

# Systematic Plant Layout

Madhu Posani

Business and Industry Specialist, Mid-America Trade Adjustment Assistance Center

Material-handling costs comprise anywhere from 30 to 75 percent of total manufacturing costs. Any savings in material handling realized through a better arrangement of the departments is a direct contribution to the improvement of overall efficiency of the operation. Plant layout, therefore, is an important phase of designing a manufacturing facility.

Any plant layout should be reviewed periodically and a layout planning done for the next 5 to 10 years. Two basic elements on which every plant layout rests are:

- Product (or material) — what is to be produced.
- Quantity (or volume) — how much of each item is to be produced.

Certain relationships which affect the planning and layout of a plant exist involving product and quantity. An initial step is the Pareto analysis and developing a product-quantity chart.

## Pareto analysis

In almost all aspects of industry there is a disproportionate relationship between elements. For example, in typical situations we find that 30 percent of a company's customers account for 70 percent of the net sales, or 20 percent of all items purchased account for 80 percent of the total material cost. This is called the Pareto analysis (Figure 1). This analysis allows one to concentrate his or her efforts on the few giants rather than the several midgets (Konz, 1983).

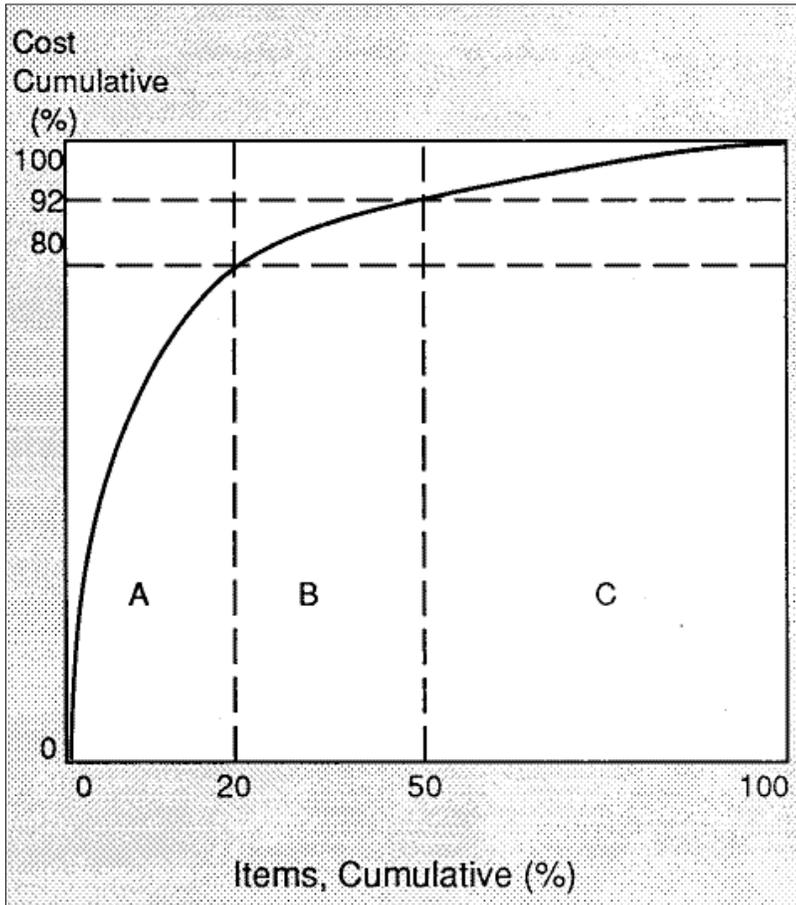


Figure 1. Pareto diagram for purchased items.

In terms of production planning, this relative proportion between the percentage of cumulative costs and items is the basis of A B C inventory control.

For the facilities planner or layout analyst, the Pareto analysis has a significant meaning. It is the basis for deciding which fundamental type of production system or layout arrangement to use — product layout (line production), process layout (job-shop), or a combination of both.

