Production and Operation Management
Professor Rajat Agrawal
Department of Management Studies
Indian Institute of Technology, Roorkee
Lecture 31
Aggregate Planning Techniques-I (Introduction)

Welcome friends, so in our last session we were discussing about Aggregate Planning Techniques. And we discussed that there are primarily two techniques, two strategies which are available, which we call as pure strategies for aggregate planning. These are level and chase strategies.

In level, we maintain a constant level of output, in chase we follow the demand pattern, if demand is increasing we increase the supply, if demand is less we decrease the supply. And then we can also use a combination of level and chase that is the third type of strategy that is mixed strategy.

So, in practice most of the time we use mixed strategy because in that you can take the advantage of level as well as chase strategy because both these strategies have their own inherent advantages. Sometime it is good to maintain a level output because in that case you need not to change your resources on a regular basis, sometime because fluctuating resources create lot of other issues also.

Particularly if you see, if you are regularly hiring your employee's laying off your employees then motivational issues may also come. We do not discuss those things in our operation management classes, but if you go to a class of human resource management, so then you can realize that if such kind of environment is there where workers are continuously under stress that tomorrow if demand is not there, weather their job will be there or not. So, it creates lot of stress, it creates lots of issues related to motivation of those employees.

So, I discussed in our last session that in Japanese system we normally follow a level production system where you have a constant rate of output and therefore even if demand is very low they will not lay off their employees because they know that it is going to affect negatively the environment in the organization.

So that is not purely a cost related issue, but it is more related to positive environment of the organization. But sometime the cost issues are also very significant, very important for the organization. And many a times, we do not hire workers on regular bases, we keep a very low number of employees on the regular bases and rest of the employees we hire on the bases of our requirement.

So, if you have more projects in hand, if you have more demand in hand, you increase the supply of your workers and try to achieve the output. And when the demand is not there, so they all will not be working for you, so that is as good as laying off your employees. So these are the common scenarios in the industry, in the practice and you must have seen around you also.

Now, in this particular session we will evaluate quantitatively, we will evaluate mathematically that how to optimally use the combination of various decisions variables. So various decision variables, I mean to say that we discuss that there is a possibility of overtime. So how many overtime hours we should go in a particular week.

There is a possibility of subcontracting, how many units we should produce using subcontracting. There is a possibility of stocking the inventory, so how many inventories we can stock on weekly bases. All these are, all these questions are nothing but decisions variables. So, I need to take a rational decision, I need to take a optimal combination of these decision variables. And for that purpose there are good number of mathematical techniques available with us. And in this particular session we will see that how to use those mathematical techniques.

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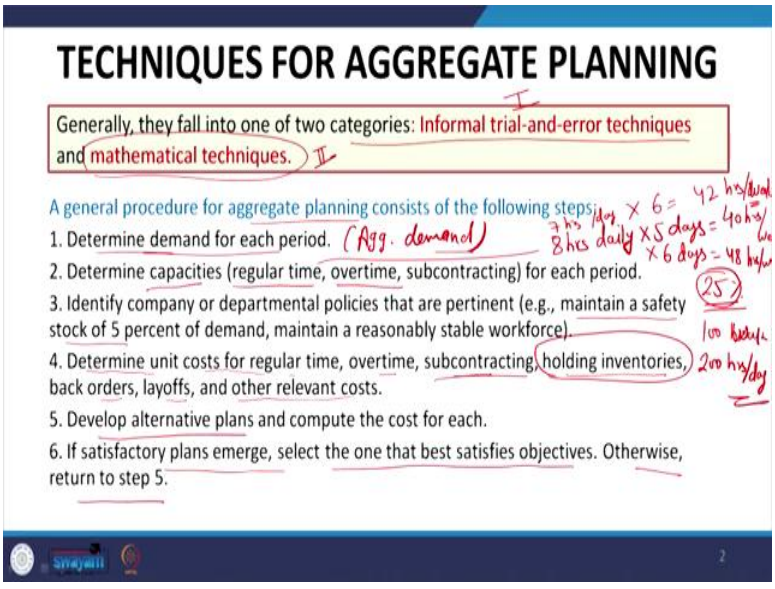

Now, to start our discussion, so there are two types of you can say two categories of solution process, one is trial an error techniques and the second is more accurate techniques which are mathematical or quantitative techniques. So you can use because when we are talking of

mathematical techniques or the techniques for aggregate planning the cost of doing or cost of applying those techniques is also important.

