Decision Support System for Managers
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Week – 12
Module – 06
Lecture – 60
DSS for Multi-item Production-Distribution Planning

Hi, welcome to this last module on 'Decision Support Systems for Operations Management'! And in this module, we are basically going to talk about 'Decision Support Systems for Multi - item Production-Distribution Planning'; ok.

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So, we will be basically discussing about the formulation of this kind of problems where, multiple items are involved and there are multiple plants; ok. So, multi-item production-distribution planning for a multi-plant operating company is the topic of today's discussion.

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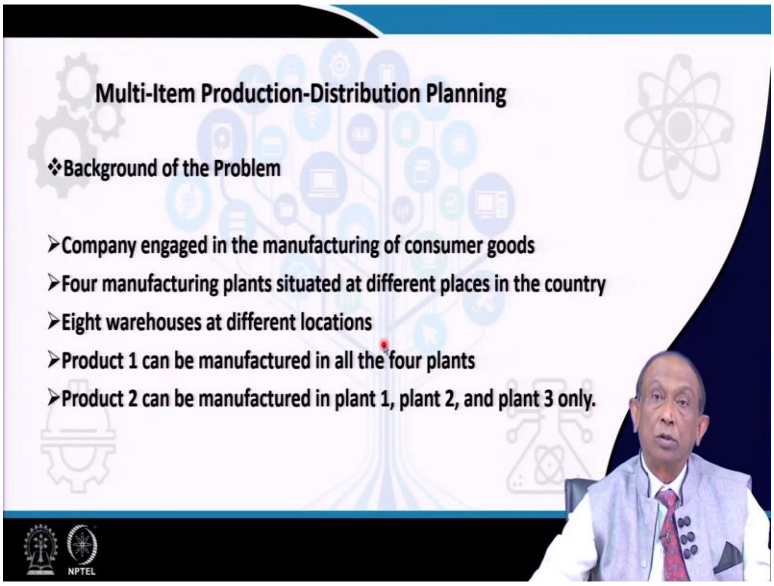

Let us talk about the background of the problem, it is a real life problem; wherein a company is engaged in the manufacturing of consumer goods basically the company is producing batteries. Now, they have four manufacturing plants situated at different places in the country and they have eight warehouses at different locations within the country and to make the whole thing much more simplified we are basically restricting ourselves to two products; ok.

So, product 1 can be manufactured in all the four plants, we have already said that the company is having four manufacturing plants and product 1 is manufactured in all the four plants. Product 2 can be manufactured in plant 1, plant 2 and plant 3 only, it cannot be manufactured in plant 4.

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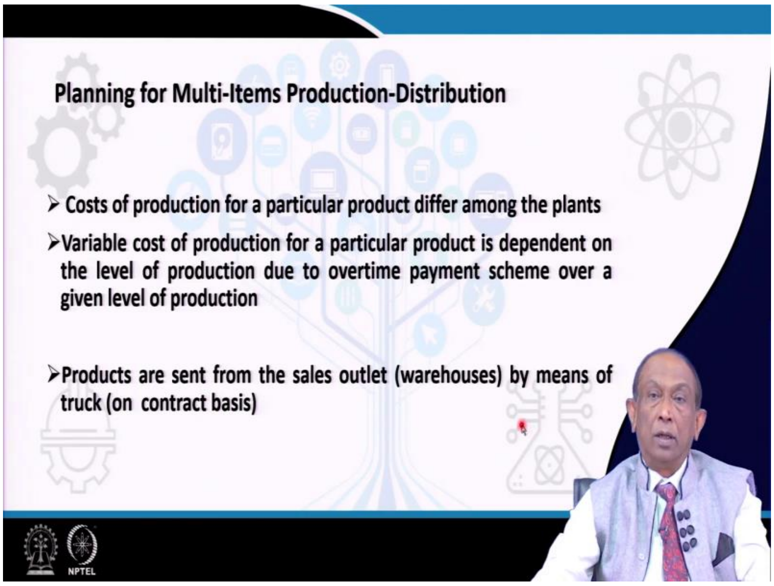

Now, the costs of production for a particular product differ among the plants this is the first observation that was noted by the operations management group of that company. Variable cost of production for a particular product is dependent on the level of production due to some overtime payment scheme existing in the company.

And this overtime payment is dependent on the amount of production that takes place over a given level of production. Products are sent from the sales outlet that is the warehouses by means of trucks and this is on contract basis.

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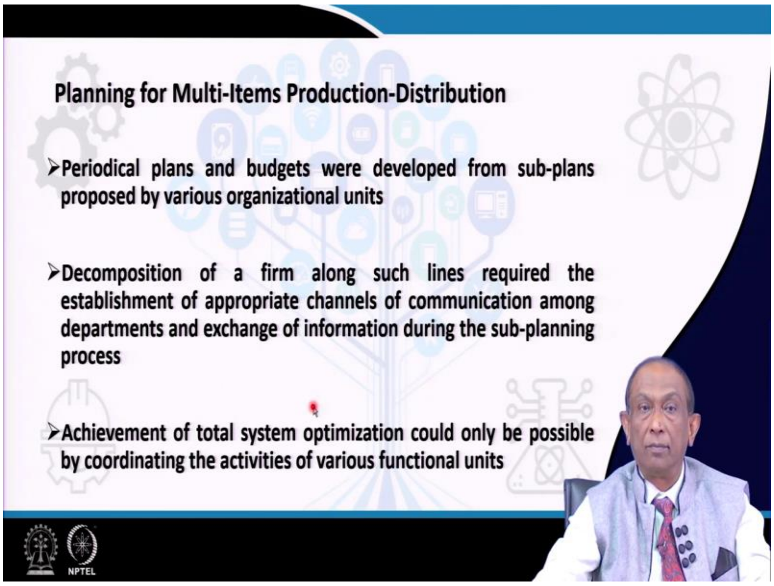

Now, in this company before such kind of decision support systems were implemented they used to have periodical plans and budgets that were developed from sub plans proposed by various organizational units.