## Product-Quantity (P-Q) chart (Muther, 1961)

Analysis of the various products (or materials or parts) in comparison with the quantities of each product is an important part of most layout projects. This is true of most materials handling, storing or production planning projects.

Generally, this analysis takes the form of:

- Some division or grouping of the various products, materials, or items involved, and
- A tally or count of the quantity of each division or grouping, or of each product, item or variety within each division or grouping.

For ease in visualizing the findings, the count is arranged in sequence and the results plotted on a graph. The result is the P-Q chart, so called for the terms product and quantity (Figure 2). The curve is plotted in the order of decreasing quantities with the largest quantity items placed first. The individual quantities, rather than cumulative figures, are used. The typical P-Q chart approximates a hyperbola that generally is asymptotic at both ends. It reveals the product varieties that are "fast-movers" and those that are "slow-movers." The items in area M (Figure 2) frequently lend themselves to mass production technique while those in area J must consistently be produced in a jobbing or a job-lot layout. Items falling in the area between M and J, and overlapping these areas, will generally mean a combination or in-between type of layout, such as a modified production line, lined-up process departments or group production.

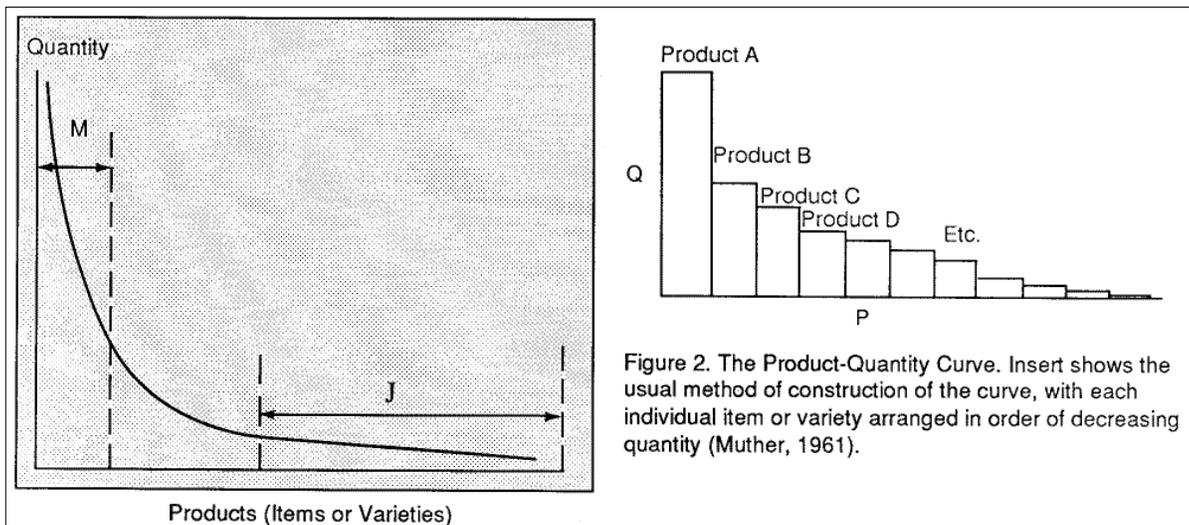


Figure 2. The Product-Quantity Curve. Insert shows the usual method of construction of the curve, with each individual item or variety arranged in order of decreasing quantity (Muther, 1961).

Figure 2.

In identifying P and in counting Q for any product, item, or variety, the actual count usually is used rather than converting to percentages as in Figure 1. The largest item is placed first, then the next largest, and so on. The count generally is best in number of pieces, weight or cubic volume, rather than in dollars. The actual unit of measure will depend on the nature of the product or items involved and on the unit used in company records available or in forecast projections which are developed.

## Significance of the P-Q chart

The chart has a fundamental relationship to the layout which should be planned.

At one end of the curve are large, individual quantities of a relatively few products or varieties. These are essentially mass production conditions and, therefore, these products tend to favor mass production methods, especially production lines or layouts by product.

At the other end of the curve are many products, each with small quantities. These are the conditions suitable to job-order or job-shop methods, especially layout by process for forming and treating, and layout by fixed position (fixed location) for assembly.

