Introduction to System Dynamics Modeling
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Lecture – 21
Supply Chain Models-IV

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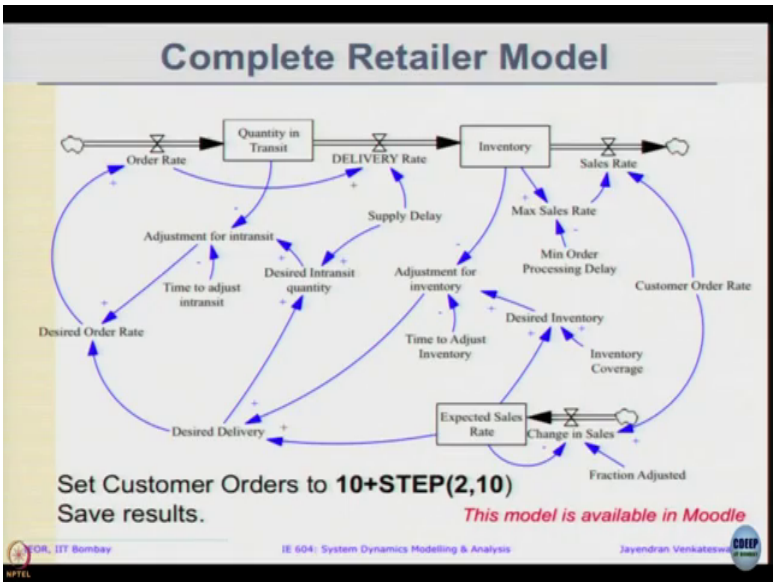

We will continue looking at our Supply Chain Model. Yes, we will be doing so, recall this is the final complete retailer model that we developed the previous class. So, we have the model. So, please open it. Now, set the customer orders to 10 plus step of 2 comma 10; 1 year model ones all are working. If you do not have it in this version just check if I mean version is available in model that you can download that also.

The key changes are you should be able to have adjustment for inventory desired delivery adjustment for in transit desired in transit also being computed through supply delay and

desired delivery as per Little's law desired inventory is now based on inventory coverage and customer orders are fulfilled only via sufficient inventory. So, all those aspects should be captured within the model.

You might have used different customer order rate. Let us try this one this represents 20 percent increase in the demand. Earlier we used some arbitrary numbers, but now we had to be little more specific. So, what you are looking at is order is 10 kgs. Suppose is 20 percent increase in the end customer demand then what happens to order rates and delivery rates, inventories etcetera is what we can actually see. 20 percent increase in one results in how many percentage increases other. We have been looking at yesterday. So, you all you got the model, it is available right.

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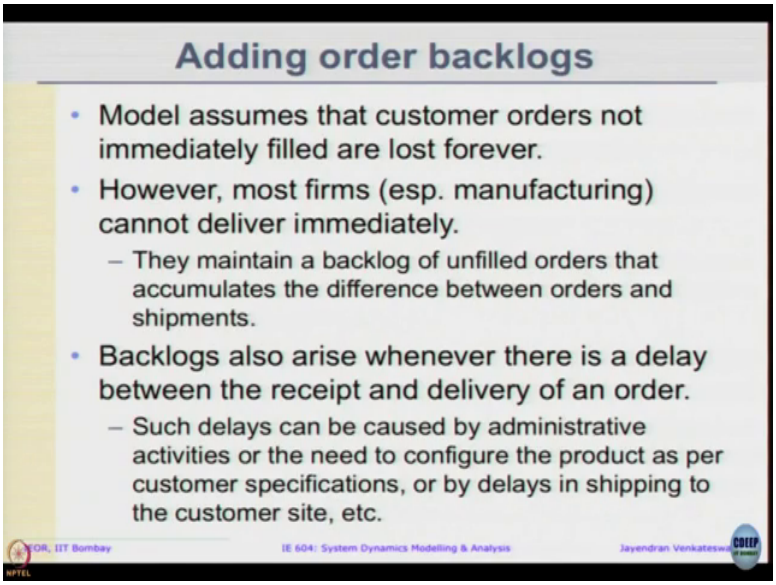

Now, we will further improve the model and add next step. So, this model as you saw assumes that customer orders are not that are not immediately filled are lost forever right. We have put customer orders is nothing, but a minimum of inventory as well as the customer orders and found that though if you have order is higher than inventory then I do not deliver that and that order is lost. It may be true in many scenarios like a simple retail shops; we saw as an examples.

But in many other firms like say manufacturing firms or even distributor ships, we may not be able to deliver immediately. They usually maintain a backlog of unfulfilled orders only when you receive when you have sufficient inventory, then you go ahead and fill it the backlog accumulates a difference between the orders and the shipments. Most manufacturers work like that.

