Introduction to System Dynamics Modeling
Prof. Jayendran Venkateswaran
Department of Industrial Engineering and Operations Research
Indian Institute of Technology, Bombay

Dynamic of Negative Feedback
Lecture - 8.2
Dynamics of Negative Feedback System: Modelling in Vensim

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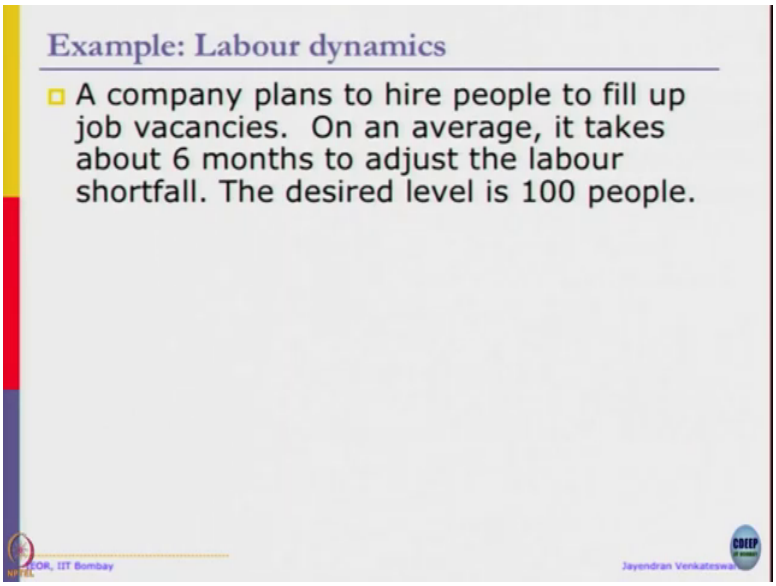

Let us look at the example now. A company plans to hire people to fill up job vacancies, on an average it takes about 6 months to adjust the labour shortfall. The desired level is 100 people. It is very simple system, that I know how many people are required? I need to spend some time to hire them hiring process takes time.

This example takes on average it takes about 6 months create advertise and people will apply and then later we make offers and some may join again still there is shortfall again you have

to apply for multiple round because you are not getting into the same type of people you need range of people of variety of talents. So, there is a very simplistic system based on that.

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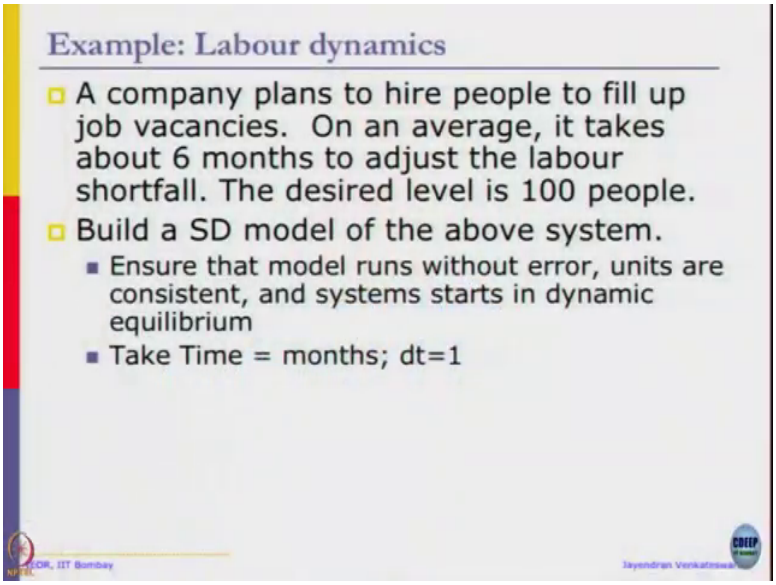

So, let us just assume that the initial value is 0, there is nobody in the system yet desired value is 100. You have to build SD model above system ensure that model runs without error, units are consistent starts in dynamic equilibrium. Let us take timing as month's time unit as months for simple reason is I have already written that on average it takes about 6 months to just the labour.

So, if we are going to use time unit of months, anywhere then everywhere it should be time unit of months. So, that makes our choice easy that is why it is taken as months. Now, let us take the time step, simulation time step as 1. See dynamic equilibrium is for physical analogy,

imagine a kind of a ball sitting on top of a hill so, at that point it is in equilibrium for any small perturbation to it will start rolling down the hill.

So, it is at a point where system when you simulate it you find that there is no dynamics in the system, the system is constant over time. And then when you make a small perturbation in the system, then system starts to change. Like if you imagine a pendulum, then dynamic equilibrium is pendulum is at rest unless you apply external force it is not going to start moving.

So, before you start simulating ensure system is at rest then we can start simulating, then we will figure out whether are we at a kind of a already at a equilibrium point where you will return to the same point afterwards or are you going to settle at a new equilibrium those things become clear. Then equilibrium is a point where system as there is no other perturbation system and all values are kind of constant.

I hope all of you have installed Vensim education version ok. So, first is let us click new model, time step is already units for time is already will be month and time step is 1.

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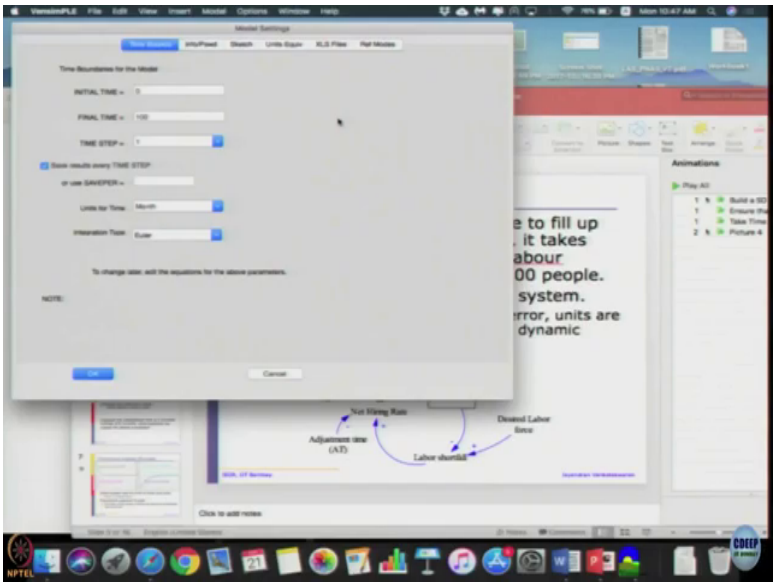

So, let us just leave it as it is, this is what we are trying to model.

