Course Name - Operations and Revenue Analytics

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Week - 02

Lecture - 09

Welcome, friends. So far, we have been using forecasting-related issues under analytics, which is a very important area for decision-making. We discussed that forecasting is, in fact, an input for various other planning activities that we do in operations management. We discussed how different types of forecasting methods may use descriptive and predictive analytics. We discussed, with the help of time series analysis and regression analysis, that many predictive analytics methods are possible to use because of the different types of characteristics you may have in your historical data. Moving further, another very important area that we discuss in operations management is inventory management.

We all know that when we have a forecast, we need to plan our entire resources using that forecast as a consideration, and for that purpose, a lot of raw material is also required. Then, we also need to consider the requirement that this much will be the demand, and how many finished goods I should have in my stock so that I can fulfill that market demand. Based on the production capabilities, I also take care of how I should have a minimum level of work-in-process inventory. So, there are many areas of inventory-related decisions in operations management.

So, in this particular session, we are going to discuss what inventory is, the role of inventory in operations management, some of the interesting terms like cycle inventory, the cost of inventory, all these things, and very quickly, we will also focus on a very common model of inventory management that you all know, which is the EOQ model. That also we will introduce here, and then the role of analytics comes into the picture when we try to understand different types of uncertainties in our external environment. We know that forecasting is just one estimate, but there can be a lot of fluctuations and errors in my forecasting data, and that will lead to some kind of uncertainty in the demand. If I know with 100 percent confidence that tomorrow there will be a requirement of 100 units.

So, today I will procure only 100 units so that I can fulfill the demand of 100 tomorrow. But, all of you will know from your common sense that it is next to impossible to say that the demand will be 100 units. It is quite possible that it may be 98 or it may go up to 105. So, considering all those uncertainties, how should we plan our inventory management? That will be the more important discussion in this particular session. So, with this, we start, as I already said, that inventory is very much required for fulfilling the requirements of our customers.

Now, as I said, there are different types of inventory: finished goods, work in process, and raw material. And you need to keep inventory because there will always be a mismatch between supply and demand. Sometimes you have uncertainties in your supply, sometimes you have uncertainties in demand, and sometimes you have uncertainties in both supply and demand. So, because of all these uncertainties between the supply and demand sides, because of this mismatch, you need to keep inventory. And now the more important issue is that for improving customer service, we should have more and more inventory.

When we are keeping the inventory, the cost is also going up; the cost is up. So, therefore, the requirement is that we need to optimize this inventory system in such a manner that you should have a decent level of customer service and, at the same time, your cost is also not increasing too much. So, that is a very interesting decision-making problem: what should be the optimal level of inventory that will help you in improving customer service and, at the same time, the cost of keeping the inventory is also not too excessive. Therefore, we have two very important questions for which we are expecting answers. The first question is: how much to order? You are going for repeat and repeat orders; there may be some scenarios where you are going only for a single order. But, if I consider a business which is a regular business, so you have to order, let us say, every month, every fortnight, every week, or whatever frequency you have.

So, how much to order, what should be the order quantity, Q, and the second important question is when to order. Should we order on the basis of some quantity level, or should we order on the basis of a time interval? You may say that, okay, I am going to order a new lot whenever the present quantity, the present stock, goes to, let us say, 10 units. I am going to place a new order. I say that I am going to place an order after every 15 days. So, we both may have our own policies, whether we are following a quantity level decision on when to order, or I am following a time-based interval for deciding when to order. In both situations, how much to order is an important question always.

Now, as I already explained, there is a significant trade-off we have to do, a significant optimization we have to perform. In earlier scenarios, we used to do this once in a year, kind of a situation. But now, we are living in the analytics world, where it is quite possible that we can do it on a regular basis. The important terminologies, now let us discuss. Whenever you are placing the order, I will explain with the help of this diagram that when you are having some annual requirement, that is, let us say, R. This is my annual requirement.

Now, you are not going to place R order quantities in a single order. You have divided R into Q quantities, and the sum of Q in one year equals R. You are placing some n number of orders in a year. Every time you are placing an order of Q quantity, and the sum of those Qs equals R. So, here we are placing the order of Q quantity, as in this illustration, it is given that Q is, I am considering Q equals 100. Now, once you give the order, you have received the Q supply. And then you start the consumption of these Q over a period of time.

These Qs are good enough for 10 days, and then again, a new supply comes like this, and you are consuming this over a period of time, again 10 days, and then again, a new supply comes. And in this way, this pattern is going, and this is known as the Saw Tooth Pattern. This is known as the saw tooth pattern, where you are getting the supply, you are consuming the supply, getting the supply, consuming the supply, getting the supply, consuming the supply, and so on. In this way, every time I am placing the order of Q quantity, that is known as the Lot Size. Now, Cycle Inventory is actually half of this lot size, lot size by 2, Q by 2, that becomes my cycle inventory.

