Project and Production Management
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Lecture - 29
Issues in Location of Facilities

The topic of today's lecture is issues in location of facilities. We are now making a transition from the first major decision in the life cycle of a production system, primarily the design of product and services to the location and layout of facilities. I think at the outset we must understand the decisions of locations are strategic.

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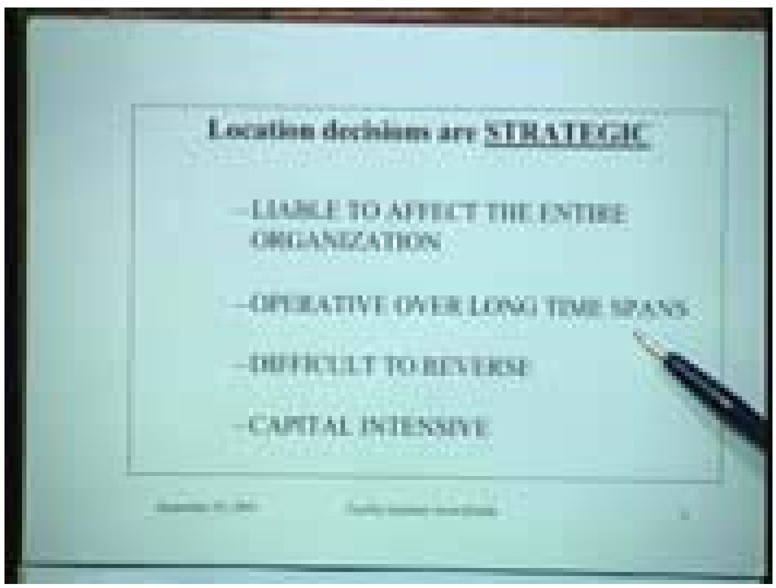

What we mean by strategic decision is that location decisions are liable to affect the entire organization unlike a tactical decision which might affect only a portion of the employees and organization. If you decide to locate the factory at Gurgaon, everyone has to go to Gurgaon and therefore it is a decision which is affecting the entire organization. Also location decision are operative over long time spans, which means it is not easy to change the decision of location once you have decided. For instance you locate a plant at Gurgaon, you cannot say that day after tomorrow I am going to change it to Bombay or to Chennai. It is not possible to do that whereas this decision will stay for a long period of time and moreover such decisions are difficult to reverse because the cost involved in reversing the decision is generally enormous. Moreover all such location decisions are capital intensive. So these are all these things suggest that location decisions are to be taken very carefully after consideration of the variety of factors which are relevant for that particular decision. However it is unfortunate that in many situations decisions of locations are based on only a single factor like free land is available somewhere and therefore the owner has attempted to set the factory up in that particular location and he might regret his decision later. Because later on he might find that he has to continue these benefits of this particular decision over the entire life span. So the point that we are making is that since location decisions are strategic in nature careful concentration of where to locate the manufacturing plant is actually required.

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Before we talk about the location of a plant, it would be worthwhile to look at this hierarchy of location. For instance what we find is at the top of the hierarchy we have the location of manufacturing. Once you have located the manufacturing plant in some location, what is the next decision? The next decision is to determine the plant layout. We are basically talking about the location of departments within the plants that you have decided to locate in the first place. So plant layout is essentially the location of individual departments within the plant location exercise itself, and then when we talk about a department, each department has been located. What you do next? You talk about physical arrangements of machines and equipments within the departments and once the machines are laid out in the departments the final decision is work place layout. That means you are trying to find out that if an operator has to work on this particular machine, the location of tools, where should the location of the raw materials etc. How should you make the hand movement and things of that kind? So it is a work place layout.

Do you notice any similarity between the various decisions? In fact who would notice that all of these are actually location problems? The only thing we change is when you go from one problem to the other; it is the entity which you are trying to locate here. The entity is the manufacturing plant itself and you are trying to locate that here the entity is the individual departments which you are trying to locate here. The entity is the machines and equipments which you are trying to locate. And here it is the tools and raw materials and seating space and these are the kinds of things that you are trying to locate. So recognizing this fact, in fact the problem of plant location is of strategic importance. The term used these days is facility location rather than plant location. If you took course on production management say 10 years ago you would study things like plant location and layout but courses nowadays we often go by the term facility location rather than plant location. The reason for this is because the same kind of mathematical models and tools can be utilized to handle a variety of facilities. So you are talking about a generalized body of knowledge which deals with the location of facilities in general. If you define the facility as a manufacturing plant, you are dealing with this problem. If you define the facility as a department then you are dealing with plant layout problem. If you define the facility as a machine or equipment you are dealing with this problem. If you are defining your facility as the tool and the raw materials, you are dealing essentially with this problem. So it is the increase generality of location models and theories which has prompted this change to facility location rather than just plant location. But nevertheless plant location is the problem of strategic importance and this is the problem of at the operational level.

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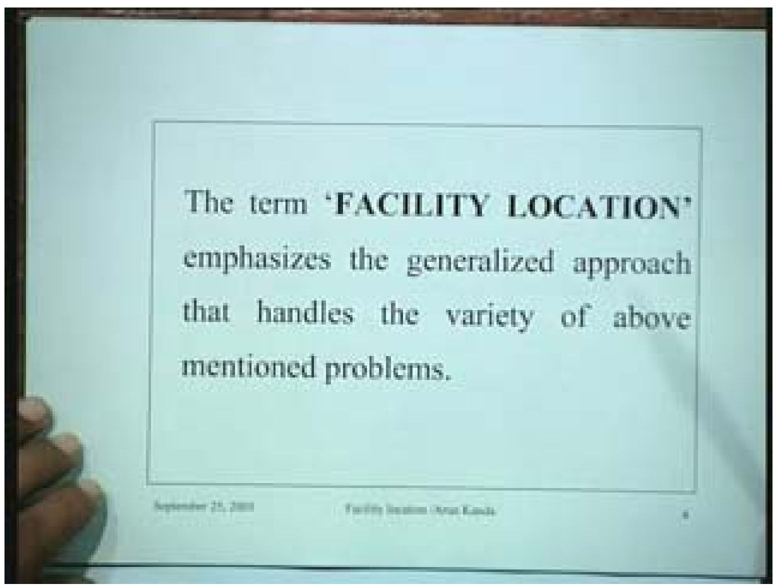

You can change this layout decisions difficult to change these decisions. So the term facility location as we just defined emphasizes the generalized approach that handles the variety of the above mentioned problems. So that is why we will be dealing with the facility location problem and in fact we will be talking about many of the generalized models that are available for dealing with facility location.

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Another important thing to realize is that location decisions are dynamic decisions, which means that it is not that you take a decision once and there is no further decisions to be taken. It is not a onetime decision. Decisions can change and these changes could be owing to changing technology. The changing nature of competition and different competitors on the scene, change of consumer tastes, all these things in fact forces us in making the various decisions about new plants, expansion, decentralization, plant shutdown. All these decisions are constantly going on. The demand is increasing. You have one plant you might want to expand. So the question is which plant you expand out of the existing plants and so on. Which one do you decentralize? And if demand falls for various reasons, you are shutting down the product and which plant needs to be shutdown. So, all these decisions are constantly under review. In fact we will consider an example where we will see how the dynamic nature of plant location manifests itself in real life decision making. However before we do that let us try to identify some of the major factors in location.

