	STD TIME MIN.	HOURS/1000 PCS/HOUR	FRACTION EQUIPMENT REQUIRED
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1	.085	1.4167	705.88	.20
2	.072	1.200	833.33	.17
3	.250	4.167	240.00	.595
4	.750	12.50	80.00	1.7857

22. Construct a FROM-TO chart for the following data. What is the efficiency of the layout?

The arrangement of the facility is given as: R B C D F W S

PART NO.	WT.FACTOR	OPERATION SEQUENCE
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X-2	5	R D C D S
Y-2W	2	R C D B F S
X7-8	3	R F D C B S
12-WD	4	R B C F W S

Solution:

Solution (Problem 22)

$$\text{EFFICIENCY} = \frac{\text{TOTAL points}}{\text{PENALTY}} = \frac{65}{138}$$

$$= 47.10\%$$

23. 800 pallets are stored on racks. These racks are 14.5 feet wide and each rack can hold 15 pallets

Required # of racks = _____

Required Aisle feet = _____

Solution:

$$800 \text{ PALLETS} \div 15 \text{ PALLETS PER RACK} = 54 \text{ RACKS}$$

$$54 \text{ RACKS} \times 14.5 \text{ AISLE FEET PER RACK} = 783 \text{ AISLE FEET}$$

24. Small screws are stored 25 per box, in boxes measuring 3"x3"x 3" and placed on shelves. The shelf dimensions are 1' high, 1' deep, and 3' wide and each unit has 7 shelves. Calculate the required aisle-feet to store 400,000 screws.

of shelves = _____

of Units = _____

Aisle feet = _____

Solution:

$$400,000 \text{ SCREWS} \div 25 \text{ SCREWS PER BOX} = 16,000 \text{ BOXES}$$

$$3" \times 3" \times 3" = 27 \text{ INCHES CUBE PER BOX}$$

$$27 \text{ INCHES CUBE} \times 16,000 \text{ BOXES} = 432,000 \text{ INCHES CUBE}$$

$$432,000 \div 1728 \text{ INCHES/FOOT CUBE} = 250 \text{ FEET CUBE}$$

$$250 \text{ FEET CUBE} \div 3 \text{ FEET CUBE SHELF CAPACITY} = \underline{\underline{84 \text{ SHELVES}}}$$

$$84 \text{ SHELVES} \div 12 \text{ SHELVES PER UNIT} = \underline{\underline{12 \text{ UNITS}}}$$

$$12 \text{ UNITS} \times 3 \text{ AISLE FEET PER UNIT} = \underline{\underline{36 \text{ AISLE FEET}}}$$

25. List five space or area requirements when planning a shipping/receiving department.

Solution:

1. personnel convenience
2. offices
3. material handling equipment
4. trash
5. pallets and packing material
6. truckers' lounge
7. buffer or staging area

26. Clearly state and explain the “unit load concept.”

Solution:

Handle multiple units of the product in as large a load and as one unit. The more items are moved as one unit, the lower the cost per unit moved.

27. Clearly state the objectives when planning for material storage facilities.

Solution:

1. Maximize the use of the building cube
2. Efficient use of time, labor, and equipment
3. Accessibility to all items
4. Rapid and easy movement of material
5. Positive item identification
6. Maximum protection
7. Neat and orderly arrangement