CHAPTER-IV
FACILITY PLANNING

To produce products or services business systems utilize various facilities like plant and machineries, ware houses etc.

Facilities can be broadly defined as buildings where people, material, and machines come together for a stated purpose – typically to make a tangible product or provide a service.

The facility must be properly managed to achieve its stated purpose while satisfying several objectives. Such objectives include producing a product or producing a service

- at lower cost,
- at higher quality,
- or using the least amount of resources.

4.1 Definition of Facilities Planning

Importance of Facilities Planning & Design Manufacturing and Service companies spend a significant amount of time and money to design or redesign their facilities. This is an extremely important issue and must be addressed before products are produced or services are rendered.

A poor facility design can be costly and may result in:
- poor quality products,
- low employee morale,
- customer dissatisfaction.

4.2 Disciplines involved in Facilities Planning (FP)

Facilities Planning (FP) has been very popular. It is a complex and a broad subject. Within the engineering profession:
- civil engineers,
- electrical engineers,
- industrial engineers,
- mechanical engineers are involved in FP.

Additionally,
- architects,
- consultants,
- general contractors,
- managers,
- real estate brokers, and
- urban planners are involved in FP.

4.3 Applications of Facilities Planning (FP)

Facilities Planning (FP) can be applied to planning of:
- a new hospital,
- an assembly department,

• an existing warehouse,
• the baggage department in an airport,
• department building of IE in EMU,
• a production plant, • a retail store,
• a dormitory,
• a bank,
• an office,
• a cinema,
• a parking lot,
• or any portion of these activities etc.

4.4 Factors affecting Facility Layout

Facility layout designing and implementation is influenced by various factors. These factors vary from industry to industry but influence facility layout. These factors are as follows:

- The design of the facility layout should consider overall objectives set by the organization.
- Optimum space needs to be allocated for process and technology.
- A proper safety measure as to avoid mishaps.
- Overall management policies and future direction of the organization.

4.5.1 Break-Even Analysis

The objective is to maximize profit. On economic basis only revenues and cost need to be considered for comparing various locations.

The steps for locational break-even analysis are :

- Determine all relevant costs for each location.
- Classify the location for each location in to annual fixed cost and variable cost per unit.
- Plot the total costs associated with each location on a single chart of annual cost versus annual volume.
- Selwct the location with the lowest total annual cost(TC) at the expected production volume.

Question:

Potential locations A,B and C have the cost structures shown below for manufacturing a product expected to sell for Rs 2700 per unit. Find the most economical location for an expected volume of 2000 units per year.

Site	Fixed Cost/year	Variable Cost/Unit
A	6,000,000	1500
B	7,000,000	500
C	5,000,000	4000

Solution:

For each plant find the total cost using the formula

TC=Fixed cost+ Variable cost/unit (volume)

= FC+VC(v)

Site	Total Cost
A	6,000,000+1500*2000=9,000,000
B	7,000,000+500*2000=8,000,000
C	5,000,000+4000*2000+13,000,000

From the above table, the cost of for the location B, is minimum. Hence it is to be selected for locating the plant.

Production Volume	Site A	Site B	Site C
500	6750000	7250000	7000000
1000	7500000	7500000	9000000
1500	8250000	7750000	11000000
2000	9000000	8000000	13000000
2500	9750000	8250000	15000000
3000	10500 000	8500000	17000000

