Introduction to System Dynamics Modeling
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Lecture - 19.1
Stock Management Structure
Stock Management Structure: Part I

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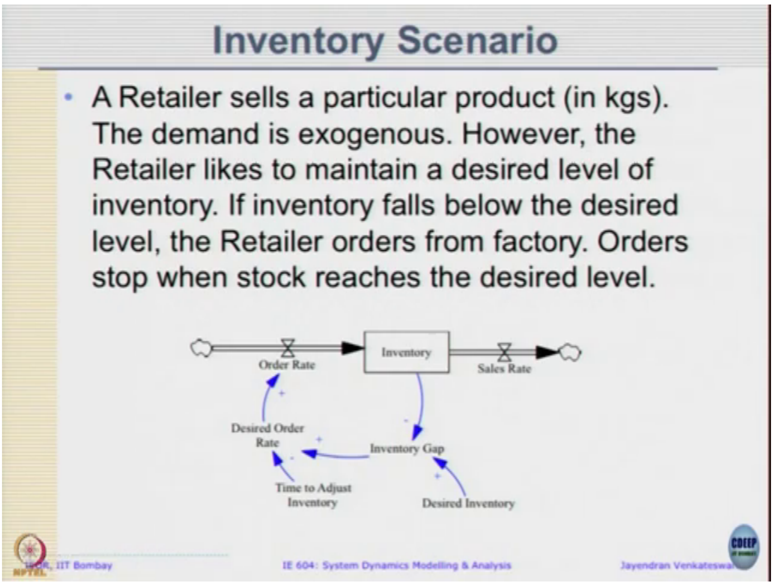

So, let us start with a very basic model; let us say a retailer sells a particular product in k gs, let us assume demand is exogenous how the retailer likes to maintain a desired level of inventory. The inventory falls below the desired level the retailer orders from factory, orders stop when stock reaches the desired level it is a very basic model.

Direct way that we have actually built similar models earlier, this two the model it has follows where the desired inventory is provided, inventory gap is calculated by the retailer who then desired what is the order rate depending on how long it takes to adjust the inventory and accordingly order is placed and then inventory increases; sales rate is exogenous to the inventory right. So, this is a typical negative feedback system right with a exogenous outflow is the model that we actually see here.

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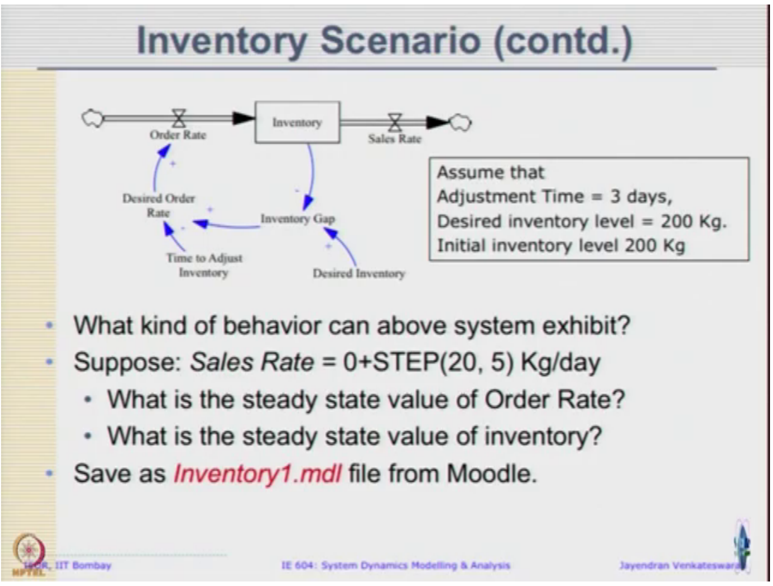

So, let us open Vensim and start modeling this; to get the values you can assume the following. Adjustment time is 3 days, you can take the simulation length as 100 and the simulation length as time step as 1 and the time units as base; go ahead and build this model.

What kind of behaviour can above system exhibit oh this is first order negative feedback system; this is simple goal adjustment behaviour right there is nothing there is no table functions, there is no complexity inventory gap is nothing, but difference between desired inventory and inventory. Desired order rate is inventory gap divided by time to adjust inventory; this you might have guessed based on the variable names as well as the causal links and order rate can be just simply set as it equal to desired order rate.

So, what kind of behaviour can above system exhibit? It is a negative feedback system, simple goal seeking behaviour. So, when you keep the sales rate as 0; so then the behaviour you will see is nothing it will be just a constant line because initial inventory is equal to the desired inventory both are 200 right. So, you expect to see a constant line. So, this is what we call as dynamic equilibrium system is dynamic equilibrium.

Now, we can subject it to some changes in the exogenous variables for example, in this case its sales rate and see what kind of dynamics we can it will exhibit. We know that this system will exhibit a goal seeking behaviour; so, if suppose the sales rate increases to 20 units at time 5; then we expect the system to reach this new goal.

What will be the steady state value of order rate? What will be the steady state value of inventory? You can do this without simulation; what should be steady state value of order rate? Order rate will be equal to 20 right; in equilibrium of steady state say the sales rate should equal to the order rate; so then order rate is 20. What will be steady state value of inventory? Will it remain at 200 or not?

Student: (Refer Time: 03:34).

It will be less; how much less? The time to adjust inventory is 3 and order rate is 20, so it should be about 140 or why do not you simulate it and see. In this constant exogenous variable then the steady new steady state value will be the; will take an value less than plus the less amount is the product of the steady state sales rate and the time to adjust inventory. So, does it reach 140? Save this model as inventory 1 dot m d l file.

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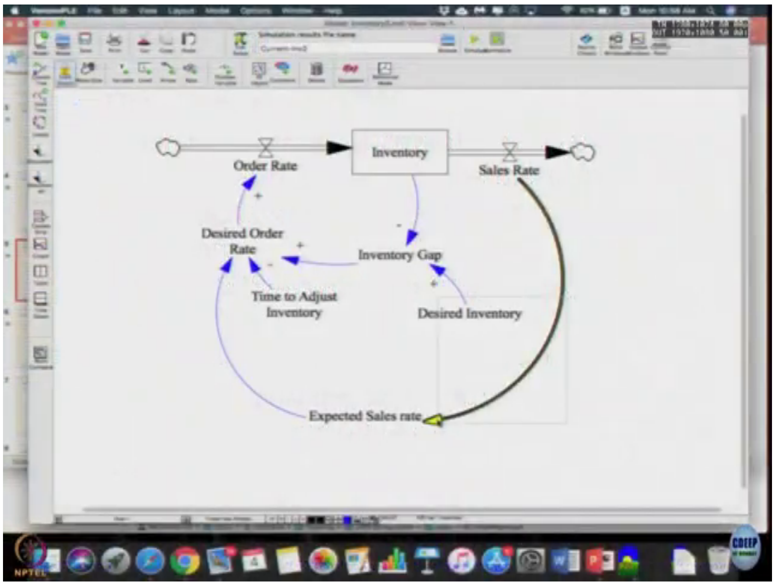

So, all of you have hopefully got this model.