Cycle Inventory= Lot size/2

Cycle inventory, in a way, is average inventory, average inventory that is there, and it is very important for us to know about this cycle inventory because most of our cost calculations are happening on this cycle inventory basis. So, because this is the average amount of inventory which you always have in your stocks, this is the maximum inventory Q, and this is the zero level; this is Q, this is 0. So, the average inventory equals Q plus 0 by 2, that is Q by 2, that is our cycle inventory.

Average Inventory= (Q+0)/2

So, this is the average inventory which you are always holding in your stocks. So, most of the cost calculations are happening on this Average Inventory Level.

Next, we discuss various costs which we are using in developing this inventory model. Two very important costs are discussed. One is the carrying cost, and another is the ordering cost. Carrying cost is also known as holding cost or maintaining cost. Generally, you are representing it as Ch and ordering cost as Cp.

$$\boldsymbol{Total\ Ordering\ cost} = Total\ no.\ of\ orders \times Ordering\ Cost\ per\ order = \frac{R}{Q} \times C_p$$

$$\boldsymbol{Total\ Holding\ cost} = Average\ lot\ size \times holding\ cost\ per\ unit/year = \frac{Q}{2} \times C_h$$

Maybe in other books, you may find a different convention for noting these two types of cost. Ch is the cost of holding one unit for one year. For example, if I am keeping one unit of product in my store for one year, I may incur, let us say, Rs 2 for rent, maybe insurance also, and on average, some kind of obsolescence is also possible. The capital which I have blocked in keeping the item, the interest on that capital, is also taken care of in the carrying cost. So, all these things are put together equal to Rs T. But generally, the carrying cost is expressed as a percentage of the material cost.

For example, let us say the material cost of a particular product is Rs 1000, and I say that the carrying cost is at the rate of 5 percent of the material cost. Then the Ch will be 5 percent of 1000. So, most commonly, you will see the expression of Ch in terms of a percentage of the material cost only. The other type of cost is ordering cost, where every time you place an order, there will be some kind of administrative expenses, some type of labor, loading, unloading, and all those issues will be involved in every order cycle. So, if you let us say think in a way that when you are ordering all the items in one go, your ordering cost will be low because there is only one order.

But then your average inventory will increase very high. You can consider two scenarios: if your total requirement is R and you place a single order of R quantity, your average inventory will be R by 2, and you have to incur your holding cost for R by 2 label throughout the year. On the other side, it is also possible that you may break this R into single units up to R times. Now, in this case, every time one unit is coming, there is some cost associated with that also, that is the ordering cost. So, we are trying to optimize and minimize the total cost, which is the sum of Ch plus Cp.

This expression gives you how we are going to calculate the total inventory cost, which is

$$\textit{\textbf{Total Inventory cost (TIC)}} = \textit{\textbf{Total Ordering cost}} + \textit{\textbf{Total Holding cost}}$$

the total ordering cost for the year plus the total holding cost for the year.

The total ordering cost is the number of orders, which is R by Q into Cp.