Now decomposition of a firm along such lines require the establishment of appropriate channels of communication among departments and they have to carry out exchange of information during this sub-planning process.

So, until and unless the entire coordination activities takes place in a most efficient manner it becomes very difficult to operate. So, that is why achievement of total system optimization in such a circumstance can only be made possible by coordinating the activities of various functional units of the plant in the most efficient manner.

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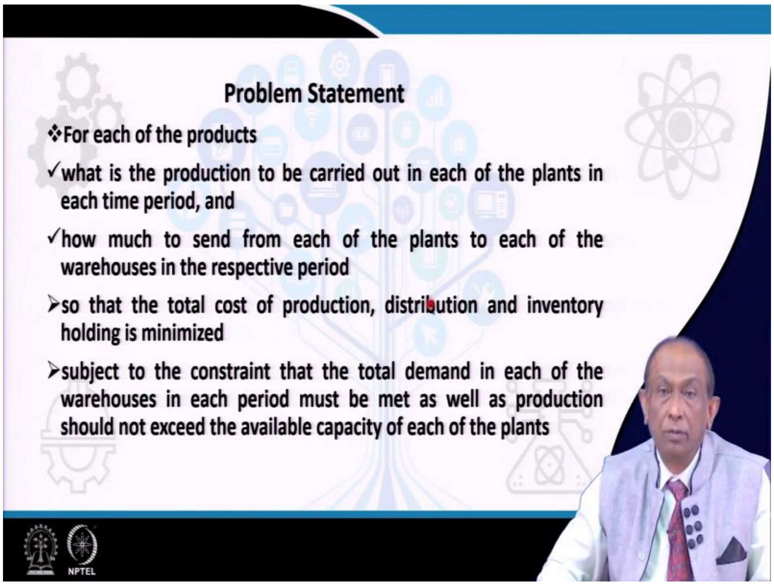

Now, when this decision support system was proposed the company management deliberated upon the different problems that they were facing and they also expressed what they expect out of the system.

So, a detailed requirement analysis was carried out and based on that the problem was formulated. So, what is the problem? The problem is that for each of the products that the plant is manufacturing, they would like to know from the system: what is the production volume that must be carried out in each of the plants in each time period; this is the first.

So, how much production should take place in each of the plant in each time period and since this is a production distribution problem from the distribution aspect how much to send from each of the plants to each of the warehouses in the respective period.

First portion is the production related the level of production to be carried out in each of the plants in each time period and in that same time period how much to send from each of the plants to each of the warehouses that is the sales outlets.

In such a way, that the total cost of production, distribution and inventory holding is minimized. So, the objective function is minimized total cost of production, distribution and inventory holding. Subject to the constraint that the total demand in each of the warehouses that is in each of the sales outlets in each period must be met as well as the production should not exceed the available capacity of each of the plants.

So, once again the problem statement is minimize total cost of production, distribution and inventory holding subject to the constraint that the total requirement in each of these sales outlets in each period must be met this is the first constraint.

The second constraint is that the production should not exceed the available capacity of each of the plants. The decision variables are the level of production that need to be carried out in each of the plants in each time period and the second one is how much to send from each of the plants to each of the sales outlets in that period in that respective period. So, let us see how the problem has been formulated.

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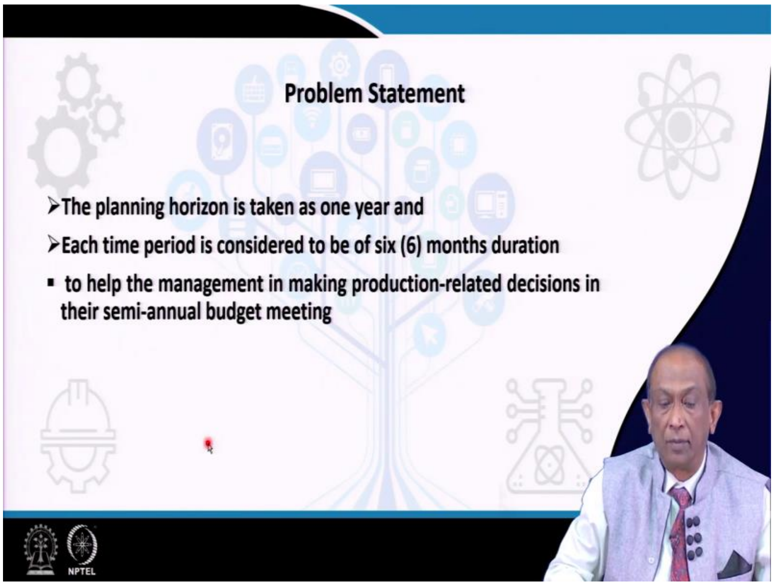

And before we get into that mathematical statement of problem formulation, we need to also state that the planning horizon is taken as one year and every year before the strategic planning of the company takes place the results of the decision support system must be made available to the planning managers.

And each time period is considered to be of 6 months duration because that will help the management in making production related decision in their semi-annual budget meeting. So, once again the planning horizon is 1 year and within 1 year each time period is of 6 months duration. So, there are two time periods within 1 year.