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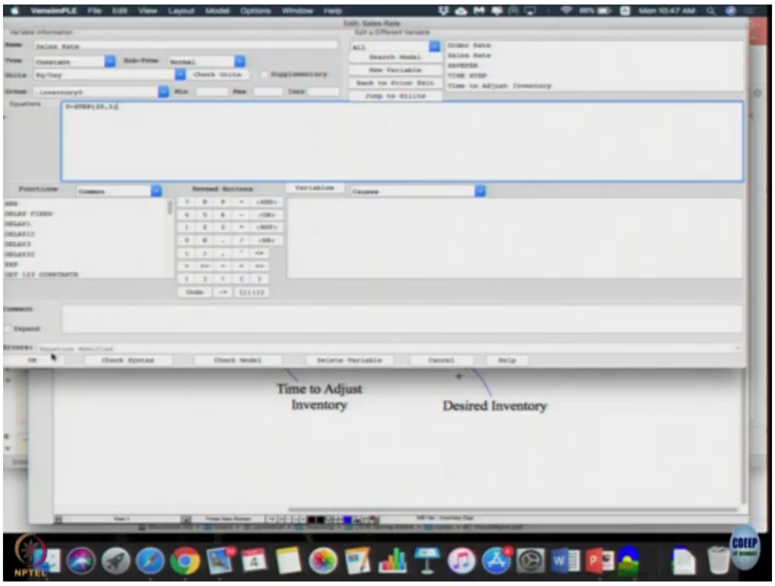

So, let me just put sales rate is 0 plus step of 20 comma 5, run it.

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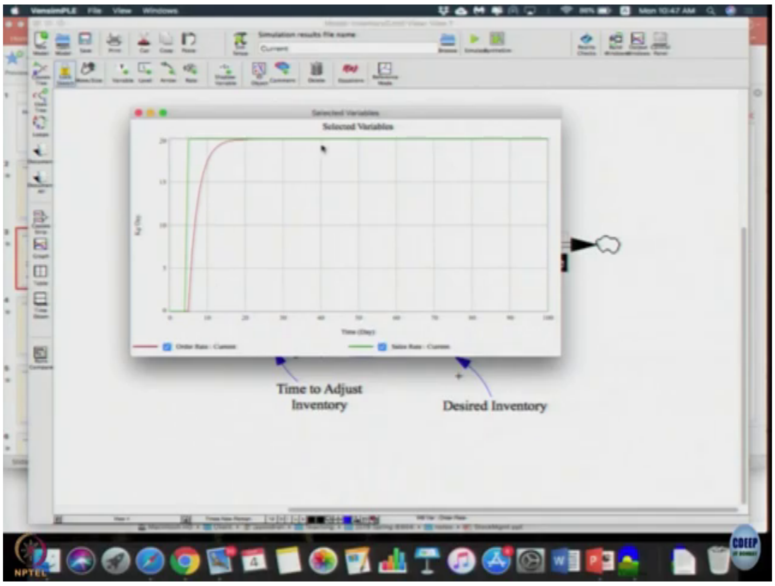

Order rate and sales rate; if you plot a graph, after sometime the order rate approaches and as a goal seeking; typical goal seeking behaviour it approaches the sales rate value, the model inventory; inventory falls down and stabilizes at a value of 140.

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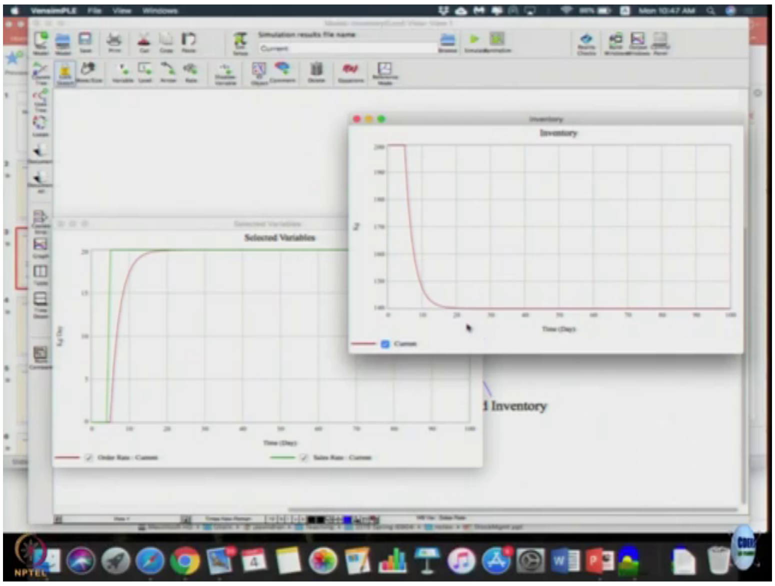

We have already seen this when we were discussing negative feedback system in phase of constant exogenous output your steady system reaches equilibrium, but at a value different from the desired value. And the amount will be equal to the time to adjust inventory multiplied by steady state value of the sales rate in this particular case.

We can expect a similar behaviour even if we change the desired inventory; instead of changing the sales rate, you know desired inventory from 200 to say 220. We can expect similar behaviour where your order rate will still exhibit a exponential change or a goal seeking behaviour right as per this and it will quickly fallback down to 0 ok. Now, let us go back to the slide and ask the next question. So, this behaviour it can exhibit is a goal seeking behavior.

