UNIT 4 FACILITIES LOCATION

Objectives

After going through this unit, you should be able to:

- understand the strategic importance and objectives of facilities location
- realise the enlarged scope of dealing with facility rather than just plant/factory location
- identify various factors relevant for general territory selection as well as those relevant for specific site/community selection
- appreciate that the location decisions are quite complex because of the existence of subjective intangible factors along with objective tangible factors
- be in a position to apply some relevant technique either subjective, qualitative or semi-quantitative in nature
- grasp some simple operational research oriented models
- realise the need for recognition of the assumptions and limitations of the quantitative models discussed
- provide a blend of some good rational qualitative judgment and the analytical model solutions
- be in a position to identify relevant factors for facility location

Structure

4.1 INTRODUCTION

Facility location decisions are strategic, long term and non-repetitive in nature. Without sound and careful location planning in the beginning itself, the new facility may pose continuous operating disadvantages, for the future operations. Location decisions are affected by many factors, both internal and external to the organisation's operations. Internal factors include the technology used, the capacity, the financial position, and the work force required. External factors include the economic political and social conditions in the various localities. Most of the fixed and some of the variable costs are determined by the location decision. The efficiency, effectiveness, productivity and profitability of the facility are also affected by the location decision. The facilities location problem is concerned primarily with the best (or optimal!) location depending on appropriate criteria of effectiveness. Location decisions are based on a host of factors, some subjective, qualitative and intangible while some others are objective, quantitative and tangible.

Concept of a facility

Traditionally, location theorists have dealt with industrial plant/factory location. However, the concept of **plant location** has now been generalised into that of **facility location**, since the facility could include a production operation or service system. The term `Plant' has been traditionally used as synonymous to a factory, manufacturing or assembly unit. This could include fertiliser, steel, cement, rice milling plants, textile, jute, sugar mills, rubber factories, breweries, refineries, thermal or hydro-electric nuclear power stations etc.

However, with the enlarged scope of a facility, this term can now be used to refer to banks, hospitals, blood banks, fire stations, police stations, warehouse, godown, depot, recreation centre, central repair workshop etc. At a lower hierarchical level is the facility/plant layout problem which will be discussed in the next unit. In such a case machines, equipment, desks, workshop, canteen, emergency room etc. could mean a facility. Thus, in fact, we could generally state that a facility could connote almost any physical object relevant to location analysis. Let us now see when a location decision arises.

4.2 WHEN DOES A LOCATION DECISION ARISE?

The impetus to embark upon a facility location study can usually be attributed to various reasons:

i) It may arise when a new facility is to be established.

ii) In some cases, the facility or plant operations and subsequent expansion are restricted by a poor site, thereby necessitating the setting up of the facility at a new site.

iii) The growing volume of business makes it advisable to establish additional facilities in new territories.

iv) Decentralisation and dispersal of industries reflected in the Industrial Policy resolution so as to achieve an overall development of a developing country would necessitate a location decision at a macro level.

v) It could happen that the original advantages of the plant have been outweighed due to new developments.

vi) New economic, social, legal or political factors could suggest a change of location of the exisiting plant.

Some or all the above factors could force a firm or an organisation to question whether the location of its plant should be changed or not.

Whenever the plant location decision arises, it deserves careful attention because of the long term consequences. Any mistake in selection of a proper location could prove to be costly. Poor location could be a constant source of higher cost, higher investment, difficult marketing and transportation, dissatisfied and frustrated employees and consumers, frequent interruptions of production, abnormal wastages, delays'and substandard quality, denied advantages of geographical specialisation and so on. Once a facility is set up at a location, it is very difficult to shift later to a better location because of numerous economic, political and sociological reasons. Economic reasons could include total costs, profits, availability of raw materials, labour, power. transportation facilities, markets etc. Social reasons could include employee welfare, employment opportunities etc. Political reasons could be because of pursuance of a policy of decentralisation, regional and developmental planning especially in a developing country like ours. There could be security considerations or risk of military invasions, sabotage from anti-social elements etc. and some may be prone to natural calamities like floods, earthquake etc. Policy matters like anti-pollution etc. would have to be given their due consideration.

Alfred Weber's analysis was one of the first attempts to base location decisions on some sort of analysis, its imperfections notwithstanding. Besides discussing the importance of transport and labour cost differentials in deciding location, the main burden of Weber's analysis is transport cost of raw material which was least mobile

One the basis of availability, he categorised raw materials into: (a) **ubiquities**-to denote those available almost everywhere like sand, water etc. and (b) **localised materials**, having specific locations, which are further divided into pure material which contributes nearly the total weight of it to the finished goods, and gross material, which contributes only a small fractions of total weight to the finished goods. It is obvious that ubiquities hardly influence the decision of location. Weber then proceeds to formulate the material index which equals the weight of localised material used in the finished product divided by the weight of the finished product.

$$\text{MaterialIndex(MI)} = \frac{\text{Weightoflocalisedmaterialusedinfinishedproduct}}{\text{Weightofthefinishedproduct}}$$

If the material index is greater than unity, location should be nearer to the source of raw material and if it is less than unity, then location nearer to market is advised. The commonsense involved in such conclusion is unquestionable. But such an approach tacitly assumes the existence of a static point of lowest transportation cost for raw material.

Later analyses by various other authors, like, Weigman, Palander, Losch, Ohlin and others have been attempted on increasingly comprehensive bases such as the interrelationship between factors like, (a) economic differences-(prices, market), (b) cost differences-(productivity, transport cost and accessibility), (c) human differences-(attitudes of founders and wage-earners), (d) national characteristics, and (e) various barriers-(political, geographic and transportation). Let us now see how a location study is made.

4.3 STEPS IN THE FACILITY LOCATION STUDY

Location studies are usually made in two phases namely, (i) the general territory selection phase, and (ii) the exact site/community selection phase amongst those available in the general locale. The considerations vary at the two levels, though there ' is substantial overlap as shown in Table 1.

Table 1

Overlap of considerations of factors in the two stages of facility location

	Location Factors	**Phase I General Terri-tort' Selection**	**Phase II Particular Selection of Site and Community**
1	Market	•	
2	Raw Materials	•	
3	Power	•	•
4	Transportation	•	•
5	Climate and Fuel	•	
6	Labour and Wages	•	•
7	Laws and Taxation	•	•
8	Community Services and Attitude		•
9	Water and Waste		•
10	Ecology and Pollution		•
11	Capital Availability	•	•
12	Vulnerability to enemy attack	•	•

A Typical team studying location possibilities for a large project might involve economists, accountants, geographers, town planners, lawyers, marketing experts, politicians, executives, industrial engineers, defence analysts, ecologists etc. It is indeed an inter-disciplinary team that should be set up for undertaking location studies.

Territory Selection

Now in step (i) for the general territory/region/area selection, the following are some of the important factors that influence the selection decision.

Markets: There has o be some customer/market for your product/service. The market growth potential and the location of competitors are important factors that could influence the location. Locating a plant or facility nearer to the market is preferred if promptness of service required, if the product_ is fragile, or is susceptible to spoilage;, Moreover, if the product is relatively inexpensive and transportation costs add substantially to the cost, a location close to the markets is desirable. Assembly type industries also tend to locate near markets.

Raw Materials and Supplies: Sometimes accessibility to vendors/suppliers of raw materials, parts supplies, tools, equipment etc. may be very important. The issue here is promptness and regularity of delivery and inward freight cost minimisation.