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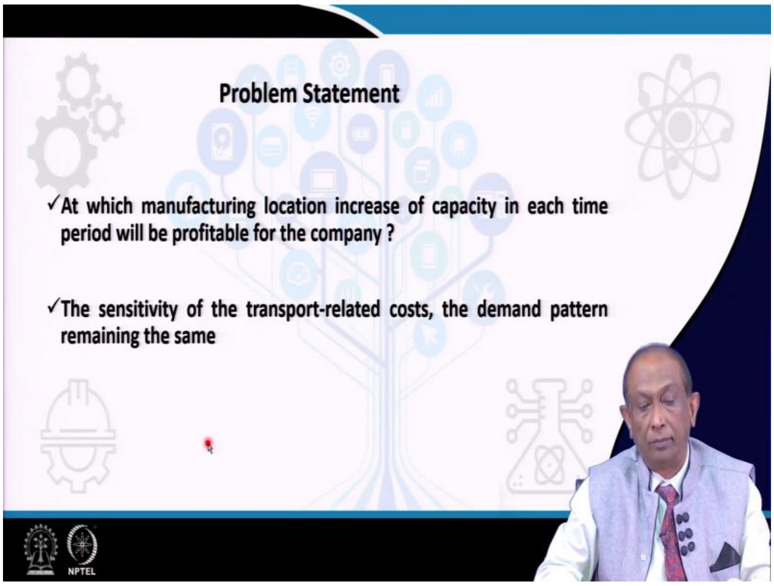

The management is also interested to know that, at which manufacturing location increase of capacity in each time period will be profitable for the company. And they also would like to know the sensitivity of the transport related costs, the demand pattern remaining the same.

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Related to collection of data the decision support systems personnel they collected forecasted demand for the products in each period at each of the warehouses that is the sales outlets. So, you require the forecast demand of different products in each period at each of the sales outlets and that was collected. Transportation costs for each type of products to be shipped from each plant to each warehouse were also collected.

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The other relevant data needed for solving this problem where the initial inventory level at each of the plants and sales outlets. The final desired inventory level for each type of products in each plant as well as in each warehouse so, initial and final inventory level for each type of products in each plant as well as in each warehouse were collected.

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The other additional data that were required or the available production capacity of the respective plants a regular time production cost of the different products as well as overtime production cost for each type of products in each of these plants.

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Inventory holding costs for each product that is for each type of items were also collected from the finance department. And also the DSS team they interviewed the operating managers to find out whether there are any other constraints due to technological restrictions or due to some existing policy of the firm and they have one such kind of constraints which was also noted and the relevant data collected.

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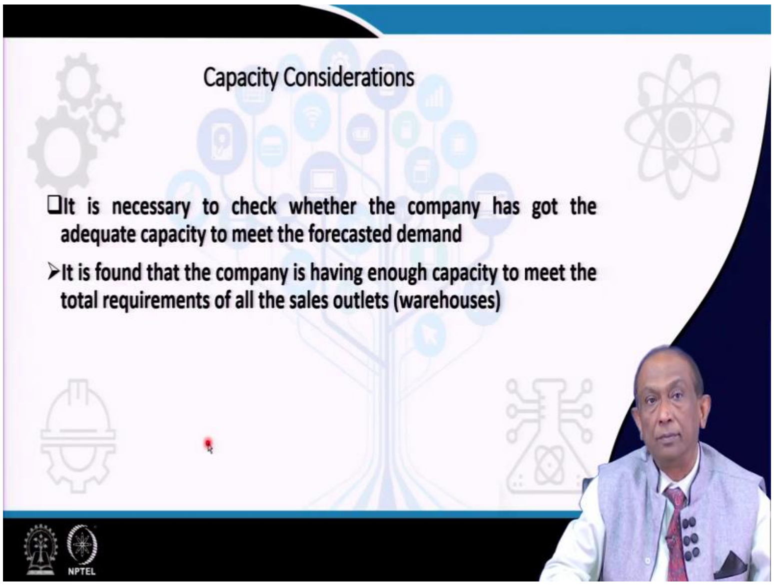

So, before the problem was solved it was necessary to check whether the company has got the adequate capacity to meet the forecasted demand that feasibility first need to be established. So, that capacity planning exercise was done separately and it was found that the company was having enough capacity to meet the total requirements of all the sales outlets that is the warehouses.

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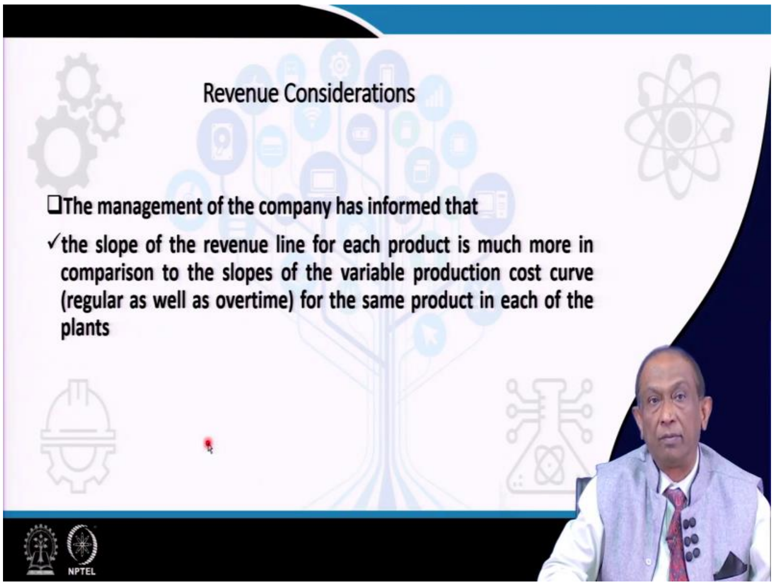

The management of the company has informed that the slope of the revenue line for each product rather the contribution of each product is much more in comparison to the slope of the variable production cost curve for the same product in each of the plants. So, definitely the products are profitable.

