Economics, Management and Entrepreneurship
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Lecture – 38
Capacity Planning (Contd.) and Plant Location

Good morning, welcome to the 38th lecture on economics, management and entrepreneurship, in our last lecture we had started the discussion on capacity planning, there we underlined the role forecasting plays in capacity planning and then we said that there is a need to have 3 different types of forecasts; one, the most likely, 2, the optimistic and 3, the pessimistic forecasts.

And then we said that one has to go to the level of finding out the requirement of individual machines by considering plant efficiency and scrap factor, then we said that once this is known, the problem then is to decide when and how much capacity to add. Now, if you recall there would be different situations, we might like to order less amount at a particular year and get it every year or we have; we may have an alternative of ordering large amount.

But obtain that at a later date beyond 1 year maybe 2 years or even 3 years, meanwhile the company has the option of going for multi shift operation or overtime or even subcontracting the work. Now, these must therefore, these options must be evaluated to find out what should be the quantum of capacity to be ordered and how much when it should arrive, recall also that I had said that if we order for a larger capacity, most likely since the investment is also quite considerable for larger capacity ordering the investment requirement the money required to get this capacity will be more.

That means, the fixed cost will be more but the variable cost may be less. Under the same time, if higher amount of capacity is ordered then there is a greater likelihood that the present capacity will fall short of the demand therefore, this excess demand must be met by going for overtime, multi shift production or even subcontracting. Therefore, when this alternative of going for higher capacity is considered, the cash flow consideration for overtime, multi shift operation or subcontracting must also be estimated.

And these cash flows must be then converted into fixed cost or variable cost, once for every such alternative, costs are estimated and costs are divided into 2 streams; namely fixed and variable, one can use breakeven analysis that we had covered earlier to decide what should be the capacity that we should order. We will illustrate that with an example thereafter, we shall consider the case, when the product may be in its introductory fades or in its major growth period.

And therefore, there is an uncertainty with regard to the demand; hence this is a risky situation and how to treat or how to take a decision under these risky situations. After we cover this, we shall take up a new topic today, we shall start a new topic and that is plant location but to start with we shall continue with our capacity planning exercises.

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Evaluation of Alternative Plant Sizes

Example:

Unit Price (p) = 100 Rs/unit

Year	2013	2014	2015	2016	2017	2018	2019	2020
Demand (D) (Units/year)	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000

Annual Capacity (units/year)	Initial Investment (P) (Rs)	Annual Fixed Costs (F) (Rs/year)	Variable Costs (v) (Rs/unit)
2,500	7,00,000	25,000	50
5,000	12,00,000	30,000	47
10,000	18,00,000	35,000	45

Find the best plant size that the company should plan for.

Here, we have assumed that the demand for a particular product from 2013 through the year 2020, increase in this fashion from 2250 units per year to 4000 units per year. The unit price of the product is assumed to remain constant at 100 rupees per unit. Let us say that there are a few alternative plant sizes such as this annual capacity could be 2500, it could be 5000, it could be 10,000, so there are 3 alternatives that we are looking for.

The minimum size of the capacity that we may add is 2500 units per year and the maximum capacity could be 10,000. The initial investment required for these 3 are estimated are 7 lakhs, 12 lakh and 8 lakh rupees. As you know the initial investment it is then distributed on its; in its useful life period considering the depreciation, hence the annual fixed cost will be much less assumed that it is 25,000, 30,000 and 35,000.

And others as I had said associated with these additions of new capacity, there are different variable costs and they have to be estimated. These details I am not discussing here, we have gone through a number of lectures on how to estimate the variable cost and the fixed cost. For example, in the variable cost we shall have labour cost, material cost, power cost, certain amount of transportation cost etc.

So, they are estimated to be 50 rupees per unit, 47 rupees per unit and 45 rupees per unit, if I consider the annual fixed cost as F and the unit variable cost as v and the price has P, then I can use the breakeven analysis method to find the best plant size that the companies would plan for, whether it would go for 25000 or 5000 or 10,000 units per year.

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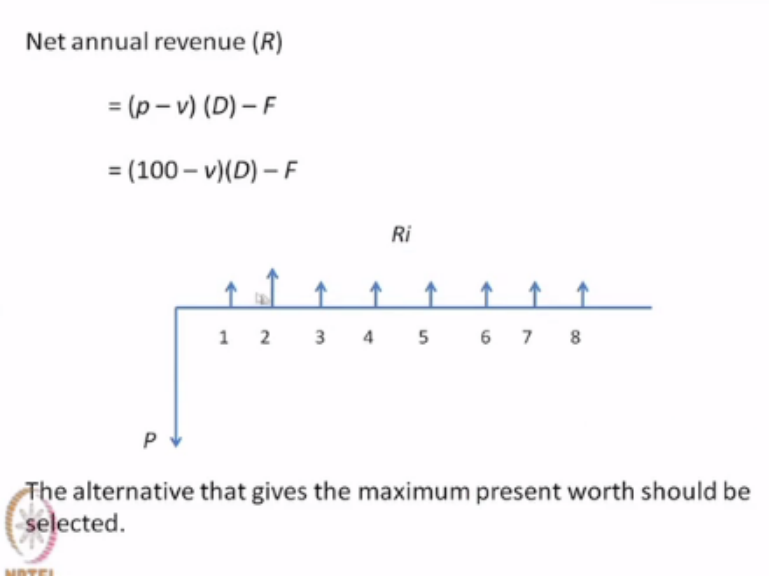

For that you can imagine a cash flow diagram of this sort, capital P is the initial investment of course, we are not much concerned with capital P right now, we will make a breakeven analysis and in the breakeven analysis, we already know that P – v into the demand D, there is the revenue, the annual revenue - the fixed cost F gives us the annual revenue.