If the raw material is bulky or low in cost, or if it is greatly reduced in bulk viz. transformed into various products and by-products of if it is perishable and processing makes it less so, then location near raw materials sources is important. If raw materials come from a variety of locations, the plant/facility may be situated so as to minimise total transportation costs. The costs vary depending upon specific routes, mode of transportation and specific product classifications.

Transportation Facilities: Adequate transportation facilities are essential for the economic operation of a production system. For companies that produce or buy heavy bulky and low value per ton commodities, water transportation could be an; important factor in locating plants. It can be seen that civilisations grew along rivers/waterways etc. Many facilities/plants are located along river banks.

Manpower Supply: The availability of skilled manpower, the prevailing wage pattern, living costs and the industrial relations situation influence the location.

Infrastructure: This factor refers to the availability and reliability of power, water, fuel and communication facilities in addition to transportation facilities.

Legislation and Taxation: Factors such as financial and other incentives for new industries in backward areas or no-industry-district centres, exemption from certain state and local taxes, octroi etc. are important.

Climate: Climatic factors could dictate the location of certain type of industries like textile industry which requires high humidity zones.

Site/Community Selection

Having selected the general territory/region, next we would have to go in for site/community selection. Let us discuss some factors relevant for this stage.

Community Facilities: These involve factors such as quality of life which in turn depends on availability of facilities like schools, places of worship, medical services, police and fire stations, cultural, social and recreation opportunities, housing, good streets and good communication and transportation facilities.

Community Attitudes: These can be difficult to evaluate. Most communities usually welcome setting up of a new industry especially since it would provide opportunities to the local people directly or indirectly. However, in case of polluting, or `dirty' industries, they would try their utmost to locate them as far away as possible. Sometimes because of prevailing law and order situation, companies have been forced to relocate their units. The attitude of people as well as the state government has an impact on industrial location.

Waste Disposal: The facilities required for the disposal of process waste including solid, liquid and gaseous effluents need to be considered. The plant should be positioned so that prevailing winds carry any fumes away from populated areas, and so that waste may be disposed off properly and at reasonable expense.

Ecology and Pollution: These days there is a great deal of awareness towards maintenance of natural ecological balance. There are quite a few agencies / propagating the concepts to make the society at large more conscious of the dangers of certain avoidable actions.

Site Size: The plot of land must be large enough to hold the propose plant and parking and access facilities and provide room for future expansion}: These days a lot of industrial areas/parks are being earmarked in which certain/standard sheds are being provided to entrepreneurs. (especially small scale ones).

Topography: The topography, soil structure and drainage must be suitable. If considerable land improvement is required, low priced land might turn out to be expensive.

Transportation Facilities: The site should be accessible byroad and rail preferably. The dependability and character of the available transport carriers, frequency of service and freight and terminal facilities is also worth considering.

Supporting Industries and Services: The availability of supporting services. such as tool rooms, plant services etc. need to be considered

Land Costs: These are generally of lesser importance as they are non-recurring and possibly make up a relatively small proportion of the total cost of locating a new plant. Generally speaking, the site will be in a city, suburb or country location. In general, the location for large-scale industries should be in rural areas, which helps in regional development also. It is seen that once a large industry is set up (or even if a decision to this effect has been taken), a lot of infrastructure develops around it as a result of the location decision. As for the location of medium scale industries, these could be preferably in the suburban/semi-urban areas where the advantages of urban and rural areas are available. For the Small-scale Industries, the location could be urban areas where the infrastructural facilities are already available. However, in real life, the situation is somewhat paradoxical as people, with money and means, are usually in the cities and would like to locate the units in the city itself.

Some of the industrial needs and characteristics that tend to favour each of these locales are now discussed. **Requirements**, governing choice of **a city location** are:

1 Availability of adequate supply of labour force,

2 High proportion of skilled employees.

3 Rapid public transportation and contact with suppliers and customers.

4 Small plant site or multi floor operation.

5 Processes heavily dependent on city facilities and utilities.

6 Good communication facilities like telephone, telex, post offices.

7 Good banking and health care delivery systems.

Requirements governing the choice of **a suburban location** are:

1 Large plant site close to transportation or population centre.

2 Free from some common city building zoning (industrial areas) and other restrictions.

3 Freedom from higher parking and other city taxes etc.

4 Labour force required resides close to plant.

5 Community close to, but not in, large population centre.

6 Plant expansion easier than in the city.

Requirements governing the choice of **a country/rural location** are:

1 Large plant site required for either present demands or expansion.

2 Dangerous production processes.

3 Lesser effort required for anti-pollution measures.

4 Large volume of relatively clean water.

5 Lower property taxes, away from Urban Land Ceiling Act restrictions.

6 Protection against possible sabotage or for a secret process.

7 Balanced growth and development of a developing or underdeveloped area.

8 Unskilled labour force required.

9 Low wages required to meet competition.

4.4 SUBJECTIVE, QUALITIVE AND SEMI-QUANTITATIVE TECHNIQUES

Three subjective techniques used for facility location are Industry Precedence, Preferential Factor and Dominant Factor. Most of us are always looking for some precedents. So in the industry precedence subjective technique, the basic assumption .is that if a location was best for similar firms in the past, it must be the best for us now. As such, there is. no need for conducting a detailed location study and the location choice is thus subject to the principle of precedence-good or bad. However in the case or the preferential factor, the location decision is dictated by a personal factor. It depends on the individual whims or preferences e.g. if one belongs to a particular state, he may like to locate his. unit only in that state. Such personal factors may. override factors of cost or profit in taking a final decision. This could hardly be called a professional approach though such methods are probably more common in practice than generally recognised. However, in some cases of plant location there could be a certain dominant factor (in contrast to the preferential factor) which could influence the location decision. In a true dominant sense, mining or petroleum drilling operations must be located where the mineral resource is available. The decision in this case is simply whether to locate or not at the source.

For evaluating qualitative factors, some factor ranking and factor weight rating systems may be used. In the ranking procedure, a location is better or worse than another for the particular factor. By weighing factors and rating locations against these weights a semi-quantitative comparison of location is possible. Let us now discuss some specific methods.

Equal Weights Method

We could assign equal weights to all factors and evaluate each location along the factor scale. For example, Banson, a manufacturer of fabricated metal products selected three factors by which to rate four sites. Each site was assigned a rating of 0 to 10 points for each factor. The sum of the assigned factor points constituted the site rating by which it could be compared to, other sites.

Table 2
Decision Matrix

Factor ↓ \ Potential Sites →	S_1	S_2	S_3	S_4
F_1	2	5	9	2
F_2	3	3	8	3
F_3	6	2	7	3
Site Rating	11*	10	24	8
Sample Calculation	11	2 + 3 + 6		

F Factor; F_1 Factor 1; S Site; S_1 Site 1

Looking at Table 2, Site 3 has the highest site rating of 24. Hence, this site would be chosen.

Variable Weights Method

The above method could be utilised on account of giving equal weightage to all the factors. Hence, we could think of assigning variable weights to each of the factors and evaluating each location site along the factor scale. Hence, factor Fi. might be assigned 300 points, factor 2 might be assigned 100 points and factor 3 might be assigned 50 points. Thus the points scored, out of the maximum assigned to each of the factors, for each possible location site could be obtained and again the site rating could be derived as follows:

Table 3
Decision Matrix

Factor	Max. Pts.	Potential Sites			
		S_1	S_2	S_3	S_4
F_1	(300)	200	250	250	50
F_2	(100)	50	70	80	100
F_3	(50)	5	50	10	40
Site Rating		255*	370	340	190

*Sample Calculation 255 = 200 + 50 + 5

Looking at the Table 3, Site 2 has the highest site rating of 370. Hence, this site would be chosen.