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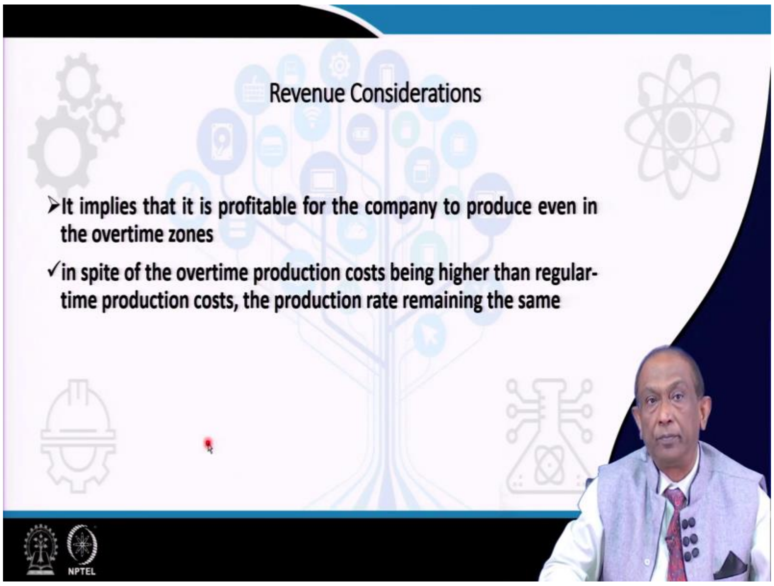

It implies that it is profitable for the company to produce even in the overtime zones. In spite of the overtime production costs being higher than the regular time production costs, while the production rate remains the same.

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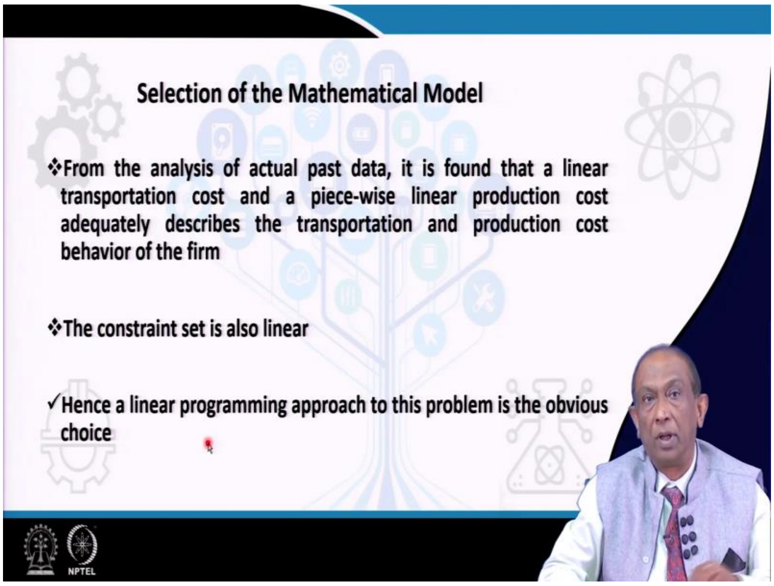

From the analysis of actual past data, it was found that a linear transportation cost and a piece wise linear production cost adequately describes the transportation and production cost behaviour of the firm.

The constraint set is also linear. Hence, a linear programming approach to this problem is the obvious choice accordingly a piecewise linear programming problem model was embedded in the decision support system. And in this lecture we are going to discuss about the formulation of that particular model.

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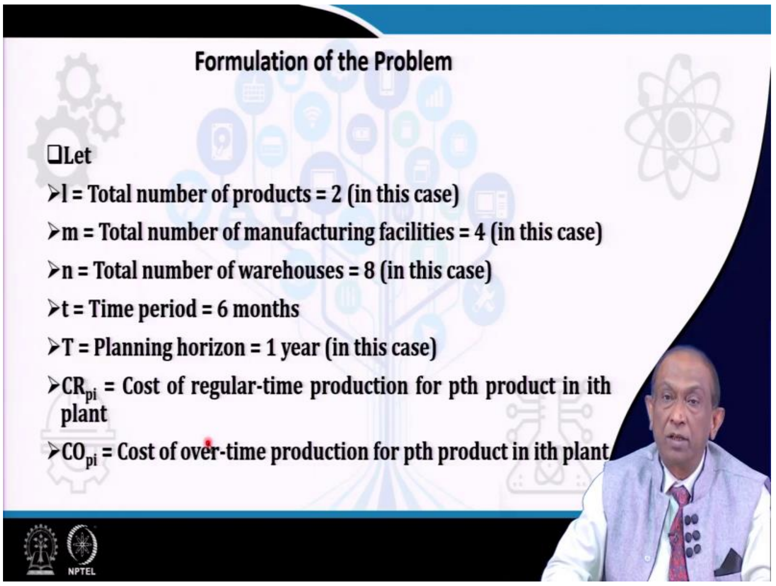

Now, there are some notations let l be the total number of products which is equal to 2 in this case, m denotes the total number of manufacturing facilities which is equal to 4 for this problem, n denotes the total number of warehouses which is 8 in this case, t is the time period equal to 6 months.

So, number of periods equal to 2 since the planning horizon which is denoted by capital T is 1 year. Let CR subscript pi CR pi equal to cost of regular-time production for the p th product in the i th plant and CO pi is the cost of over-time production for the p th product in the i th plant.