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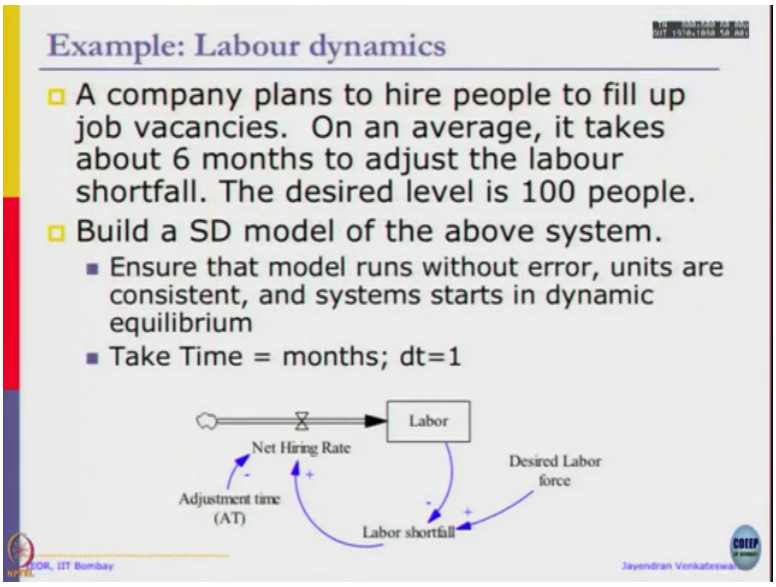

So, labour is a stock here and net hiring rate is your inflow, we have an adjustment time coming in, labour shortfall which is nothing but difference between desired labour force minus the labour, ok. So, this is what we are going to model. I may do a slightly different terms (Refer Time: 03:23) my head.

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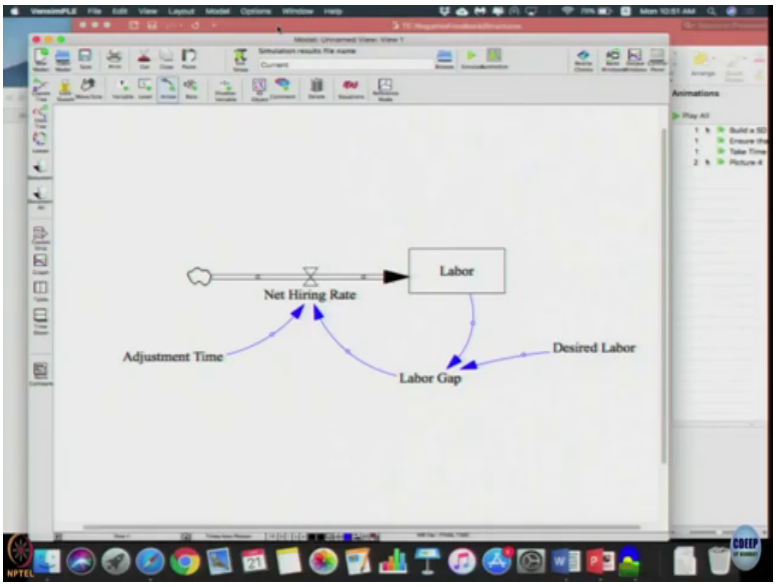

So, we have labour, I am clicking outside and then it is not click and drag just click once outside and click once inside. Net hiring rate desired labour gap, adjustment time. Once it is done then I am just going to connect them. The arrows can be straight lines it need not be curves that has no value to the model as an aesthetic aspects.

So, it can be just simple straight lines, you can make it this curve looks slightly better looking that is all, it does not affect your model Whatsoever, to connect it you have to connect the arrow say click on labour, click on labour gap it will draw blue arrow, that is it.

In the diagram I use we can put the plus and minus signs to do that you can right click on the arrow and there is option called as polarity here in that you can say plus or minus whatever you want. So, that will appear next to the arrow. So, you right click it, you can get the plus or

minus. I am just clicking the arrow head and clicking the adjustment time between minus because we are dividing the adjustment time.

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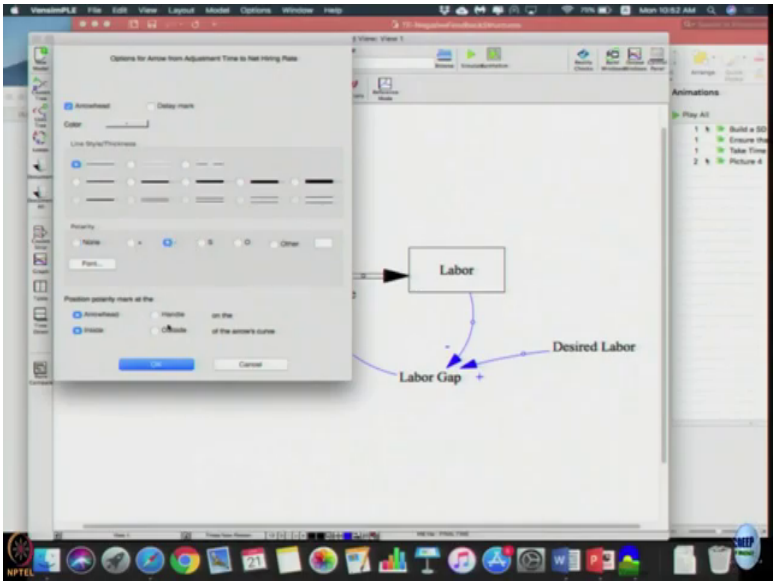

Hence, as if time increases net hiring rate will fall down as the direction is opposite. Again plus minus are just for visual aspects; now click this equation f of x is what shows to me, we will have something called as equation and f of x click that. So, it will go black and white, it will go dark mode that is it in common terminology these days.