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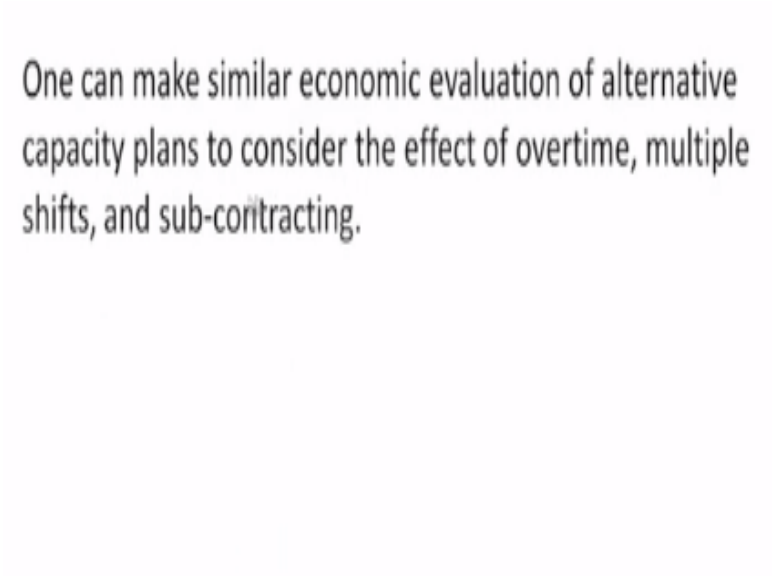

And from there, the breakeven; one can make similar economic evaluation of alternative capacity plans to consider the effect of overtime, multiple shifts and subcontracting, one can find out which is best.

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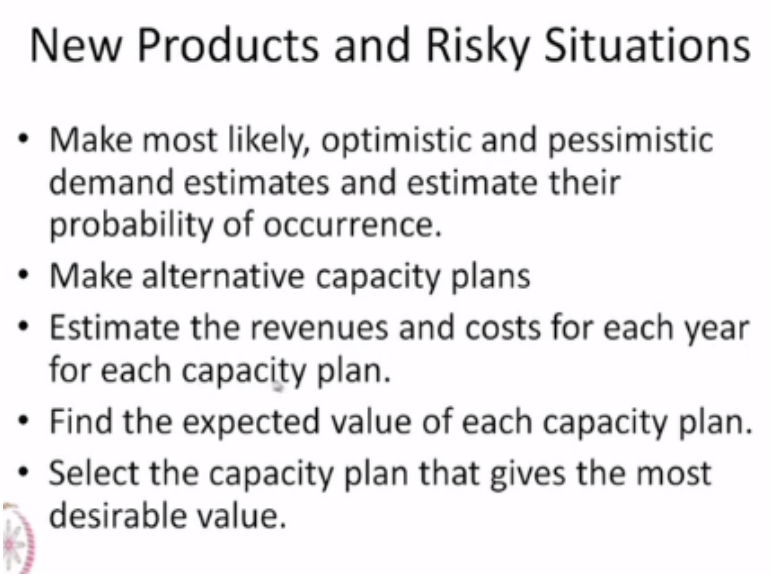

Now, let us consider so long, we had been considering situation of a product which in its; which is in its maturity phase, meaning that the demand fluctuations are not much and that they can be easily predicted whereas, if the product is in its introductory phase or in its major growth period, then the demand may not be very much predictable accurately, hence one has to go for most likely projections; optimistic projections and pessimistic projections.

And also find out and also estimate the probability of their occurrence, meaning that whether the demand is most likely probably will be having a probability of little high compared to the

optimistic projections and pessimistic projection probabilities that are less, so that all these probabilities adding would give a value 1. Then make alternative capacity plans as we had done earlier.

And estimate the revenues and costs for each year for each capacity plan, this also as we had done earlier. Now, we find the expected value of each capacity plan and select the capacity plan that gives the highest expected value, this we shall illustrate with the help of an example.

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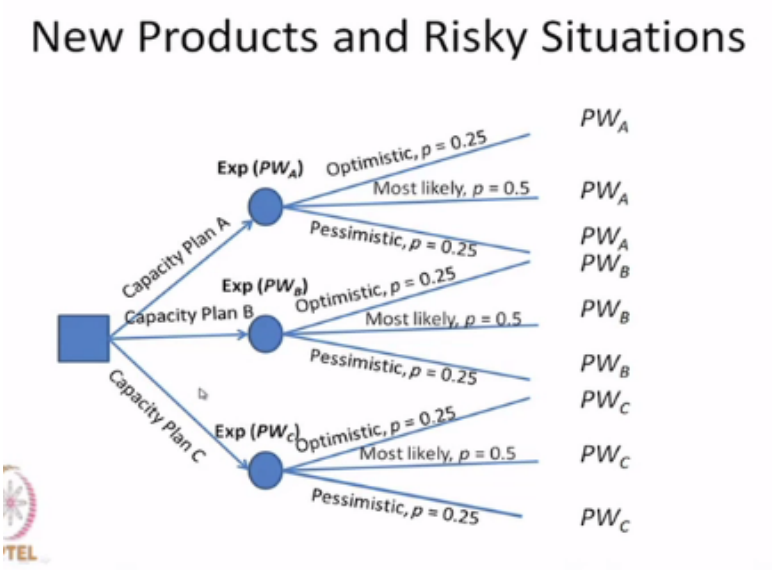

This is called a decision tree and the approach taken here to evaluate and find the best alternative is known as a decision tree approach. Here, you will see 3 types of symbols; one, a square symbol, a circular elliptic; ellipse symbol and then certain lines. So, what we are showing here, this is called this ellipse or circle, it looks like an ellipse here, they are called chance nodes and the square node is called a decision node.

It says that we have 3 decisions to make or 1 decision to make out of 3 alternatives, one is we can go for capacity A, another alternative is capacity B and another alternative is capacity C, so we have 3 alternatives and this is the place, where we have to take a decision whether to go for this or this or this. Suppose, we take capacity A that means we order for capacity A, then there are 3 possibilities.

These are governed by nature; these possibilities or probabilities are governed by nature, this is a random phenomenon, it may be optimistic scenario, the demand may be very good, the demand may be very bad, meaning it is pessimistic or demand may be somewhere medium, so

this therefore this node is called a chance node governed by nature whereas, this is a decision to be taken by the management therefore, it is called a decision node.

And these are chance nodes, now if the demand is optimistic, we assign now the probabilities. We say that most likely scenario is 0.5 probability and optimistic and pessimistic chance is 0.25 probability, it is; now if the demand is 0.25 and if we go for capacity plan A then what are the cash flows and what is its present worth? I do not have to go for details of this, you have to make estimates of different the revenues and the costs associated in future years.

