Introduction to System Dynamics Modeling
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Lecture – 15.3
Information Delays Delays: Higher Order Information Delay

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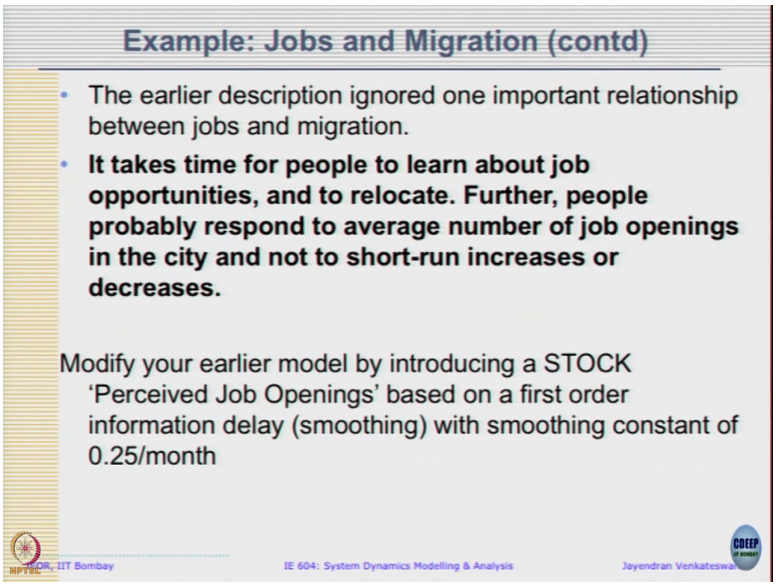

The earlier description ignored one important relationship between jobs and migration. It takes time for people to learn about jobs and job opportunities and to relocate right, it is going to take some time. Further, people probably respond average number of job openings city and not to short term increases or decreases in the job openings right; so that is what you are going to react to.

Now, we are going to modify this our existing model by introducing a STOCK called as perceived job openings and based on a which will be based on a first order information delay

with a smoothing constant of say 0.25 per month. So, pursued job openings let us just create that.

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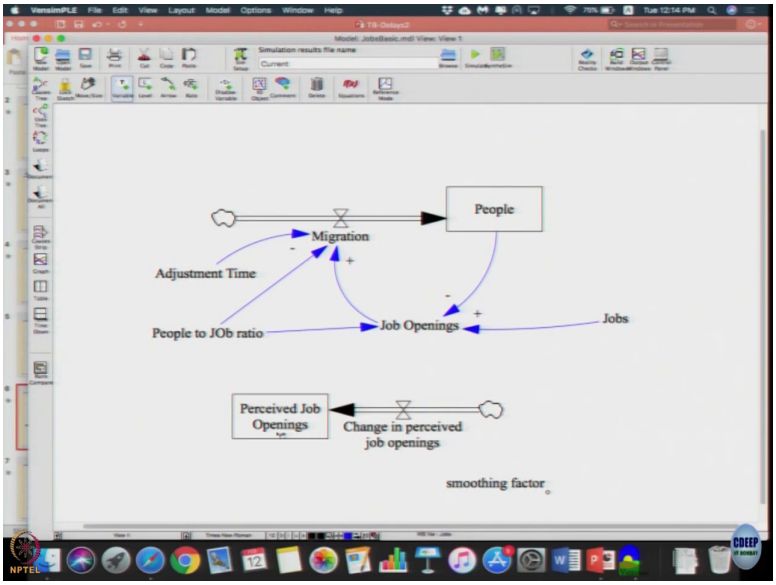

So, created stock as soon as created stock immediately you add a flow because stocks can only be change through flow else if we too tempted to just put another variable and your system may not work the way you expect it to. So, immediately we just change it ok; this is a change in perceived openings and the new information let us model smoothing factor. Now, this perceived job openings reacts to the actual value of job openings right. So, here a reported value or the actual value will be the job opening itself.

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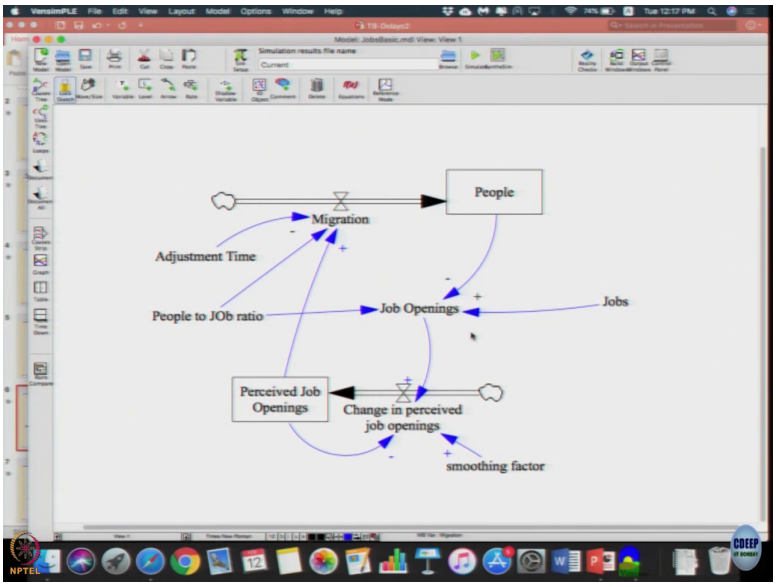

So, this and your current value will be the perceived job openings and now instead of reacting to the job openings; they are going to react migration reacts to perceived job openings. So, I am going to click delete, delete thrash bin, then you click this arrow, click arrow click perceived job openings; which feeds into migration.