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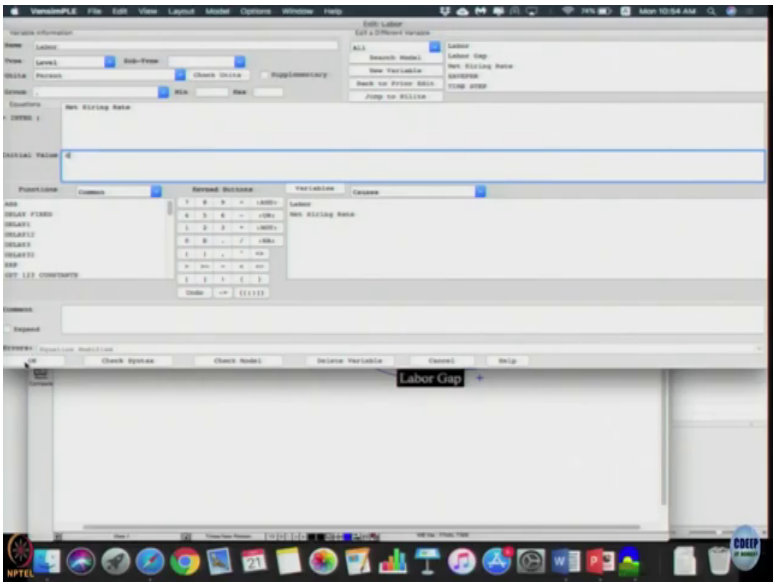

So, once in dark mode you click let us start with labour, you click labour; let us start from the top name labour if fine type is level and if the level or stock is same. So, nothing to change there; units, unit is person and initial value it asks are in already integrating net hiring rate we do not touch it; so, we go to the initial value let us put initial value as 0; let us click, ok.

Let us go to desired labour, let us go to units, again the units will be the same person. Here equation it is a constant value, let us start to the equation as 0; let us put the desired labour values also 0. Now let us go to labour gap, what will be the units for labour gap, so, click the drop down already the other units that you have already typed will come by default Vensim goes two units one is dmnl which means dimensionless other is the time unit itself which is month.

So, then we have defined person so, this solves as 3 person difference of persons again person difference as we want is desired labour minus labour. So, if we click the variable here, the same will appear there you click it ones or you can type it it is up to you. But all the variables listed in this box where I am pointing it my arrow has to be used in the equation it is defined in this equations box, if not it will throw an error. For example, if I just write it like this, labour gap is decide labour and click ok, I will get an error saying following inputs are not used.

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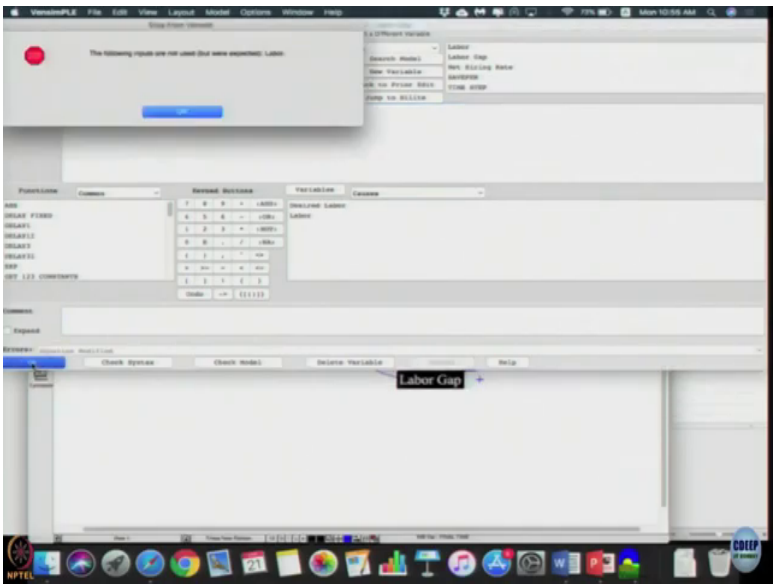

So, it prompts you are saying that there are two inputs you are not used font. So, you click and then put a minus sign, put labour then we clicked ok. Let us note adjustment time, adjustment time unit if we can see type is already constant, it is not getting affected by anything else. So,

it automatically selected as a constant, the unit is month we are measuring time in months and problem statement have 6 months. So, I am just going to put a value of 6 into this, ok.

The last comes in at hiring rate person per month. So, net hiring rate is labour gap divided by adjustment time; net hiring rate is units is person per month, the equation is labour gap divided by adjustment time.