So how much benefit you are going to get and how much resources you are using for getting that solution. So if you are going to have a more robust mathematical technique that will require more costlier resources and that may not be desirable all the time. So in that case informal trial and error method may be more suitable, but somewhere cost parameters are very much sensitive and in that particular case you need to gover very sophisticated solutions and in that particular case, quantitative techniques more sophisticated mathematical algorithms are useful.

Now, what is the general process, general steps which we follow in our aggregate planning. Let us see what are those steps. So the first step is to determine demand for each period. So, what is the aggregate demand? Determine demand means aggregate demand, because you have already seen that we are not talking of each end product, we are talking of some total of all the end products, so we are talking of aggregate demand in this particular case.

Second is determine capacities. With respect to regular time, what is the regular time available? So, sometime you have a situation that 8 hours daily and week is of 5 days. So each worker is available to you for 40 hours per week. In another factory it is a 6 days week, so regular time may be 48 hours per week.

In some other factory workers are working only for 7 hours a day and they enjoy one hour of lunch and it is a 6 days of week kind of arrangement, so it has 42 hours per week. So, this is the regular time capacity available per worker. And then depending upon the number of workers in your plan, if you have 100 workers, so 4,200 hours are available, 4,000 hours are available or 4,800 hours are available that may be the availability of the resource on the regular time bases.

Overtime bases, country to country there are conditions that overtime cannot be X percentage of regular time. So if in India, let us say this condition is 25 percent that if one employee is working for 8 hours a day for regular time so he cannot work more than 2 hours on overtime in a day. So you can also determine the capacity of overtime available with you.

So if you have 100 workers per day, if 100 workers are there so your capacity is determine by 25 percent of regular time. So you have 200 hours per day, as your overtime capacity.

Similarly subcontracting capacity, if you have 2 subcontractors and their capacity is 100 units per day, so you have total subcontracting capacity as 200 unit per day.

So with that type of arrangement, you should know that how much capacities of different type are available with you. So assessing the demand, assessing the capacity, these are the first two steps. Then third is identify company or departmental policies that are pertinent, for example maintain a safety stock of 5 percent of demand. Maintain a reasonably stable work force, so in your organization you have some such type of policies, so what are those policies of your organization.

So it is again in your hand that what type of safety stock level you want to maintain, 5 percent, 10 percent, 20 percent etcetera and what is the reasonable level of work force output you want to maintain, so that policy you have to determine and that is the organization level activity.

Then next step is determine unit cost for regular time, overtime, subcontracting, holding inventories, backorders, layoffs and other relevant cost. You need to determine the cost parameters with respect to all these different types of decision variables. If am going to stock one unit for one week, I am going to stock one unit for one week, so how much it is going to cost me.

It may cost me 2 rupees per week to hold 1 unit in my stock. So that becomes an example of cost of holding the inventory. If I am producing 1 unit in regular time, so cost of production is coming 60 paisa, if I am producing 1 unit in regular time, the cost of production is coming 60 paisa, but if I am producing the same unit in overtime period the cost of production is coming 75 paisa.

So, maybe regular time and overtime always overtime is costlier than the regular time. So that is the cost parameters with respect to regular time and with respect to overtime. Similarly subcontracting, if I am making a product on my own the cost is coming 60 paisa per unit, but when I am making this product through some subcontractors the cost may come 80 paisa per unit, because subcontractor will also take some profit. So, that is the additional cost of subcontracting.

And similarly cost of hiring, cost of laying off whenever I am hiring a worker I am incurring a cost of let say 100 rupees per worker for hiring. Whenever I am laying off a worker I am incurring a cost of 40 rupees per worker for laying off, so these are the cost parameters with

respect to hiring and laying off also. So whatever type of decisions variable are there which we have already discussed in our previous session, according to them we need to determine the cost parameters. Because these cost parameters are the most important thing in deciding our combination of various decisions variables.

Develop alternative plans and compute the cost for each then you can think of various combination these decision variables. You can think of various combinations of these decision variable and these combinations are alternative plans. And whatever alternative plans you have thought of then on those alternative plans you have to compute the cost for each of these plans.

So whichever plan gives you least total cost that is the most suitable plan for our adoption. So that is, so if satisfactory plan emerges select the one that thus satisfy objectives otherwise return to step 5. Otherwise we need to develop more alternative plans and then see, which plan is more suitable for our purpose.