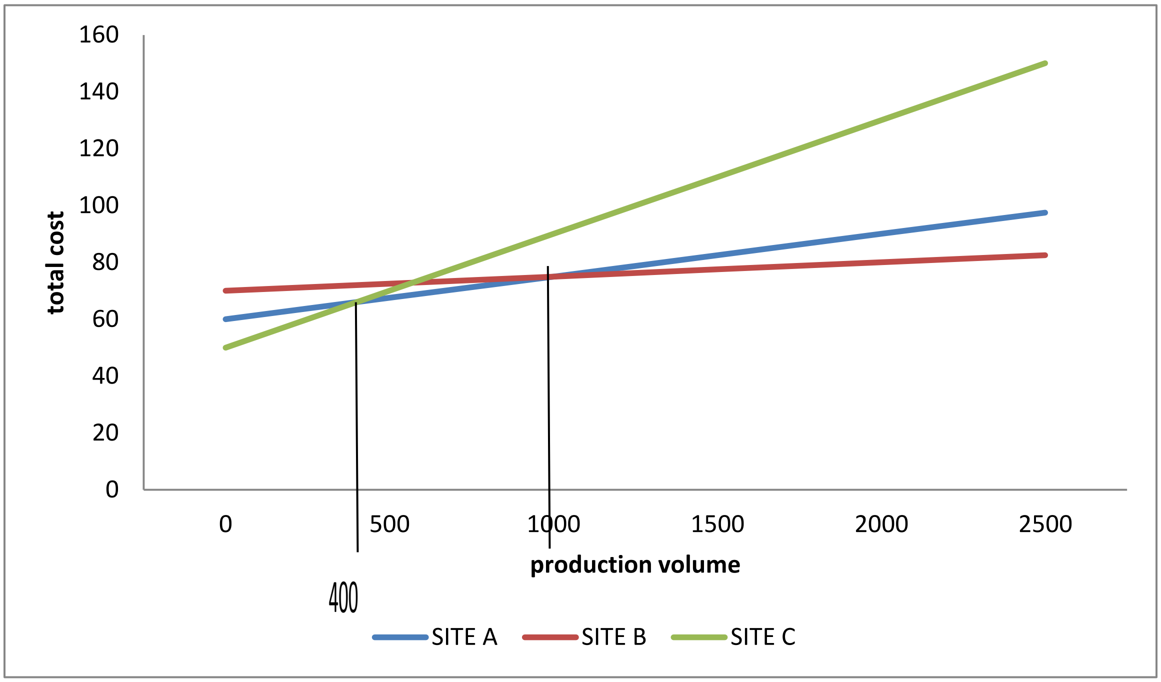


Fig 3.1 Break even analysis

From the graph, the different ranges of production volumes over which the best location to be selected are summarized.

Range of production volume	Best plant selected
0≤Q≤400 400≤Q≤1000 1000≤Q	A B C

The same details can be worked out using a graph

From the graph one can visualize that the site c is desirable for lower volume of production. For higher volume production site B is desirable For moderate volumes of production site nA is desirable. In the increasing order of production volume the switch over from one site to another takes place as per the order below

Site C to site A to site B

Let Q be the volume at which we switch the site C to site A

Total cost of site C ≥ Total cost site A

$$5000000+4000Q \geq 6000000+1500*Q$$

$$2500Q \geq 1000000$$

$$Q \geq 400 \text{ Units}$$

Similarly the switch from site A to site B

Total cost of site A ≥ total cost of site B

$$6000000+1500Q \geq 7000000+500Q$$

$$1000Q \geq 1000000$$

$$Q \geq 1000 \text{ Units}$$

The cutoff production volume for different ranges of production may be obtained by using similar procedure.

4.5.2 GRAVITY LOCATION PROBLEM

Objective- The objective of the gravity location problem, the total material handling cost based on the squared Euclidian distance is minimized

Assumption:- If the same type of material handling equipment / vehicle is used for all the movements, then it is equivalent to minimize the total weighted squared Euclidian distance, since the cost per unit distance is minimized

a_i = x-co-ordinate of the existing facilities i

b_i = y- co-ordinate of the existing facilities i

x = x-co-ordinate of the new facilities

y= y-co-ordinate of the new facilities

w_i= weight associated with the existing facilities i. This is the quantum of materials moved between the new facility and existing facilities I per unit period

m= total no of existing facilities

the formula for the sum of the weighted squared Euclidian distance is given as:

$$f(x,y) = \sum_{i=1}^{m} w\,i[(x - ai)^2 + (y - bi)^2]$$

The objective is to minimize f(x,y)