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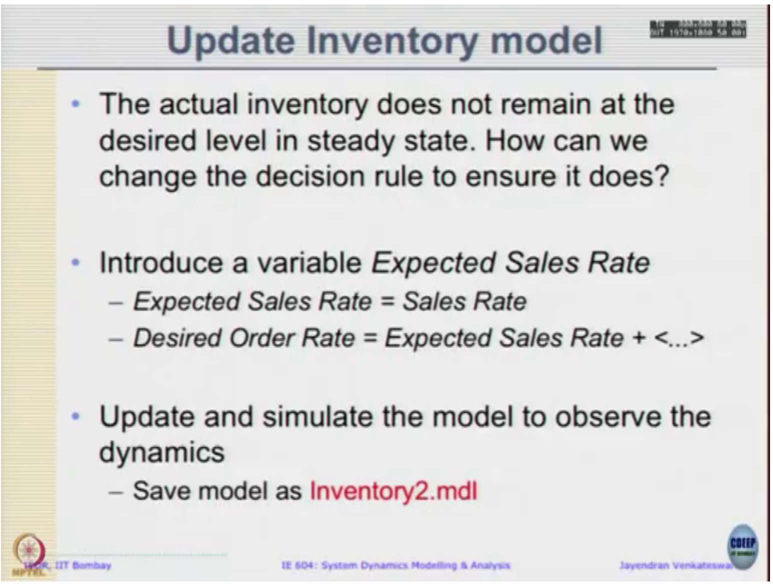

Now, you show this model and people are not happy because the actual inventory does not remain at the desired level in steady state. What we want in the steady state was be 200 kgs; for steady state value the simulation predicts that it has to be 140 kgs and that is going to be keep changing depending on how much we have the sales rate right; tomorrow if sales rate falls down then again my steady state value is going to change.

But how can we change the decision rule to ensure that it actually maintains the desired level in steady state. How can we do that? Some of the relation the sales rate, we know that every week the sales rate is removed, but I only add one third of it to the order rate right; one third of the difference is added to the order rate.

So, in first week if you already know the sales rate is it possible for us to give that user sales information (Refer Time: 06:48) sometimes reasonable to assume that we know the sales rate right. After the sales has occurred, the sales rate is assumed to be known. So, what if we were able to use the sales rate in our model then let us see whether it can maintain the desired level of inventory.

Let us introduce a new variable expected sales rate; let just make it expected sales rate equal to sales rate and let us make desired order rate equal to expected sales rate plus whatever the equation you wrote inside your desired order rate. So, let us just do both these; introduce a new variable expected sales rate, current sales rate expected sales rate; I mean desired order rate, now has an additional input called expected sales rate plus your inventory gap divided by time to adjust the inventory. Let me model it along with you guys let us call a variable expected sales rate arrow.

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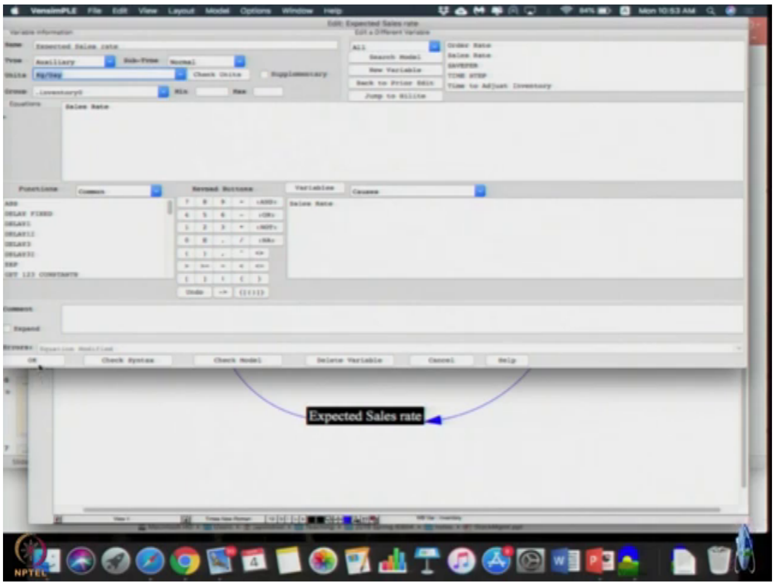

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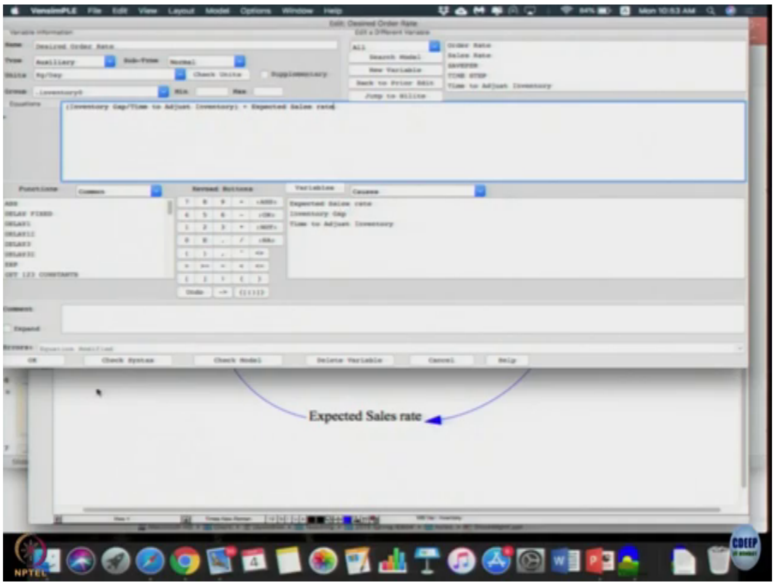

Sales rate result is expected sales; sales rate kg per day, desired order rate equivalent desired order rate will be this, inventory gap by time to adjust inventory plus expected sales rate, got it?

Student: (Refer Time: 08:36).

Got it; takes forward.

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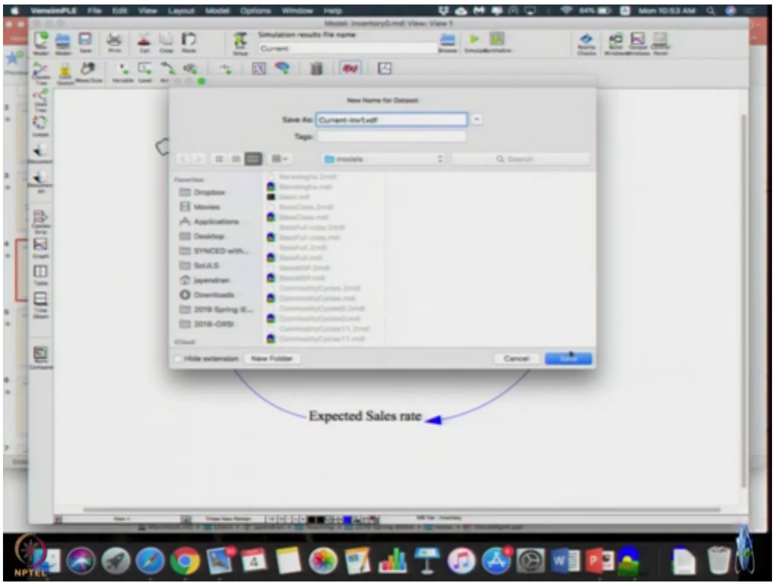

Let me simulates; I am not going to overwrite, let us look at the order rate and sales rate graph.