And then discount it to the present to find out the present worth of alternative A, similarly if the demand is most likely demand scenario that we had projected, its associated present worth can also be calculated for capacity plan A and similarly if the demand is pessimistic then what is the present worth of all the cash flows associated with this demands in projection. Once you know or you estimate the present worth associated with the 3 possibilities, then we can find out the expected value of present worth of capacity plan A.

How we find out? We multiply this value, which is a numerical value with 0.25 or this product of 0.5 and PWA here calculated for the most likely demand scenario plus the product of 0.25 into the present worth associated with this pessimistic scenario and whatever we get that is the value of expected value of the present worth of capacity plan A. Following a similar procedure, we find out the expected value of the present worth of capacity plan B.

Meaning, you will have to make the present worth calculation for this demand scenario, this demand scenario and this demand scenario separately and then 0.25 multiplied by this + 0.25; 0.5 multiplied by this + 0.25 multiplied by this, like this you find out this and assuming that they are all positive; present worth is positive meaning the revenues are greater than the cost then this value is; these 3 are also positive.

So, the best alternative to go for will be that particular plan for which the expected value is the highest that means find out that value that capacity plan for which this is; this 3; one of these 3 is maximum.

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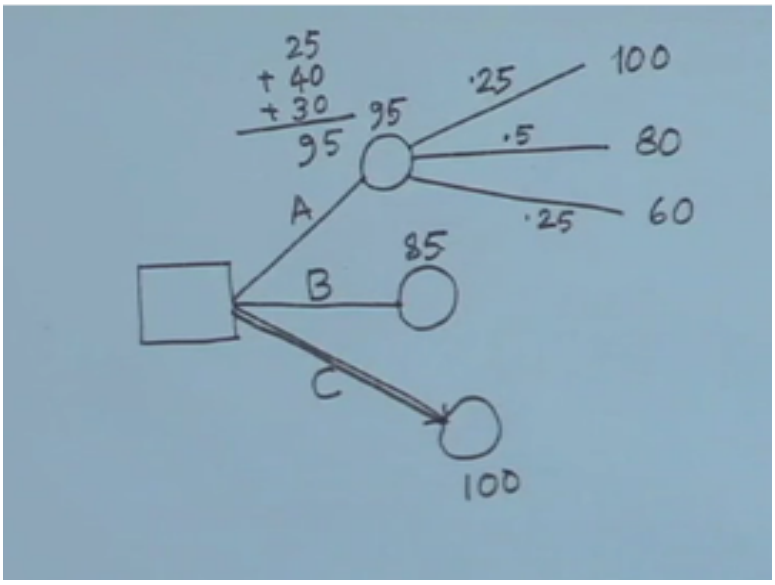

I had given an example say here, we take this is the decision node, this is the chance node, let us assume that this is 0.25 and this is 100, this is 0.5 and this is 80, this is 0.25 and this is 60, then the expected value here is this into this is 25 + this into this which is 40 + this into this which is 30 that gives a value 95, so the expected value of alternative A here is95, similarly we calculate for B, let it be 85 and for C let this be 100.

So, the best alternative to go for will be go for C rather than A and B, the maximum of these 3 that is what I am proposing, so we have seen how to go for capacity planning for 2 types of situations, when the demand is more or less deterministic and that is possible when the product is in its maturity phase, we have also seen how to use the decision tree approach, when a product is in its major growth period or in its introduction phase.

Now, we shall move to a new topic and that is plant location. Now, plant location is a strategic decision, it has long term implications because once a plant is fixed, many costs get fixed permanently for example, if a plant is located near its raw material source then the cost of transportation of the raw materials from the source to the factory is less. So, this cost will remain permanently less for many, many years.

At the same time, if a plant is located far away from the market to which it subscribes to which its supplies material, then the cost of transportation of finished products to the market is permanently high. So, you can see that plant location influences long term costs and is very important. There are large numbers of other factors that also influence a plant location decision for example, the climate, the labour relationship; the power taxes.

And of course, there are other factors, now we will consider how to consider these factors and how to finally decide which location is the best. There are quite a large number of approaches but we shall not discuss all of them, we shall only consider the very basic question of locating a plant and how the decisions are taken, the very simple models.

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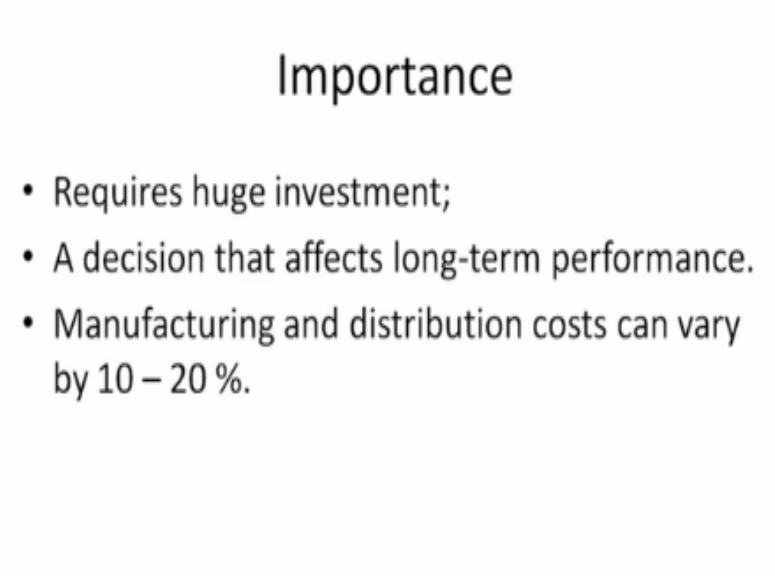

So, plant location; as I said plant location decision is important, it requires huge investment and a decision that affects long term performance, it has been seen that the manufacturing cost and the distribution costs can vary by 10 to 20% purely by plant location decision.