This is quadratic in nature the optimal values for the x and y may be obtained by equating partial derivatives to zero

$$\frac{\delta f(x,y)}{\delta x} = o \quad , \quad \frac{\delta f(x,y)}{\delta y} = 0$$

$$x* = \frac{\sum_{i=1}^{m} wiai}{\sum_{i=1}^{m} wi} \quad ,y* = \frac{\sum_{i=1}^{m} wibi}{\sum_{i=1}^{m} wi}$$

Optimal location (x*,y*)=($\frac{\sum_{i=1}^{m} wiai}{\sum_{i=1}^{m} wi}$, $\frac{\sum_{i=1}^{m} wibi}{\sum_{i=1}^{m} wi}$)

These are weighted averages of the x-coordinate and y-co ordinates of the existing facilities.

Problem

There are five Existing facilities which are to be served by single new facilities are shown below in the table

Existing facility (i)	1	2	3	4	5
Co-ordinates (ai,bi)	(5,10) (15,20)	(20,5) (30,35)	(15,20) (25,40)	(30,25) (28,30)	(25,5) (32,40)
No of trips of loads/years (wi)	100 200	300 300	200 400	300 500	100 600

Find the optimal location of the new facilities based on giving location concept

SOLUTION

$$X^*=\frac{\sum_{i=1}^{5} wiai}{\sum_{i=1}^{5} wi}=\frac{(100*5+300*20+200*15+300*30+100*25)}{(100+300+200+300+100)}= 21$$

$$Y^*=\frac{\sum_{i=1}^{5} wibi}{\sum_{i=1}^{5} wi}=\frac{(100*10+300*5+200*20+300*25+100*5)}{(100+300+200+300+100)}=14.5$$

4.5.3 SINGLE FACILITY LOCATION PROBLEM

Objective – To determine the optimal location for the new facility by using the given set of existing facilities co-ordinates on X-Y plane and movement of materials from a new facility to all existing facilities.

Generally we follow rectilinear distance for such decision. The rectilinear distance between any two points whose co-ordinates are (X1,Y1)and(X2,Y2) is given by the following formula

$d_{12}=|X1-X2|+|Y1-Y2|$

some properties of an optimum solution to the rectilinear distance location problems are as follows:

1. The X-coordinate of the new facility will be same as the X-co-ordinate of some existing facility. Similarly the Y co-ordinate of the new facility will coincide with the Y coordinate of some existing facility. It is not necessary that both coordinates of the new facility
2. The optimum X or Y-co-ordinate location for new facility is a median location. A median location is defined to be a location such that no more than one half the item movement is to the left/below of the new facility location and no more than one half the item movement is to the right /above of the new facility location.

EXAMPLE

Consider the location of a new plant which will supply raw materials to a set of existing plants in a group of companies, let there are 5 existing plants which have a materials movement relationship with the new plant. Let the existing plants have locations of (400,200),(800,500),(1100,800),(200,900)and(1300,300). Furthermore suppose that the number of tons of materials transported per year from the new plant to various existing plants are 450,1200,300,800 and 1500, respectively the objective is to determine optimum location for the new plant such that the distance moved(cost)is minimized

SOLUTION

Let (X,Y) be the coordinate of the new plant

The optimum X-coordinate for the new plant is determined as follows

Existing plant	X coordinate	weight	Cumulative Weight
4	200	800	800
1	400	450	1250
2	800	1200	2450
3	1100	300	2750
5	1300	1500	4250
		Total	4250 tons

Thus the median location corresponds to a cumulative weight of 4250/2=2125 from above the table, the corresponding X-coordinate value is 800, since the cumulative weight first exceeds 2125 at X=800

Similarly, the determination of Y coordinate is shown below

Existing plant	Y coordinate	weight	Cumulative Weight
1	200	450	450
5	300	1500	1950
2	500	1200	3150
3	800	300	3450
4	900	800	4250
		Total	4250 tons