Weight-cure-Rating Method

We could have yet another method of evaluating a potential location site. We could assign variable weights to each factor. The locations are then rated by a common scale for each factor. The location point assignment for the factor is then obtained by multiplying the location rating for each factor by the factor weight. For example, rating weights of one to five could be assigned to the three factors F, (Labour climate), F2 (community facilities) and F_3 (power availability and reliability), as 5, 3, 2 respectively. Now for each of the factors, sites S_1, S_2, S_3, or S_4could receive 0 to 10 points as follows. Now each site rating could be obtained.

Table 4
Decision Matrix

Factor	Factor Rating Weights	Potential sites			
		S_1	S_2	S_3	S_4
F_1	5	2	5	9	2
F_2	3	3	3	8	3
F_3	2	6	2	7	3
Site Rating :		31*	38	83	25

*Sample Calculation $31 = (5)\times 2 + (3)\times 3 + (2)\times 6$

As shown in Table 4, the sample calculation should hopefully suffice to obtain the site ratings. Hence, site S3 with the highest rating of 83 is chosen.

Factor-Point Rating Method

Now for a last one, establish a subjective.- scale common to all factors. Assign points against the subjective scale for each factor and assign the factor points of the subjective rating for each factor. For example, five subjective ratings--Poor, Fair, Adequate, Good and Excellent were selected to be used in evaluating each site for each factor. For each of the factors, `adequate' was assigned a value zero and then negative and positive relative worth weights were then assigned the subjective ratings below and above adequate for each factor in Table 5.

Table 5
Factor Point Ratings Sample

		Poor	Fair	Adequate	Good	Excellent
Factor	F_1 water Supply	-15	12	0	6	10
	F_2 Appearance of site	-3	-1	0	1	2

The range between minimum and maximum weights assigned; to a factor in effect weighs that factor against all other factors in a manner equivalent to the method (iii) described just previous to this one. Each location site S_1 to S_4 were then rated by selecting the applicable subjective rating for each factor for each, location and the equivalent points of that subjective `factor rating assigned to the factor. Thus we can now obtain Table 6.

Table 6
Decision Matrix

Factors	Potential Sites			
	S1	S2	S3	S4
F1	(Adequate) 0	(Fair) 12	(Good) 6	(Adequate) 0
F2	(Adequate) 0	(Poor) 3	(Excellent) 3	(Fair) 1
F3	(Adequate) 0	(Adequate) 0	(Adequate) 0	(Adequate) 0
Site Rating	0	-15	9	-1

*Sample Calculation - 15 = (-12) + (-3) + (0)

Accordingly Site 3 with the highest rating of 9 would be chosen.

In most cases, hardly any attempt is made to establish a direct relationship between the site rating point value and the cost values. Usually, this is left to the management

The location analyst presents to management both the cost and the intangible data results. In such cases, management could take a decision based on a simple composite measure method illustrated below with the aid of a numerical example.

Composite Measure Method

Let us enlist the steps of the composite measure method

Step-1 Develop a list of all relevant factors.

Step-2 Assign a scale to each factor and designate some minimum.

Step-3 Weigh the factors relative to each other in light of importance towards achievement of system goals.

Step-4 Score each potential location according to the designated scale and multiply the scores by the weights.

Step-5 Total the points for each location and either (a) use them in conjunction with a separate economic analysis, or (b) include an economic factor in the list of factors and choose the location on the basis of maximum points.

Now let us illustrate the composite measure method with a numerical example. There are three potential sites and five relevant factors like transportation costs per week, labour costs per week, finishing material supply, maintenance facilities and community attitude. The costs are in rupees whereas for the last three factors, points are assigned on 0-100 scale. The data collected is shown in Table 7 below.

Table 7
Payoff Matrix

		Potential Location Sites		
Factors		S_1	S_2	S_3
Transportation cost/ week (Ra)	F_1	800	640	580
Labour cost/week (Rs.)	F_2	1180	1020	1160
Finishing Material Supply	F_3	30	80	70
Maintenance Facilities	F_4	60	20	30
Community Attitude	F_3	50	80	70

The location analyst has pre-established weights for various factors. This includes a standard of 1.0 for each Rs. 10 a week of economic advantage. Other weights applicable are 2.0 on finishing material supply, 0.5 on maintenance facilities and 2.5 on community attitudes. Also the organisation prescribes a minimum acceptable score of 30 for maintenance facilities.

First of all let us look at the economic factors F_1 and F_2 for which monetary values were possible. If we total the costs for each site, we get the costs for sites S_1, S_2 and S_3 as Rs. 1980, Rs. 1660 and Rs. 1740, respectively. Thus site S_t would be the worst cost wise. Site S_2would have an economic advantage over site St to the extent of

Rs. (1980 -1660) = Rs. 320. Similarly, site S3 would have an economic advantage over site St to the extent of Rs. (1980 -1740) = Rs. 240. Now the monetary value in Rs. can be converted to a point scale as you would realise that a standard of 1.0 is to be assigned for each Rs. 10 per week of economic advantage. Thus we could get the following Table 8.

Table 8
Decision Matrix

		Potential Location Sites		
Factors	**Weightage**	S_1	S_2	S_3
Combine (F_1 + F_2) Economic Advantage	1.0	0	32	24
F_3	2.0	30	80	70
F_4	0.5	60	20	30
F_3	2.5	50	80	70
Composite Site Rating		*215	402	354
* Sample calculation $215 = (1.0)\times 0 + (2.0)\times 30 + (0.5)\times 60 + (2.5)\times 60$				

Activity A

Facilities Location Based on the previous table, the location analyst chose site S2 on the basis that site S2 has a maximum location site rating of 402. Do you agree? State reasons for either agreeing or disagreeing.

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Now on referring to certain prerequisites for certain factors, because of the nature or the situation., a constraint in the form of a site scoring at least 30 on account of maintenance had been given. You would be able to observe that this basic requirement is not met by site S2. In fact any further calculations for S_2 need not have been carried out as soon as one detected this flaw. However, we deliberately persisted on going through all the calculations. There could have been the possibility of revision of the maintenance clause constraint viz., perhaps it might have been felt that a bare minimum score of 15 would suffice. In such cases, therefore, it is better to go through all the calculations and when finally taking a decision, do keep the constraints in mind.

4.5 LOCATIONAL BREAK-EVEN ANALYSIS

Sometimes, it is useful to draw location break-even charts which could aid in deciding which location would be optimal. The location of a Tractor factory in a South Delhi site will result in certain annual fixed costs, variable costs and revenue. The figures would be different for a South Bombay site. The fixed costs, variable costs and price per unit for both sites are given below in Table 9.