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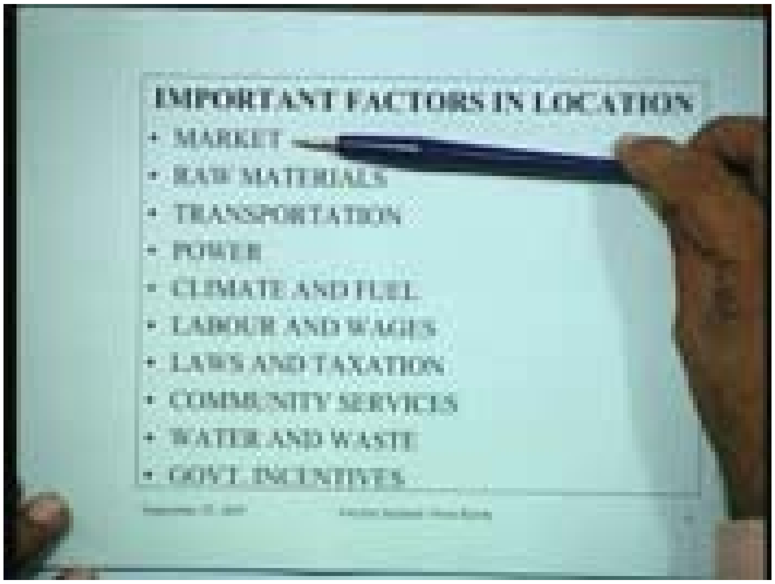

We are talking here primarily about plant location. So if you are talking about the location of manufacturing plant, which are the factors which are relevant? Obviously the market is a very important factor. How do you think the market would affect the location of a manufacturing plant? That is one thing. Transportation cost and location of the market would be in fact be an important factor. That is what is really significant for us. It is that the plant has to produce some of products and these products have to be transported to the market and in fact in earlier models of transportation, what was felt was that if you find out the distribution of demands especially which could occur at different points in space, and if you then calculate a center of market very much like center of gravity by assuming that the weightage is given to the individual points is equal to the market demand at that point, then the earlier theories of locations said that the center of market is the best place for locating the manufacturing plants. Now although this was not a wrong argument, it was an incomplete argument because it was considering only the market.

The same thing could be true about raw materials because raw materials are needed for the plant. So the manner in which the raw materials are available could affect the location of the manufacturing plant. Let us for instance take an example of how raw materials can be affect the plant. Let us say for instance that we could possibly think of 3 kinds of raw materials. We could think of pure materials. By pure material we mean those materials which do not lose weight. The process is going on. Let us take for example of a simple situation. Let us for instance consider that this is the market and the raw material source is what we call pure materials. Pure materials mean if I locate the plant here or here or wherever, it makes any difference to the cost of transportation in pure materials. The total weight of the input is equal to the total weight of the output.

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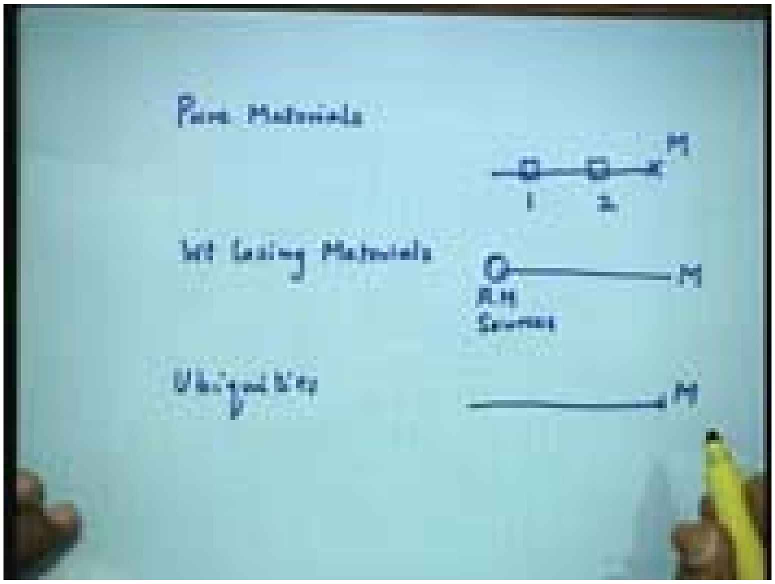

So it does not matter whether I locate the plant at station one or at station two in terms of the total cost, because the total cost of transportation is going to be the same. So when you are dealing with pure materials where you locate the plant is not governed by the availability of pure materials but it could be governed by other factors. For instance it might be convenient to locate the plant at the market itself because that way you will ensure the minimum transportation of the finished products from the plant to the customer itself. This is of course one reason.

This is what happens in all assembly lines. All assembly operations are essentially pure materials, i.e., the total weight coming in is equal to the total weight which is going out and when that happens with pure materials you do not have any such problems. You can locate the plant anywhere on the line on the other hand let us looks at weight losing materials. Weight losing materials mean that suppose the total weight of the input is 1 ton, the final amount that shows up in the final product is may be only 10 kgs. So you have a lot of materials. Materials will lose weight, so if you take the same example in this particular situation, what would be the best place to locate the raw material? Obviously the best place to locate the plant would be close to the raw material sources. So we have the raw material sources here and what you find is because this will minimize the total cost of transportation. This is the reason why steel plants all over the world are located at the site of ores. Steel manufacturing is basically using weight losing material. You use a lot of ore, lot of limestone, lot of coke and ultimately the product that you get in terms of weight is much less. So it is always preferable to locate the plant at the site of the raw materials. So although here it did not make any difference, but weight losing materials make all the difference.

Third category of raw materials may be what we can call ubiquities. By ubiquities we mean those raw materials which are available with equal ease everywhere, say typically air in water. If the raw materials are of this nature where you can get air and water everywhere with equal ease and manufacture this is what would be the optimal decision for locating the plant. Obviously in this case the decision is to locate the plant at the market because you would minimize the total cost of transfer. I think this example should bring home to you that the nature of the raw materials plays a significant role in the optimal location of the manufacturing plant. If there are pure materials, it does not matter. Where you locate other factors governed. If you are using weight losing materials it is better to locate at the raw material source and if you are dealing with ubiquities then of course it is preferable to locate the plant at the market, as far as it is concerned. So considerations like these are important when you are talking about the location of a plant.

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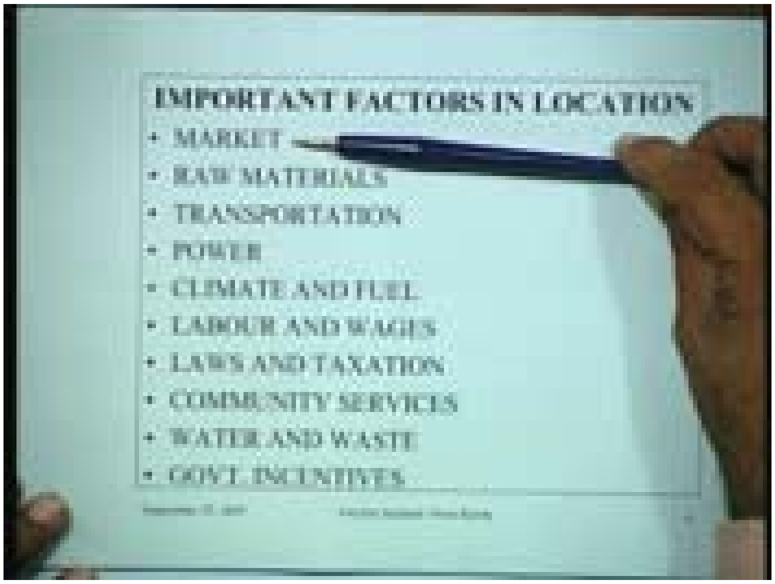

So we have talked about the influence of the market, the influence of the raw materials, similarly, ease of transportation and transportation cost is a major factor. The availability, dependability of power is an important factor in location. Climate, and fuel is an important factor in location, labor and wages are important. The availability of labor and the wages you pay them is an important factor. This would be location depended. Laws and taxation could vary from one site to the other so these could be factors that might be important for determining the location. Community services could be important when you are trying to find out the best location decision. Government incentives are for instance the government might want to encourage industrialization of the particular state and therefore it might announce a kind of package of benefits for entrepreneurs. It might say for instance there is 0 tax to be paid or tax holiday for 5 years. So those kinds of incentives could also determine where you want to locate if you have the various decisions. Then another important factor that has to be considered is what is going to be the annual cost of operation at a particular site. The annual operational expenses for a plant which will consist of things like the raw materials you consume the transportation expenses, the real estate expenses, the fuel costs, sundry state taxes, electric power and water. All these expenses would generally vary from location to location. So if you are trying to compute the annual cost of operation for different sites, we will have to compare these relative cost and then come up with the figure for the annual operating expenses at different sites.