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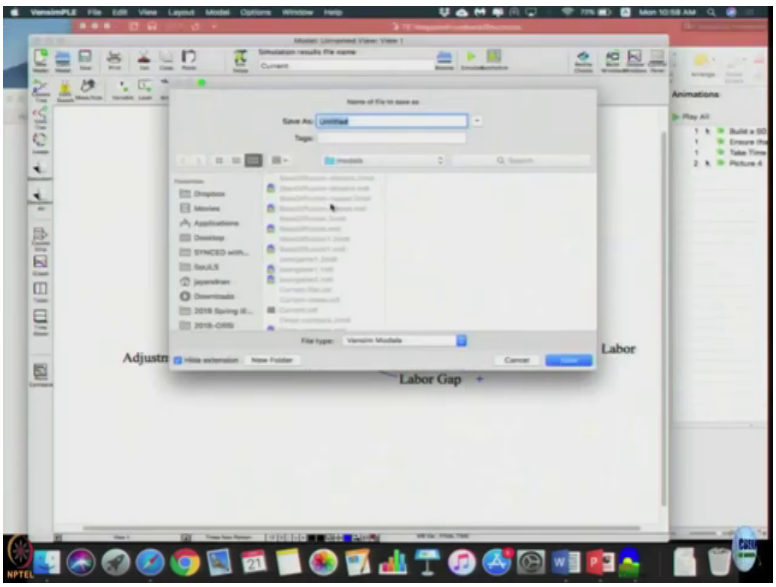

I am just going to save the model, yeah. So, let us again all take a look at labour is units person initial value 0, net hiring rate says net hiring rate you just leave it. We go to desired labour units is person the equation 0, I click ok. Labour gap, units person equation desired labour minus labour adjustment time units month; equation 6, it just a constant 6, a net hiring rate units is person per month labour gap by adjustment time.

It is case sensitive and word sensitive, somewhere you use person somewhere else you use persons or it is just a string it will say it is wrong; units do not match, it just a piece of software it is not going to pass your English. Once you have got this you can do model.

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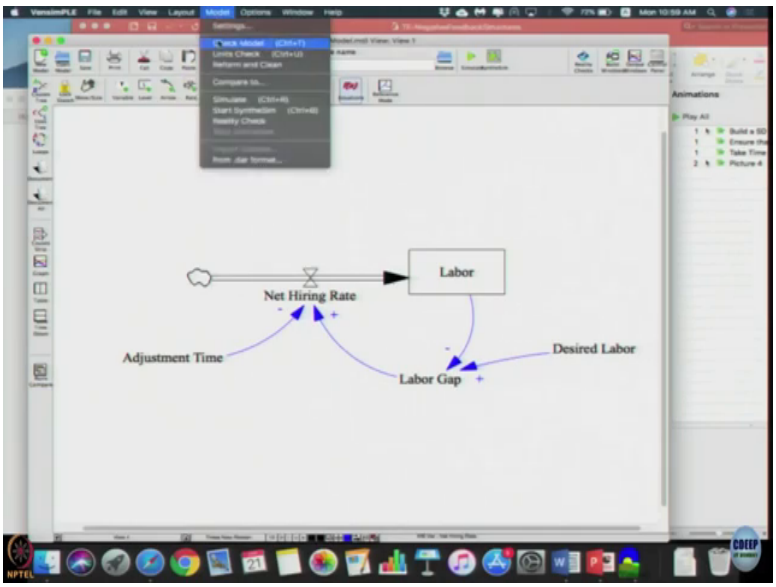

Check model, it should say model is ok.

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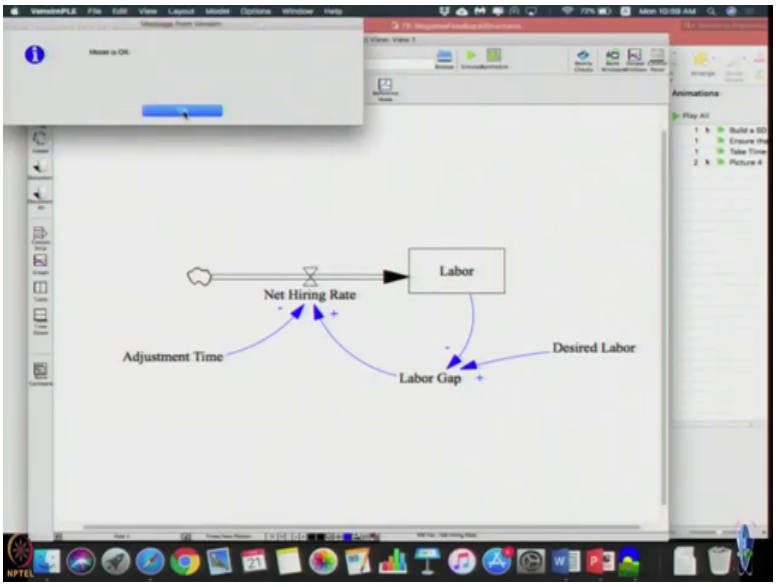

So, now let us click simulate.

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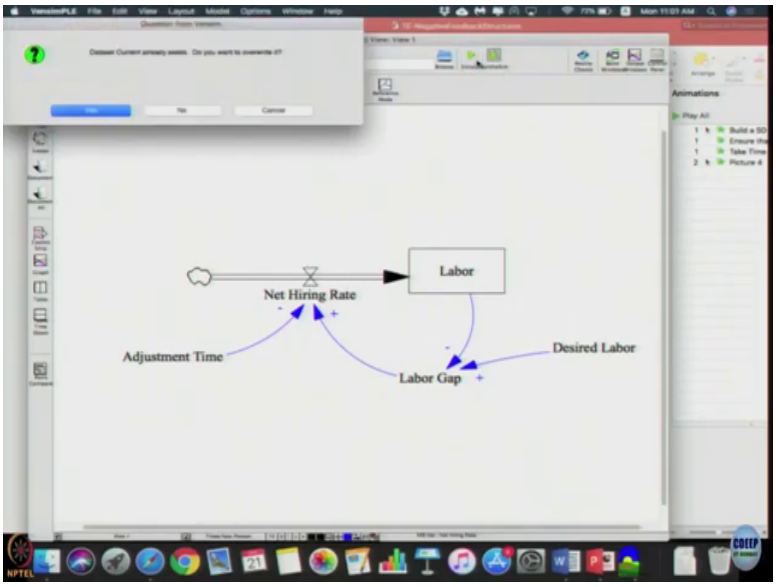

It will ask data set already exist you want to overwrite just say yes, the simulation is already done. Now, you can select any say let us select labour that is a stock, and if you click the graph on the left menu bar, this one which is being highlighted right now 1, 2, 3, forth one from the bottom.