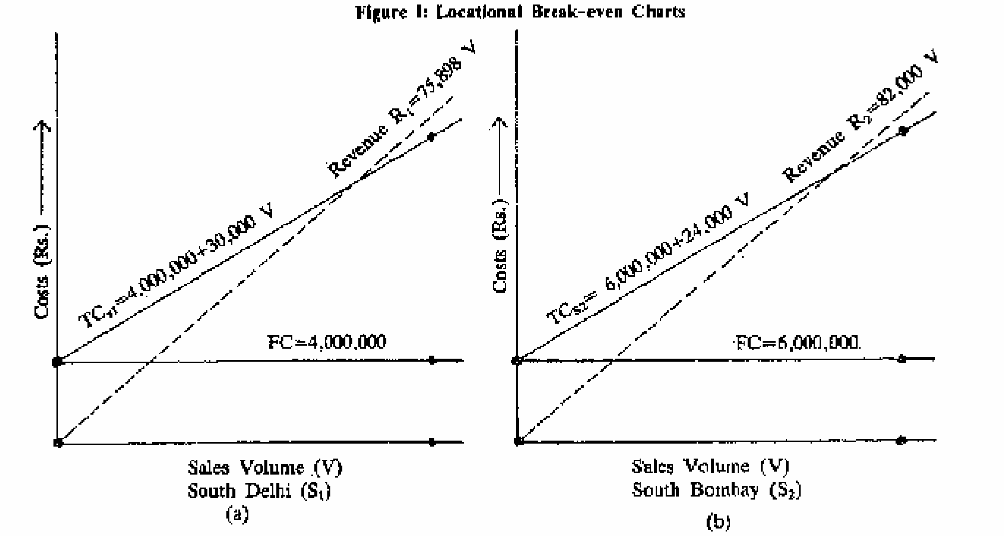
Table 9

Cost Data

Location Site	Fixed Costs	Variable Costs	Price Per Unit
South Delhi (S_1)	40,00,000	30,000	75,898
South Bombay (S_2)	60,00,000	24,000	82,000

Let us assume that the expected sales volume as estimated by a market research team is 95.

Figure I: Locational Break-even Charts



The data of Table 8 is depicted pictorially in Figure I showing the location break-even charts. Now the break-even point is defined to be the point or volume where the total costs equal total revenue. Thus for each site S i and S 2, the break-even point can be determined by using a simple formula (which could be easily derived) as follows:

$$\text{Break-even Volume (BE)} = \frac{\text{Fixed Costs}}{\text{(Revenue per Unit-Variable Cost per Unit)}}$$

At the South Delhi Location S t

$$BE = \frac{40,00,000}{75,898-30,000} = 87.1497 = 88 \text{ tractors}$$

and at the South Bombay location S_2

$$BE = \frac{60,00,000}{82,000-24,000} = 103.448 = 104 \text{ tractors}$$

Let us see what would be the profit or loss for the two sites at the expected volume of 95 Units. The calculations are shown in Table 10.

Table 10
Cost Comparisons

South Delhi (S_1)		South Bombay (S_2)	
Costs		Costs	
Fixed	40,00,000	Fixed	60,00,000
Variable	28,50,000	Variable	22,80,000
	68,50,000		82,80,000
Revenue		Revenue	
75,898 x 95 = 72,10,310		82,000 x 95 = 77,90,000	
Profit = (72,10,310—68,50,000) = 1,80,155		Loss = (77,90,000—82,80,000) = 4,90,000	

Activity B

What would be the expected revenues for an estimated volume of 95 Units if the factory is located at (i) at South Delhi and (ii) at South Bombay? Where you would like to locate the factory?

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Now what. do we find? The South Delhi (S_1) site is preferable, eventhough the revenues are lower, since the Company will lose money by locating the plant in south Bombay (S2).

4.6 SOME QUANTITATIVE MODELS FOR FACILITY LOCATION

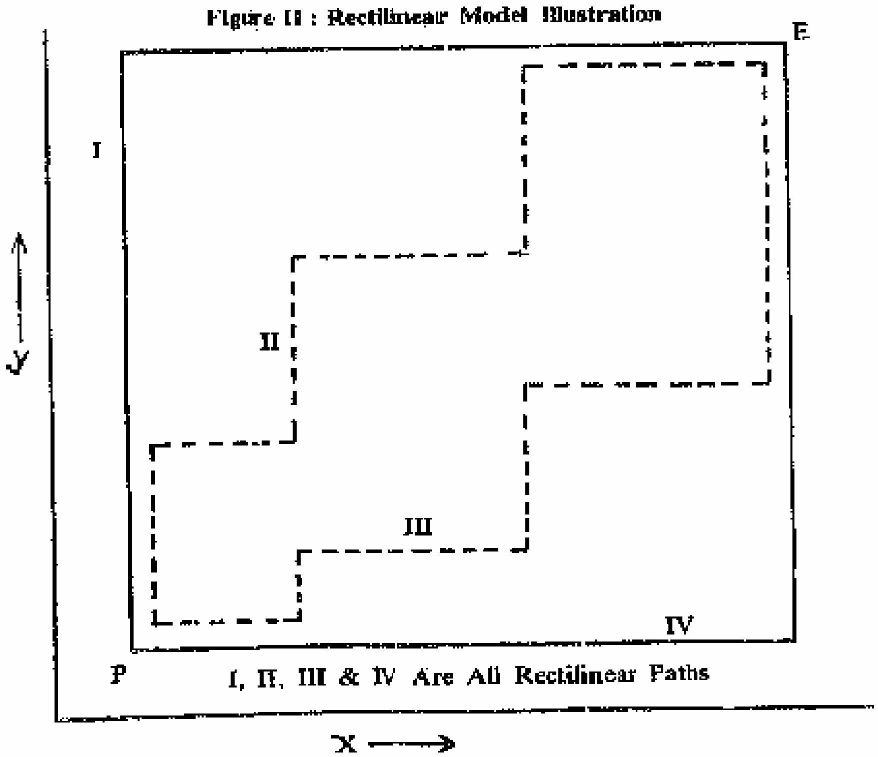
Various types of quantitative models (or operations research models) have been used to help determine the best facilities location. Let us describe a few models that are simple to understand and powerful enough to give some good answers that could aid you in taking a location decision.

Median Model

Let us discuss the simple median model which is based on the assumption that the mode of interaction or the path of movement/transportation of load is done on a rectangular/rectilinear pattern. The movement is similar to the movement of `rooks' on a chess board. Thus all movements are made horizontally along and east-west and/or vertically in a north-south direction. Diagonal moves are not considered. You could refer to Figure II for a diagrammatic portrayal of the rectilinear path. The paths I, II, III and IV are all alternative rectilinear paths between two reference points say a new facility, P, having coordinate locations (x, y) and an ancillary existing facility, A having coordinate locations (a;, b;). Though there are alternative rectilinear paths, the rectilinear distance between the points A and P is however unique and it is mathematically stated as

$$Dr = \text{Rectilinear Distance} = |x-a_i| + |y-b_i|$$

Figure II : Rectilinear Model Illustration



I, II, III & IV Are All Rectilinear Paths

Now there would be some interaction by way of say the annual number of loads to be moved between two reference points. We could safely assume that the transportation cost for a load is proportional to the distance for which it is moved. This assumption could be questioned on the plea that there is a `telescopic' scheme of rates charged in actual practice by Indian Railways. The total transportation cost is obtained by adding the number of loads to the times the rectilinear distance is moved.

$$(TC) \text{ Total Transportation Cost} = \sum_{i=1}^{m} Li \times Di$$

Where L; is the number of loads to be moved between the new facility to be located and the ancillary existing P^h facility (say raw material sources or market distribution outlet points), D; is the rectilinear distance between a new facility and i^{th} existing facility and `m' is the number of ancillary existing facilities.

Thus as a Iocation analyst, we essentially want to determine the `least transportation cost' location solution. The simple median model can help answer this question by using these three steps.

i) Identify the median value of the total number of loads moved.