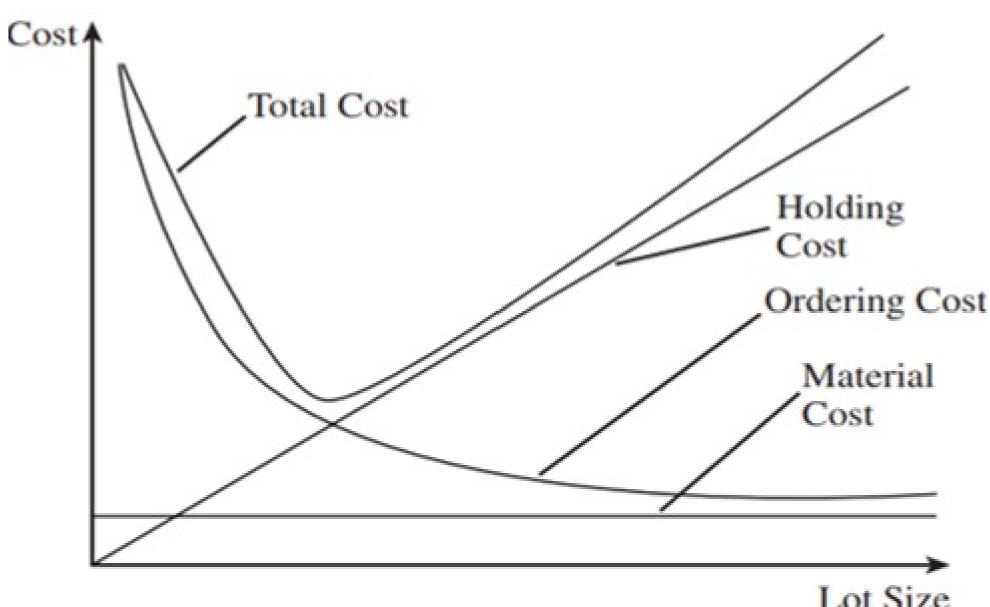
Ordering Cost= R/Q*Cp

R by Q gives you the number of orders in a year, and Q by 2 is the average inventory multiplied by the cost of carrying the inventory. So, this becomes the total inventory cost, and this is to be minimized. When we do the maxima and minima, we get the expression known as EOQ, economic order quantity, under the root of 2RCp upon Ch, a very important expression.

$$Q^* = \sqrt{\frac{2RC_p}{C_h}}$$

Though, in our analytics, we are going to discuss more advanced things, this basic model, EOQ, is the fundamental of entire material management and entire inventory management.

So, I request all of you to please keep this EOQ in your mind all the time. However, it is also important to use the values appropriately in this expression, 2RCp upon Ch, whole under root, because many times people get confused in writing the values of Cp and Ch. What should be the appropriate value of Cp and Ch? With the help of examples, we will be discussing this.



Now, one more important thing: if you see the graph on the screen, here you see we have different types of cost. On the x-axis, we have the lot size, which is Q, and on the y-axis, we have the cost. Now, here, if you see this graph, there is a cost, the holding cost, which is Q by 2 into Ch. The formula for holding cost is Q by 2 into Ch. So, as your Q is increasing, the holding cost is increasing, and a very clear linear relation is visible. You can see this straight line, which is crossing the origin because if Q is 0, the holding cost is also 0. Then, another cost is the ordering cost, which is R by Q into Cp. As you can see in this formula, Q is in the denominator. So, as the value of Q is increasing, the ordering cost is decreasing, which is also very much evident from this graph, which is representing the ordering cost. Now, the third is the total cost, which is Q by Ch plus R by Q Cp. Now, if you see this particular graph of total cost, it is very interesting that as your Q is increasing up to a particular level, this total cost is decreasing.

It is decreasing, decreasing, decreasing, and up to a particular point, it has decreased, and then if you start increasing your Q, it is further increasing. So, it is showing a very interesting behavior, and you can see that at a particular level where it is the lowest, where the total cost is lowest, this is actually your Q star or EOQ. One more important thing you can identify is that at the EOQ level, at this level, your total ordering cost equals your total holding cost. So, if I use the principles of analytics simply, if I am in a situation where I do not know whether I am giving the right order quantity or not. But if I say that my annual ordering cost and annual holding cost are almost equal, the ordering quantity which I am using in my organization is more or less equal to EOQ.

There is no need to calculate any other thing. Whatever your order quantity is, using that order quantity, if these two costs are almost equal, you should say that you are operating at the minimum inventory cost. But, if these two costs are different, then maybe there is a scope of reducing your inventory cost. So, that is a very important managerial takeaway from this particular discussion. At this particular lowest level of Q, the formula for the minimum total inventory cost is also available here, which is under root 2 RCp into Ch.

Minimum total cost: $TIC_{min} = \sqrt{2RC_pC_h}$

There are some simple assumptions we use in developing this basic EOQ model, like Cp, Ch are constant, and the consumption rate R is also constant throughout the year. Now, the challenge is, even though the cost may not be constant throughout the year, but still, for the purpose of developing the model, I can assume very easily and conveniently that these two costs are constant. But, the consumption rate is a question; the consumption rate that I am assuming at the beginning of the year may not remain the same, even in every cycle, the consumption rate may change. Every cycle, like what I mean to say is that here you see that this is one cycle, this is another cycle, and this was the first cycle. So, in every cycle in this diagram, I am suggesting that one consumption cycle is for 10 days.

But, it is quite possible that in one cycle these 100 units are able to survive for 11 days, and in another cycle these 100 units are over in 8 days. So, practically there will be variation in the consumption rate also from period to period. But, we assume that these are constant over a period of time, and we assume that whatever the order quantity Q is, my supplier is giving the same order quantity every time, and when I am expecting that these orders will come to me, these orders come actually on that very day; there is no delay in the supply also. Now, after these things, there are some very simple things also, one more important terminology that is lead time. The time when I am placing the order here.

If you remember in the beginning of the class, I said that there are two very important questions. One is when to order, and how much to order? How much to order is Q. How much that is Q. When to order? That is still unanswered.