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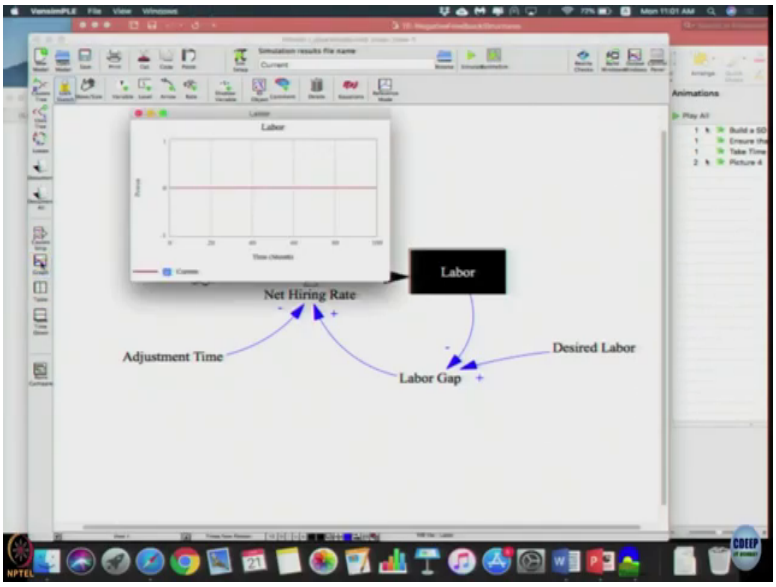

It will get a straight line, there is no change in it. So, the system will always be in dynamic equilibrium when what happens? When desired state and current state is the same or when net flow is 0, the net flow is 0 then it has to be the same in this case. So, for example, if desired labour is 100 labour is also 100 then it will still be in equilibrium, no change will happen. So, this is what is called as dynamic equilibrium; over time things are still in equilibrium nothing is changing.

So, now we want to see what will happen when any of these cumulates changes. So, let us go open the equation click desired labour and make the desired labour 100, you click ok. Let us click play overwrite dataset yes, now let us click labour.

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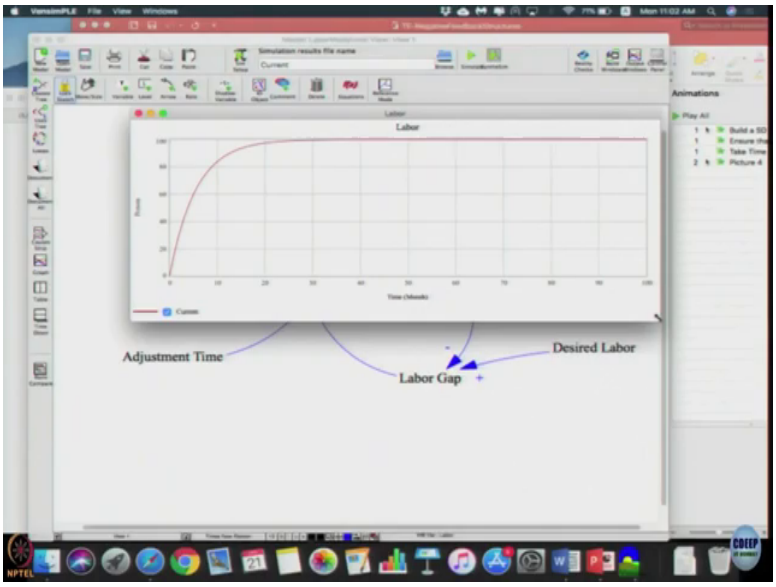

I will start saying this now is goal seeking behaviour asymptotic growth has happened. So, overtime discrepancy has been adjusted over time, until the labour force reached its goal of 100 percent yeah; so, this is entire graph. So, let us see what happens is, to visualize it better I am going to change the model settings to instead of final time as 100.

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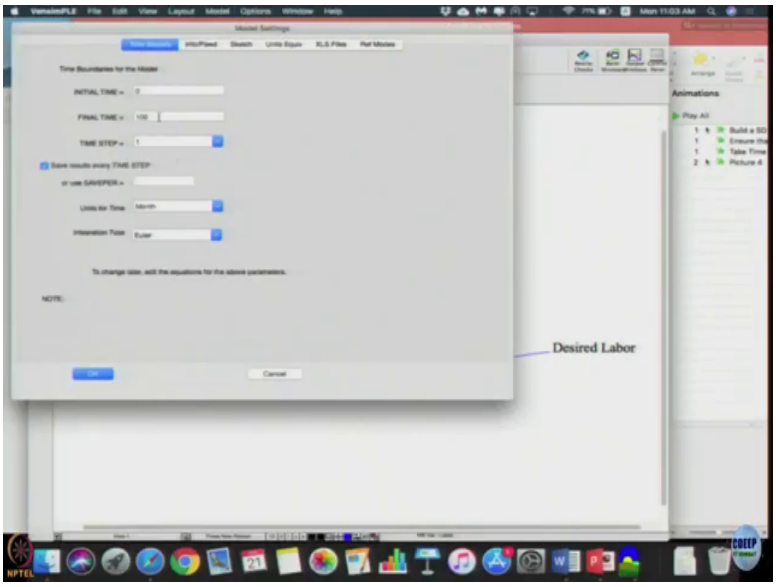

Let me keep it as say 30 final time step; I am just taking the final time step as 30 to get a better resolution graph ok, I am going to explain things, ok. So, this is the value of this stock that should be able to see even if (Refer Time: 13:17) goes 100 is fine, but so, let us observe what happened at time 6. So, your adjustment time remember it was 6. So, all you are trying to see is what happened after one adjustment time went ahead. So, adjustment time 6, the gap fulfilled is about say 65 so, out of 100 65 was fulfilled.