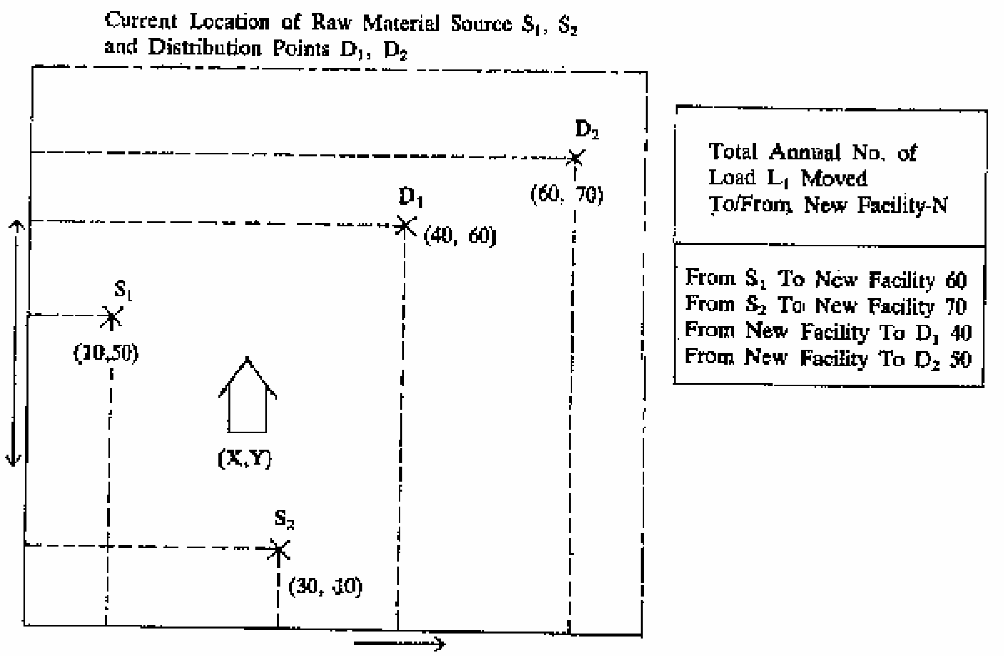
ii) Find the X-coordinate value of the existing facility that sends (or receives) the median load and

iii) Find the Y-coordinate value of the existing facility that sends (or receives) the median load.

The x and y values found in steps (ii) and (iii) define the desired optimal (best) location of the new facility.

Let us illustrate the above steps with a small example. Let us assume that a new processing plant is to be located. It would be receiving certain raw materials from two supply sources, S t and S2. It would be sending its finished products to two distribution points, Dl and D2. The coordinate locations of the sources and distribution points are shown in Figure III below.

Figure III : Sample Problem Data



Now in step (i), we have to identify the median value of the total number of loads moved. The total load moved is 220 (viz. 60+70+40+50=220). The median number of loads is the value that has half an equal number of loads above and below it. When the total number of loads is odd, the median load is the middle load; in case of an even number, the median loads are the two, middle loads. Thus for 220 loads, the median loads are 111 and 110 since there are 109 above and below this pair of values.

In step (ii) Let us now determine the X-coordinate of the median load. We could place in an ascending order the x-co-ordinates of the existing facilities viz. it is just going horizontally from left to right in Figure II. Thus the order of the existing facilities would be as S t , S2, D t and. D_2 having annual loads of movement of 60, 70, 40 and 50, respectively. Loads 1 to 60 'are shipped by source St at X_i = 10, Loads 61 to 130 are shipped by source S_2 at X 2 =30. Since the median loads (110) and (Ill) fall in the interval 61 to 130, therefore, x=30 is the best x-co-ordinate location for the new facility.

Similarly, in step (iii), we can determine the y-co-ordinate of the median load. In this case we move vertically upwards. From Figure; Ill, it can readily be seen that this ascending order would be represented by the existing facilities S_2, S i , D_1 and D_2 with annual movement of loads to the tune of! 70, 60, 40 and 50, respectively. Loads 1 to 70 are shipped by source S 2 at Y_2 =10. Loads 71 to 130 are shipped by source S i at Y_i =50. Since the median loads (110 and Ill) fall in the interval 71 to 130, therefore Y=50 is the best Y-coordinate location for the new facility.

Thus the optimal best location for the new manufacturing facility is (x = 30, Y = 50). Location at this point minimises annual transportation costs for the above production distribution system.

Now the total transportation cost as explained earlier on is $TC = \sum_{i=1}^{m} Li.\ Di$ and as Di is the rectilinear distance

$$TC = \sum_{i=1}^{m} [Li|x-ai|+|y-bi|]$$

Let us assume that each distance unit cost is Re. 1 per load.

At x = 30, y = 50 viz. the optimal location of the new facility, the total cost TC can be computed as follows:

a) Cost for S, to New Facility = 60 [130 -10 I+ 150- 501] = 60 (20+ 10) = 1200

b) Cost for S_2 to New Facility = 70 [130- 30 I+ 150-101] = 70 (0 + 40)=2800

c) Cost for New Facility to D, 40 [130 - 40 I+ 150 - 601] = 40 (10+10) = 800

d) Cost from New Facility to D_2 = 50 [130 - 60 I + 150 -701] = 50 (30 + 20) = 2500

TC = (a) + (b) + (c) + (d) = 1,200 + 2, 800 + 800 + 2,500

viz. TC = 7,300

Activity C

Supposing the new facility is located at a place at x = 50, y = 30. What would be the total transportation costs in this case? Is it a better location than the new location at a (x = 30, y 50)?

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The median model is very simple to operate. It could suffer from some major disadvantages such as:

i) It assumes that only one single new facility is to be located

ii) every point in the (x, y) plane has been assumed to be an eligible point for the location of the new facility.

iii) the median model is valid when the movement is based on a rectilinear mode only.

Let us now look .at another model, which though a single facility model, doesn't assume the rectilinear mode of interaction. This is popularly known as the Gravity Model.

The Gravity Model

The technique determines the low cost `Centre of Gravity' location of a new facility with respect to the fixed ancillary existing facilities like source suppliers (S_1, S_2 etc.) and distribution points (D_1, D_2 etc.) for which each type of product consumed or sold is known. Let us use the same data as that of the median model and thus let us refer to Figure III once more. The only difference is the mode of interaction between the single new facility and the existing facilities. In this case we assume that all goods move in a straight line joining the ancillary facility and the new facility. This is the so-called Euclidean' mode of interaction and is in fact the shortest distance between any two reference points.

Thus De =Euclidean Distance = $[(x-a_i)^2+(y-b_i)]^{1/2}$

Thus the total transportation costs in this case are m

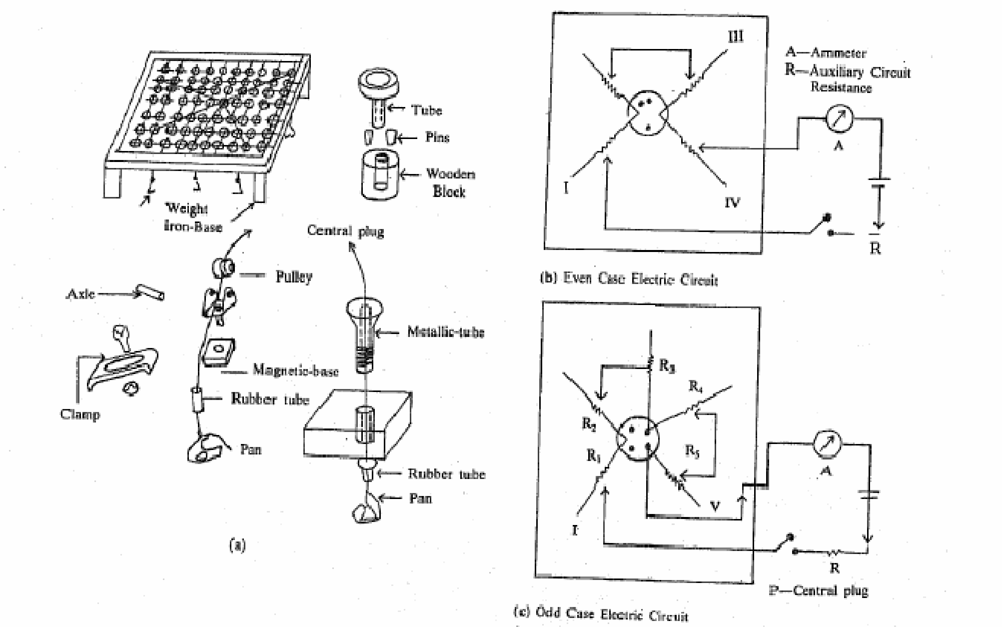
TC$_e$ (Total transportation cost) (Euclidean case) = $\sum_{i=1}^{m}(LiDi)$