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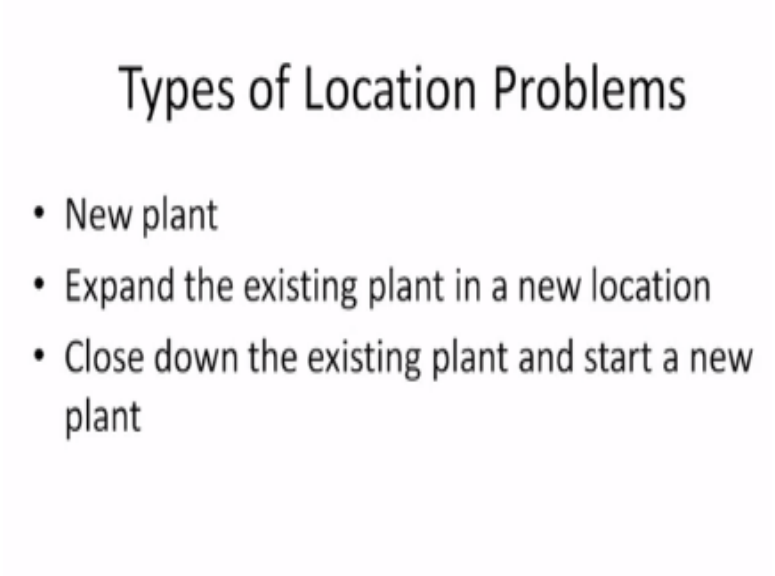

Now, there can be different types of location problems, an entrepreneur who starts a new plant that is one type of a problem but if the plant is already existing, the problem could be adding a

new location when the company is thinking to expand its facilities because of higher demand existing in the market or the company may be deciding to close down an existing plant because of various contingencies and would like to start a new plant in a new location.

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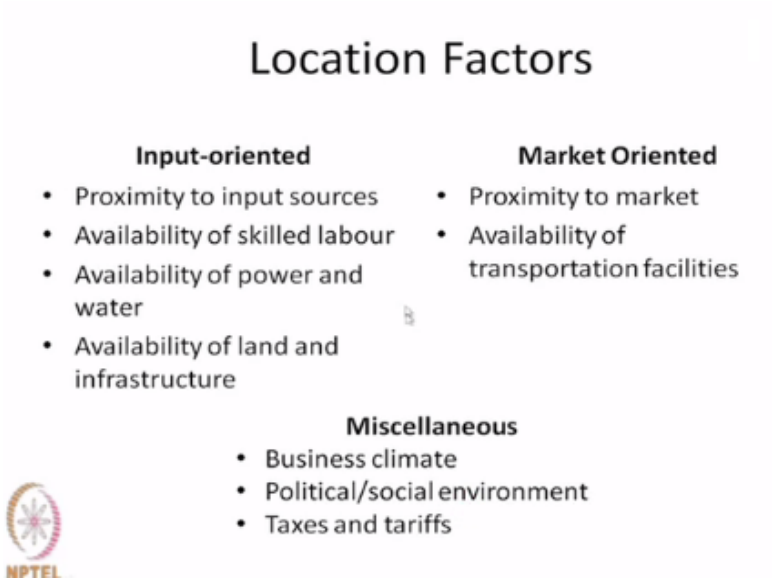

The question is where to locate? The first thing that one considers in deciding a location is to enumerate the factors. There are different ways in which factors can be categorized, we have categorized factors in one way here and that is factors that are input oriented, factors that are output oriented and miscellaneous factors. There are other classifications that are available but let us see this classification.

Input oriented location factors; one as I was telling you proximity to input sources, availability of skilled labour, availability of power and water, you can see this is material, this is labour, this is power, water, availability of land and other infrastructural facilities. For example, IT services, banking services, transportation services they all come here and it could also be market oriented principally, whether it is close to the market to which it serves.

And of course, other transportation facilities to carry goods and of course, there can be other things like dealers; availability of dealers, networking facilities etc., in addition to these 2, there is a third type of factor which may be large in number but only 3 are cited here; the business climate, political social environment, union activities, taxes and tariffs and things like that. So, you can see that location factors can be many.

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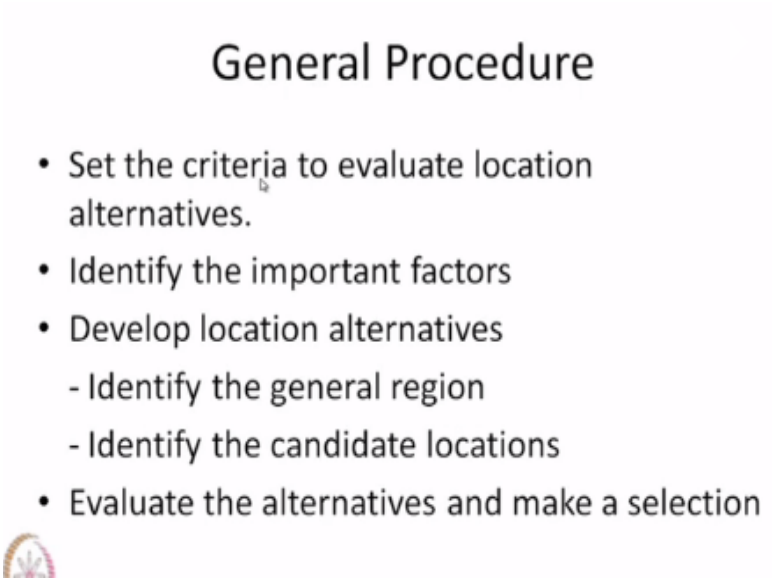

The question is how to evaluate these factors and use them to decide which location is the preferred location. Now, the general procedure for tackling a plant location problem consists of 4 steps; set the criteria to evaluate location alternatives, what the criteria, what are the criteria we are going to use, identify the important factors, developed location alternatives. First decide which region then decide, what are the locations in those regions or that region?