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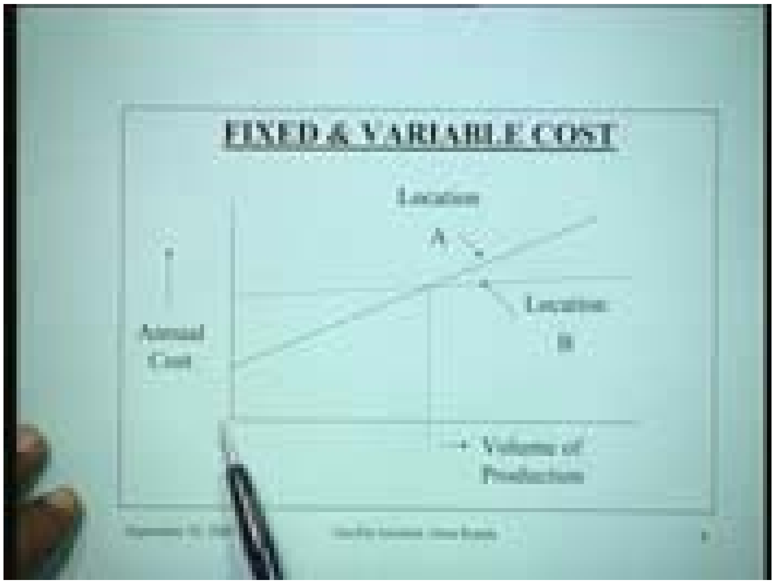

Now a very interesting analysis is a simple break even analysis. It can be done by for instance if we have two sites, let us say we have the site A, location A and location B. Let us say for the time being, location A is the site like Delhi, location B is the site like Mumbai, if you compare these two sites, what you find is that Delhi is being comparatively less industrialized. It is easier to get land in some areas. So the fix costs are relatively smaller and the unit variable cost is typically higher i.e., the operational cost will be higher. Why, because the infrastructure probably is not as strong to supply the raw material and various other components of cost. Similarly in Mumbai it is very difficult to get land. It has very expensive sites therefore the fixed cost is higher in Mumbai, much higher. But comparatively, the unit cost or annual cost is lesser because much better infrastructure exists when it comes to dealing with these things. So if you now compare these two you find that you get a break even volume of production corresponding to this value. So the decision then is if your volume of production is lower than this, you should prefer location A i.e., Delhi. However, if the volume of production is greater than this particular volume, then you should prefer location B. So this kind of analysis of fixed and variable costs can be compared by taking into consideration the nature of costs at different locations. So how do you determine the best location for all possible ranges of operations?

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Just to give you an idea of a mathematical model which can be used, in fact it is a mechanical analog that you are talking about, for finding out the best location of a manufacturing plant and of course you can solve this problem analytically too. But I think the mechanical analog is very interesting and instructive. This particular model that we are about to discuss is known as varignon’s frame, named after the inventor. This Frenchmen decided this particular frame for finding out the best location for a manufacturing plant. Model for this particular case is shown here.

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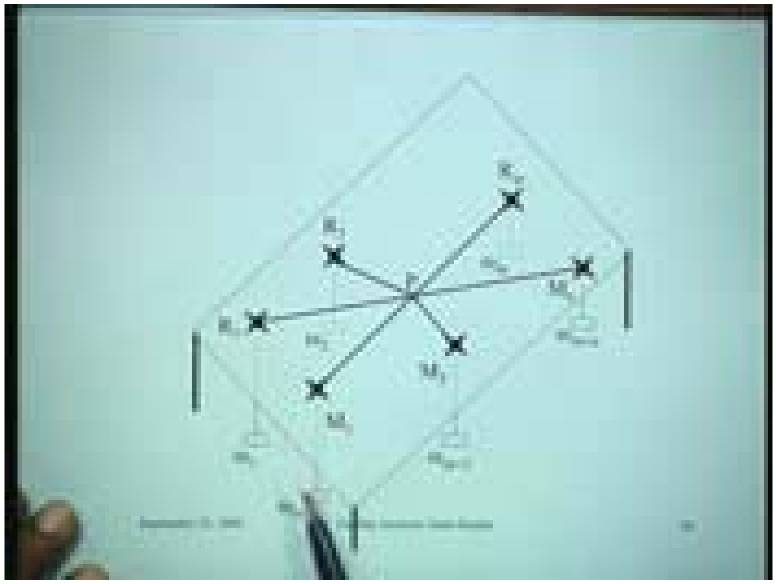

Suppose we take a table and on the table we drill holes corresponding to the raw material sources. Suppose there are in general m raw materials sources, so R_1, R_2 upto R_n are the locations of the raw material sources and we have drilled hole in this particular table here. Then we talk about the markets. This product which we are talking about is going to be produced utilizing the raw materials from these sources and the market consists of number of retailers or people who are going to buy this product. Let us call this market as M_1, M_2 and so on up to M_n. So you drill holes corresponding to these locations, then what we do is we take M + n strings, and we tie them to a common knot. So from the common knot all the m + n strings are hanging then this is the place of the common knot and you pass string through each of these points.

Understand that we pass a string through each of these points and corresponding to each of these, m + n points, we hang a weight w_1 w_2 and so on up to w_m + n, say we just discuss in a minute, how this weight has to be calculated. But I think you should appreciate the general nature of this particular model. So having got the weights for this, you allow the system to come to equilibrium. So assuming that there is no friction on the table, the point where the common knot comes to equilibrium, this common knot will shift from here to here. You can leave it anywhere. Ultimately it will come to a point where the knot is stationary, so that particular point where the knot P comes to equilibrium is the optimum location of the manufacturing plant according to the varignon frame. That means you discover that this is the best place to setup the manufacturing plant. If you setup a plant here, the raw materials are going to flow like this. The assumption is that the flow of raw materials to the plant and all these are Euclidean or straight line. So we assume the raw material flow like this and from this (Refer Slide Time: 26:14) point. All the products flow in straight lines to the market under these setup assumptions. This is actually the optimum point for the location of the manufacturing plant. Here is how we calculate the weight and assumption for the model.