viz TCe= $\sum_{i=1}^{m}$ Li $[/x-a_i/^2+/^y-b_j/^2]$

Our aim, once again, is to determine the location of the new facility at (x,y) such that TCe ,viz. the total transportation costs are as minimum. We will not get into a discussion on certain analytical problems and difficulties in obtaining optimal solutions at this stage/level, but rather present an analogue model and a gravity model which are simple to understand and could be readily applied.

The concept underlying the technique is best visualised as a series of strings to which are attached weights corresponding to the loads/weights of raw materials consumed/dispatched at each source and of finished goods sold/received at each distribution point/market. The strings are threaded through holes in a flat plain metallic sheet; the holes correspond to the ancillary facility locations. The other ends of the string are tied together to a small concentric ring. The ring will finally reach an equilibrium based on the principle of equilibrium of coplanar forces. This equilibrium will be the centre of mass or the ton-mile centre. It is for this reason that this model is also called the Gravity Model. This mechanical analogue model constructed on a Varignon frame does suffer on account of friction. Banwet[2] and Vrat have devised a superior. electro-mechanical analogue model, the details of which are given in Figure IV. The electrical analogue depends on making an appropriate electrical series circuit. The resistivity of the wire in resistance per unit length is synonymous to the weights/loads. Due care and precautions have to be taken for preventing short circuits by appropriate insulation devices. It will be noticed that when the central plug/ring is moved to different locations, the total resistance in the circuit changes. Determining a point with minimum total resistance is analogous to the gravity solution viz. the least cost location solution.

Figure IV : Analogue Model-Details



(c) Odd Case Electric Circuit
R1, R2, R3, R4, R5 Analogous to Ancilliary facility Locations I, II, III, IV, & V, respectively.

$$x = \frac{\sum_{i=1}^{m} L_i (a_i)}{\sum_{i=1}^{m} L_i} \qquad y = \frac{\sum_{i=1}^{m} L_i (b_i)}{\sum_{i=1}^{m} L_i}$$

Thus for our example under discussion now from supply sources S_1, S_2 to the new facility

$$\sum_{i=1}^{2} L_i = 60 + 70 = 130$$

$$\sum_{i=1}^{2} (L_i a_i) = (60 \times 10) + (70 \times 30) = 600 + 2100 = 2700$$

and from new facility to distribution points D; and D2

$$\sum_{i=1}^{2} (L_i) = 40 + 50 = 90$$

$$\sum_{i=1}^{2} (L_i a_i) = (40 \times 40) + (50 \times 60) = 1,600 + 3,000 = 4,600$$

$$X = \frac{\sum_{i=1}^{2} L_i a_i \text{(source-new facility)} + \sum_{i=1}^{2} L_i a_i \text{ (New facility - distribution points)}}{\sum_{i=1}^{2} L_i \text{(source-new facility)} + \sum_{i=1}^{2} L_i \text{(New facility - distribution points)}}$$

$$X = \frac{2700 + 4600}{130 + 90} = \frac{7300}{220} = 33.19$$

Similarly y can be determined on similar lines from supply sources to the new facility,

$$\sum_{i=1}^{2} (L_i b_i) = (60 \times 50) + (70 \times 10) = 3000 + 700 = 3700$$

and from the new facility to the distribution points

$$\sum_{i=1}^{2} (L_i b_i) = (40 \times 60) + (50 \times 70) = 2400 + 3500 = 5900$$

Total load $\sum_{i=1}^{4} Li = 220$ as before

$$\text{Hence } y = \frac{\sum_{i=1}^{2} L_i b_i \text{(sources-new fac)} + \sum_{i=1}^{2} L_i b_i \text{(new fac.-distribution points)}}{\sum_{i=1}^{2} L_i \text{(sourges- new fac.)} + \sum_{i=1}^{2} L_i \text{(New fac- distribution points)}}$$

$$\text{or } y = \frac{3700 + 5900}{130 + 90} = \frac{9600}{220} = 43.63$$

Thus the gravity model solution is to locate the new facility at a point (33.19, 43.63) for which least total transportation costs would be incurred in the case of Euclidean (strictly square of Euclidean) mode of interaction.

Let us compare the results of the median and gravity models. The median model for the rectilinear mode of interaction assumption gives the optimal location of the facility at (30, 50) whereas the gravity model for the Euclidean (strictly squared Euclidean) mode of interaction gives the optimal location of (33.10,43.63). It is therefore necessary for the modeller to know the exact nature of the mode of interaction between the new and ancillary facilities, it is quite possible that the location solution could be highly sensitive to the mode of interaction.

You would have noticed that we have only discussed the location problems dealing with just a single new facility and also what is termed as a **minisium** objective of

minimising the sum of weighted appropriate distances. There could be cases when the location as determined above turn out to be non-feasible, because of existence of certain restrictions or limitations. Methods are available for drawing iso-cost contour lines which aid the decision maker to take subsequent appropriate decisions.
Sometimes a **minimax** objective might be more suited in which case the location analyst attempts to minimise the maximum weighted appropriate distances. Such a criterion would be applicable in emergency like facility location problems of fire stations, hospitals etc. Minisium objective situations are appropriate for locating factories, warehouses etc.
There are quite a few operational research techniques that aid the location analyst. Some of these are linear programming, transportation along with, heuristic programming, simulation, direct search procedures, graph theory, goal programming etc. Banwet has given a comprehensive review and progress in facilities location which could be referred to by those interested in further reading on the subject.
You would have observed that facilities location decision is based on a set of factors some of which are tangible/objective whereas some are intangible/subjective in nature. Brown and Gibson have proposed a composite location measure to aid the decision makers.

Composite Location Measure Model-2

Let us now discuss Brown Gibsons model which provides a composite location measure of the objective and subjective factors. We illustrate the procedure with the help of an example,
Step-1. First of all identify the factors that deserve to be included in the study and determine which of these must be absolutely satisfied, e.g., there is no point in choosing a site having a scarcity of water whereas the plant requires an abundant water supply. Say the objective factors are labour, marketing, utilities and taxes. Now for the subjective factors, these could include housing, recreation and competition.
Step-2. Let us derive an objective factor (OF) for i^{th} location site by multiplying that site's rupee cost (C_i) by the sum of the reciprocals of all the costs $\sum(1/C_i)$, and take the inverse of the product.

$$OF_i = [c_1 \times \sum(1/c_i)]^{-1}$$

Viz
Thus if we have the following data for three possible sites, OF can be obtained as below:

Site (i)	Annual costs in thousands of Rs				Total C_i
	Labour	Marketing	Utilities	Taxes	
1	248	181	74	16	519
2	211	202	82	8	503
3	230	165	90	21	506

$\sum(1/C_i)$ = 1/519 + 1/503+ 1/506 =0.005891

OF1 = (519 x 0.005891)-1 =0.3271
OF2 = (503 x 0.005891)-1 =0.3374
OF3 = (506 x 0.005891)-1 =0.3355

Step-3. Let us now deal with the subjective intangible factors with the help of a forced pair-wise comparison rating method. This procedure is first applied to rank the importance of the factors (I_k) for housing, recreation and competition; and is then applied to each site to rate how well that site satisfies the factors (S_{ik}). These two ratings are combined to obtain a subjective factor (SF_i) ranking for each site as

$$SFi = \sum(I_k \cdot S_{ik})$$

The factor comparison is made in pairs. If one factor is preferred over the other, the one preferred is given 1. point whereas the other factor is given 0 points. Thus the table below is quite self-explanatory. If one is indifferent between the two factors, 1 point each can be assigned as seen in decision 3 while comparing factors B and C.