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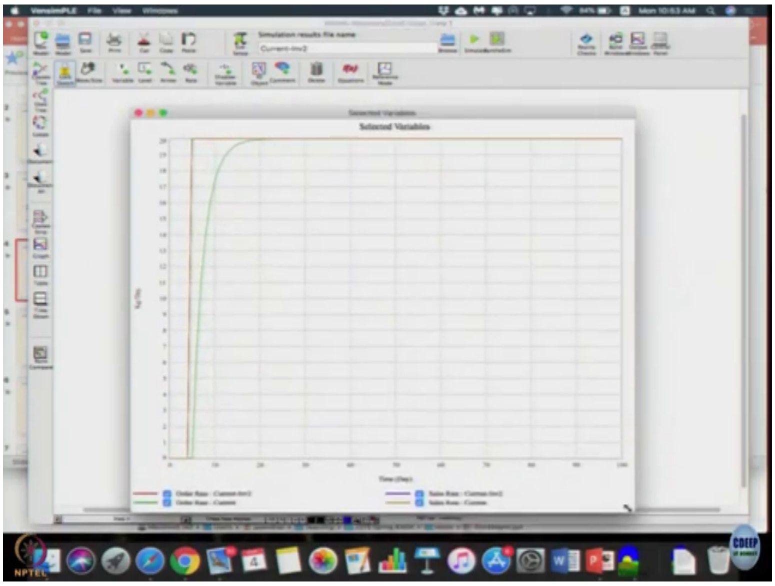

The order rate and sales rate are exactly the same, I just overlapped the previous simulation run along with this one, to get the exact same behaviour for the order rate and sales rate so; that means, addition of the sales rate actually did not affect my order rate.

Sorry; sorry to change in dynamics actually this is the order rate and sales rate now it those resembles order rate, we will get a step graph here right; immediately changed to that. Just ignore previous statement; previously, we got this graph for step change in sales rate; we got exponential smoothing behaviour right here.

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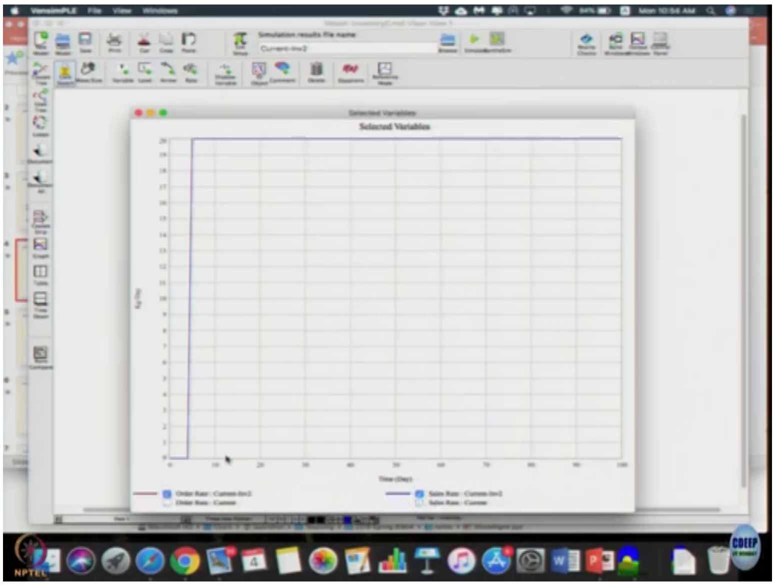

But when we changed it to include the order rate, it immediately reacted and the order rate value become equal to sales rate almost instantaneously.

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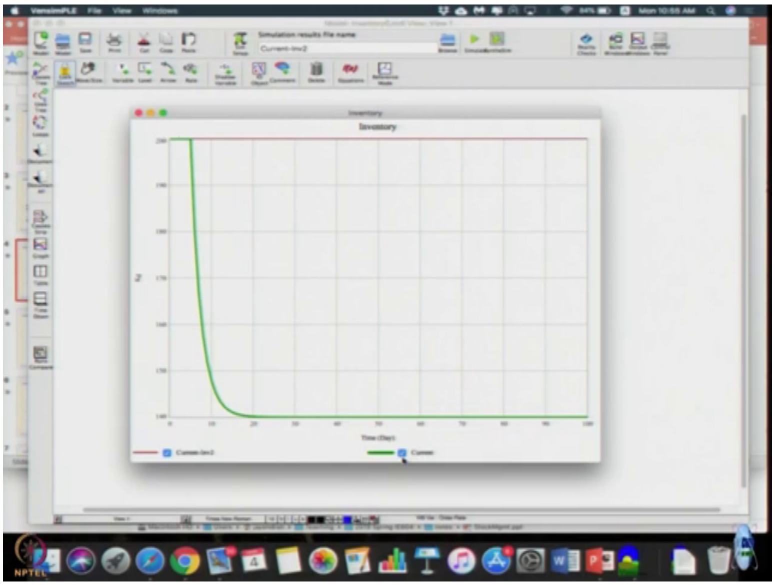

Because of which my inventory is a straight line in this case as compared to the previous case where it dropped down and became came to 140. So, desired inventory is now equal to your the inventory is equal to desired inventory because we had the sales information with us which we accounted for you know decision making. Assuming that if the sales rate, then we accounted for that in order rate anticipating the sales is going to happen which immediately started offsetting; the sales and the order side offsetting the sales and the inventory continue to remain constant ok, save this as separate model.

Now, let us understand what we did in the model; we just included the sales rate and immediately tried to adjust our order rate. But in reality that is difficult to happen only; at the end of the week you know what is the week what is the sales in the previous week right at the end of the week or end of the day say your units are day.