Now, let us see when time unit became 12. At time 12 the value is say about 88, I would say I do not know exact value, but I am just guessing probably it is 88 here at 6 it is about 65. Or rather at time 6 about 65 percent was fulfilled, the gap was fulfilled. Now, at time 12 total was at 88 which will be about 65 percent of the gap between 165, the previous time say 65,

100 minus 65 about 35 about 65 percent of 35 that much percent would have been fulfilled at time 12.

So, at every time unit at every interval of adjustment time about 60 percent of a discrepancy or 65 percent of a discrepancy gets fulfilled and asymptotically it will reach its desired goal that is how the scenario works in this model.

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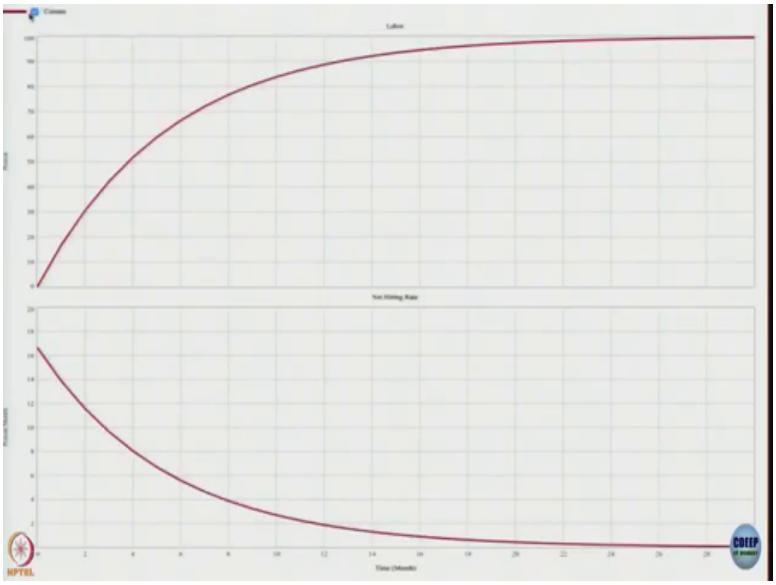

Now, let us take a two different things the top represents the labour this net hiring rate how I open this graph was, I click the labour, I click labour and click this causes strip, causes strip causes strip means; it will plot the this one and plot all the inputs into this so, that is what causes me to understand what caused the dynamics of labour to change like this.

There was only one input which was hiring rate, net hiring rate and unlike your exponential growth systems in this current hiring rate is going to keep falling down exponentially. Things starts around 16.5 or something or may be let yeah 16.5 and gradually comes down to 0; this is expected because at equilibrium the system has to reach net hiring should be 0; because once you reach the goal you do not need to do any further hirings, goals in a remaining constant.

So, you want to know the numbers, we just click labour and click this table time down, you will get time on access and get the actual values which it computes every time, ok.

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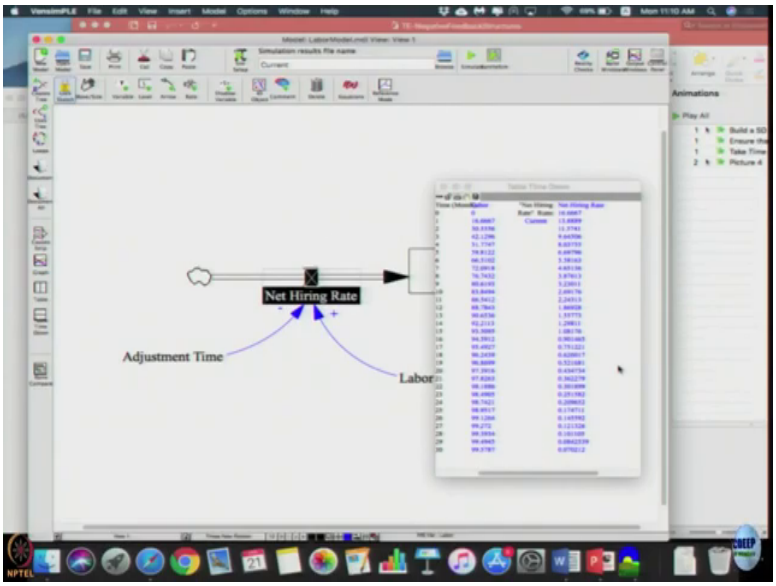

It may be considered (Refer Time: 16:32). So, once you get this labour do not close this window; do not close this window I am just resized it move it to the right. Now you just click somewhere here, click hiring rate and again click the same drop down, then you will find that

the hiring rate is also added as another column in the same sheet there. So, you can start comparing the values.

So, if you select multiple things and click the graph both the things will be displayed. You can do 10 to 1 by 1 or you can use shift. So, if I do labour and net hiring let us see what happens I selected both.

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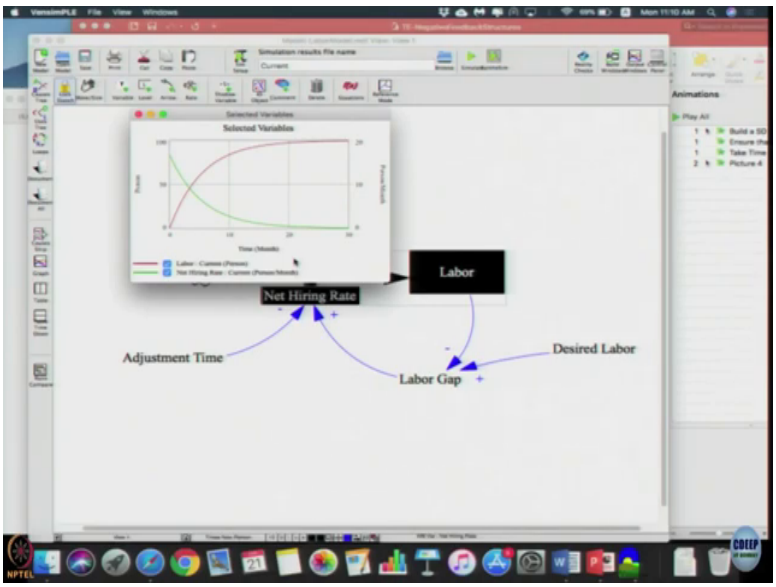

Now, I am going to click graph I get both the graphs simultaneously. So, very simple feature but very useful all I have to do is what are the variables I want I use shift to select all of them and click that graph button then I get multiple graphs in one picture to so, that I can see exactly how it changes. But be careful about the units, because here it uses left y axis and right y axis, left y axis it is used for stock right y axis is used for persons per month.