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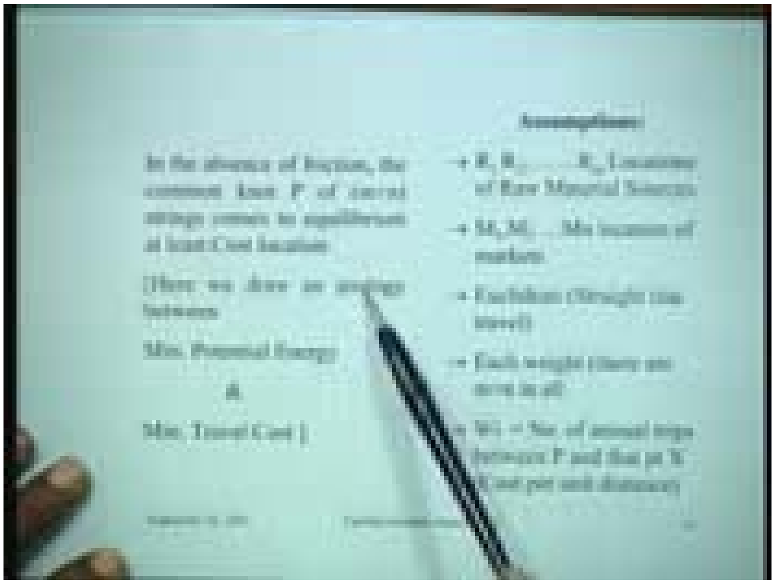

We have said that in the absence of friction the common knot p of m + n strings comes to equilibrium at the least cost location. Basically what we have done in this model is that we have drawn an analogy, what we have drawn between the string comes to equilibrium when the potential energy is minimum. So we have tried to draw an analogy between the potential energy and the travel cost. The system is so designed that there is an analogy between the potential energy and travel cost. So the moment you say that the potential energy is minimum, it implies that particular point. The travel cost is also minimum. Of course some of the assumptions, R_1 to R_n are locations of raw material sources, M_1 to M_n are location of markets. We are assuming Euclidean or straight line travel and in each, how many weights are there? m + n, there are m + n in all. And this is how we calculate each weight. Each weight W_i is the number of annual trips between P and that point multiplied by the cost per unit distance. Look at this weight. Let us look at the diagram again.

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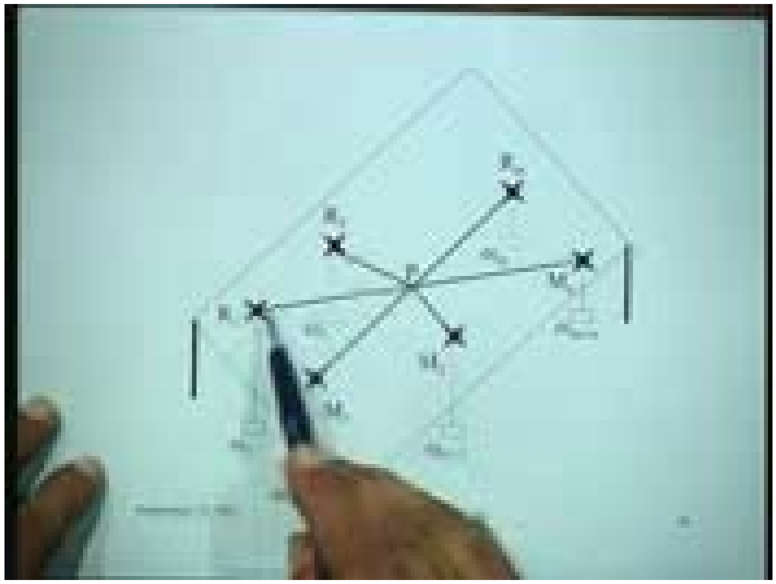

Suppose this is the point, a raw material source and this is the point P, the factory. So what we are trying to say is that the number of annual trips for instance, the raw material is to be transported from here to here and trucks, And you expect on an average that there is going to be 1 truck per month. So, on the long run you are having 12 trucks floating going from R_1 to P in a year. Then what is the cost per unit distance? because you do not know the cost per unit distance. Like the rate you might say that as far as the truck is concerned, it will cost me something like 15 rupees per kilo meter, if I go in a taxi, the pay may be 6 rupees per kilometer. Whatever it is, there will be rate associated with this. So what we are saying is 12 trucks per annum multiplied with 15 rupees per trip. 15 rupees per kilometer is the cost of this. So 12 into 50 would become the weight that would be relevant for this. The advantage of this particular scheme is that it can take care of different modes of travel. For instance the mode here to here is the train travel comes by train. That amount per kilometer on the average multiplied with total number of train trips that you are going to make per annum and so on. This is going to be manually delivered. Then cost per unit distance of manual movement is multiplied with the expected number of trips. So we take into consideration both the mode of travel and frequency of travel. The distance traveled is automatically taken care of. But we are trying to find out this distance basically, that is what the optimization problem is. Ultimately this is multiplied with this distance and summed up, for all these values should be a minimum. So this point comes out such that the total cost of transportation of both raw materials and finished goods is minimized. So this is the model which can actually give us some insides into some of these things.

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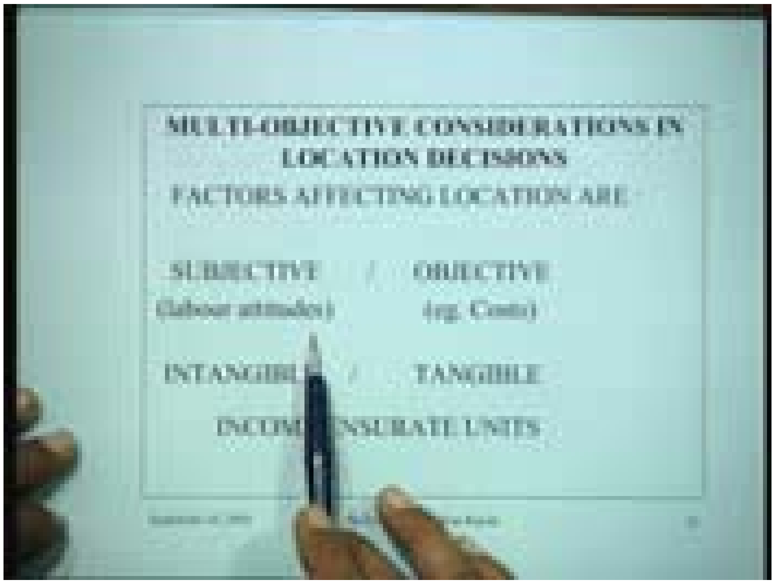

Now as we said plant location decision involves multiple objectives. We had looked at the kinds of factors that are involved. Some of these factors could be subjective like labor attitudes. Some of the factors could be objective like cost; some of the factors could be intangible. And many of these factors would always be measured in incommensurate units. If we are talking about costs, a total investment is measured in lakhs of rupees. If we are talking about annual cost, it measured in rupees per unit time and then if you are talking about labor attitudes that are subjective you can say cooperative, medium and restive. That could be one way of classifying this. These are all in different units. So you cannot add one to the other and that is what we mean by saying that the factors themselves could be intangible and tangible and could be incommensurate. When you are evaluating different factors for plants you have to consider these considerations and arrive at a possible scheme for evaluation of all the factors. In fact what we will do in the next lecture is look at a decision matrix approach with proper evaluation of weights of factors and normalizations of scores for ranking of alternative locations. This is done through a case study which we will take up in the next lecture.