Thus the median location corresponds to a cumulative weight of 4250/2=2125 from above the table, the corresponding Y-coordinate value is 500, since the cumulative weight first exceeds 2125 at X=500

The optimal (X*,Y*)=(800,500)

4.5.4 MINIMAX LOCATION PROBLEM

Objective- To locate the new emergency facility (X,Y) such that the maximum distance from the new emergency facility to any of the existing facilities is minimized

Fi(X,Y)= Distance between the new facilities and the existing facilities

Fi(X,Y)=|X-ai|+|Y-bi|

Fmax (X,Y)=maximum of the distance between the new facility and various existing facilities

Fmax(X,Y)= $\underbrace{max}_{1\le i\le m}$ {|X-a_i|+|Y-b_i|}

The distance between new facility and existing facility may be rectilinear or Euclidean

m=different shops in an industry

in the event of fire in any one of these shops a costly firefighting equipment showed reach the spot as soon as possible from its base location. Movements within any industry are rectilinear in nature. Our objective is to locate the new fire fighting equipment within the industry such that maximum distance it has to travel from its base location to any of the existing shops is minimized.

Step 1

Find c_1, c_2, c_3, c_4 and c_5,using following formula

$c_1 = \underbrace{min}_{1\le i\le m} (a_i + b_i)$ $c_2 = \underbrace{max}_{1\le i\le m} (a_i + b_i)$ $c_3 = \underbrace{min}_{1\le i\le m} (-a_i + b_i)$ $c_4 = \underbrace{max}_{1\le i\le m} (-a_i + b_i)$

$c_5 = \underbrace{max}_{1\le i\le m} (c_2 - c_1, c_4 - c_3)$

Step 2

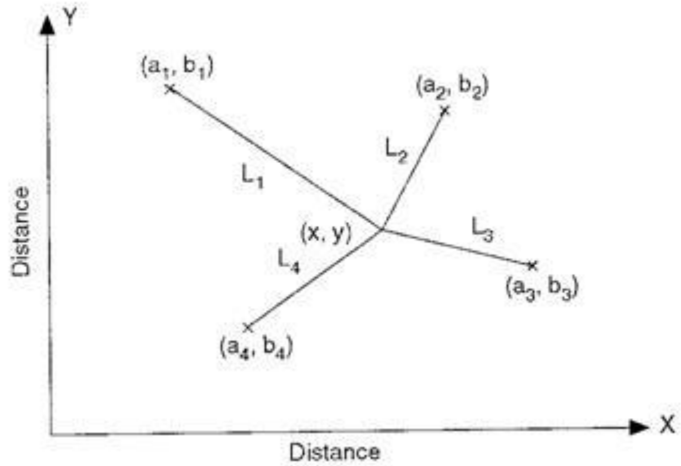
Find the points P_1 and P2 using the following formula

P1=[1/2($c_1 - c_3$), ½($c_1 + c_3 + c_5$)]

P2=[1/2($c_2 - c_4$), ½($c_2 + c_4 - c_5$)]

Step 3

Any pt(X*,Y*) on the line segment joining points P1 and P2 is a minimax location that minimize fmax(X,Y)



GRAPH OF MINIMAX LOCATION PROBLEM

EXAMPLE

In a foundry there are seven shops whose coordinates are summarized in the following table. The company is interested in locating a new costly fire fighting equipment in the foundry determine the minimax location of the new equipment

SL NO	EXISTING FACILITIES	CO-ORDINATE OF CENTROID
1	Sand plant	10,20
2	Molding shop	30,40
3	Pattern shop	10,120
4	Melting shop	10,60
5	Felting shop	30,100
6	Fabrication shop	30,140
7	Annealing shop	20,190

SOLUTION

The movement of new equipment is constrained within in the foundry the assumption of rectilinear distance more appropriate