So normally, the idea is simply that whichever plan gives you the minimum possible cost that is the suitable plan for our aggregate planning. Now, first as we just discussed that there are two methods, one is informal trial and error technique and the second is more robust kind of technique that is the mathematical technique.

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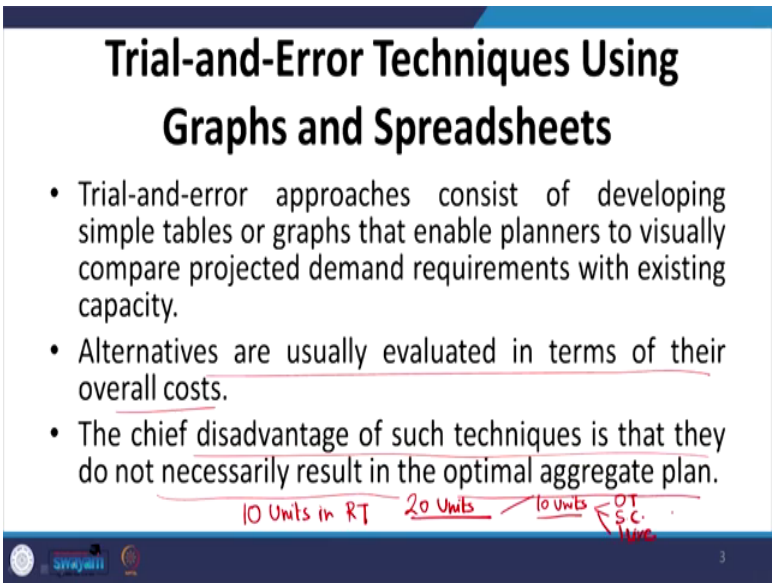

Let us discuss this trial and error technique using graphs and spreadsheets. Now, in this trial and error approaches which consist of developing simple tables or graphs that enable planners to visually compare projected demand requirements with existing capacity.

If you recall in our previous session, we discussed two types of strategy level and chase and we discussed those strategies with the help of diagrams that this is my normal capacity. And as with respect to normal capacity sometime demand is increasing, sometime demand is decreasing and that was helping us to visualize that during the period of demand extra demand some back orders are generated and these back orders will be full filled when the demand will be low. So that type of system we have seen.

And we also saw that how with the demand I can follow the chase strategy and I can increase or decrease my capacities. So that is the visual representation of our demand pattern and the supply pattern. Then alternatives are usually evaluated in terms of their overall cost.

So whatever type of strategy, whatever type of combination you are going to follow so you are going to compare normally on the bases of their overall cost. The chief disadvantage of such technique is that they do not necessarily result in the optimal aggregate plan, because you can evaluate only some limited number of alternative plans.

All possible alternatives cannot be evaluated, you can think of some limited number of alternatives 2, 3, 4, 5, but there can be infinite such combination. I say that how I am saying that there can be infinite number of combination, there is a option that I can make 10 units in my regular time and there is a demand of 20 units which I have to fulfill.

Now, additional 10 units there are multiple options for these additional 10 units. You can use overtime, you can use subcontracting, you can hire more workers, now these 10 units can be divided between overtime, subcontracting and hiring of the workers in multiple ways and all those combinations will not be possible, will not be feasible to calculate under this trial and error approach using the spreadsheet.

So I can evaluate some limited number of alternatives, but it may not guarantee me, it may not guarantee me that this is the best solution or this is the optimal aggregate plant. This is the lowest possible cost that I cannot guarantee. I can only guarantee that within the available options, within the considered options this is the best solution.

So that is the biggest you can say limitation drawback of this system that manually or even with the help of computers you can evaluate only limited number of options and mathematical technique will certainly help us that is the major advantage of mathematical technique over these trial and error system that you can say yes, definitely, this is the best

solution which is there for this particular system. Because that is helping in infinite solutions and out of that infinite number of solution you take the best solution or the optimal solution.

Now, the assumptions which are to be followed or on the bases of which this trial and error method is developed, let us see what are those assumptions quickly.