Factor	Comparisons Decision 1	2	3	Sum of preferences	Factors Rating (I_k)
A: Housing	1	1		2	2/4=0.5
B: Recreation	0		1	1	1/4=0.25
C: Competition		0	1	1	1/4=0.25
			Total	4	1.0

Next each of its factors A, B and C is then evaluated for site preferences in a similar manner

Factor A: Housing

Site	Decision 1	2	3	S_{AK}
1	1	0		0.33
2	0		0	0
3		1	1	0.67

Factor B: Recreation

Site	Decision 1	2	3	S_{BK}
1	0	0		0
2	1		1	0.67
3		1	0	0.33

Factor C: Competition

Site	Decision 1	2	3	S_{ck}
1	1	0		0.25
2	1		0	0.25
3		1	1	0.50

Summary of subjective factors

Factor	Site Rating 1	2	3	Importance
A	0.33	0	0.67	0.5
B	0	0.67	0.33	0.25
C	0.25	0.25	0.50	0.25

We can now calculate the subjective factor value (SFi) for each site as follows:

$$SF_1 = (0.5)\ (0.33)\ + (0.25)\ (0)\ + (0.25)\ (0.25) = 0.2275$$

$$SF_2 = (0.5)\ (0)\ + (0.25)\ (0.67)\ + (0.25)\ (0.25) = 0.2300$$

$$SF_3 = (0.5)\ (0.67)\ + (0.25)\ (0.33)\ + (0.25)\ (0.50) = 0.5425$$

Step-4: Now depending on the parties concerned would depend a weightage (X) given to the objective versus subjective factors. Let us say we give a two thirds weightage to objective and only one third weightage to the subjective factors.

Viz, X = 0.667.

Step-5: Assuming that all sites that failed to meet the minimum levels set for the critical factors in step-1 have been eliminated for the remaining sites, a composite location measure (LM_i) can be obtained as follows:

$(LMi) = X\ (OF_i) + (1\text{-}X)\ SFi$

Using the data generated in ste^{p}s 2, 3 and 4, we have

LMi = 0.67 (0.3271) + 0.33 (0.2275) = 0.2942
LM2 0.67 (0.3375) + 0.33 (0.2300) = 0.3020
LM3 = 0.67 (0.3355) + 0.33 (0.5425) = 0.4038

The site 3 is preferred. A sensitivity analysis could be done by varying the values of X. It will be seen that if X is very close to 1, site 2 would be preferred.

Bridgeman's Dimensional Analysis

As has already been observed, while selecting plant locations, we want to optimise different objectives which are interrelated but cannot be represented in the same dimensions. The location decision can be taken by making use of Bridgeman's dimensional analysis. Let us construct the utility payoff matrix once again as shown in Table below:

Factors	Potential Locations Sites SI:	S2	S3	S4	Weightage of factors
F1	X11	X12	X13	X14	WI
F2	X21	X22	X23	X24	W3
F3	X31	X32	X33	X34	W3

where X_{ij} = utility of having the plant in" location j with respect to the i^{th} factor.

The utility values could be put in Rs. for the quantifiable cost oriented factors whilst the non-quantifiable non-cost factors are worked out by using a rating scale. In this method we compare pair-wise locations in ratio with each other. A ratio R, a dimensionless quantity is then obtained as follows:

say we compare sites S_t and S_2

$$\text{Hence } R_{12} = \frac{\text{Preference for location 1}}{\text{Preference for location 2}}$$

$$\text{Viz}^{wi} R_{12} = \left(\frac{X_{11}}{X_{12}}\right)^{w1} \times \left(\frac{X_{21}}{X_{22}}\right)^{w2} \times \left(\frac{X_{31}}{X_{32}}\right)^{w2}$$

If R_{12}>1, then the outcome of location site S_2 is better than the out-come of location I. In this manner we can get other pair wise comparisons and would be thus in a position to choose the best site.

Let us take an example.

All Illustrative Example

Factors	Si	S2	Weight
Building cost and equipment costs	2500,000	1500,000	4
Taxes (per yr.)	250,00	100,000	4
Power cost (per yr.)	100,000	150,000	4
Community Attitude	2	4	1
Product quality	4	6	
Flexibility to adapt to situations	5	30	2

Hence R12

$$\text{Hence R12} = \left(\frac{2500,000}{1500,000}\right)^4 \times \left(\frac{2500,000}{100,000}\right)^4 \times \left(\frac{2500,000}{150,000}\right)^4 \times \left(\frac{2}{4}\right)^1 \times \left(\frac{4}{6}\right)^5 \times \left(\frac{5}{30}\right)^2$$

viz., R_{12} =0.02. As R_{12}< 1, hence location site' l is better-than location site 2 and is therefore selected.

4.7 SOME CASE EXAMPLES

By now we have had quite an exposure to qualitative, semi-qualitative, quantitative and analytical techniques which could aid in taking a proper location decision. A location decision is quite a difficult and complex problem especially in the context of a developing country like ours which has a large variety of problems.

The distribution of industrial activity has been extremely uneven, because of unreasonable and neglected policies of the rulers/administrators of the country over the years. Almost about 50% of factory workers are found in Bombay and Calcutta. In 1951, 42% of factories were in the above two cities where 67% share of total industrial capital was invested and 63% share of industrial workers was engaged. Such tendencies of centralisation are because of factors of agglomeration. Agglomeration refers to the advantages gained due to production being made less expensive due to the concentration of industries. In the industrial field, one can easily note the clustering/grouping together/localisation of the jute industry in West Bengal and Textile Industry in Bombay and Ahmedabad. However, if due to any reason, the industrial unit is either unsuccessful or some difficult labour problems crop up, then there are a lot of subsequent hardships. Also with the point of a view of war and safety, the concentration of industry might not be a wise decision. The concentration of industry leads td the accumulation of unreasonable amount of workers which in turn creates crowded conditions, pollution, housing, schooling problems etc.

After independence, the government is trying to bring about a regional balance in industrial location as reflected in the Industrial Policy resolutions that favour dispersal/decentralisation (because of the advantages of deglomeration factors). Balanced growth of all the areas or judicious dispersion of facilities in all the regions enables the nation to utilise both human and physical resources more effectively and efficiently. Agricultural, mineral and other resources can properly be tapped. Moreover, employment opportunities would be more equitably distributed. The needs of a particular area or community t would also be served. It would foster national unity and check regional dissatisfaction. The North-Eastern Region has been neglected for quite some time. It is now being given its due consideration. Several problems of a socio-economic nature such as, acute shortage of housing and essential food materials, spread of epidemics, diseases, gambling etc. arise due to the creation of slums. The slums can hopefully be reduced by proper dispersion of industries. The people come to cities in search of employment. This migration could be checked provided the right opportunities are provided at the right time.