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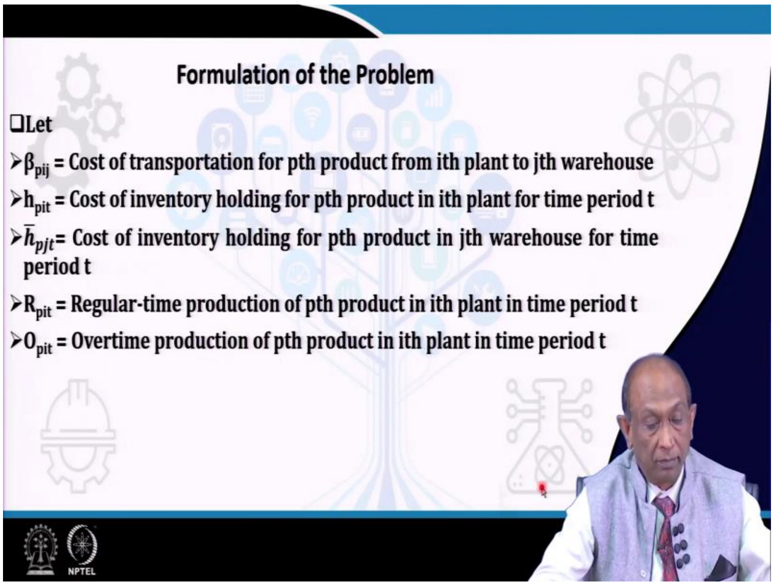

Beta pij if the cost of transportation for the product p from the i th plant to the j th warehouse, small h pit is the cost of inventory holding for the p th product in the i th plant for the time period t, h bar pjt is the cost of inventory holding for the p th product in the j th warehouse for time period t. R pit denotes the regular time production of the p th product in the i th plant in time period t and O pit is the overtime production of the p th product in the i th plant in time period t.

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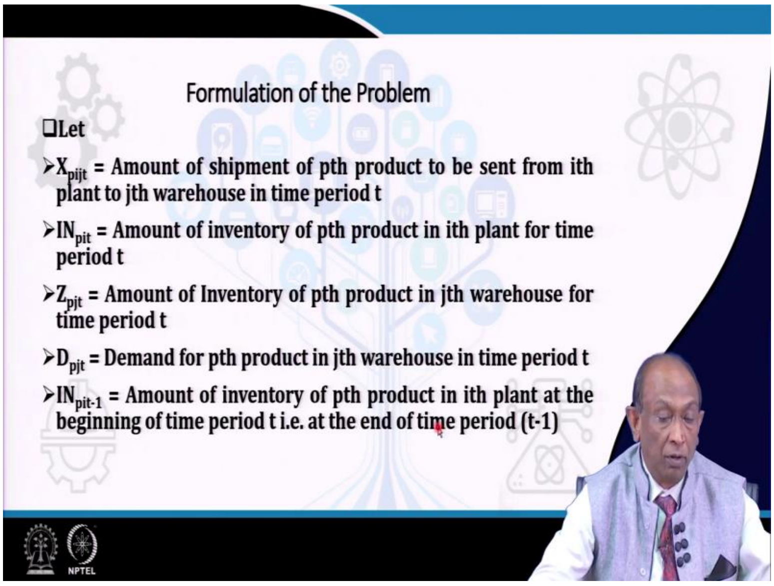

So, the decision variables are X pijt is the amount of shipment of the p th product to be sent from the i th plant to the j th warehouse in time period t. IN subscript pit is the amount of inventory of the pth product in the i th plant in time period t. Z th pjt is the amount of inventory of the pth product in the j th warehouse in time period t.

D pjt is the demand for the pth product in the j th warehouse in time period t and IN pit minus 1 is the amount of inventory of the p th product in the i th plant at the beginning of time period t that is at the end of time period t minus 1 initial inventory.

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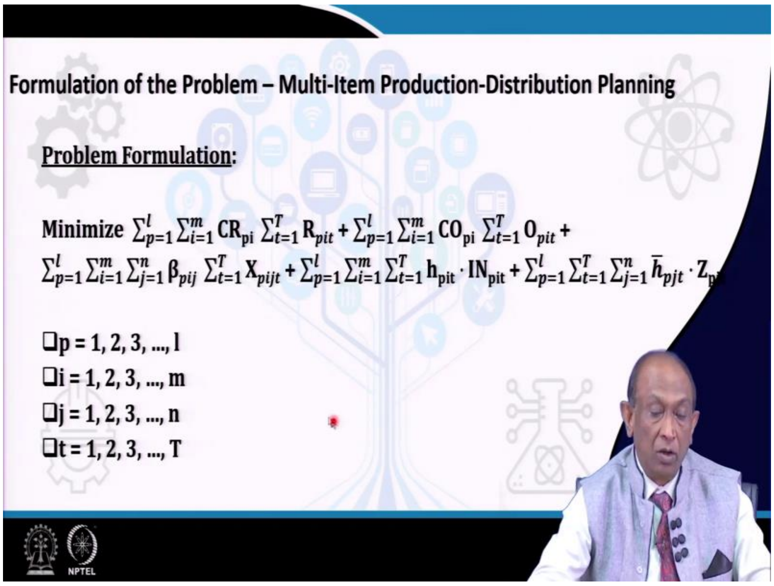

So, the problem formulation is minimize sum over p equal to 1 to l since we have two products. So, the value of l is 2 i varying from 1 to m, CR pi into R pit; that means this portion denotes the regular time production cost plus CO pi into O pit. So, this portion denotes the overtime production cost.