Descriptions of the basic types of layout plans are shown in Figure 3.

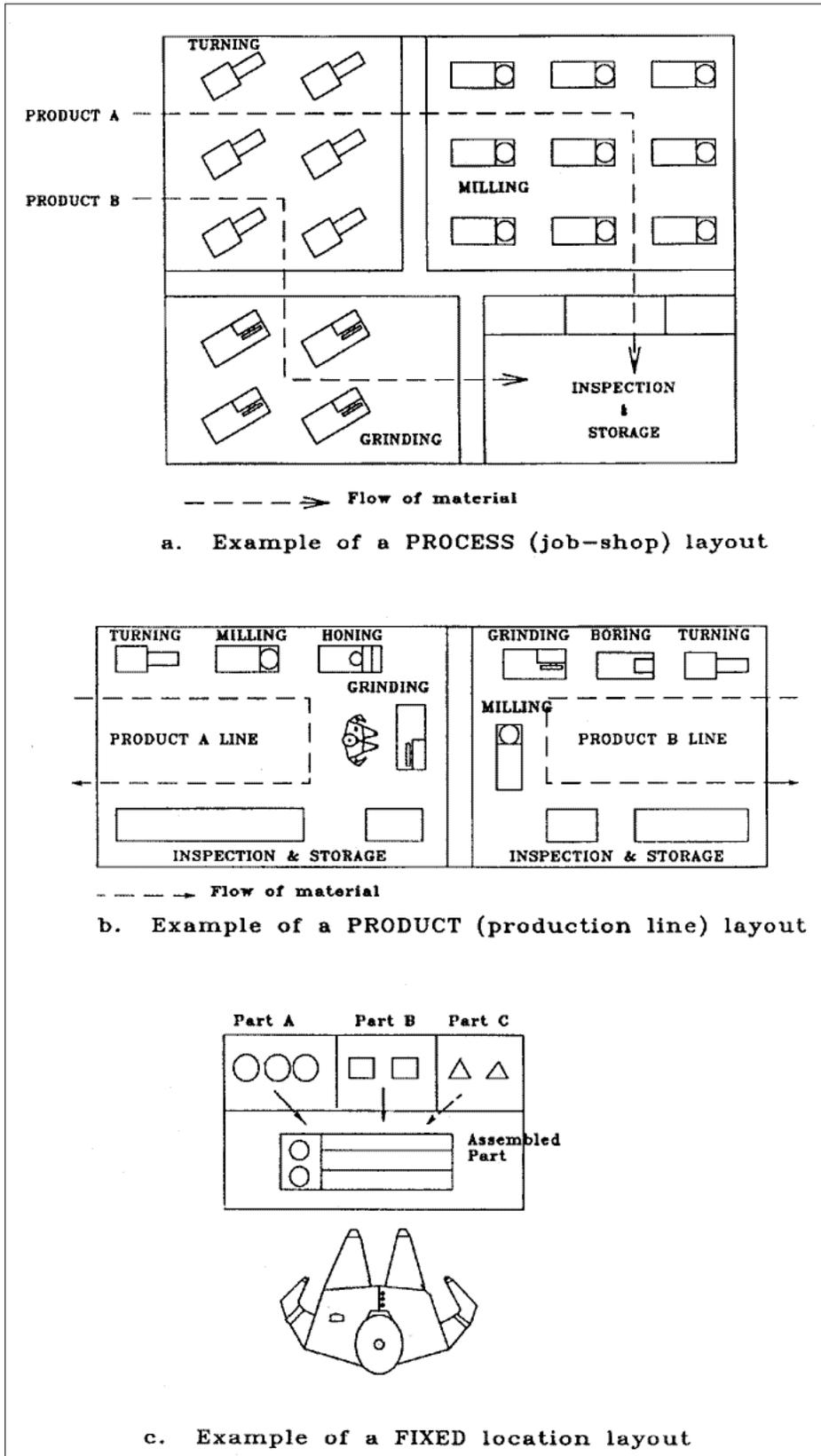


Figure 3. Examples of a process, product and fixed location layouts.