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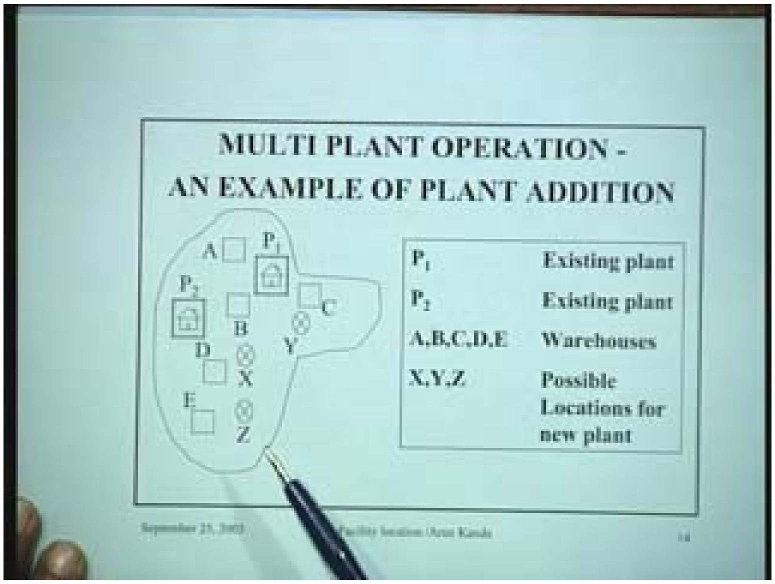

What we will however illustrate at the moment is the use of analytical model for solving the location problem. So what we will consider is a case study of multi plant operation and an example of plant addition. So what is happening is currently, let us say a company has two plants P_1 and P_2 located at two geographically distinct locations in the country. So P_1 and P_2 are the existing plants and these plants supply to the various warehouses. There are 5 warehouses distributed in the country, A in the north, B in the central region, C in the east, D somewhere close to the west and E in the south. So these are the warehouses to which these plants actually supply. And these warehouses have the responsibility of distributing the product to the corresponding retailer in the respective regions. But what is generally happening is that the demand for the product has been growing so that the total production capacity is not able to meet the growing demand for the various warehouses.

So the company has felt the need for setting up a new manufacturing plant and size. Survey has been conducted over the country and three possible locations X, Y and Z have been identified. These are possible locations for the new plant. Basically we are interested in finding out of these locations, the best location for the company. This is the statement of the problem for plant location.

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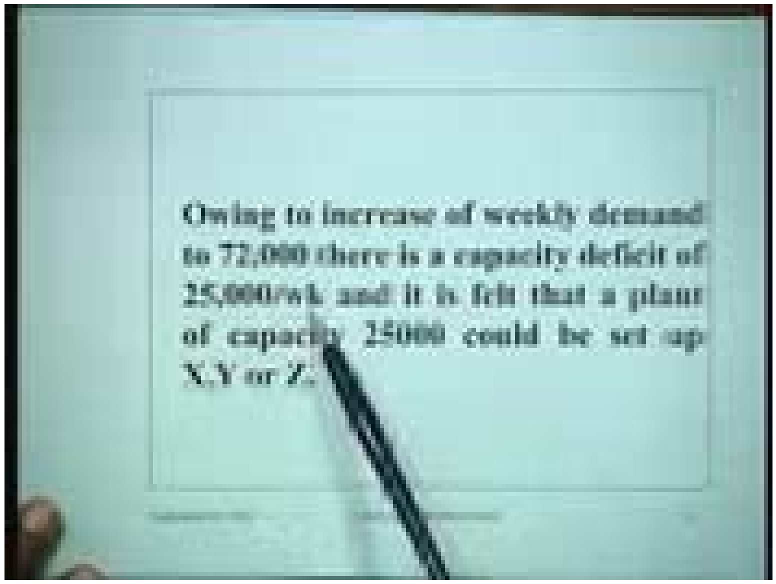

Basically the conditions which have triggered this are owing to increase the weekly demand to 72,000. There is a capacity deficit of 25,000 per week and it is felt that a plant of capacity 25,000 could be set up at either X or Y or Z. That is the whole analysis. So the increased demand is here and now we know that additional plant with this capacity has to be setup X, Y or Z and all that we are interested in doing at the moment is finding out what would be the optimal decision.

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When we consider this decision we would need data rather than cluttering the entire table with all the data, I would just like you to appreciate that this would be the kind of data that is required. So for instance it is known that the cost of transportation from plant 1 to A, cost of transportation P_2 to A, cost of transportation from 3 potential sizes X, Y and Z to A are estimated here. And the weekly forecast of demand is given. Similarly all these columns would be estimated and what we would have is ultimately, the capacity corresponding to these plants which is the existing capacity and we have already identified that X, Y and Z should have a total capacity of 85,000 to meet these demands. Of course you take the unit production cost at the various locations. Because cost of production will vary from individual locations, from P_1 to P_2, P_2 to X to Y to Z because of the various factors like raw material cost and so on. It will vary. So this would be the nature of the problem data that you would be dealing with. We assume that we have this data and we will see how we would carry out the analysis see what we have to do.

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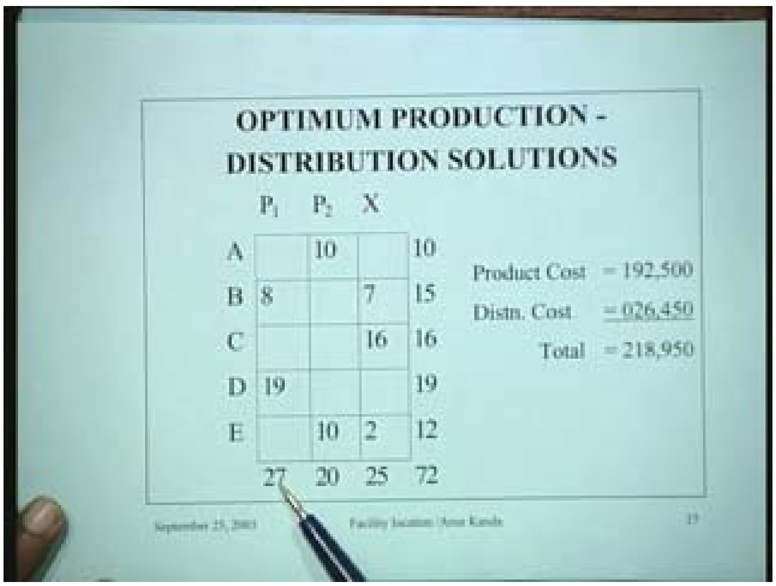

Basically when we look at the problem suppose we setup the plant at X, then our possibility would be, we would have an existing plant at 1, plant at 2 and plant at X. And our warehouses are these. This is the demand in thousands of units and the capacity would be 25,000 for X_{27} and X_{20} here which are the existing capacities and the total capacity at all India level would be 72,000. So what we can do is we can solve this problem. In this case we work with only distribution cost here. So we have the cost of distribution. So this is the standard transportation problem which we solve. When you solve this standard transportation problem you get the minimum cost of distribution and the minimum cost of distribution is 26450 for solving this problem and then you have to add this production cost. The production cost at P_1 of producing so much; at P_2 of producing so much and at X of producing so much. The total production cost is here and the total cost for this option if I setup the plant at X will obviously be 218, 950 which consider both the production cost and the cost of distribution. Rather the optimal cost of distribution something will have to be done for the other two cases. If we setup the plant at Y we again have to solve a transportation problem of this nature. We get the distribution cost which is 26,960. We get the production cost as 1. We get the 93,750. And the total cost is 220,710 exactly the same manner and this is the optimal solution which specifies that the total production of P_2 for instance 20 units. 10 should be sent to A and 10 should be sent to E and similarly the total production of P_1, 19 should be sent here and so on.