So, end of the day you know what the sales happened in the previous day and based on that information you will not order for the next day that is tomorrow correct. So, there is some sort of information lack which is involved before you can use the sales rate in your ordering pattern. So, let us try to capture that information delay now explicitly.

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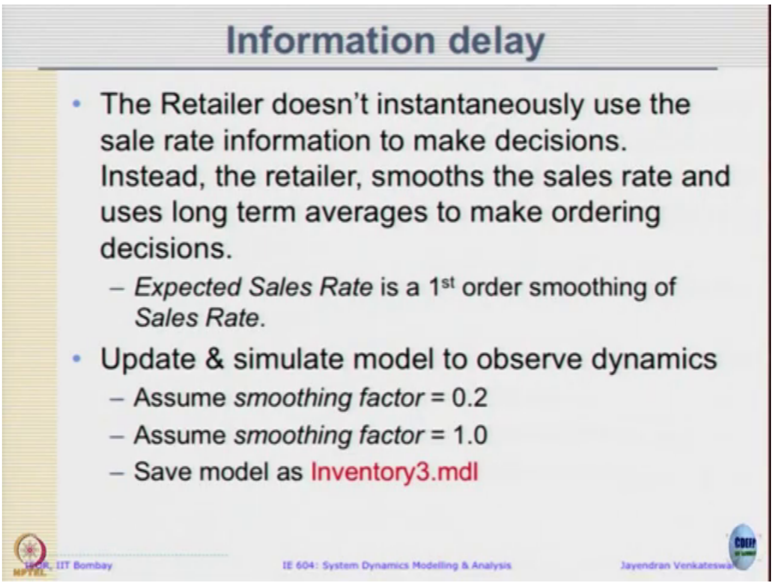

Retailer does not instantaneously use the sales rate information to make decisions that is the demand. Instead the retailer smoothes the sales rate and uses long term average to make the ordering decisions just because sales rate immediately changes you may not react to the change because we do not know whether it is short term or long term changes as soon as sales rate changes; we adjust this expected sales rate slowly overtime before he uses it in a decision making.

To model that, we should now improve on our model; here; so this is why you should notice the information that or notice the modeling aspect where if we use as a variable versus if you are going to smooth it; what is going to happen that is what we are going to find out.

So, to do first order exponential smoothing that is do it explicitly. So, let us model the expected sales rate as a stock and do a first order exponential smoothing based on that. So, we will update the model and observe dynamics assuming the smoothing factor of 0.2. So, what we are going to do is we are going to introduce a instead of this causal link, there is going to be a information delay here, but we are going to model it explicitly; we are not going to use a smooth function or anything, we are going to model it explicitly.

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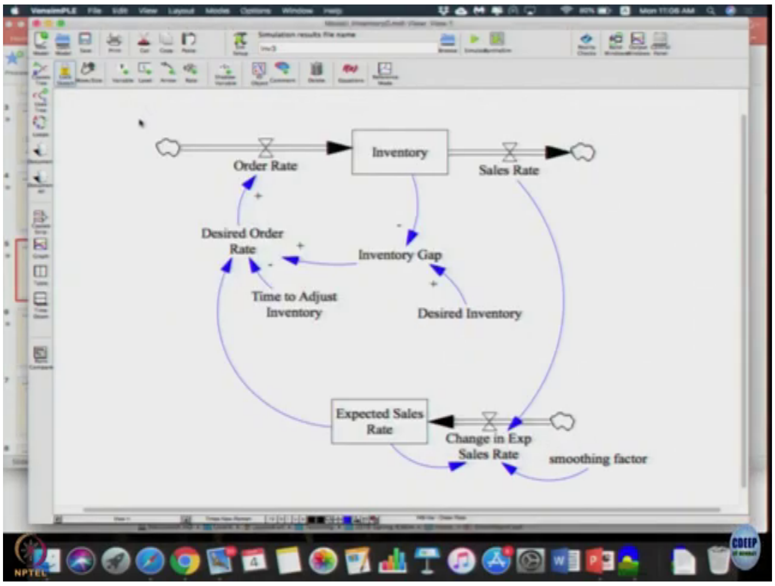

To do that; just bare with me here, I am going to delete this; select the variable introduce expected sales rate as the stock, change in expected sales rate smoothing factor got this.

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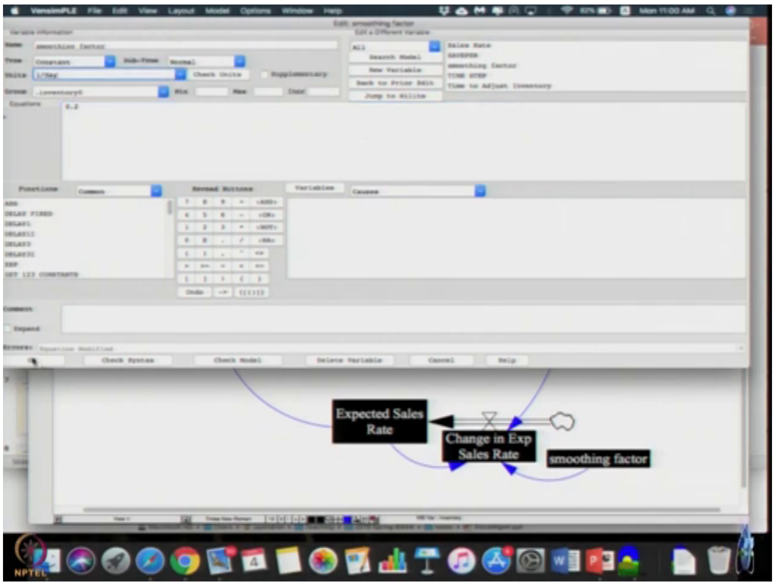

So, smoothing factor; let us start it with the 0.2; 1 per day is the unit, change in [exp/expected] expected sales rate.