This means that some of the products lend themselves to a conveyORIZED, automatic type of layout while others require highly flexible handling methods and standardized equipment, arranged for universal operations. As a result, by dividing the products and producing them in two different types of layouts, efficiency may be obtained for both, whereas to make one layout plan for all products may be a less effective compromise.

When there is a "shallow" P-Q curve, generally a universal handling system and a single-layout arrangement is practical for all the items (Figure 4 a). Because the bulk of the production is in the center area of the curve, plan for an overall efficiency even though items at both ends of the curve may not be produced with complete effectiveness. On the other hand, when there is a "deep" curve, there is a tendency to divide the products and the production areas into two difference layouts and handling systems (Figure 4 b).

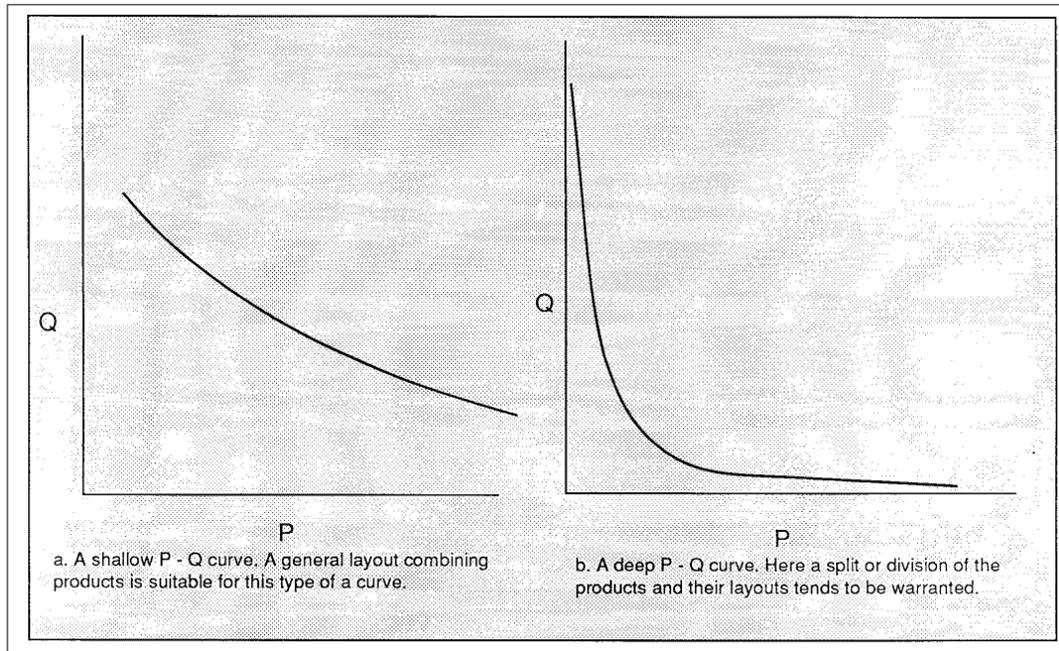


Figure 4. Significance of the P-Q chart (Muther, 1961).

## Activity relationships

In most industrial plants, the emphasis is commonly placed on flow of material as the basis for layout arrangement. A flow pattern is determined and diagrammed, and the rest of the activities are then fitted in and around that pattern. Actually, this is not the best practice as a general rule for layout procedure.

### Flow alone not best basis for layout

There are several reasons why the flow of material, as determined predominately by the routing, cannot be the sole basis for the layout arrangements.

- The supporting services must integrate with the flow in an organized way. This integration results from total analysis — analysis of the reasons underlying why certain supporting activities should be close to certain producing or operating areas. The maintenance crib, the supervisor's office, the locker and rest rooms, all have a relatively preferred closeness to each of the producing areas. They are all parts of the layout — they must be planned into it — yet they are not part of the flow of materials.