So, we are going to minimize regular time production cost plus overtime production cost plus beta pij multiplied by X pijt; that means, this is the transportation cost from the i th plant to the j th warehouse for the p th product and then we have summed it over. So, we are considering all the products and from all plants to all warehouses. This portion denotes the inventory holding cost at the plant level and this portion denotes the inventory holding cost at the warehouse level.

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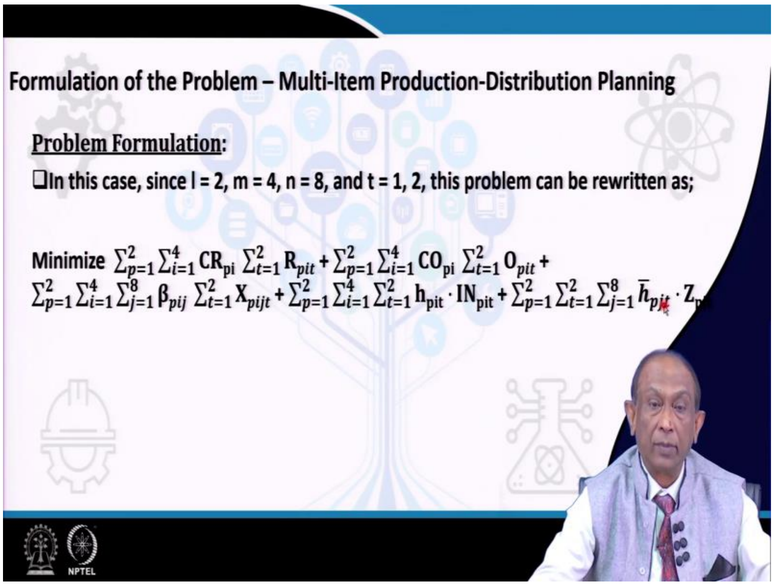

So, when we are putting the corresponding values we get the objective function like this. Constraints; first constraints is we have total 14 Constraints for material balance at plants.

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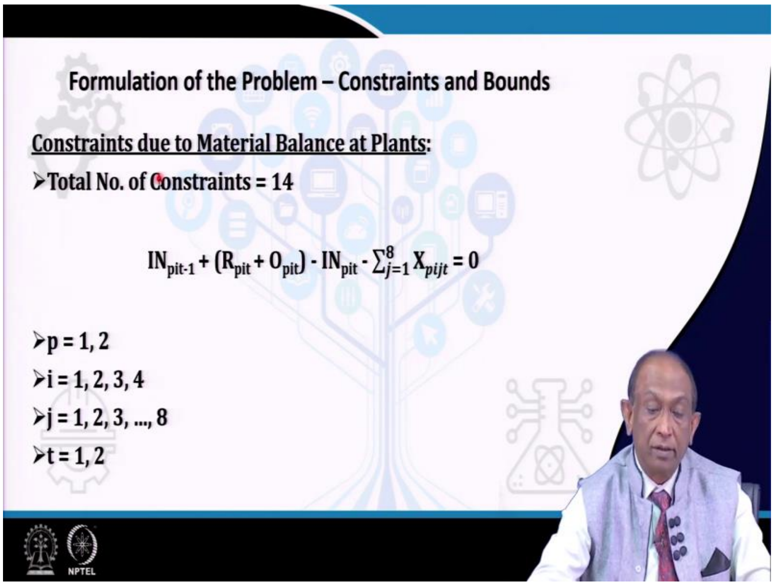

So, this equation is initial inventory plus the sum of regular plus overtime production minus the dispatches from the plant to the warehouses will give raise to the final inventory of the product be at the plant i for the time period t.

That means the material balance equation is initial inventory plus the sum of regular and overtime production minus the dispatches will give the final inventory we have made side transfer. So, we get this equation and when we consider all the products all the plants and the all the warehouses total number of constraints will come out to be 14.

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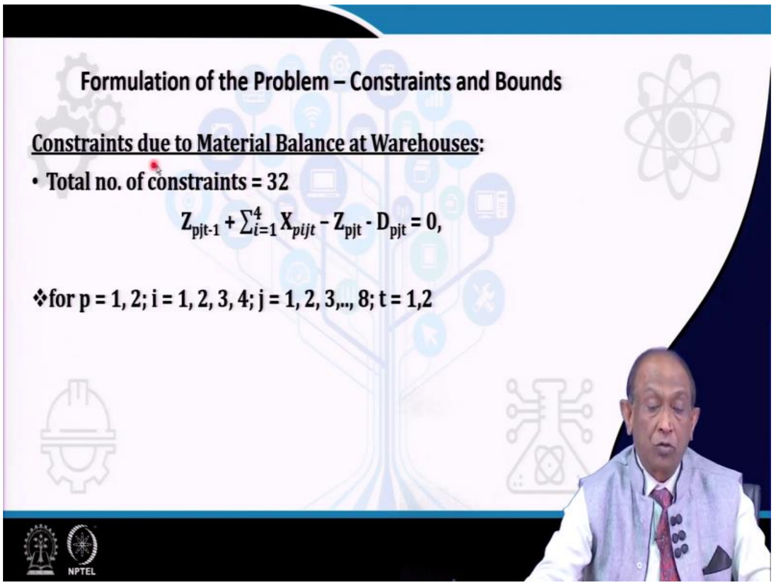

Constraints due to material balance at warehouses. Here again the initial inventory for a product at a particular warehouse plus the total amount of receipt for the same product from all the plants to that particular sales outlet in that period; minus the demand for the same product from that sales outlet in that period will give raise to the final inventory of the product p in that sales outlet over the time period t. So, we have 32 constraints.