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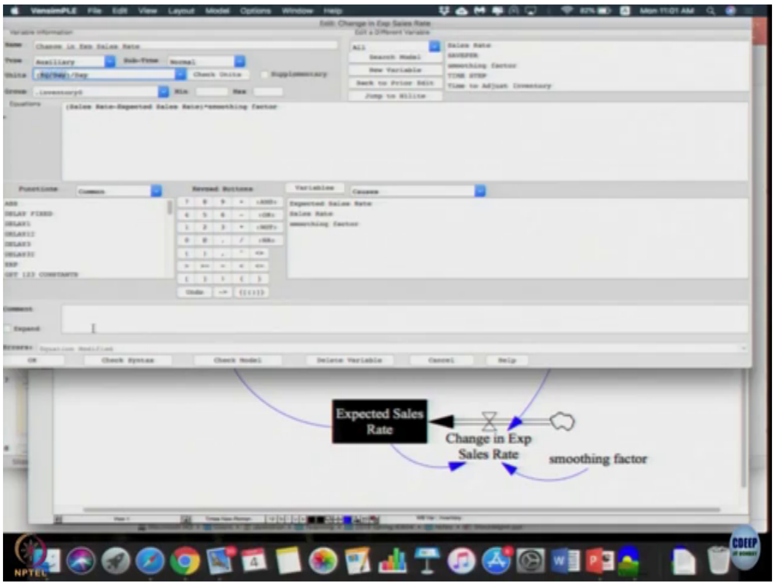

The sales rate minus expected sales rate multiplied by the smoothing factor because I am just adjusting at based on the current value of the stock. So, as sales rate increases; my expected stock also need to increase. So, that is how you are doing sales minus the expected sales rate multiplied by the smoothing factor of 0.2 unit of this is kg per day of the expected sales rate.

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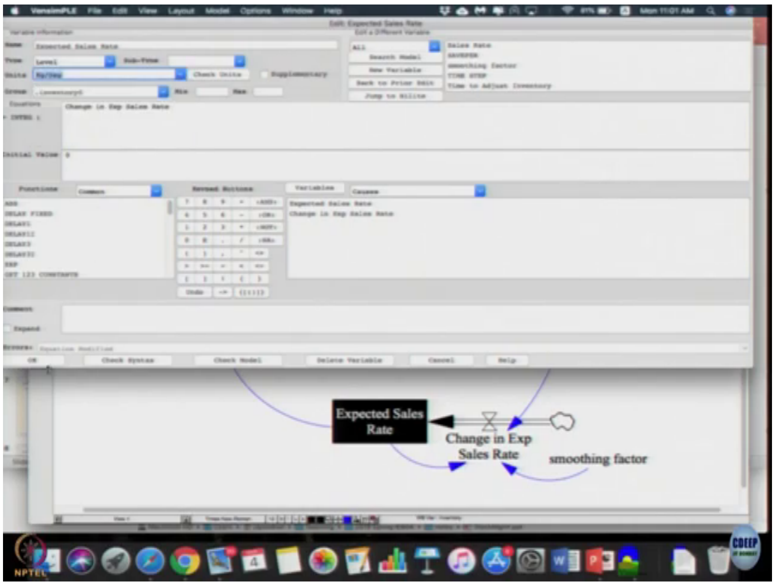

So, initially sales is 0; so we can have the expected sale initial value as 0; the units of that will be kg per day.

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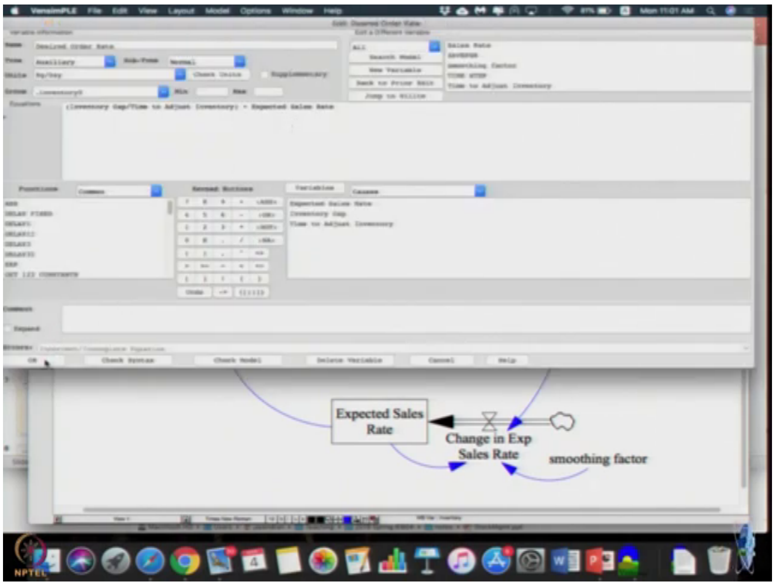

My desired order rate continues to remain the same as expected sales rate plus whatever the adjustment in the inventory so that equation does not change, but you just have to open it and click it again.

So, what is your model here is a classical exponential smoothing forecasting method. So, in any other operation management related course; if you are said about exponential smoothing, is exactly what it does there that smoothing factor is nothing, but your probably you call it a smoothing constant that is the same thing.

Student: (Refer Time: 15:45).

Yeah.

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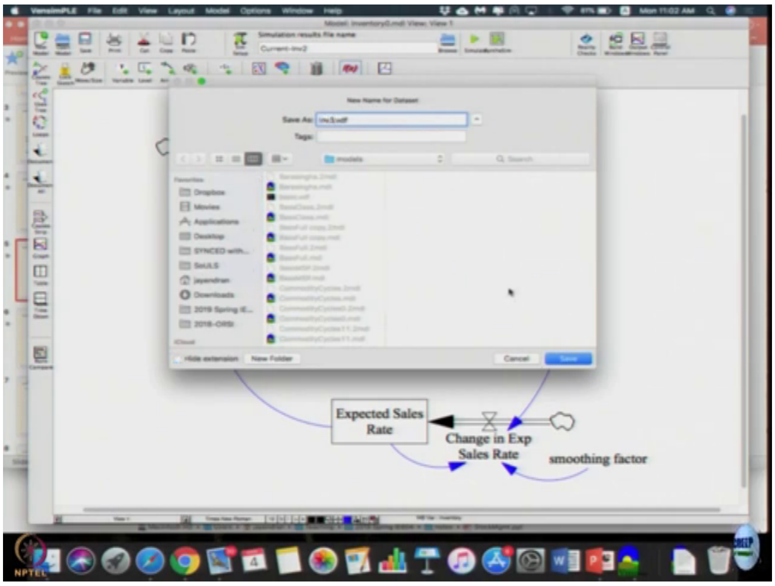

You got this? That simulates that is 3.