- Even in heavy material-movement plants where the influence of material flow will dominate the layout planning, flow will not be the sole basis for arranging the process operations and equipment. Basically, planners chart flow to determine the sequence of operations or which departments should be near each other. But flow of materials is only one reason for this closeness. There are many others, and these may conflict with or at least cause adjustments in the closeness as based on the analysis of flow. For example, the routing may call for the sequence: form, trim, treat, subassembly, assembly, and pack. For best flow of material, treating should lie between trimming and subassembly. Treating is both a very dirty and a dangerous operation, therefore, it should be kept away from the delicate subassembly area and its high concentration of workers. The effect of factors such as these — or the distribution of utilities, the cost of controlling quality, the employee comfort and the like — must be compared with the importance of material flow, and adjustments made as practical.

Thus a systematic way of relating service activities to each other and of integrating supporting services with the flow of materials is necessary.

## **Systematic layout steps (Konz, 1983)**

### **Step 1:**

The relationship chart (Table 1) is the first step. Divide the facility into convenient activity areas (office, lathes, drill press, etc.). For more than 15 areas, analyze in two sections (e.g., layout of assembly departments and layout of component departments). For "closeness desired between areas," assign a letter grade as follows:

A = absolutely necessary

B = important

C = average

D = unimportant

E = not desirable to be close

Letters are used rather than numbers because they imply more precision to the judgment than is available. Avoid too many A relationships. About 10 percent As, 15 percent Bs, 25 percent Cs and 50 percent Ds is a good goal. Support A, B and E relationships with a "reason for closeness." Reasons will depend upon the problem but common reasons are:

- product movement
- supervisory closeness
- personnel movement
- tool or equipment movement
- noise and vibration

**Table 1. Relationship chart (Konz, 1983).**

Area #	Area Name	Office	Lathes	Drill Press	Punch Press	Plating	Shipping	Die Storage
		1	2	3	4	5	6	7
1	office							
2	lathes	D						
3	drill press	D	B/2V					
4	punch press	E/5	D	B/2				
5	plating	D	C	D	D			
6	shipping	C	D	D	C	B/2		
7	die storage	D	D	D	A/4	D	B/4	

## Step 2:

Assign floor space to each activity area, along with physical features and restrictions. An example is shown in Table 2.

**Table 2. Space allocation (Konz, 1983).**

Area name	Desired area (sq. m)	Restrictions/physical features
1 office	50	Air conditioning
2 lathes	40	Minimum of 10 meters long
3 drill press		40
4 punch press	50	Foundation
5 plating	30	Water supply, fumes, wastes
6 shipping	20	Outside wall
7 die storage	<u>50</u> 280	Crane

### Step 3:

Make an activity relationship diagram (Figure 5). First, list all the A relationships from the relationship chart, then the Bs, Cs, Ds and Es. Then make a diagram with just the As. Then add the Bs, keeping in mind the E restrictions. Then add the Cs, then the Ds. D relationships are not represented by lines.