So, if you have more variables it will start to superimpose multiple y axis one on top of each other, ok. So, just be careful we can try that also Let us see what it does let us do net hiring, labour, labour gap all three other two are constants I am not putting it. So, because it is up to our intelligence to figure out which graph is mapped against what, but you get enough evidence.

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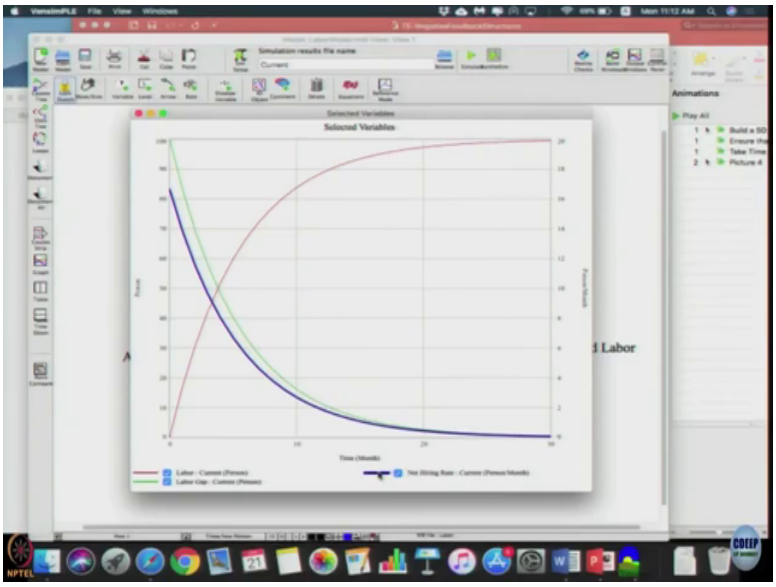

So, already shows here labour and bracket it says person; that means, the unit of labour is person, labour gap is person the same units are appearing in this graph here. So, if you do not write the units it will just show it as blank. So, you will not know what is happening, same thing net hiring rate is a person per month. So, it must be person per month; you know it is blue (Refer Time: 18:39) I highlighted as you go here it highlights. So, there are these kind of subtle features which is makes it very useful and powerful, ok.

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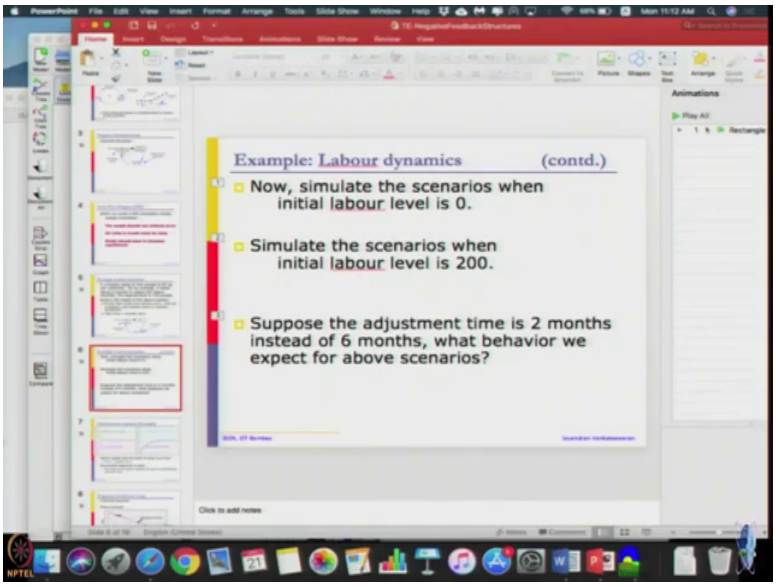

Now, let us we have already done this simulate the scenarios when initial labour is 0; simulate the scenarios initial labour is 200, let us try that. So, I am not changing anything yet but, 100 itself I want to know what it is. So, when I click play it will ask you this question current data set already exists do you want to overwrite it you just said no.

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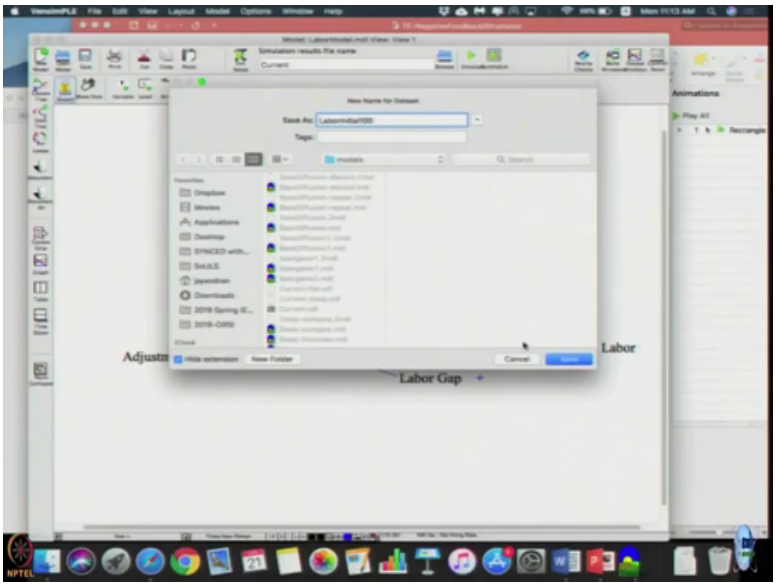

So, here we can say labour 100. So, labour initial value is 100; let us click save. So, that data set is now stored as labour initial 100; desired labour stays at 100 labour changes from 0 to 200 change labour to 200 initial value of labour 200, desired labour continues to be at 100; desired labour goes to 200 then when I click simulate again it will as overwrite this labour initial 100. You said no do not overwrite it, save it as labour initial 200, (Refer Time: 20:07) that is labour initial 0 anyway labour initial 200; even if we did not get overwrite we will come back.