The co ordinate of the centroid of the existing shops are

(a1,b1)=(10,20) (a2,b2)=(30,40) (a3,b3)=(10,120) (a4,b4)=(10,60) (a5,b5)=(30,100) (a6,b6)=(30,140) (a7,b7)=(20,140)

Step 1

$c_1 = \underbrace{min}_{1 \le i \le m} (a_i + b_i)$ = min [(10+20),(30+40),(10+120),(10+60),(30+100),(30+140),(20+190)]

=min[30,70,130,70,130,170,210]=30

$c_2 = \underbrace{max}_{1 \le i \le m} (a_i + b_i)$ = max[30,70,130,70,130,170,210]=210

$c_3 = \underbrace{min}_{1 \le i \le m} (-a_i + b_i)$=min[(-10+20),(-30+40),(-10+120),(-10+60),(-30+100),(-30+140),

(-20+190)]=min[10,10,110,50,70,110,170]=10

$c_4 = \underbrace{max}_{1 \le i \le m} (-a_i + b_i)$ =max[10,10,110,50,70,110,170]=170

$c_5 = \underbrace{max}_{1 \le i \le m} (c_2 - c_1, c_4 - c_3)$=max[(210-30),(170-10)]=max[180,160]=180

P1=[1/2$(c_1 - c_3)$, ½$(c_1 + c_3 + c_5)$]=[1/2(30-10),1/2(30+10+180)]=(10,110)

P2=[1/2$(c_2 - c_4)$, ½$(c_2 + c_4 - c_5)$]= [1/2(210-170),1/2(210+170-180)]=(20,100)

Any point X*,Y* on the line segment joining pts (10,110),(20,100) is a minimax location for the firefighting equipment.

4.6 Layout Design Procedure

Layout design procedures can be classified into manual methods and computerized methods.

Manual methods. Under this category, there are some conventional methods like travel chart and Systematic Layout Planning (SLP).

Computerized methods

Under this method, again the layout design procedures can be classified in to constructive type algorithm and improvement type algorithms.

Construction type algorithms

Automated Layout Design program (ALDEP)

Computerized Relationship Layout Planning (CORELAP)

Improvement type Algorithm

Computerized Relative Allocation of Facilities Technique (CRAFT)

4.6.1 Computerized Relative Allocation of Facilities Technique (CRAFT)

CRAFT algorithm was originally developed by Armour and Buffa. CRAFT is more widely used than ALDEP and CORELAP. It is an improvement algorithim.It starts with an initial layout and improves the layout by interchanging the departments pairwise so that transportation cost is minimized.

CRAFT requirements

1. Initial layout
2. Flow data
3. Cost per unit distance
4. Total number of departments
5. Fixed departments
   Number of such departments
   Location of those departments
6. Area of departments

4.7 Algorithms and models for Group Technology

In this section Rank Order Clustering (ROC) and Bond Energy Algorithms are the methods can be applied to Group Technology (GT).

4.7.1 Rank Order Clustering Algorithm (ROC)

This algorithm was developed by J.R King(1980).This algorithm considers the following data**.**

- Number of Components
- Component Sequence

Based on the component sequences, a machine-component incidence matrix is developed. The rows of the machine-component incidence matrix represent the machines which are required to processes the components. The columns of the matrix represent the component numbers.

STEPS IN ROC LOGARITHM

Step 0 : Input : Total no of components and component sequences

Step 1. From the machine component incidence matrix using the component sequences

Step 2. Compute binary equivalent of each row.

Step 3. Re arrange the rows of the matrix in rank wise (high to low from top to bottom)

Step 4. Compute binary equivalent of each column and check whether the column of the matrix are arranged in rank wise (high to low from left to right)? If not go to step 5 otherwise go to step 7

step 5. Rearrange the columns of the matrix rank wise and compute the binary equivalent of each row

Step 6. Check whether the rows of the matrix are arranged rank wise? If not go to step 3; Otherwise, go to step 7

Step 7. Print the final machine component incidence matrix.

By following this steps the problems can be solved.