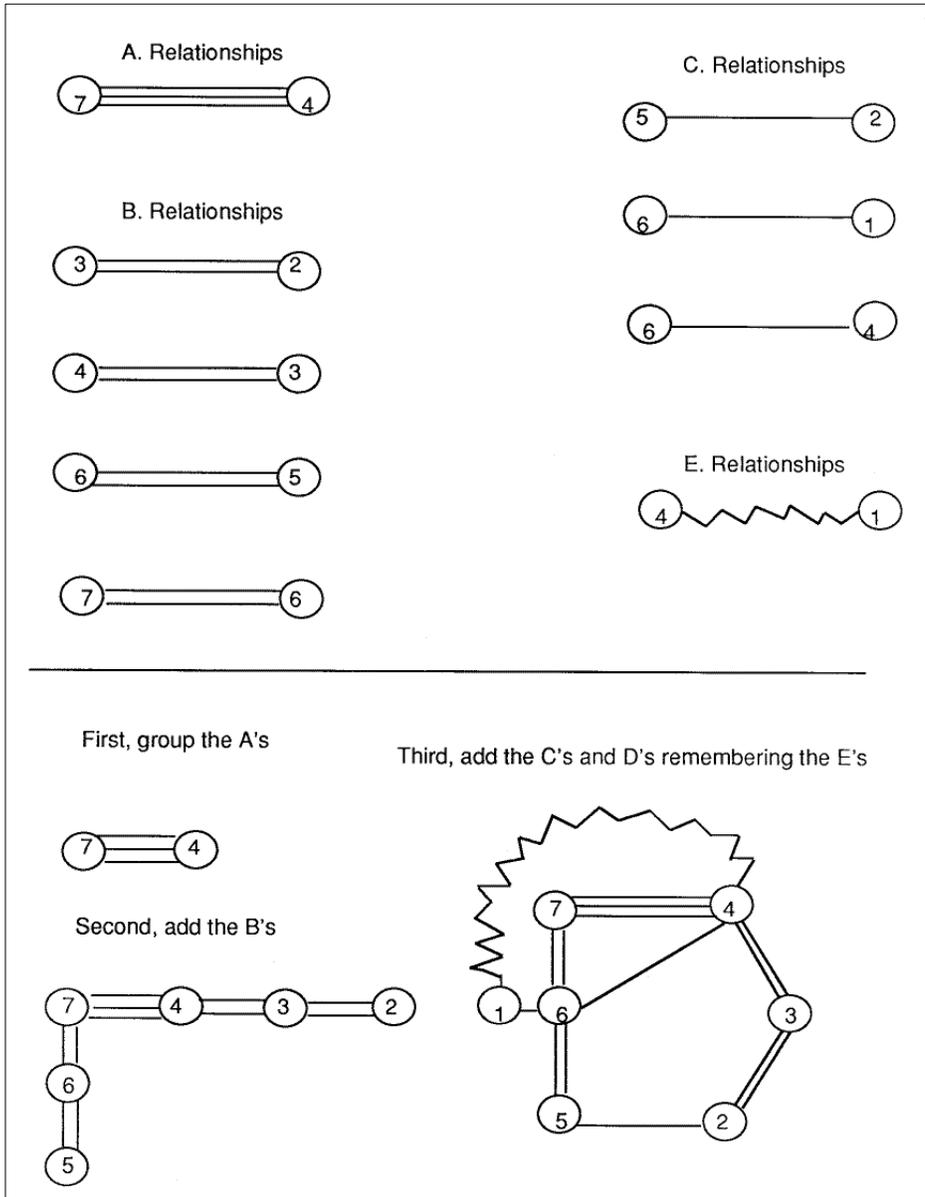


Figure 5. The activity relationship diagram. First, group the As, Bs, Cs and Es; then group all of the As, add the Bs to the As (remembering the Es) then add the remainder. It may help to think of the lines as rubber bands pulling together. Thus, three lines for A relationships indicate maximum pull. On the contrary, the wavy line for the Es is a like spring keeping them apart (Konz, 1983).

## Step 4:

Make a scaled layout of at least two trials from Step 3 using the areas and restrictions from Step 2 (Figure 6). First, use scaled pieces of stiff paper for each department. The reason for at least two layouts is to obtain an optimal layout rather than a layout which "works." It may be desirable (to keep the overall building shape rectangular) to slightly modify some of the desired areas from Step 2.