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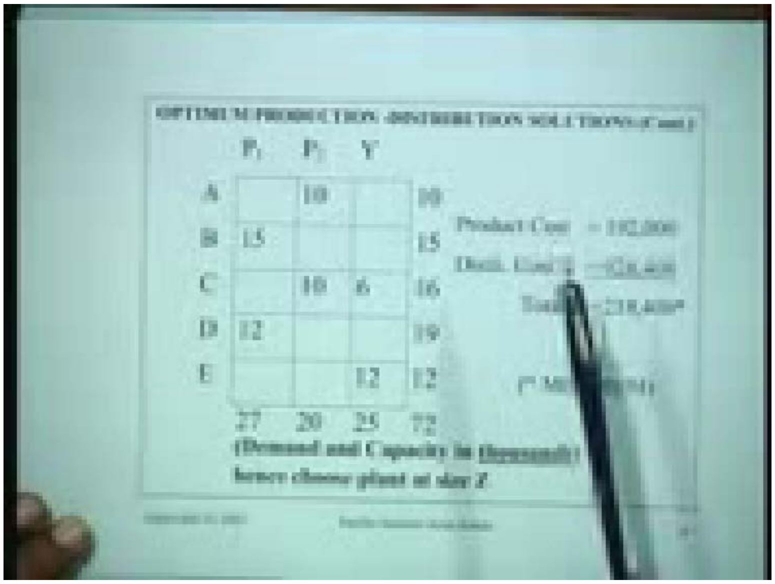

As far as the third one is concerned we will have the optimum production distribution solutions continued and in this particular situation where this should be Z and we are now talking about setting up of the plant at size Z. So again we solve the transportation problem of the same nature and we get this cost and it so happens now. You compare the 3 costs and it so happens that the total cost of production and distribution is minimum at size Z. This is the minimum so hence we choose the plant at size Z. So this was a fairly simple approach to determine where to setup the plant considering both the cost of production and distribution and evaluating for each of the options, what the total cost is likely to be. So we have determined this. This is the case of a plant addition.

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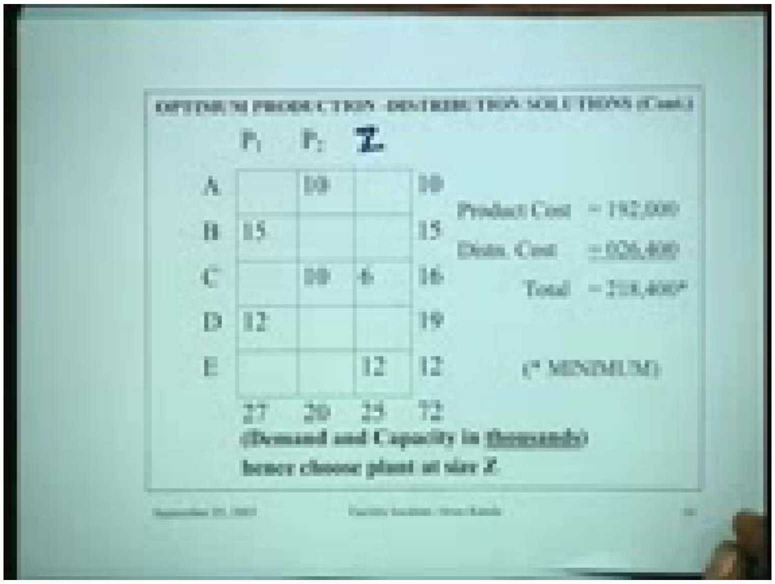

Now as we indicated earlier, let us carry the case a little further and say suppose the plant has been setup the size Z, and suppose it is operating for a year or two then demands are always dynamic in nature.

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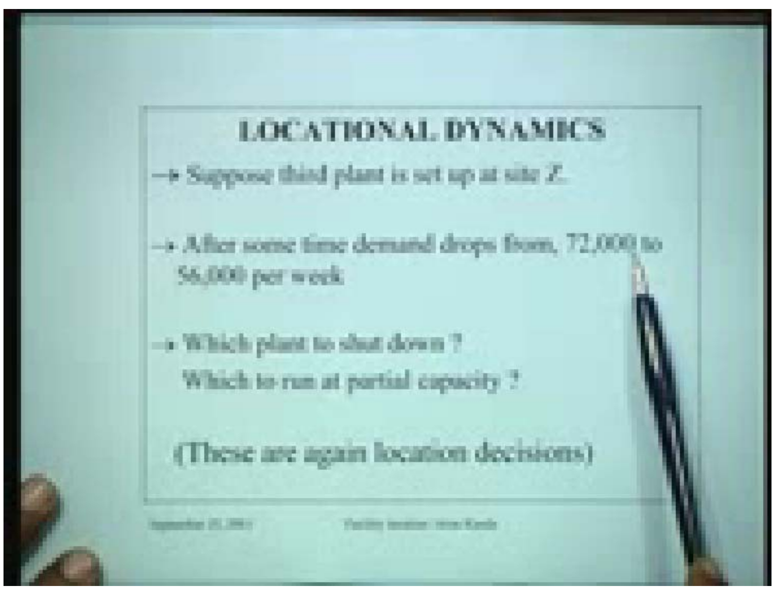

Let us suppose the demand falls, we are talking about the locational dynamic, so we are saying essentially that suppose the third plant is setup at site Z, after sometime demand drops from 72,000 to 56,000 per week. That means we have now planned our plants for a total capacity of 72,000 but there is a fall in demand and the new demand now is only 56,000 per week. So the question now is not which plant to add but which plant to shutdown and which plant to run at partial capacity. These are the decisions. These are also locational decisions. Let us see how we can answer this particular question. When the demand drops and we have already preplans in operations 1, 2 and z and now we want to find out which particular plant to shutdown.

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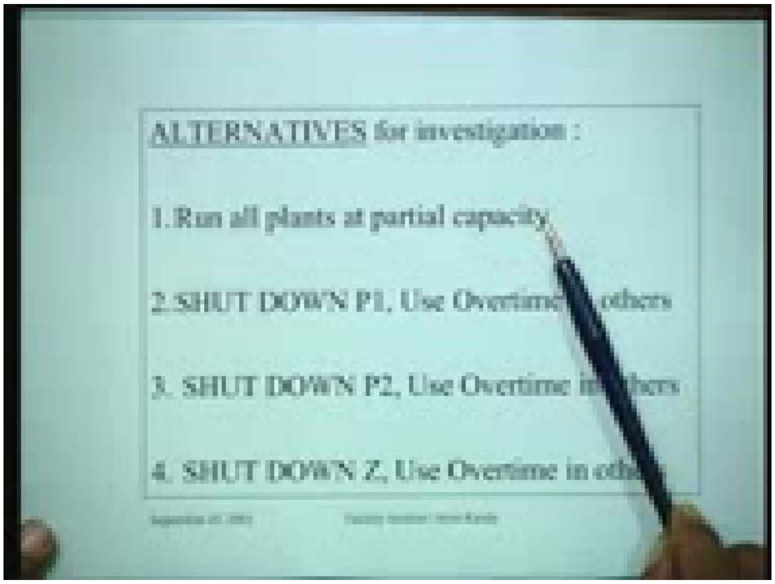

Basically the alternatives before the managements are these four. They can run all plants at partial capacity and you are not producing everything. You produce partial capacity. So we will find out how much each plant should produce to minimize the cost or you have these 3 plants. So you can try to shutdown plant 1 and if you shutdown plant 2 you might have to use overtime in the other plants to meet the demand. Similarly you can shutdown plant 2 and use overtime in the other plants or you can shut down plant Z and use overtime in others. So these are the options. So we have essentially four options available to us and what we are going to do is evaluate these 4 options to find out what is best for the company to do, which particular plant to shutdown under the circumstances.
So what we are trying to say at this stage is we would need an additional data. What kind of data would we need this.