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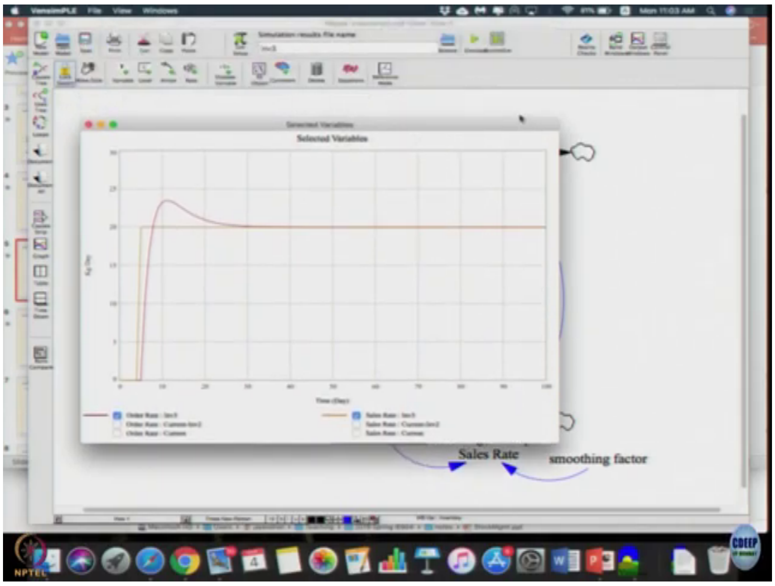

Let us look at the order and sales rate that is why I am having too many graphs; let us observe what is happening to the order rate. Sales rate immediately increases by a step order rate actually increases beyond that and then saturates to the value of 20 right.

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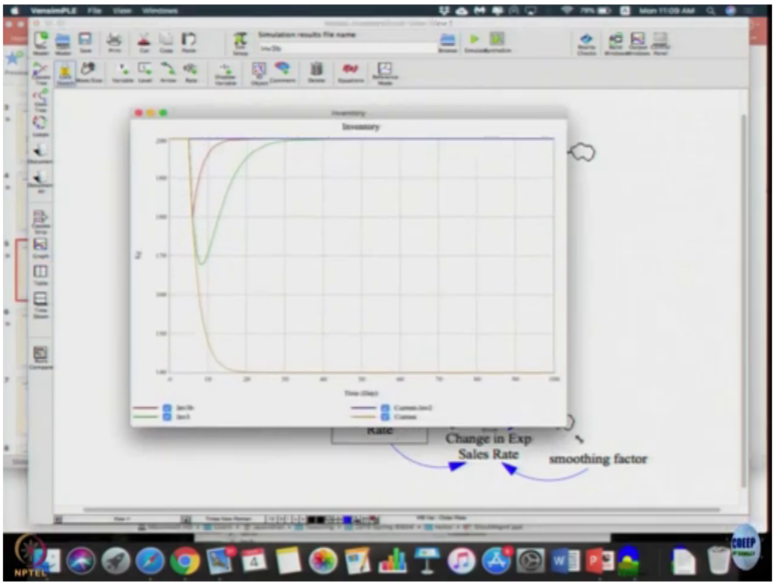

The inventory does initially fall down to represent the actual thing that has happened right. So, suddenly on day 5; when inventory or sales increased by 20, your inventory will fall down. So, that is actually captured on day 5 it is increases it increased to 20 so that the inventory has fall down by 20 right and it takes some time to adjust.

But after it has adjusted overtime it; it is able to recover and reach back the same desired value of inventory of 200. So, even though we introduced a new information delay that only delayed us reaching the desired value of inventory, it did not reach any other new value of desired inventory; it reached the same 200 value of desired inventory, but after some delay is attributed to the information delay that occurs for us to account for a change in the new steady state value of sales is being captured in this model.

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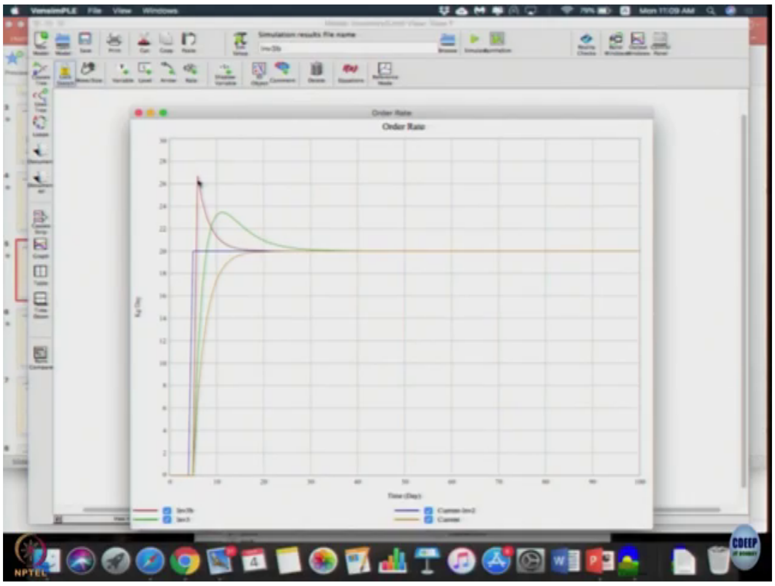

However, to achieve that interesting part is their order rate.

Student: (Refer Time: 18:06).

Yeah. Here, you can see all the three order rates in this graph; the green colour or the blue colour represents the orig first order exponential and the first model that we wrote goal seeking one.

In second one, if the instantaneous sales rate was available then immediately I could react, but not a very realistic model, but once you added information delay; we can start for see; it is not really goal seeking behaviour, we are starting to see the initial aspects of a oscillation which is in the model that is there is just a one single oscillation.

So, this point here we can refer it as the amplitude that is the maximum in which the order is ever going to go; then followed with your phases. So, order increases beyond your sales rate and then gradually falls down to achieve the desired value.