For example, I am placing the order here. This is the point, and I am receiving the supply here. So, the time between placing the order and receiving the supply is known as lead time. So, in our basic EOQ model, we have assumed just now I told you that lead time is constant. However, in practical situations, it is possible that lead time may not be constant; there may be some variation in the lead time also.

So, with the help of this simple example, we can understand how these situations are developed. We have a requirement of 1,000 units per month. So, the annual requirement becomes 12,000, and we have the cost of different types of Cp and Ch. Cp is the cost of placing the order or the ordering cost. So, that is mentioned as 4000 in this problem. Ch is given as 20 percent of the material cost.

So, it is 0.2 multiplied by 500. So, these are the values of Cp, Ch, and R. When I use this formula of EOQ, I get EOQ equal to 980. When EOQ equals 980, the cycle inventory will be 980 divided by 2, which is 490, and the number of orders per year will be 12,000 divided by 980. So, between 12 to 13 orders, you have to place every year, 12 to 13 orders.

$$Annual\ demand = 1000 \times 12 = 12000 = R$$

$$Q^* = \sqrt{\frac{2RC_p}{C_h}} = \sqrt{\frac{2 \times 12000 \times 4000}{0.2 \times 500}} = 980$$

$$Cycle\ inventory = Q^*/2 = 980/2 = 490$$

$$No. of\ orders\ per\ year = R/Q^* = 12000/980 \approx 12.24$$

Now, after understanding these particular issues of a very specific case, but practically speaking, in all our models, there will be a lot of fluctuations and uncertainties. We are not going to work with certain models in our practical lives. So, whenever there are uncertainties, how can analytics help us in taking care of our uncertainties?

Like, you see this particular diagram, the upper part of the diagram, this is the upper part up to this level. This is the same model which I discussed a few minutes back. But, actually, what is happening is that because there are uncertainties, I have to keep some cushion with me. If the demand is not constant, and the demand consumption is not constant, it is higher than the requirement to fulfill the customer's needs. To remain a customer-oriented organization, I should have enough inventories with me.

And for that purpose, safety stock is created. So, now for me, the question is how much to order and how much safety stock to keep. Because safety stock is a kind of cushion for me to handle uncertainties. Whenever you have uncertainties, you have to create some kind of protection for yourself. So, safety stock is a kind of protection for me.

So, now because of the safety stock, my average inventory is going to increase. Earlier, when there was no concept of safety stock, average inventory was equal to cycle inventory. But now, because of safety stock, average inventory is cycle inventory plus safety stock.

$$Average\ inventory = Cycle\ inventory + Safety\ stock$$

So, my average inventory equals Q by 2 plus safety stock. And therefore, my cost of holding is also going to increase because now the cost of holding Ch per year will be Ch into Q by 2 plus safety stock.

So, all of a sudden, my cost of keeping the inventory is going up, and therefore, we are going to discuss in detail the calculations of safety stock itself and how we are going to handle the issues of safety stock. You can easily understand that the calculations of safety stock will depend on how much uncertainty we are going to handle, and if you have more uncertainty, you need to have higher safety stock; if uncertainties are less, obviously, you will have less safety stock. So, the amount of uncertainty is very important. Now, from where will the uncertainty come? In our earlier classes, we discussed descriptive analytics that whatever historic data you have, you can have two important characteristics.

One is a measure of central tendency, and another is variation. So, this variation is basically the measure of uncertainty in our demand, and that will help us in the calculation of safety stock or safety inventory. So, safety stock calculations for us will be based on these two or three important aspects. What is the appropriate level of product availability? If, let us say, demand is 10, and demand can go up to 15 in a period.

So, every time it may not go up to 15. Sometimes it may go up to 15 also. So, I keep, let us say, 13 units. I am okay that sometimes if demand is going up to 15, there may be a few customers. These customers who are not served the product because I may not have that much inventory.

So, there may always be a few customers in case of uncertainty who may not be able to get the products from the readily available stocks. So, this is the measure of product availability. Then, if I am ready to have a particular level of product availability, that okay, 90 percent product availability is okay. For example, to maintain 90 percent of product availability, how much safety stock is needed? Because as my product availability increases, I want to have more product availability, you can easily understand it will increase my requirement of safety stock.

And then, we also need to see just improving the product availability, and then accordingly increasing the safety stock is not the end for us. We also need to see that, on one side, we should be able to improve the product availability without increasing the safety stock. That is how we can have less uncertainty in our demand data, so that we can offer higher product availability with a lower requirement of safety stock. So, all these things are important parts of this uncertainty handling in inventory management. We will continue with some kind of detailed discussions on our safety stock calculations in our subsequent classes.

With this, we come to the end of this particular class. Thank you very much.