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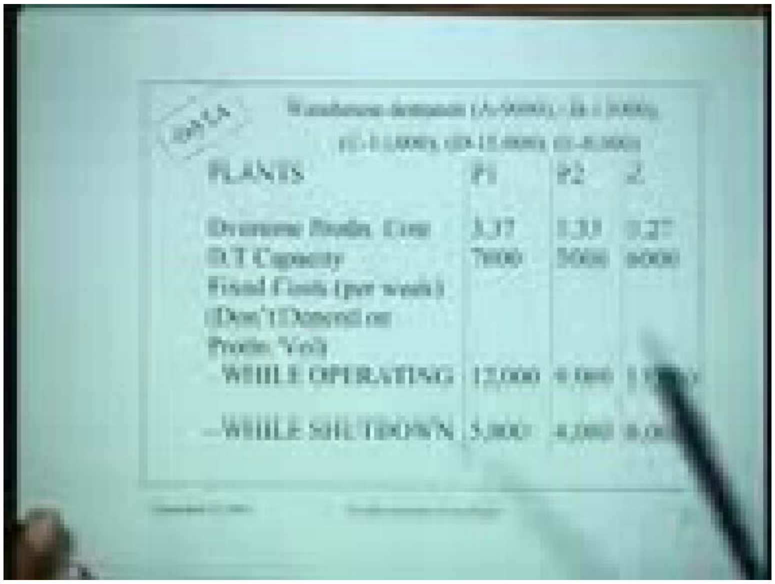

You know for instance that the demand has fallen, so you need to know what is going to be the regional demand of various warehouses. So you estimate that demand for A is 9000 unit, for B it is 13,000 units, for C it is 11,000 units, for D it is 15,000 and E is this. This exercise would have to be done. It is a forecasting exercise. It is an exercise of estimating what is going to be the demand, so that is what we have done here. Then for the various plants that is P_1, P_2 and Z we would require various costs, for instances if you run a plant at overtime, it is estimated that the cost overtime cost of production for the plant, the regular time production cost, we already know. So this is the additional data that we are talking about. This is 3.37, 3.33 and 3.27. So overtime production cost could vary. Why could overtime production cost vary? This could vary because weight rate could be different at different locations, of course there are other costs pertaining to raw materials etc which could also affect these costs, and then you have the overtime capacity. After all overtime capacity is limited so we can produce 7000 here, 5000 here and 6000 at most per week in overtime. Then there are fixed costs. What are these fixed costs? Fixed costs per week do not depend up on the production volume. Now there is a plant already existing. We can think in terms of two kinds of fixed costs, while operating and while shutdown. If the plant is operating then we expect the fixed cost to be 12,000, 9000, 13,000. If the plant is shutdown, the cost would vanish all the cost will not vanish. So from 12,000, it can come down to 5000 because you still have to give the department, so you have to keep paying salaries to the various people who are permanent employees of the company and so on. While shutdown the costs are not 0 but they come down from 12,000 to 5000, 9000 to 4000, 13,000 to 6000. So if you decide to shutdown a plant, these are the fixed costs. If it is operating, these are the costs. I think this is the feature that you have to understand because of the behavior of various types of costs.

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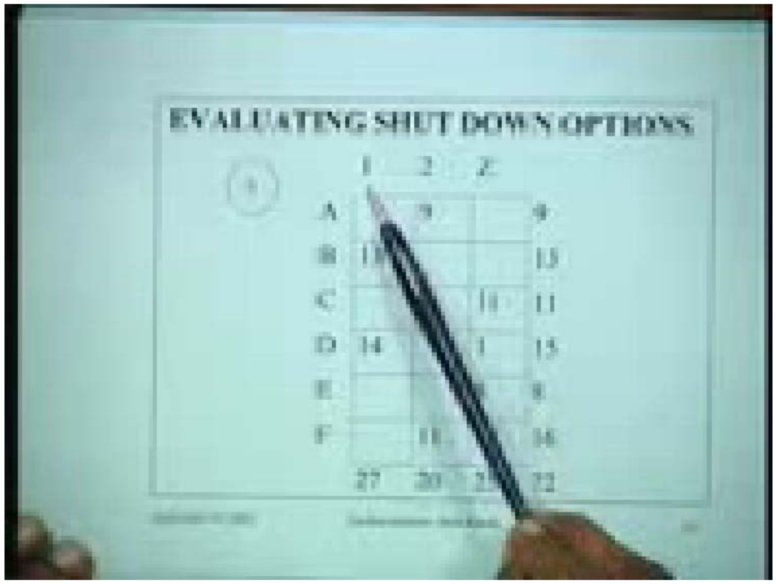

Now, we start to evaluate the four options that we are talking about what was the first option we will be talking about shutdown options so the first option was basically keep all the plants 1, 2 and z running. So when you run all i.e., keep all the plants running, these are the capacities of the plants and these are the demands at the various warehouses. You again solve the transportation problem. So you get this kind of solution and solve this problem.

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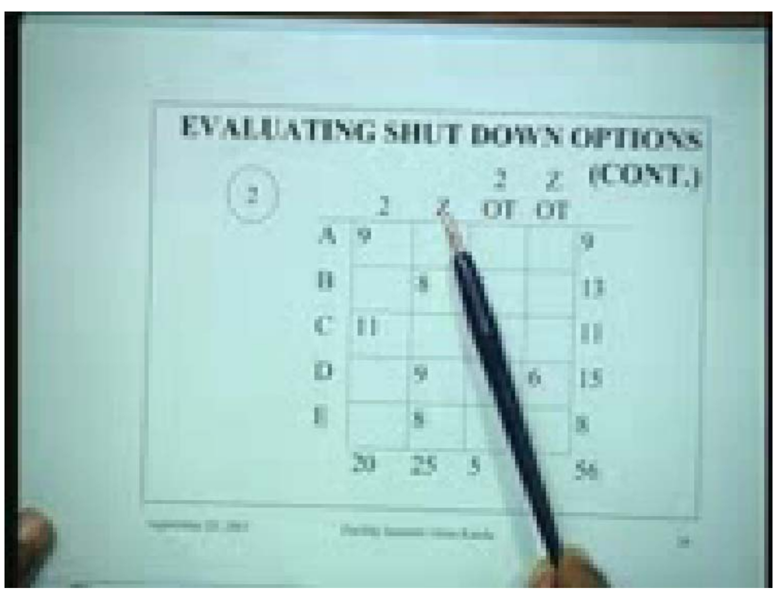

You get a solution now take the second option, what is the second option? Second option was we shutdown plant 1. So if we shutdown plant 1, what happens only plant 2 and plant Z are available. 1 is not available however you have the possibility of using overtime on 2 and overtime on Z. So the costs that you will take into consideration here will now be the cost of production and distribution. If you take these costs and solve this problem you find that the 2, Z, i.e., 2 on overtime and Z on overtime. The solution is something like this which means we are talking only about the optimal solution and what is going to happen is that plant 2 should produce 20,000 units. Plant Z should produce 25,000, 5,000 units overtime on plant 2 and 6,000 units overtime on Z and this will meet the requirements and this will have the certain cost implications. This is how you solve this transportation problem. Now in the same manner we can consider the other two options.

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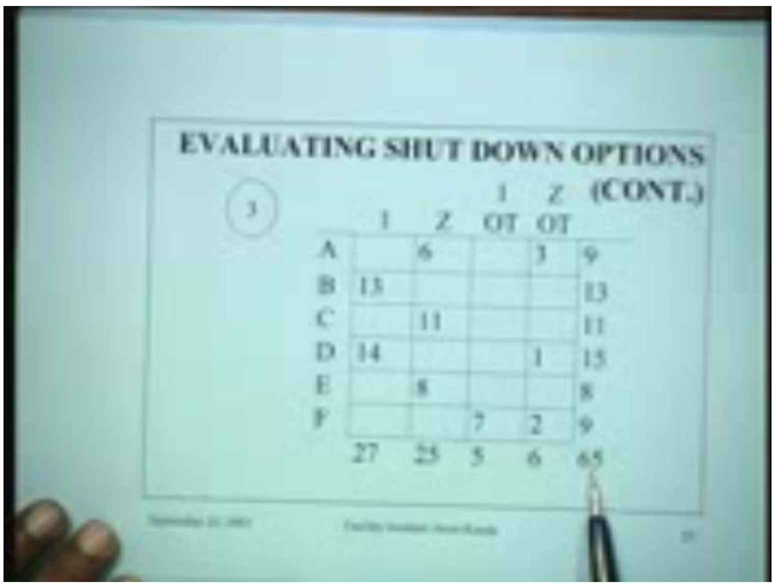