In fact, some of it make to order kind of policy where they even start the production or procurement only after you make the order or even in some retail shops like medical shops and other businesses where if you may demand and they may procure it for you right. So, that aspect is called as backlogging and then fulfilling order when inventory becomes available. So, that is one reason why we might have a backlog.

Reason number 1 is if I am unable to fulfill the order immediately, then that quantity remaining quantity is kept as a backlog that is the difference between the orders and the shipments. Now, backlog also arises whenever there is a delay between the receipt and the delivery of the order; receipt when the retailer or whatever the player receives an order on the time he is going to ship the order.

Whenever there is a delay it has to be accounted until that point in time as a backlog. Delays to be various reasons like administrative activities or need to configure the product as per customers specifications. For example, if you are going to buy a car, you may not be able to juts walk in and drive away the car, you may have to go then you have to give your choice and your preferences, then all your bank details and you may need to pay up front some money you may need to if you are buying on a loan, then loan paper has to be processed.

But until then the order is already in backlog. So, there may be some administrative delays involved, but that order officially then goes into a backlog and once all these processing are done which includes administrative activates or need to configure product as per customer specification or bit delays in shipping to a customer site here. It remains in the backlog until it actually reaches the customer.

So, of all these reasons we may choose to model a backlog. So, first task for today is to include this backlog in our previous model of a single player supply chain model. So, let us take the first case when the orders are we do not have sufficient inventory to fulfill the orders, then the remaining quantities backlogged and filled later.

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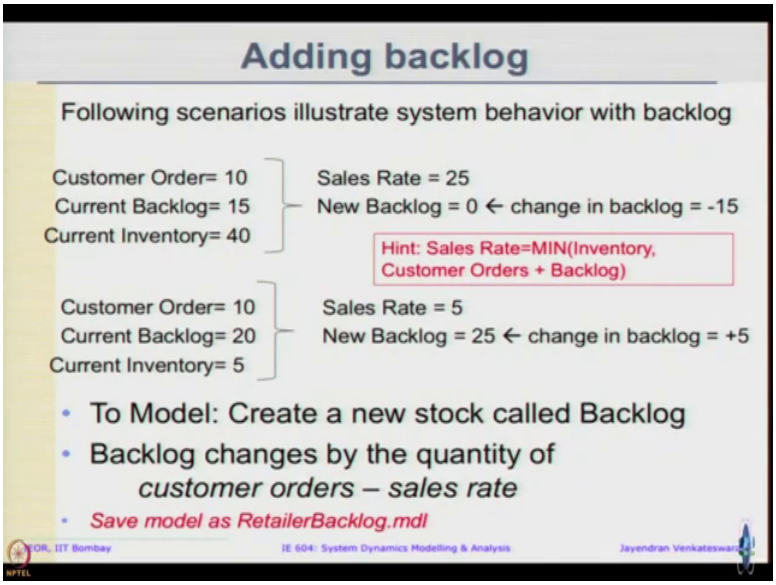

So, to illustrate that just take these two scenarios. The following scenario illustrates the behavior with the backlog. Suppose customer order is 10 units, you already have a current

backlog of 15 units and current inventory is 40 units. That means, we have sufficient inventory to satisfy both the customer order as well as the backlog. So, my sales rate becomes 25 units and new backlog is 0 since they already fulfilled this backlog, the new backlog becomes 0. Change in backlog can be captured as a minus of 10 units.

We will come to that or consider second scenario. So, here I have sufficient inventory to cover both order and backlog hence I am able to satisfy both of them. So, 10 plus 15 became 25. The second scenario customer order is 10 units, current backlog is 20 by current inventory is only 5. So, in that scenario my sales rate is governed by the inventory of 5 units. So, among 20 plus 10 so, total to be shipped is 30 units, but unfortunately you are able to ship only 5 units. So, new backlog become 25 units.

That is whatever is shipped out is only 5 units. So, difference between the customer order and sales rate is put as a added to the backlog. So, we are going to model this within a existing retailer model, you save it has retailer backlog model as a separate model. So, to do this, you are going to create a new state called as backlog and backlog changes by the quantity of customer orders minus sales rate.

So, this is a flow inside the stock the change in backlog will be governed by this equation, but you have to come up with equation of how to determine the sales rate. So, let us take 10 minutes to model it. Those two joining as now what you are trying to do is include a backlog in our existing retailer model that we used yesterday last class. So, you have the retailer only model the single player model with the adjustments for supply line adjustments for inventory and also the maximum sales rate also incorporated right the final model that we built this one.

So, we are going to modify this model by including backlog ok. So, we will do that you have to include a backlog and if it is a stock, then there has to be a flow the flow is also given the equations or flow is given. Now, how do we relate this backlog to my sales rate? You can figure out the equations by looking at the two scenarios that is illustrated there. So, that is a purpose of scenario.