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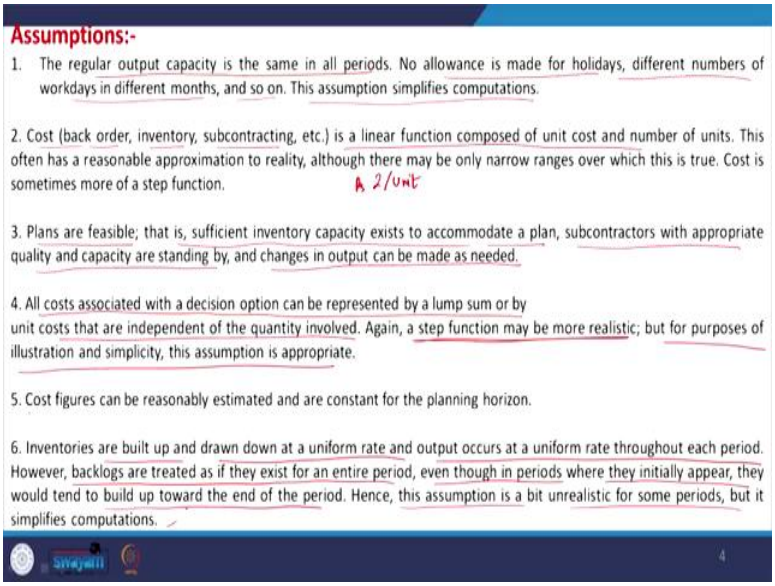

The regular output capacity is the same in all periods. So in all periods the regular output capacity is similar, no allowance is made for holidays, different number of work days in different months and so on. And this assumptions simplifies our computations. In practical it is possible that if it is a month of March or it is a month of October and you have more number of holidays in that, so even if you have constant number of employees, but because of number of holidays are changing in month to month, some month may see 5 Sundays, some month may see only 4 Sundays.

And because of that also the output in a particular month may vary. But here we are assuming that in all the months the output is similar, output is same so we are not taking into account the number of holidays etcetera in a particular period.

The second is though practically it may happen, but for the sake of our calculation model building we are not taking that into account. The second assumption is cost, the cost related to backorders, inventory and subcontracting these important costs will come again and again, is a linear function composed of unit cost and number of units.

That if cost of you can say subcontracting is 2 rupees per unit, rupees 2 per unit the subcontractor says that I will make units at the rate of 2 rupees per unit. So whether you are asking subcontractor to make 1 unit or 100 unit, he will charge at the same rate of 2 rupees per unit. Normally it is possible that if you say to a subcontractor that I want 10 units or 20 units he will charge 2 rupees or 2 rupees 25 paisa.

And when you say that I am giving you an order of 100 units then he may charge 1 rupee 80 paisa. So may be it is possible that with respect to change in quantity when you are giving order in large quantities this subcontractor may charge a lower rate. But we, so if it happens that with respect to quantity the cost parameters are changing then it is a nonlinear relationship.

Here we are assuming that cost is a linear function and it is composed of unit cost end number of units. So with respect to backorder, so weather it is a backorder of 1 unit or backorder of 50 units. So if penalty is 25 paisa per period for 1 unit, so irrespective of how many units are there it will be calculated as a linear function. So that is the second assumption.

The third assumption is plans are feasible that is sufficient inventory capacity exist to accommodate a plan, subcontractors with appropriate quality and capacity are standing by and the changes in output can be made as needed. If subcontractors are not available the quality of subcontractors are doubtful. And you do not have confidence weather they will be fulfilling the requirement or not, then this whole plan is not possible.

So we are taking this assumption that our subcontractors are well qualified, they have enough capacity and we can execute, whatever type of plan we develop we can execute that type of plan. Whether it is with respect to inventories, whether it is with respect to subcontracting, whether it is with respect to overtime etcetera.

So if I develop a plan were I say that each of my employee has to do overtime of 2 hours daily, but then I realize that my workers union is not supporting me. Worker union say that we are not going to have any kind of overtime, we will not like to work overtime, we have our other activities involved, and so in that case this mathematical program will not be able to help me. So I am assuming that all the things are in proper place and whatever is the outcome that I am able to execute.

Then another assumption is all cost associated with a decision option can be represented by a lump sum or by unit costs that are independent of the quantity involved. Again, it is to some extent an extension of 0.2 hour that all these things all the cost associated with our decisions can be expressed in terms of unit quantities. And that again gives the idea that cost and the units are linear function to each other.

Then though, we have also mentioned that a step function may be more realistic that this relationship may change with more number of quantities, you will enjoy a some economies of scale. And therefore, if I am producing 5 units the cost will be per unit much higher, but if I am producing 50 units cost of production per unit should decrease.