If we shutdown plant 2, what will happen obviously is plant 2 is not available. The only plants which are available are the 1 and Z. You can resort to overtime on one and overtime of Z. And you have various warehouses. You can solve the transportation problem again and you can find out the optimal solution in this manner. Similarly we can evaluate the situation where we shutdown plant 3, if we shutdown plant 3 obviously, only one in Z are available. So we can do overtime on 1, overtime on Z, so our sources are these and our destinations are these. We notice here that when we are talking about A B C D E and F, F is in fact something which is the dummy warehouse which has been added only to balance the supply and demand and the solutions again obtained for this problem is shown here, where you know how much to shift from 1 to B to C to D, that is 9000 units, 3000 units, 15,000 units and this 3 here shows that as far as the overtime capacity is concerned, you are going to utilize overtime to send items to warehouse B and so on. I think the point here is that we have looked at the 4 options that are there. Essentially let us try to recapitulate what we did. We have looked at 4 options which are there before us. These four options in terms of shutting down are; first, do not shut down, any plant. So you are running all the three at partial capacity then shutdown plant 1 then shutdown plant 2 and then shutdown plant 3. You have these various transportation problems which we have solved.

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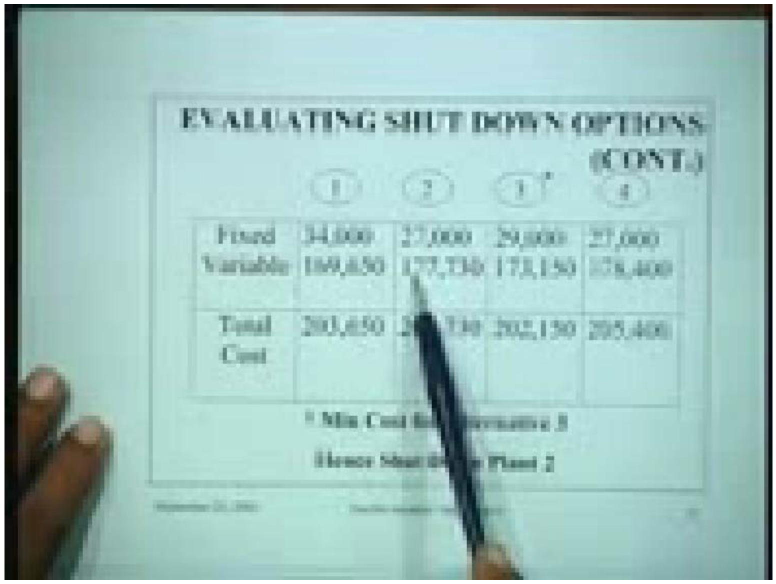

So what we try to do is we evaluate these shutdown options and the significant things to note here is that corresponding to these 4 options 1, 2, 3 and 4 we find that it is this cost which we have determined by the transportation model. The lower one and then we can add the fixed cost corresponding to that one as the case may be. I think it is important to realize here as to how we make use of the fixed cost at this stage. See in the first option what is happening? No plant is being shutdown and when you have no plants that is being shutdown, it means all the plants are operating. So the fixed is going to be 12 + 9 +13 = 24. It will be going to be 12 + 9 = 21 + 13 = 34 and this is the cost 34 here which appears at right, so 34,000 is the fixed cost associated with this option. When you consider option 2 what did we have to do? We have to be careful in selecting the fixed cost. Option 2 was the case where we shutdown plant 1 and other was operating. So let us look at the situation. If plant 1 is shutdown, the cost is not this, one but just this one (Refer Slide Time: 52:56). But the other two are operating so 5000 + 9000 + 13,000and so that is 27,000. So you have a figure here of 27,000. So it has to be selectively done. What was this option?

Let us consider, we do it for all these cases and things would be clear. This was the case when plant 2 is shutdown. When plant 2 is shutdown, what happens is the cost here is 4,000. Plant 2 has been shutdown so 12,000 + 4000 = 16,000 + 13, 0000 = 29,000. So that is the fixed cost here and similarly what was option 4? That is shutdown plant 3, so plant 3 means plant Z, so if we shutdown plant Z, we find that the total cost is going to be 6000. So 12,000 + 9000 + 6000 that is 27,000. You have the cost here. The point that I am trying to make here is that we have accommodated the calculation of the fixed cost. The nature of the fixed cost under shutdown and under operating conditions has been incorporated here. These are the values that we have obtained from the optimization in the four cases. So the total cost is now here and now if you compare the total cost we are interested in picking up that option which is the cheapest. So the cheapest option is option number 3 which means it is best to shut down plant 2.

You notice an interesting thing here. This is what we mean by locational dynamics. First there was a need to setup a plant at size Z and then the demand cell and we found that it was best to shutdown another plant not the one that we are setting up there. Now we are shutting down plant 2. So if you look at this history, what we are trying to essentially say is that the location decisions are dynamic and these kinds of decisions decision making has to be done constantly when you are dealing with these various situations.

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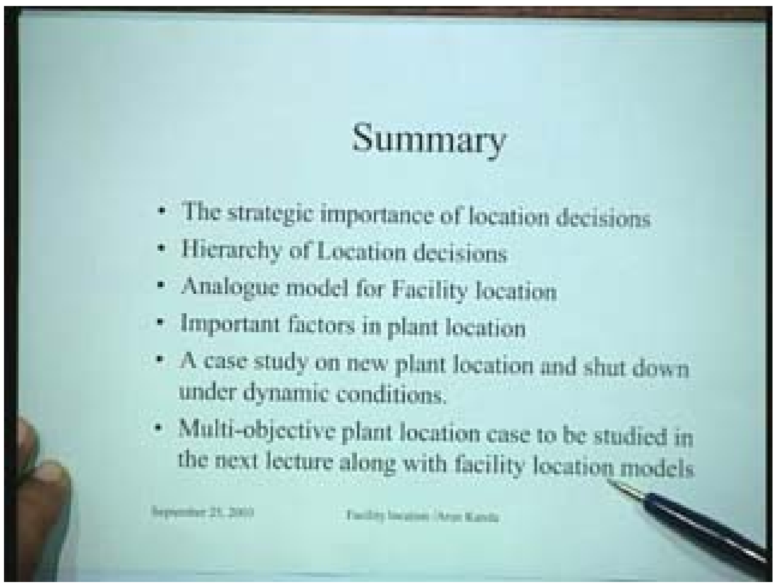

Finally let us summarize what we have tried to do with this particular lecture. I think the most important thing that we must realize is that location decisions have a strategic importance because these decisions are there to stay for a long time. They affect the entire organization and they are costly in that sense and therefore there is a need for looking at location decisions more systematically, more scientifically. That was the message then we looked at hierarchy of location problems to suggest that the problem of location is general. And that is why we could term this theory as facility location theory where the facility would mean that you deal with anything and you are essentially dealing with a location problem. We looked at varignon frame which was an analogue model for facility location. It was a very interesting model in terms of strings and weights. Of course it could be clumsy to use, which could have a mathematical simulations for this particular model. But nevertheless it is one of the earliest models used for determining the optimum location. Important factor in plant locations were identified. A case study on new plant location and shutdown under dynamic conditions was demonstrated. We saw how to locate a plant and how to subsequently shutdown that particular plant and of course based on this analysis, we do a case study next time of a multi objective plant location case which will talk about, not only the various factors for location but also other facility location models can be used to determine analytically, the location problem.

Thank you very much.