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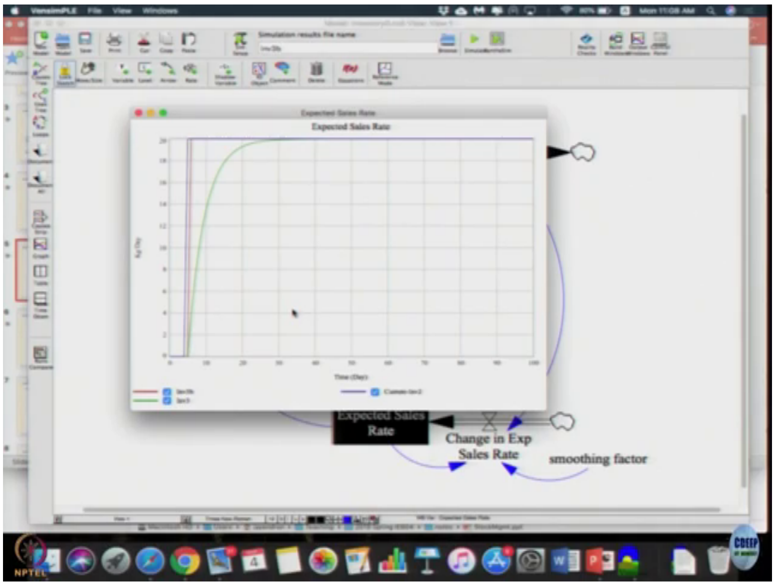

Let us observe how the expected order rate expected sales rate sorry change this. Previously, the expected sales rate would have changed instantaneously because use instantaneous information, but now it will gradually approach because it is a first order delay and exhibits a goal seeking behaviour.

Any questions on this?

Student: (Refer Time: 19:33).

It is clear right?

Now, let us make the model a little more realistic; assume smoothing factor is 1. So, what does smoothing factor 1 represent? Say initially say expected sales is 0, sales rate became say 20; so 20 minus 0 is 20. So, if I give smoothing factor 1; that means, entire 20 units is added in the immediate period; so our expected sales rate will be equal to the sales rate immediately, let us not use over instantaneously. Let us see what happens in that scenario.

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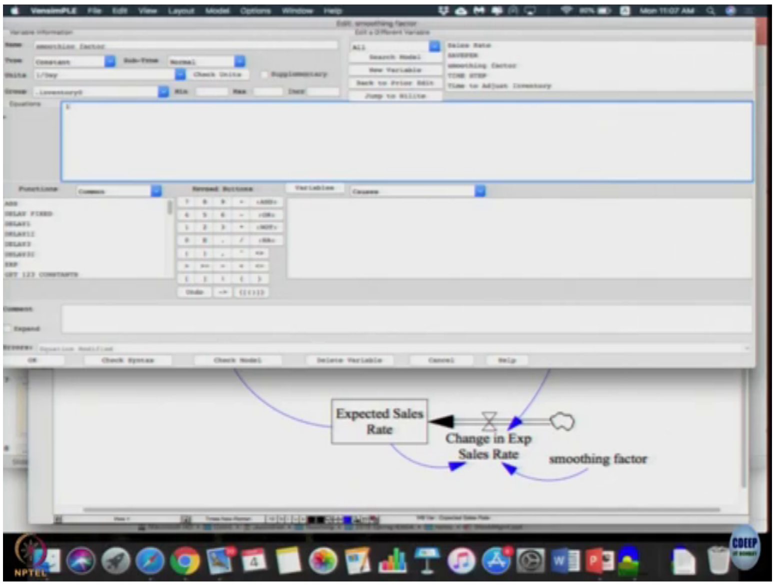

So when sales smoothing factor is closed to 0 or let us say around 0.2 step; then we give higher weightage to give lower weightage to the recent sales information. So, it takes longer to achieve steady state, but when value is closer to 1; we give more weightage to the current sales information. So, it; so let us see what will happen.

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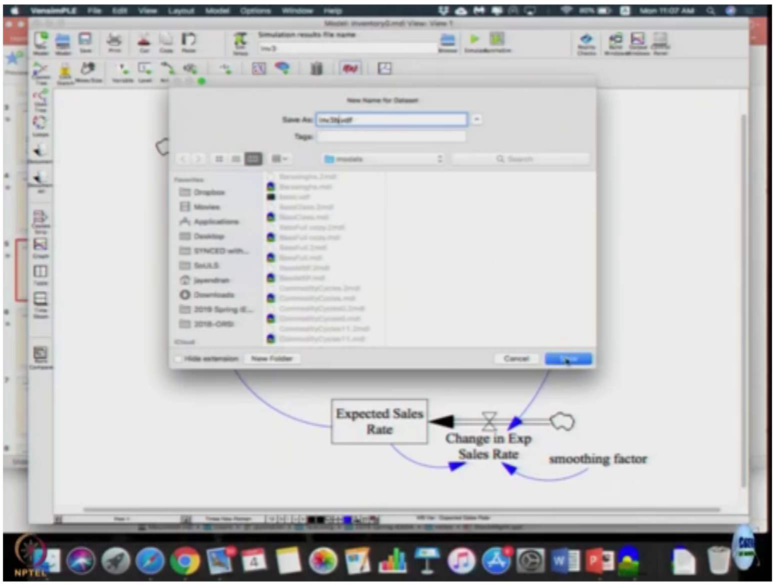

So, I just made it 1; let us simulate, now let me call this inventory 3 b; let us see what happens to the sales rate graph first. The sales rate does almost immediately become 20, in this case also the previous case where it took long time to meet 20.

Now, I have one more graph called inventory 2. So, this represents the previous case when there was no stock; you directly connected expected sales rate to sales rate right. So, compared to that there is still a one period lag within the system; that means, as soon as you started looking at the information delay, a minimum of one period lag is already introduced into the system. So, that you have to be careful of right; that means, at the end of today you got the sales information and in tomorrow's order the you say what today's sales was 20 units; so tomorrow let me order 20 units.

So, that is what you are doing in the previous case what you told is today sales is 20 units; let me order 20 units today, for using today itself. So, that is our unrealistic part there where we knew sales you know end of the day. So, we are using it to adjust the inventory for the day 2; that is the next day. So, is a one period delay.

Let us see what will happen to our order rate, there are lot of lines; this one here with a peak, sharp peak that is the inventory values; the smoothing factor is 1. It still overshoots and then as the exponential decay or goal seeking behaviour to reach the steady value. So, higher the smoothing factor; so after it is you are going to reach your goal right.

Let us look at inventory, here you can observe inventory as a sharp fall after it immediately starts to rectify much earlier. So, smoothing factor is lower then you are quickly reacting to recent changes. Whether it is desired or not depends on the scenario, but in this particular case it results in reaching your desired level of inventory much earlier.

So, all we did was introduce with our physical flow of material and information delay within the system which itself allowed it to overshoot its goal and then again it fell back to reach it. So, that is like kind of the origins for the oscillation that is occurring; whereas, the information delay within a physical system that is going to lead to some oscillations.