So it says that step function may be more realistic, but for the purpose of elastration and simplicity this assumption is appropriate that cost of production in regular time is again considered to be a linear function of quantity. So in practice it is good to have a step function, as we understand of economies of scale.

Then another assumption is cost figures can be reasonably estimated and our constant for entire planning horizon. So our these cost parameters, which we considered in second and in forth all these parameters, all these values of cost are going to remain constant in the planning horizon. Then another is inventories are built up and drawn down at a uniform rate and output occurs at a uniform rate throughout each period.

However, backlogs are treated as if they exist for an entire period even though in periods where they initially appears, they would then do built up towards the end of the period hence this assumption is a bit unrealistic for some periods but it simplifies our computations.

What we understand that inventories are built up and drawn at a uniform rate. So inventories are built up at a uniform rate and these are drawn also at a uniform rate. But what happens in practice, normally, inventories are built up at the end of the period because initially you are consuming and whatever is the demand these are consumed and inventories are built up in some step functions.

If you remember the diagram which we had in our previous session, so building of inventory and consuming of the inventory was shown as a step function. But the assumption which we are taking that it is a uniform rate at which inventories are built up or consumed. So it is more like in our assumptions we are assuming that it is like a saw teeth pattern, where a kind of slope is there for the consumption rate and slope is there for the production also.

So it is more matching with our EPQ model, Economic Production Quantity model the assumption is mention in that we are developing the inventory in a constant rate and consuming also in a constant rate, but practically what happens inventory is built up in the step function and inventory is consumed also in the step function way. But because of simplification of calculation we are considering these assumptions.

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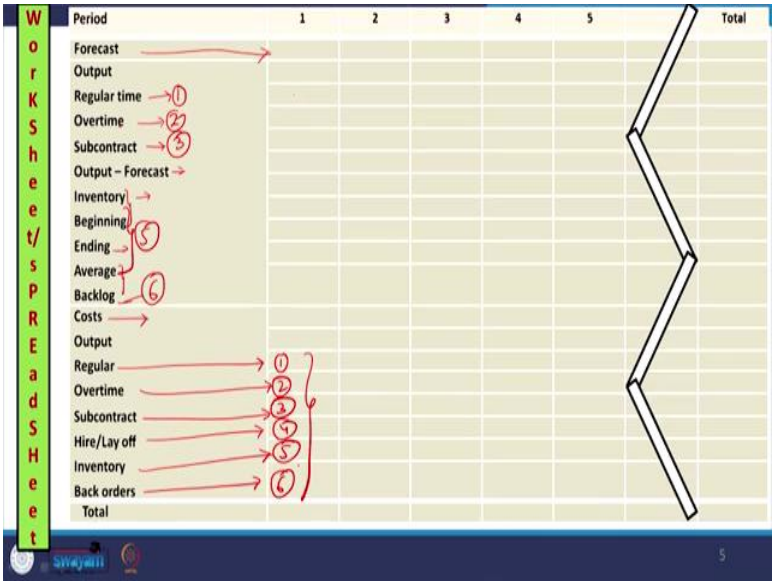

Now, this type of work sheet we use for our understanding and on this type of worksheet we are going to do the calculation. Now, let us see what are the different type of components of this worksheet. Here these are the periods and here you have the forecast available the aggregate forecast for different periods.

And now, output of regular time, overtime, subcontract output form the forecast, the inventory beginning and this is inventory beginning, the inventory ending and average, the backlog all these type of calculation we do and on the bases of that you are calculating the different types of cost.

So here the regular cost, so whatever is you are producing in the regular time depending upon the cost of regular production that cost value will come here. The output of overtime, if I say that regular time production, so regular time cost will come here. Overtime production, so overtime cost will come here. The subcontract production subcontracting cost will come here.

Similarly, depending upon your laying off and hiring of employees that type of cost will come here. Depending upon your average inventory level, so this inventory beginning, ending and average so sometime we pay inventory cost on depending upon situation to situation you pay inventory either on the bases of ending inventory or the average inventory.

So on the bases of this inventory issue you have the inventory holding cost. And then if some backlogs are there, so you have to pay some penalty on those backlogs. So how many orders under backlog, so that number is here and on the bases of that you incur the backlog cost also. And then you get the total of these different cost for different periods. And depending upon the type of strategies you will have different level of values for the output and on the bases of these outputs you will create these different types of calculation. So this is our chart this is our, you can say spreadsheet for development of the calculation for trial and error method.