Let us see where some industries other than the jute and textile industries which prefer a climate having high humidity are located.

Steel Plants: We find that most of the steel plants lie along the Bihar, Bengal, Orissa belt. In the manufacture of steel, it is always economical to transport the finished product rather than the raw material inputs like coal, lime-stone and iron ore because during production considerable weight reduction is involved. You might be knowing that there also exists a port based steel plant at Vishakhapatnam, which in addition to taking advantage of proximity of iron-ore and coal also avails of the port facilities which aids in importing plant and machinery during the construction phase of the steel plant and in exporting the finished products when the plant goes into production.

Cement Plants: Again in the case of cement manufacturing plants, the raw materials lose weight significantly in the process of transformation, and so the cement plants are located near the lime stone and coal deposits.

Fertiliser Industry: The main feed stocks for the fertiliser industry are gas, oil or naphtha and coal. Here gain the fertiliser plants are located near the source of raw materials. The locations of fertiliser plants at Namroop and Thal Vaishet based on gas, and those at Ramagundam, Talcher and Sindri based on coal are examples. In the case of naphtha or oil based plants most of the feed stock required is imported and hence, the plants are located near the ports.

Mangalore Fertilizers at Mangalore, Madras Fertilizers at Madras, FACT at Cochin and Hindustan Fertilisers at Haldia are the relevant location examples.

Machine-tool Industries: Unlike the previous cases discussed, in the machine-tool industry case, the proximity to the source of -raw material is not very significant. A number of other factors such as market factors and infrastructure will come into the picture. The machine tool industry is scattered over different parts of the country such as Bangalore, Bombay, Calcutta, Ludhiana etc.

Nuclear Power Stations: The selection and evaluation of sites of nuclear power plants throughout the world have become increasingly difficult in recent years as pressure from various societal segments has resulted in strict consideration of the institutional environmental, safety, socio-economic and engineering factors affecting the siting, construction and operation of such facilities. A comprehensive site selection process presents a formidable task to the decision makers. The site selection methodology combines selective screening to narrow down the search area and a classification and rating scheme to rank siting possibilities in order of preference for detailed consideration.

The basic procedural steps used in the selective screening policy are summarised below:

a) Countrywide screening-land availability, water availability seismotectonic areas,

b) Candidate regions screening-hydrology, geology, land use, meteorology, accessibility, transmission lines, demography topography.

c) Candidate siting areas screening-ecology and other factors as in (b) above.

This concludes the `regional' approach heading to an aggregate of possible sites to be evaluated in detail for their suitability to host a nuclear power plant facility. Basic siting considerations are, listed below:

a) Institutional-required service data or on line availability, system reliability requirements, size and number of units/sites, search area boundaries.

b) Engineering-safety-geology (seismic), hydrology (flooding and effluent disposal), demography, meteorology.

Functional: cooling water availability, geology (foundation, soil characteristics), accessibility (people, materials and components, transmission grid).

c) Environmenial-Ecological sensitivity (site, transmission corridors; site environs); terrestrial, aquatic. Land Uses: (compatibility) dedicated lands, areas of historic and archaelogical significance, water quantities and qualities, climatology, demography, aesthetics,

d) Economic-Land costs, cooling system alternatives, site preparation costs: geology and topography, transmission line corridors, site: dictated special engineering safeguards.

e) Socio-economic: Land owner dislocations, competitive use of resources (water and land), community attitudes and public acceptance, economic influence on existing life styles.

It is essential to conduct detailed studies for. the potential impact of nuclear power plant operation upon the natural characteristics of the ecology and environment. Many electric generating facilities have been located along the banks of rivers etc. so as to strategically utilise readily available cooling water for plant condenser needs. It is important to plan for effluent disposal so as to minimise pollution whether it be in the air, water or soil.

4.8 SUMMARY

In this unit we have dealt with an important strategic long term and non-repetitive problem namely the facilities location problem. The traditional factory/plant location concept has enlarged to include non-manufacturing enterprises, service industries etc. You would have realised that facilities location depends on a large number of factors, some concerned with the general territory selection whereas some factors that are relevant for site/community selection. A large number of methods are proposed that include subjective, qualitative, semi-quantitative and quantitative models for facility location. Locational break-even analysis is also an aid. Weights and ratings of factors are discussed; a median model for the single facility rectilinear mode and a gravity model for the Euclidean norm have been outlined. Some composite location measure models like the Brown and Gibson's model and the Bridgeman's dimensional analysis have been explained. A brief mention of a electro mechanical analogue model for solving Weber location problems has also been made. At the end, some case examples of different types of activities like steel, cement plants etc. have been discussed.

4.9 KEY WORDS

Agglomeration: Refers to advantages gained in production due to centralisation/ concentration of industries.

Deglomeration is the antithesis of Agglomeration. It leads to a reduction in the cost of production due to decentralisation.

Euclidean norm: The shortest path obtained by joining the reference points by a straight line.

Facility: A facility could connote any physical object, be it a factory, hospital or bank, relevant to location analysis.

Location of a facility: Geographic site at which a productive facility is suited. between the two reference points.

Minisium objective: An objective whereby the location analyst wishes to minimise the sum of weighted appropriate distances between all relevant reference points.
Rectilinear norm: A path obtained by either moving horizontally or vertically between the two reference points.

4.10 SELF-ASSESSMENT EXERCISES1

1 A manufacturer of farm equipment is considering three locations (P,Q and R) for a new plant. Cost studies show that fixed costs per year at the sites are Rs. 4,80,000, Rs. 5,40,000 and Rs. 5,04,000, respectively whereas variable costs are Rs. 100 per unit, Rs. 90 per unit and Rs. 95 per unit, respectively. If the plant is designed to have an effective system capacity of 2,500 units per year and is expected to operate at 80 per cent efficiency, what is the most economic location? If the operational efficiency that can be obtained is only 60%, what effect would this have on the site you had determined earlier on?

2 An equipment supplier has collected the following data on possible plant locations. Costs are in Rs per year

	Site P	Site Q	Site R
Rent and utilities	Rs. 20,000	Rs. 24,000	Rs. 30,000
Taxes	4,000	3,000	2,000
Labour	1,90,000	1, 60,000	1, 80,000
Materials	2,60,000	2,64,000	2,54,000
Community service	Good	Poor	Average
Community attitude	Indifferent	Indifferent	Favorable

If you were responsible for making the decision on the basis of the information given above, which site would you select and why?

3 Discuss the factors that influence the location of a plant with particular reference to Mathura Petroleum Refinery. Do you justify such a decision?

4 It is generally felt that "rural areas are good for locating large plant, semi-urban areas for locating medium-sized plants, and urban areas for small-scale plants". Comment.

5 A particular city is trying to find the best location for a master solid waste disposal station. At present four substations are located at the following coordinate locations: station 1 (4, 12), station 2 (6.5, 4) station 3 (11, 9) and station 4 (1, 13).

The number of loads hauled monthly to the master station will be 300, 200, 350 and 400 from stations 1, 2, 3 and 4, respectively.. Use the simple median model to find the best location.

6 For the data given in exercise 5, what would be the best location in case the gravity model is used? Which do you think is the appropriate model to apply in the above situation-median or gravity model?

7 What are the steps of a facility location study? In case you want to locate a soft drink bottling plant, what factors would you consider relevant for taking a location decisions? How would you go about conducting the location study?

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