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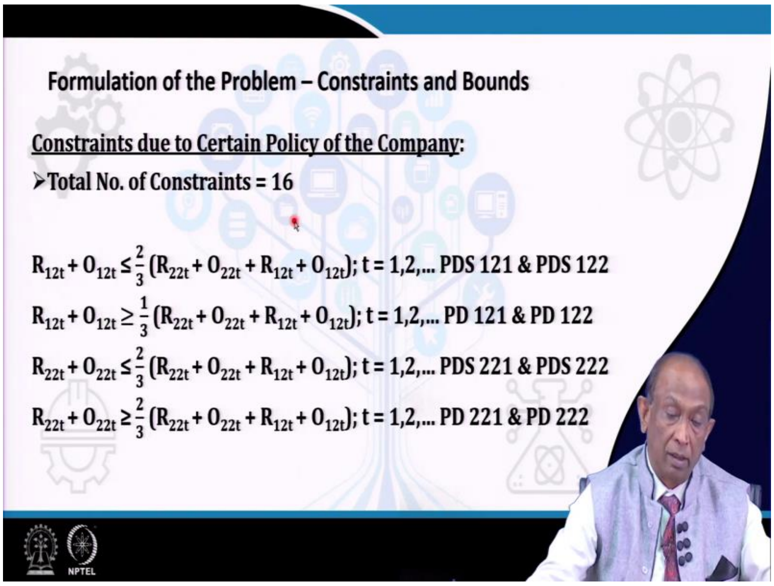

There were constraints due to certain policies of the company what they said that for the product 1; in the second plant over a time period t a regular time production plus overtime production for the first product in the second plant must be less than equal to two- third of the total production considering the second product.

So, the total production for the first product in the second plant must lie between one-third of the total production considering all the products but less than two-third. So, this is basically a policy level constraint, and this constraint is also for the second product like this, there are certain policy constraints which have been incorporated.

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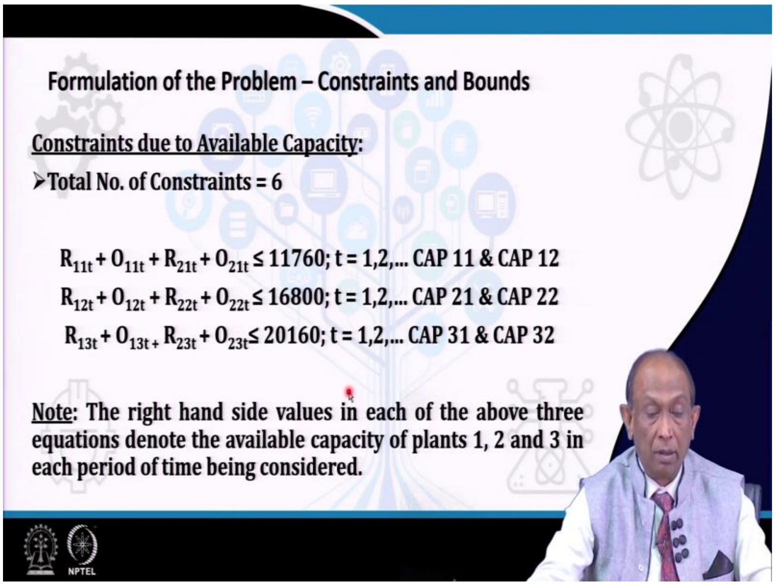

Constraints due to available capacity total number of constraints are 6 the first equation is regular time production. For the first product in the first plant over time period t plus overtime production plus the regular time production for the second product in the first plant plus the overtime production of the second product in the first plant in the same period.

So, this is the total production in the first plant, considering both regular and overtime and both the products combined that must be less than equal to sum value which we have specified by the company management for the first plant depending on the capacity planning exercise that they had done.

Similarly, in the second plant the total capacity restriction in terms of numbers were this much and for the third plant, for the fourth plant they did not specify anything. So, the right hand side values in each of the above 3 equations denote the available capacity of the plants 1, 2 and 3 in each period of time being considered.

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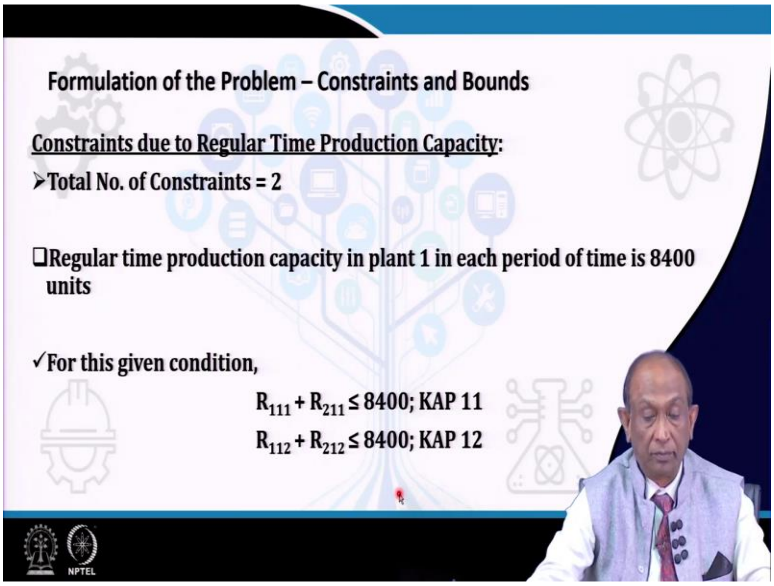

Constraints due to regular time production capacity, the regular time production capacity in plant 1 in each period of time is again given in terms of some number of units. So, for this given condition we have these 2 sets of constraints.