It shows how the it shows current backlog, new backlog, it shows the customer orders, it shows what is sales rate using which and your common sense used be able to figure it out. We see the above scenario, the sales will be minimum of inventory and customer orders plus backlog. So, minimum of that correct; show minimum of inventory and the sales ratio minimum of.

Earlier you had sales rate minimum of inventory and customer order minimum of inventory comma customer orders plus backlog for it will logically work. Just incorporate that the you can adjust it for invent what I say units error. Basically this is what you wanted to right. Sales rate is minimum of inventory and customer orders plus backlog, but if you do this there is units error mismatch.

So, that you fix it instead of inventory what did you use? You used max sales correct. In you change that inventory to max sales so; that means, instead of backlog what do you need to do, you figure it out. Instead of inventory, we are using max sales you already modeled it right. So, this is logical equation that we will have right. Even if we do not care about units errors still you must be able to finish this model based on these things written here. Then the model must be able to run, then we can set the initial value of backlog to be 0. Initially it should be 0 ok.

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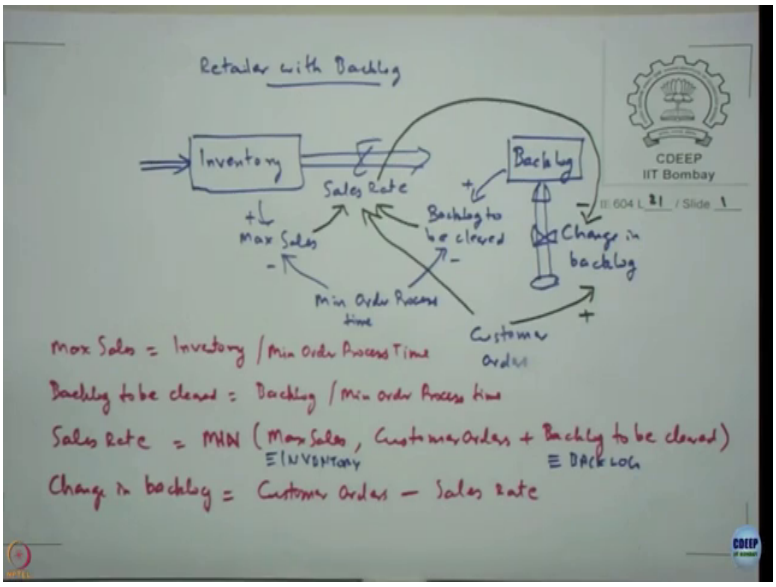

Zoomed in version of the model is shown here along with the underlying equations stock inventory, sales rate, max sales minimum order time exactly the same as before and customer orders. New thing to be added is backlog, change in backlog just as we described. This change in backlog was given as customer orders minus sales rate. So, connected customer order and sales rate to it and then we write the equations for that.

Now, the sales rate is minimum of inventory back inventory comma backlog plus customer orders. But since I cannot directly add inventory, I had to first convert it into max sales as per inventory and give it into the sales equation. And backlog similarly as to be converted backlog to be cleared which is nothing, but backlog divided by minimum order processing time.

So, units match then if again rate into sales rate by the sales rate equation the minimum of max sales which is kind of equivalent to your inventory and backlog to be cleared is equivalent to your backlog. So, this max sales and backlog to be cleared it comes in only for units toward units error. Please incorporate this model.

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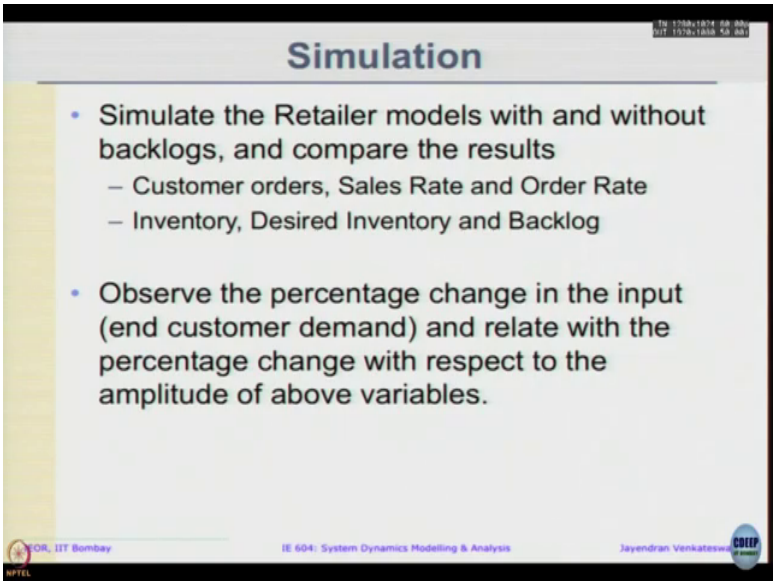

Then this what I want you to do. Simulate the retail model with and without backlog and compare the results in with backlog case. Show the graph without backlog case. Create the graph of customer order sales rate and order rate in the single screen. And another one having inventory desired inventory and backlog in a single graph and observe the percentage change in the input and relate to the percentage change with respect to the amplitude of the above variables or input change 20 percent step of 10 increased to 12 plus 2 units 20 percent increase in step input results in how much percent increase in the order quantity.