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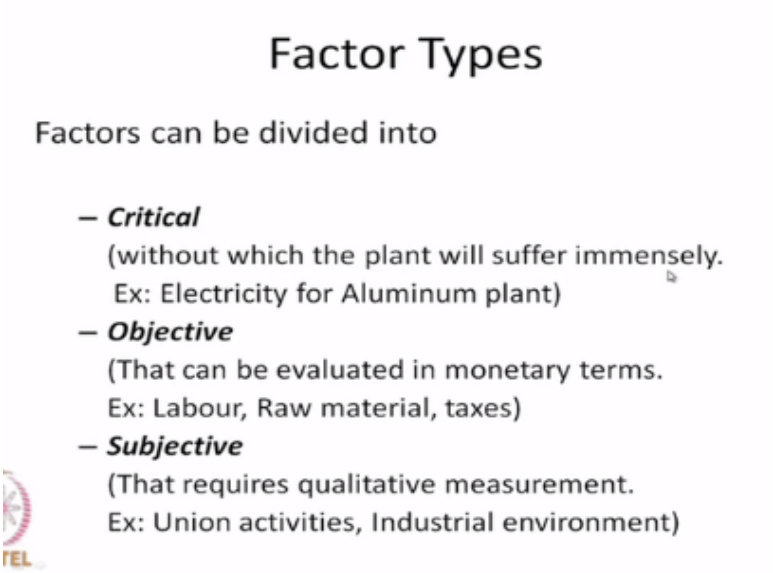

And finally, evaluate these candidate locations and decide, another type of classification effector, which is usually used when we go for evaluating the location is that factors; a factor can be a critical factor or an objective factor or a subjective factor. Now, a critical factor is one without which the plant will suffer immensely. For example, an aluminium plant, the requirement is high amount of power.

So, if power source is not available, aluminium plant cannot exist there, it is a critical input or critical factor for setting up of an aluminium plant, so one has to consider the nature of the product or service that the business would like to give and what is the most important factor without which the plant will suffer greatly that is considered the critical factor. Then there are factors that can be evaluated in monetary terms easily.

For example, labour, raw material, taxes, power and things like that they can be evaluated in monetary terms and subjective factors are those that are difficult to evaluate in monetary terms and therefore qualitatively, they are measured such as union activities, how strong is the union activities, industrial environment whether it is conducive whether there are many other industries already existing so on and so forth.

Now, a subjective factor or an objective factor could also be critical, hence critical we say that if a factor is critical, then there must be enough amount of that factor available in that location, for that location to be considered as a candidate location. If the amount of that factor, which is a bare minimum for setting up of the plant, is not available in a location then that particular location should not be considered as a candidate location.

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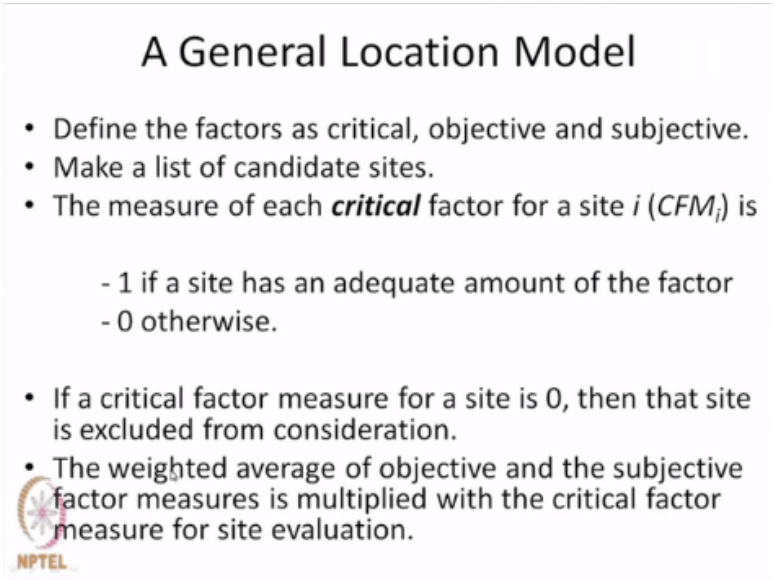

That is how critical factor is decided, now we suggest a general location model, what it does in this model is first to define factors as critical objective and subjective, already we have defined what they mean. Then make a list of candidate sites, then the 3 sets of factors separately find out their weights or measures. First the critical factor; the measure of each critical factor for a site i, it is either 1 or 0, CFMi is critical factor measure for site i.

It is either 1 or 0, 1; if the site i has an adequate amount of the factor, else it is 0, this is how the critical factor measure is defined. So, one has to subjectively decide whether the amount of that factor is adequate to carry out operations of the plant in that site. If it is less than adequate then it is 0, if it is adequate or quite adequate, then it is 1. If a critical factor measure for the site is 0 then that site is excluded from consideration.

Then the weighted average of objective and the subjective factor measures is multiplied with this critical factor measure for site evaluation. Now, let us find out how this weighted average of objective and subjective factor measures is calculated?

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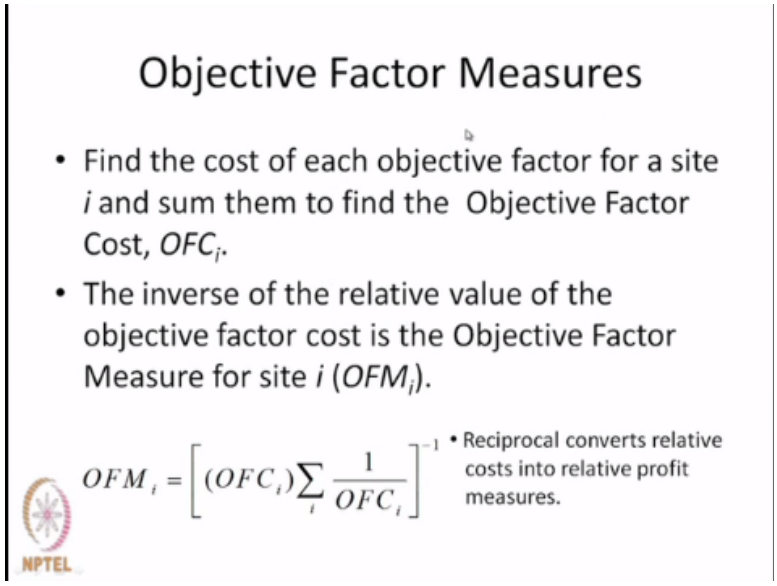

First, the objective factor measures, there are 2 steps. Find the cost of each objective factor for a site i and sum them to find the objective factor cost OFCi that means for every site i, find out the value of each objective factor, add them up, the sum is the objective factor cost for that site i; OFCi, then use this formula to find out objective factor measure for the site i. Here, we have taken inverse -1, inverse, the reciprocal converts relative costs into relative profit measures.