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Now, observing graph, since it have approaching it from we are not changed the bottom; I mean we have not changed the model desired labour is 100, current labour is 200 that means, effectively we need to fire people. So, the net hiring rate here actually means I am removing from the system.

But, the same model works by just changing your inputs as you can see the labour is now falling to 100, it will be what kind of say mirror image of the graph that we got here. We are adjusting the discrepancy in every time unit about 60 percent of the discrepancy is getting adjusted, ok.

Even if I not able to both the graphs I will do the instructions again I will write it and put it in model, I can say curve those instruction. Basically before simulating for each setting you do the under what it should be stored here in the top, you can see the name here you give it and

store it. So, and automatically all those data set will be alive as long as simulation is up and running, I mean your Vensim is open. So, all those graphs gets superimposed.

We can also see how the net hiring works. So, here as you can see these are the people who were hired in the first case and the initial labour was 0. So, we hired lot of people and then slowly reduce the number of new hires. In this case lot of people are laid off and then as over a time less and less people are laid off, then initial value is 200. So, the system remain the same, we just change the parameters and the model became even for letting people go the same model was used.

When we change the adjustment time what do you think will happen? So, adjustment time from 6 became 2, how do you expect the shape to change? But, adjustment time is lower he must reach the goal sooner and faster, earlier, right. So, we can try that go to equation change adjustment time to say 2; run it overwrite and we will going to put no labour initial 200 82, click save go to labour graphs that I am going to remove one of it it is, ok.

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I just removed these two lines. So, I am just putting two graphs one adjustment time was 6 which is a green one and the red one when adjustment time is 2. When initial value of stock was 200, the goal is 100 both reaches the same goal except as the expert as adjustment time is longer it takes longer time or adjustment time a shorter. It will has to reach the goal earlier which is same dynamics that we can expect, but the shape of the system continues to be asymptotic.

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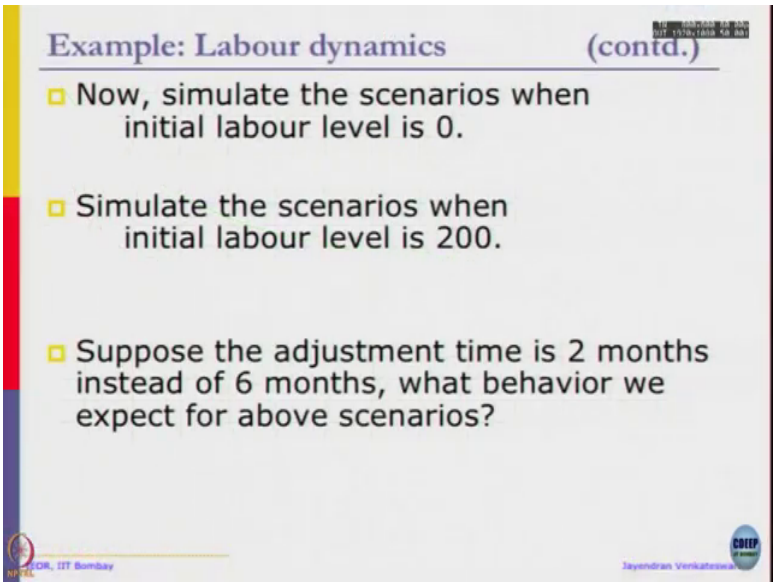

So, adjustment time is 2 months in 6 months we just saw that, ok.

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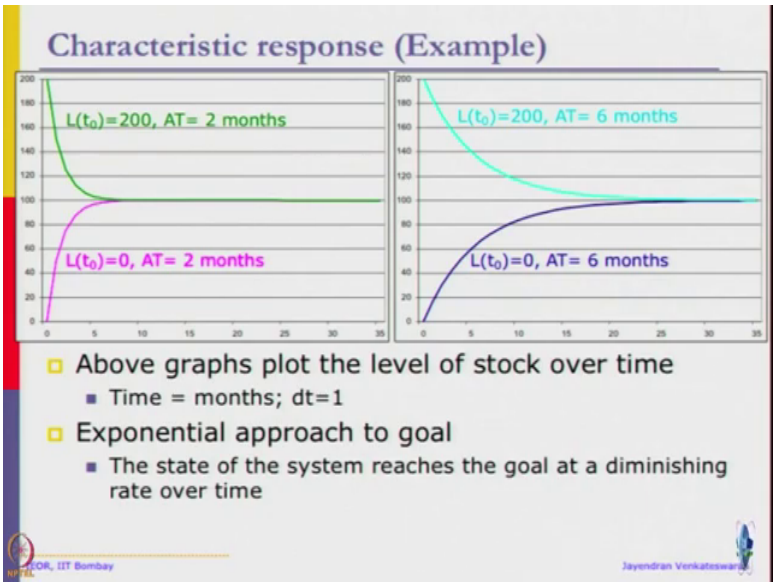

So, I have the graph here also. So, when the initial level is 200 and adjustment time is 2, initial level is 0 adjustment time is 2 because it will be mirror image except that you are approaching the goal from either the top or the bottom as the case may be. And as adjustment time becomes longer it is going to take even longer to reach your goal, that is what this graphs are telling us, but as each adjustment time process we will be adjusting about 60 to 65 percent of the discrepancy. An exponential approach to goal happens state of system reaches the goal at diminishing rate over time.