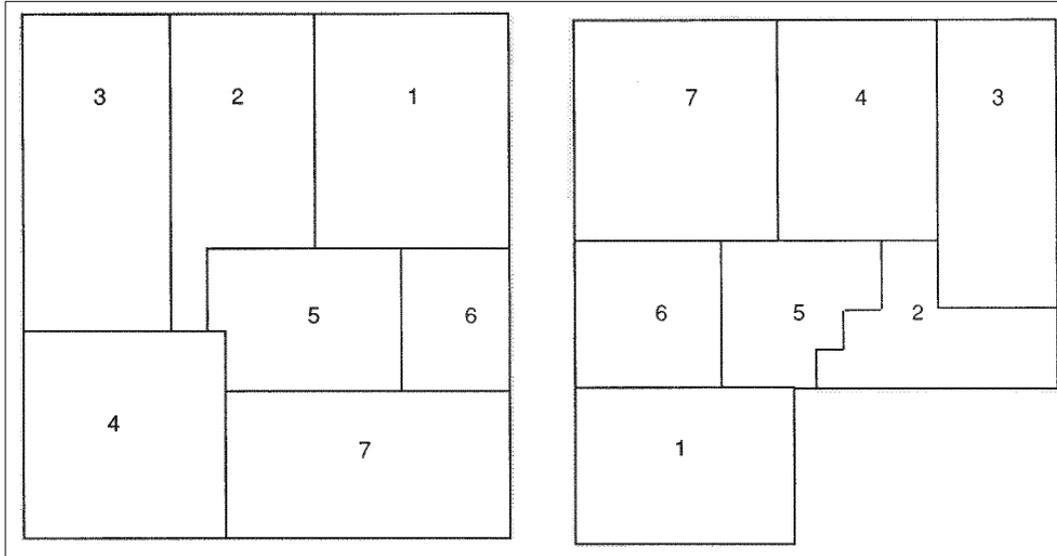


Figure 6. Step four. Scaled layout, makes several alternative arrangements (Konz, 1983).

## Step 5:

Evaluate the alternatives (Table 3). The relevant criteria and their weights will change from situation to situation. Grade each layout (A = Excellent = 4; B = Good = 3; C = Average = 2; D = Fair = 1; and F = Bad = 0) and calculate the layout's "grade point." If there is an existing layout, include it as one alternative. Defining the best as 100 percent, calculate the percent for the alternatives, then go back and select features from the alternative to get an improved set of designs.

**Table 3. Evaluation of alternatives. Criteria and weights depend upon the specific management's goals (Konz, 1983)**

Criterion	Weight	Present	Alt 1	Alt 2
Minimum investment	6	A 24	B 18	A 24
Ease of supervision	10	C 20	C 20	B 30
Ease of operation	8	C 16	C 16	C 16
Ease of expansion and contraction	2	C 4	C 4	B 6
<b>Total points</b>		64	58	70
<b>Relative merit</b>		91%	83%	100%

## Step 6:

Detail the layout (make a working drawing) and present these improved alternatives to management personnel. After their modifications, install the final design.

## Summary

For an industrial business to be successful over the long term, it must be a low cost manufacturer. Any savings in material handling through a better plant layout results in a sizable reduction in manufacturing costs. Also, productivity can be improved through a better arrangement of supporting services. Plant layout, therefore, is a crucial step in setting up a new facility or revising an existing one. The systematic plant layout procedure allows a planner to design an optimal facility analytically.

## References

- Konz, S. (1983), *Work Design: Industrial Ergonomics*, New York: John Wiley and Sons, Inc.
- Konz, S. (1985), *Facility Design*, New York: John Wiley and Sons, Inc.
- Sule, D.R. (1988), *Manufacturing Facilities: Location, Planning, and Design*, Boston, MA: PWS-KENT Publishing Co.
- Tompkins, J.A., and J.A. White (1984), *Facilities Planning*, New York: John Wiley and Sons, Inc.
- Muther, R. (1961), *Systematic Layout Planning*, Boston, MA: Industrial Education Institute.
- Hales, H.L. (1984), *Computer-Aided Facilities Planning*, New York, N.Y.: Marcel Dekker, Inc.

---

University of Missouri. Published by University Extension, University of Missouri-Columbia. Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. Ronald J. Turner, Director, Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, Missouri 65211. • University Extension does not discriminate on the basis of race, color, national origin, sex, religion, age, disability or status as a Vietnam-era veteran in employment or programs. If you have special needs as addressed by the Americans with Disabilities Act and need this publication in an alternative format, write ADA Officer, Extension and Agricultural Information, 1-98 Agriculture Building, Columbia, MO 65211, or call (573) 882-8237. Reasonable efforts will be made to accommodate your special needs.