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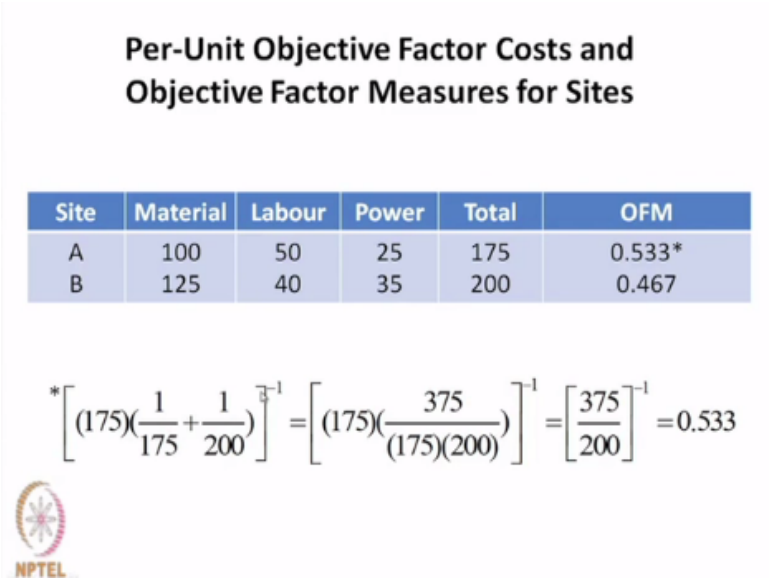

So, OFCi is the cost associated with the objective factor cost associated with site i and multiplied this and inversion of that. We give an example here, let us say that there are 2 sites; A and B and let us say that we are considering only 3 objective factors; factors that are considered that are possible to be measured objectively by monetary terms. Let us say that these are figures for rupees per unit; material cost in terms of rupees per unit, labour cost for rupees per unit, power cost rupees per unit.

For site A, estimate says that these costs add up to 175 rupees per unit and for site B, material costs 125, labour cost 40, power cost 35 and this is 200 rupees per unit. Then according to that formula, we find out the relative cost invert it to find out the objective factor measure for each site A and B. For example, for site A, it is 175 multiplied by 1/ 175 + 1/200 to the power -1 and this is this, which is 0.533.

This is how this objective factor measure is calculated for site A and for site B, we calculate 0.467 in the similar fashion. So, this is how the objective factor costs, these are objective factor costs and the objective factor measure, these 2 are the objective factor measures are calculated.

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Subjective Factor Measures

- Estimate the relative weight of each subjective factor k (Subjective Factor Weight, SFW_k).
- Estimate the importance of each subjective factor k for each site i (SW_{ik}). The weights are normalized so that they add up to 1.
- Thus find the subjective factor measure (SFM_i) for each site i.

$$SFM_i = \sum_k (SFW_k)(SW_{ik})$$

Now, go for the subjective factor measures, here there are 3 steps; estimate the relative weight of each subjective factor k, call it SFWk; subjective factor weight, estimate the importance of each subjective factor k for each site, call it SWik, the weights are normalized, so that they add up to 1 and then find out the subjective factor measure SFMi, which is basically a weighted average.

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Subjective Factor Weights and Subjective Factor Measures for Sites

	Water Supply	Climate	Labour Relation	SFM
Importance Weight of Factor	0.5	0.2	0.3	
Site A	0.8	0.4	0.5	0.63*
Site B	0.2	0.6	0.5	0.37

*(0.5)(.8) + (0.2)(.4) + (0.3)(.5) = 0.63

Now, weighted sum; I have given an example to illustrate how to find out the subjective factor weights and the subjective factor measures for sites, assume that we have 2 sites; 2 candidate sites A and B and we have 3 subjective factors, let us say water supply, climate, labour relation. Let us assume that for our business, we consider water supply, these are the importance weight of factor.

We are assuming that water supply; these weights add up to 1 as you can see, so they have been normalized, so this is 0.5, we give an importance weight of 0.5 to water supply, 0.2 to climate and 0.3 to labour relation. Then we say we consider site A, for site A, the water supply position is in a scale of 0 to 1, it is quite good compared to site B, so this is 0.8 and this is 0.2. So, far as climate is concerned site B, however is better, A site better; 0.6, site A is 0.4.

Whereas, both sites are considered equally good or equally bad in terms of labour relation, now that we have attached some values that means, we have evaluated site A for water supply, site A and B and both sites, we have evaluated for climate and for labour relation and each of these factors is given a weight such as this, we can now find out the weighted sum. For site A, the weighted sum is 0.63, which has come by multiplying 0.5 with 0.8, adding 0.2; product 0f 0.2 and 0.4.

And then once again adding the product of 0.3 and 0.5, 0.5 * 0.8 + 0.2 * 0.4 + 0.3 * 0.5 and that is = 0.63 and in a similar fashion this can be found to be 0.37 and as you can see these 2 add up to 1, this is the subjective factor measure for site A and site B. So, this is an example of how to go for calculate subjective factor weights and subjective factor measures.

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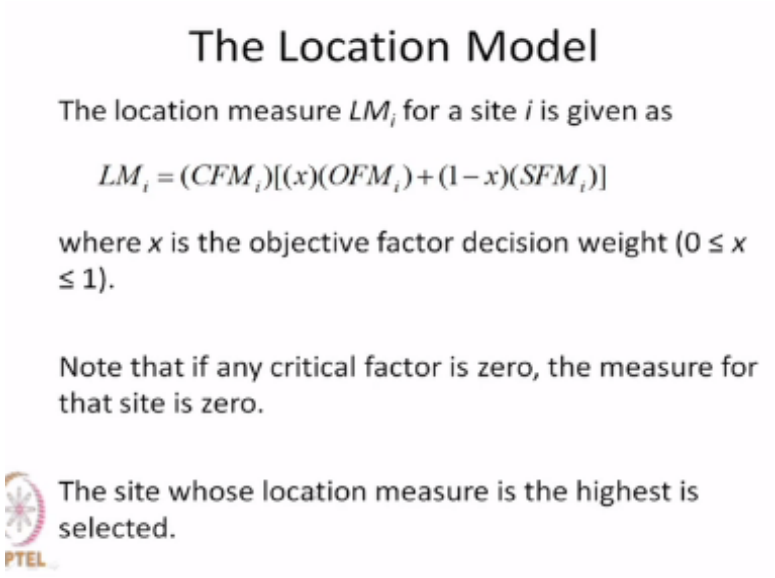

Now, that we have found out the subjective factor measure, objective factor measures and the critical factor measure, we can find out a grand model, we can now make a grand model, we can call it a location measure for site i, here within the bracket, we have put x times the objective factor measure for site i + 1 – x * SFMi meaning, that we give certain matters to objective factor measure and 1 - that let us to SFM; subject factor.