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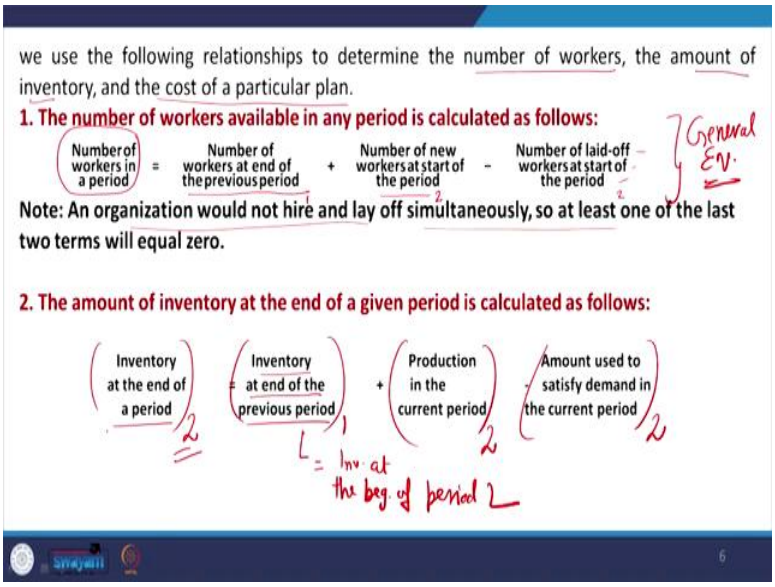

So in this trial and error method we use you can say some of the calculation methods like number of workers in a period, how to determine the number of workers in a particular period. So now number of workers at the end of the previous period plus number of new workers at start of the period, minus number of laid-off workers at start of this period.

Because in a period you have to take determine you have to take the decision about the number of workers and you have to take decision about the inventory level and then the cost of a particular plan is evaluated. So just giving you the example that how the number of workers at a particular period is evaluated and because depending upon the number of workers at a particular period you know what can be the regular time output, what can be the overtime output.

Both these regular time and overtime output is dependent on the number of workers at a particular period. So number of workers at the end of the previous period, so if I am talking of second period, so how many number of workers were there at the end of first period,

number of new workers at the start of these period, how many new workers I have hired in this particular period.

So number of workers at the end of second period… at the end of first period, new workers hire in the second period and number of laid-off workers at the start of this period. So maybe some workers are hired, some workers are laid-off, so on the bases of that you get the number of workers in a particular period.

And that will decide the regular time availability and the overtime availability for a particular period. An organization would not hire and lay off simultaneously, so this equation which is it is a very general equation, but out of these two terms, last two terms in this equation one of them will be 0 because you will not be hiring and laying off simultaneously, either you will be hiring or you will be laying off.

So out of these two, one will be 0 at a particular period. The second is you will calculate the amount of inventory at the end of a given period. So as I mentioned sometime, we calculate the inventory cost on the bases of average inventory, sometime we calculate the inventory cost on the bases of ending inventory.

Now, the calculation of ending inventory is, inventory at the end of the period is inventory at the end of the previous period. If I am talking of inventory at the second period so at the end of previous period means first period and production in the current period, production in the second period, minus amount used to satisfy demand in the current period that is the second period.

So with this what was the ending inventory of the previous period plus what you produce in the current period minus what you consumed in the current period, so whatever is the left with you that is the inventory at the end of the period number 2. And that is because this inventory at the end of the previous period 2 is equal to inventory at the beginning of period 2 also, it is also inventory at the beginning of the period 2.

So in case your inventory cost is calculated on the bases of average inventory, so then you have to take the average of this inventory at the beginning of this period 2 and inventory at the end of period 2 divided by 2, so that becomes the average inventory for period 2. So it depends that in some situation we calculate the inventory cost on the basis of ending inventory and in some situation, we calculate the inventory cost on the basis of average inventory.

So if it is on the basis of the average inventory, so you have to take average of this term and this term divided by 2 and that is going to give you the inventory cost. So now we have understood the formula for calculation of our regular time, overtime, inventory, availability etcetera. And now, we will use some numerical example to showcase the use of this formula and how we are going to use this in our spreadsheet that we are going to do in our next session, thank you very much.