And including backlog should it remain the same or different? That is other aspect that we have to do in this course. Analysis not enough, we just build the model and say see are the results I expect you to interpret it how much percentage increase is happening. Is there a difference between when we did not have a backlog and sales lost versus we had backlog and we are accounting for it is it these are change in amplitude, what about the duration, is there any fluctuation around the mean because of that has to be observed.

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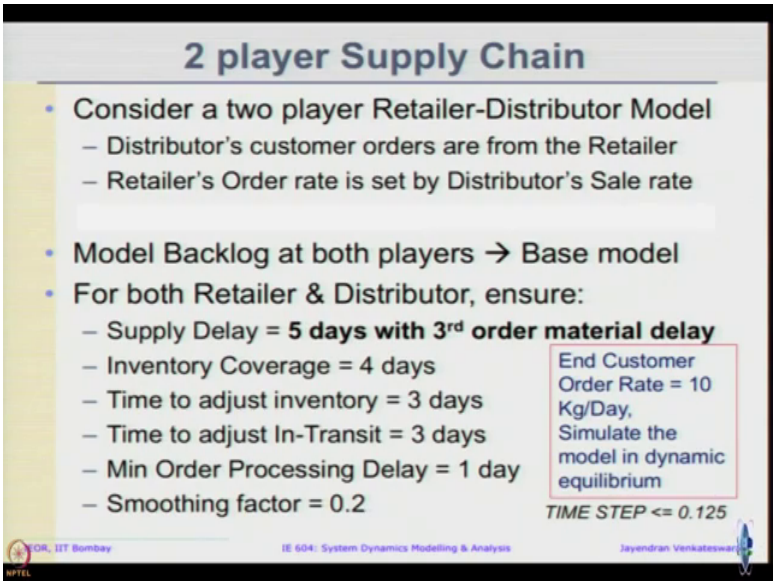

I will give you the flavor of things what kind of scenarios you may end up doing. So, now, let us move on to two player supply chain. Consider two player supply chain. The retail distributor model we already built the distributors customer order or from the retailers orders and retailers order rate is set by distributors sales rate right. We had made that the models available model, you can use it.

Now, incorporate the backlog aspect in both the for retailer and distributor in this model. We will make that as base model and in that base model, do these settings for both players the inventory coverage is 4 days time to adjust inventory is 3 days in transit 3 days minimum order passing delay is 1 day, smoothing factor is 0.2 also include a supplied delay. We had a supplies delay, delay fixed instead of that replace it with the average 5 days delay with 3rd order material delay.

Using the Vensim function delay n even you to incorporate for the three stocks instead of delay fixed replace that function delay n. Vensim help will tell you what to do once you read it you will be able to figure out what is to enter and then just start the model in dynamic equilibrium. So, once you have this base model, we will run couple of what if scenarios to understand the implication of different policy decisions within our two player supply chain. It is already build the backlog model once. We must be able to copy paste it or replicate it quickly in both the locations.

So, we have backlog at the retailers and also backlog at the distributor side also. In a default model, other than the supply delay everything should be the same numbers 4, 3, 3, 1, 0.2 exactly the same. All you have to do is incorporate the backlog and set order rate as 10 kg per day and time step as 0.125 or any number lower than that is only things you have to incorporate. Yes it will take some time to make the backlog, but it should not take you more than couple of minutes.

So, now the purpose of building simulation model is to conduct what if analysis. Evaluate various scenarios or policies as we may call it or even this case do sensitivity analysis different terms you may use. So, once you have the base model, we are going to use it to evaluate and understand what happens when some things change. You can build a intuition better about the performance or a system right as only we get it if we actually simulate it to see under late the variables right.

If something changes, then may order fluctuation is becomes higher or lower eventually that is the intuition you want to build. To the smoothing factor which I wrote as point two refers to

that fraction adjusted in your expected sales rate per in the same thing. So, to figure out the one of the important ones, you need juts think about what we are modeling here we had seen customer order exogenous fine because decision, we are making ordering decision.

So, we want to see whether how that order decision changes with respect to the actual end customer sales. Now to talk things there is going to contribute your cost during inventory, how much you are ordering backlogs, whether things going to add to your cost. So, then those becomes more interesting variables. We do not plot this is what we start with.