We can give point for 40% weight here and 60% weight here or we can give 80% weight here and 20% weight here, this again we can decide and this is multiplied by critical factor measure, remember that CFM can take only value 0 or 1, if it is 0, the location measure is not considered at all, so we will consider only the value of CFMi as = 1. Here, the value of x can change to find out how sensitive the location measure is for different weights that we assign to the objective factors and to the subjective factors, x is between 0 and 1.

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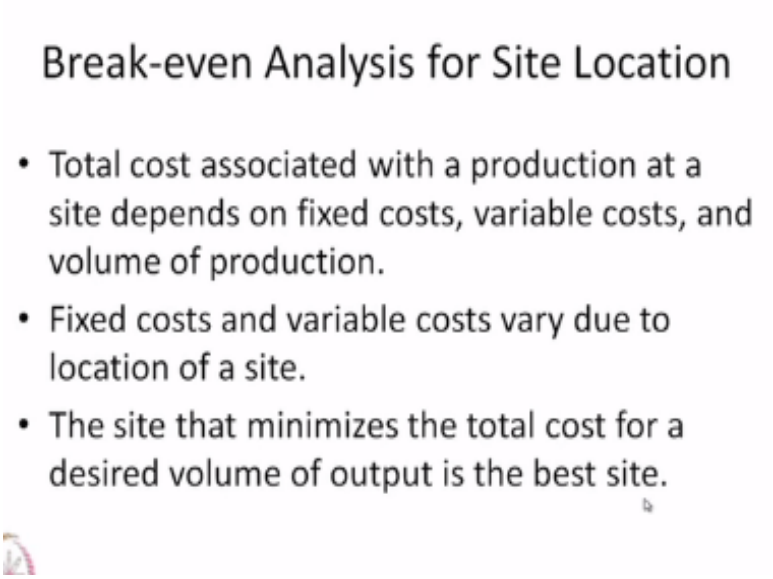

The site whose location measure is the highest is selected or if it is that we are only considering cost and not profit, then the site was location measure is the lowest is selected. Now, one can use a breakeven analysis for site selection just as we had told for capacity planning, total cost associated with a production at a site depends on fixed cost, variable cost and volume of production.

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Example:

Consider three candidate sites A, B, and C with the following costs:

Location	Fixed Costs (Rs)	Variable Costs (Rs)
A	1,000,000	200
B	750,000	250
C	200,000	150

Find the range of output for which each site is the best choice.

Fixed cost and variable costs vary due to location of a site, the site that minimizes the total cost for a desired volume of output is the best site, this is another approach for site location. This is an example; consider 3 candidate sites A, B and C with the following costs. Suppose that we have estimated the fixed costs and the variable costs associated with location A, B and C in this fashion, then we can find out the range of outputs for which each site is the best choice.

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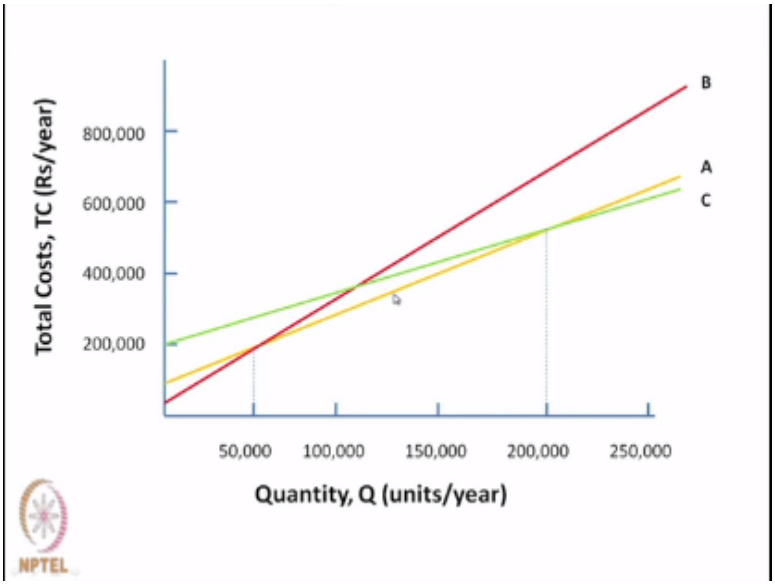

This is shown here, this is the total cost for A, this green line, no; this yellow line A and for B it is this, the lower value of a fixed cost on the higher variable cost and C is the high fixed cost and low variable cost. Now, we can see that between A and B, the breakeven point is here and between A and C, the breakeven point is here. Considering this, we can say that use B in this region that means, B is best if your volume of production is less than 50,000.

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Each site is the best for the volume of output shown below.

A: 0 – 50,000 units/year

B: 50,000 – 200,000 units/year

C: > 200,000 units/year

C is best, if your volume of production is 200,000 or more and in between you go for A that means if your volume of production is between 50,000 and 200,000, then go for site A. Each site is the best for the volume of outputs shown below. A is good between 0 to 50,000, B between 50,000 to 200,000, C > 200,000 units.

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Multiplant Location

Production and Distribution Cost Considering New Site *X*

To / From	Market *P*	Market *Q*	Market *R*	Market *S*	Supply (units/year)
Plant *A*	25*	35	45	40	100
Plant *B*	45	35	65	80	100
New Site *X*	45	55	25	65	70
Demand (units/year)	80	90	60	40	270

* Cost of production and transportation (Rs/unit)

NPTEL

Now, at the end, we take up a problem of multi plant location, this is the case of a business that already has two plants in two different locations and it is supplying its output to different markets but it is finding that the demand has gone up and therefore, it is deciding to set up another plant in certain location. I am illustrating this with the help of an example. Now, look at this, here I am assuming that there are already 2 plants; plant A and plant B.