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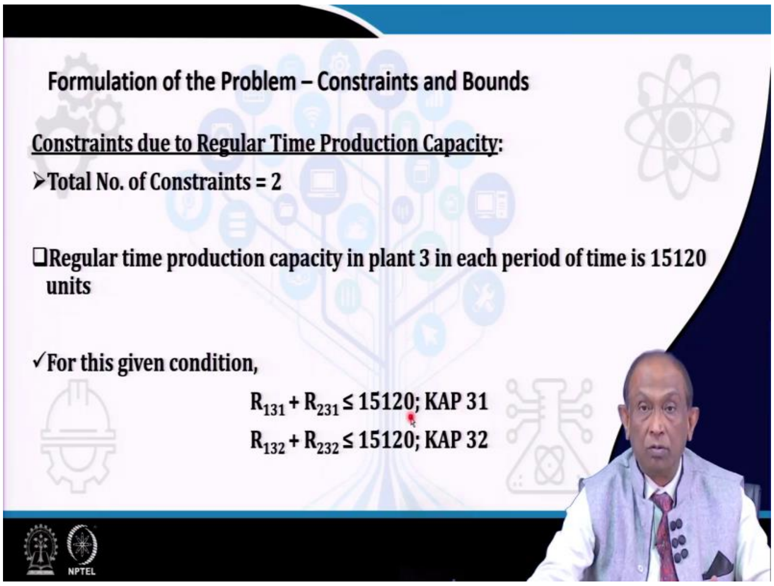

Similarly, for plant 2 and plant 3 these are the restrictions for regular time production capacity.

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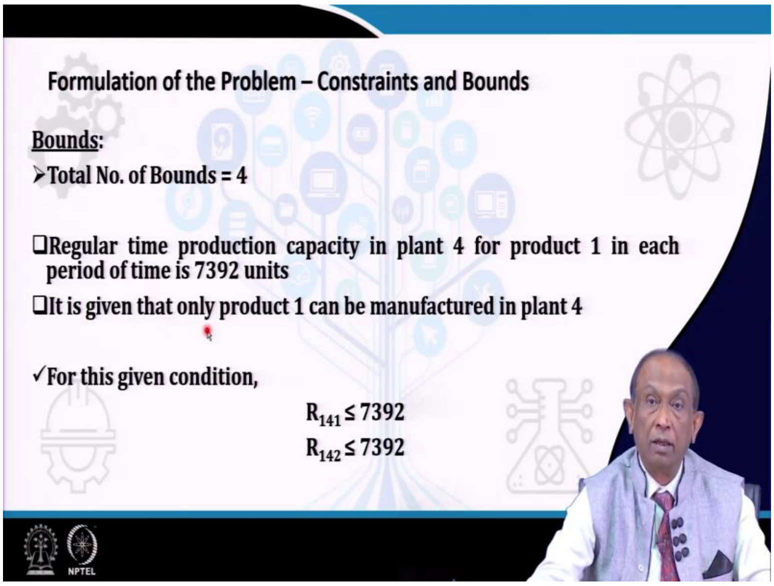

And there were certain bounds there were 4 regular time production capacity in plant 4 for product 1 in each period of time is given and it was mentioned right in the beginning that only product 1 can be manufactured in plant 4. So, for this condition we have these two inequalities.

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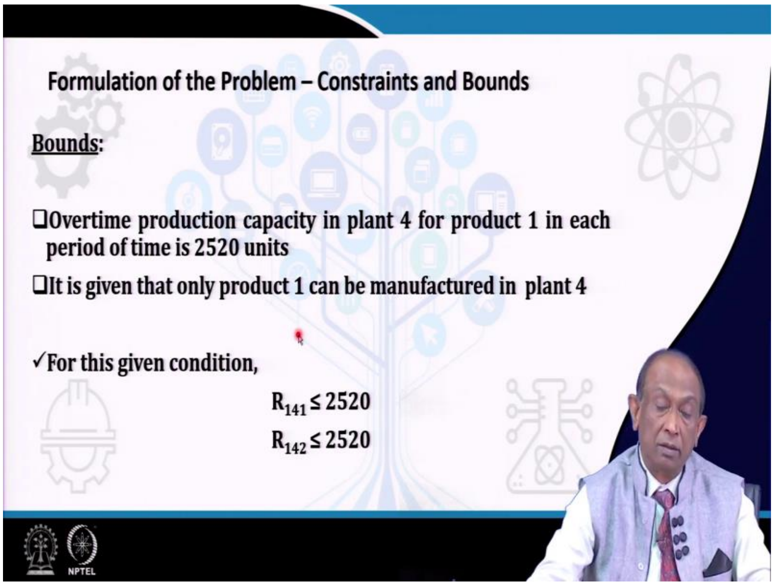

Similar inequalities were obtained considering overtime production capacity in plant 4 for product 1 and that limit was 2520 units. So, for these given condition these two inequalities hold good.

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And these are the references that were used for formulating this problem; this problem was solved by embedding some python code inside a decision support system because they wanted to be a regular exercise for their semi-annual budget and strategic planning process.

Only thing the capacity restrictions instead of the numbers that were supplied, the code was designed in such a manner that these right hand side constraints were equated to some variables, where the managers can periodically change the right hand side constraint values and the linear programming problem was solved. Such kind of problems also if one wants to carry out a one-time exercise, they can use excel solver.

But in that case you have to use the premium solver version because the problem size can be very large. And then like what we discussed in the product mix problem, you can carry out sensitivity analysis to give answers to those questions which the management was interested in right at the beginning of the problem we studied that. So, thank you all for your cooperation and support!

Thanks a lot!