And there are 4 markets; P, Q, R and S like North India, South India, East India, West India, so market P, Q, R and S. Now, plant A has a capacity of 100 units per year, it can supply 100 units per year, plant B can supply 200 units per year, it could be a year or it could be a month and the demand from market AP; the demand of market P is 80 of Q is 90 of market R is 60 and market S is 40 units per year.

So, the total demand is coming to 270 units per year, I am sorry, this is 100, so the total supply is 100 + 100 + 70 is 270; 100 and 100, 200 and the demand is actually 270, so the present 2 plants are unable to supply these 70 units that are demanded by various markets therefore, the company is thinking to go to either site X or to site B, this is the next one here also, there is a mistake it should be 100.

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Production and Distribution Cost Considering New Site *Y*

To / From	Market *P*	Market *Q*	Market *R*	Market *S*	Supply (units/year)
Plant *A*	25	35	45	40	100
Plant *B*	45	35	65	80	100
New Site *Y*	45	55	25	65	70
Demand (units/year)	70	60	80	60	270

So, this is site X and this is site Y, the same thing we have written in site Y, now what are these other things? These are the things; this is the cost of production and transportation, plant A can supply to market P or Q or R or S or to any other combination. Now, if I consider production cost that is fixed but the transportation cost differs that will depend on the distance from plant A to each of these markets.

Therefore, the transportation cost and the production cost together will be different for different plant market combination. Here, we are saying that if I transport one unit of product from plant A to market P then the cost of production and transportation comes to 25 rupees, plant A to market Q, it is 35 rupees per unit, plant A to market R, it is 45, plant A to market S, it is 40 and similarly, we can find out the actual values.

Now, if we go for new site X and if this 270 has to be satisfied, the demand of 270 has to be satisfied then new site X must have a capacity of 70 and the production cost and the transportation cost together for every for new site X and market P could be 45, this is estimated as 45, 55, 25 and 65. Now, the corresponding figures for market Y are different, the corresponding figures for plant this row and this row, the entries are the same.

But for the new site Y, the values are different for example, they were 45, 55, 25, 65 and now it is 45, no this would be; I have not changed this, actually they have to be changed; 45, 55, 25, 65 and this could be anything else but not exactly the same, it could be 40, 50, 45 or 35 and 85. Now, you see from the new site X to market P; 45, 55, 25 and 65 whereas, now it is 40, 50, 35 and 85, they are different.

But the capacity of the new site; it can supply 70 such that the total demand which is 270 its equal to the supply; total supply 270. Now, this is fondly known as a transportation problem in linear programming. We can actually find out which plant should supply how much material to which market, so that the cost of production and transportation becomes the minimum. We are not discussing a linear programming problem or a transportation problem.

But we are merely mentioning that this has the structure of minimizing the transportation cost but the decision variable is how much to supply from plant A to market P, from plant A to market Q, R and S, similarly how much from B to P, Q, R, S and similarly from how much from Y to P, Q, R, S, provided we go for Y and in a similar fashion, we can also find the same values for A, B and X.

Find out; so that of course, so that the total demand in each market is satisfied and the total production in plant A, B and X is supplied to the markets. Now, we can find out the total cost of production and transportation, if new site X is there and in a similar fashion, we can find out the total cost of production and distribution, if new site Y is decided.

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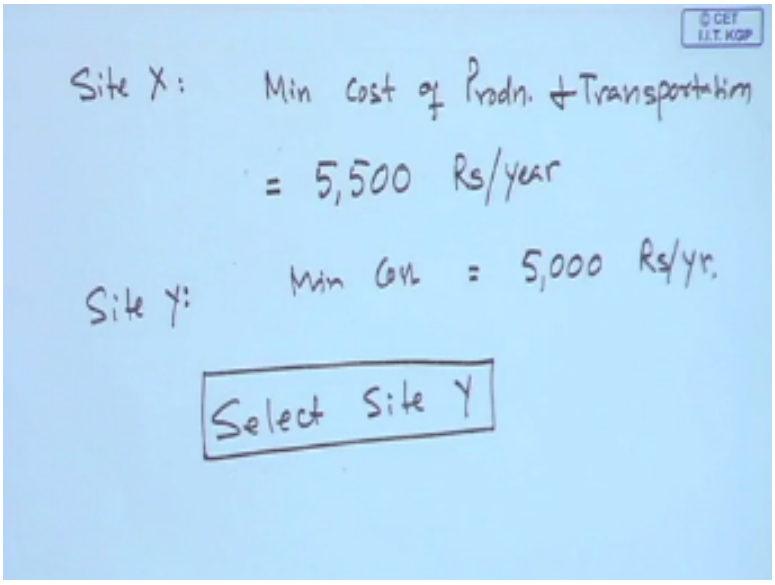

Now, suppose site X is selected, then the minimum cost of production and transportation could be 5500 rupees per year and for site Y, the minimum cost could be 5000 rupees per year, it means select site Y. So, friends in our discussion on plant location, we basically said that there are various factors that influence plant location decision; they can be classified in various ways. A convenient way of classifying is to classify them as critical without which or if the factor is not adequate.

If such a critical factor is not adequate for a particular site that site must not be considered further, it should carry a measure of 0, then the other remaining factors can be classified as either objective or subjective. We must find out a measure for all the objective factors for every site i. Similarly, we must also find out a measure for subjective factors for each site i and then we can find out a location measure for each site i.

The one that gives the minimum, if it is a cost criterion or a maximum, if it is a profit criterion to select which location is to be used. This is general location model but if the factors can be subjectively or I am sorry, if these factors can be objectively evaluated in terms of fixed cost and variable cost, we can use also a breakeven analysis to find out which sites should be selected, if the production capacity is estimated.

And then finally, we discussed a method of multiplying location where a company may be already having a few locations, a few plants it is deciding to go for another plant and is thinking of which site to select, so there we said that the criterion should be minimizing the total cost of

production and distribution or transportation. There are various other situations of where to; how to select sites, we are not discussing them any further.

In our next class, we shall consider designing production system, in that we shall talk about different products, product service strategy and we will then talk about layout decisions and thereafter we shall take up many other functional problems such as production planning and inventory control planning. Thank you very much.