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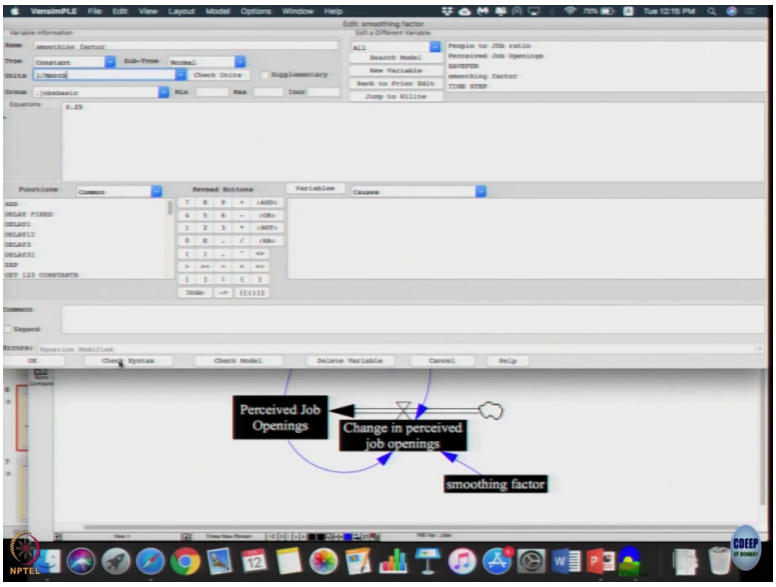

Now, if you select your equation thoughts are going to be black that is a smoothing factor is 0.25 one per month.

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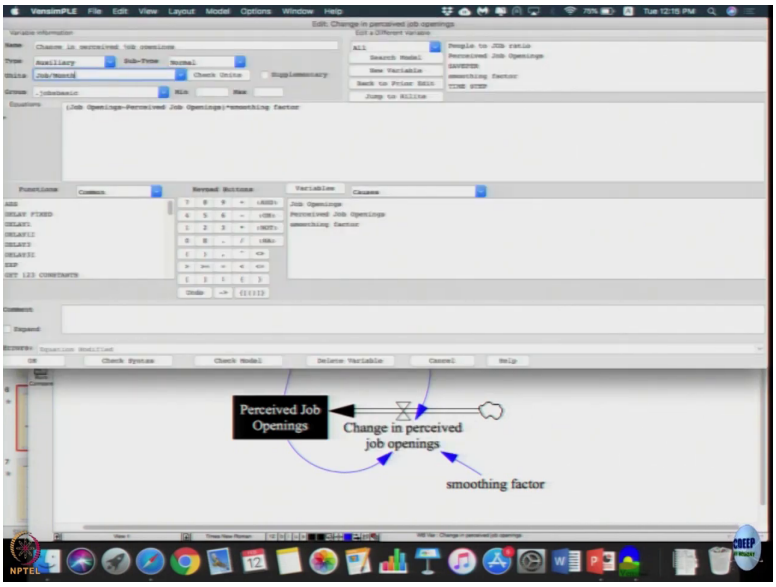

Change in perceived values is both units are same; job openings minus perceived job openings multiplied by smoothing factor, units is job; unit of job opening is job. So, this has to be job per month oh sorry, this should be job per month.

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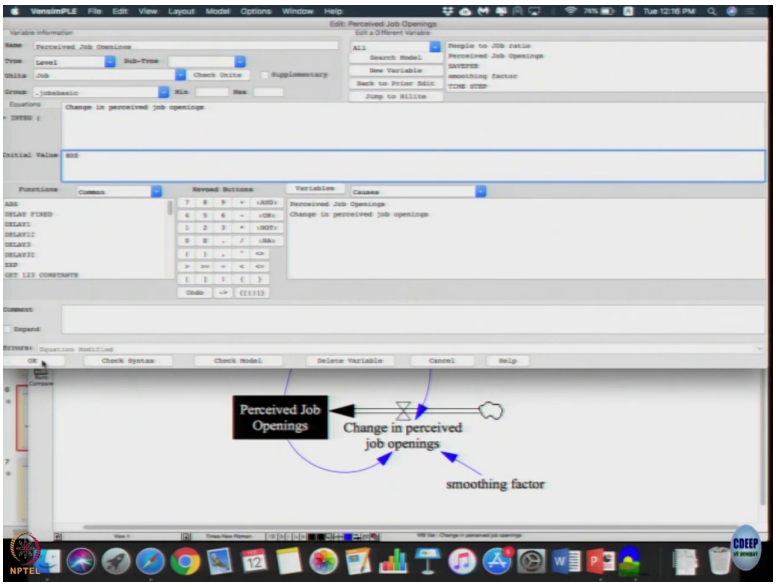

Perceived job openings let us keep; it as 800, sorry job 800.

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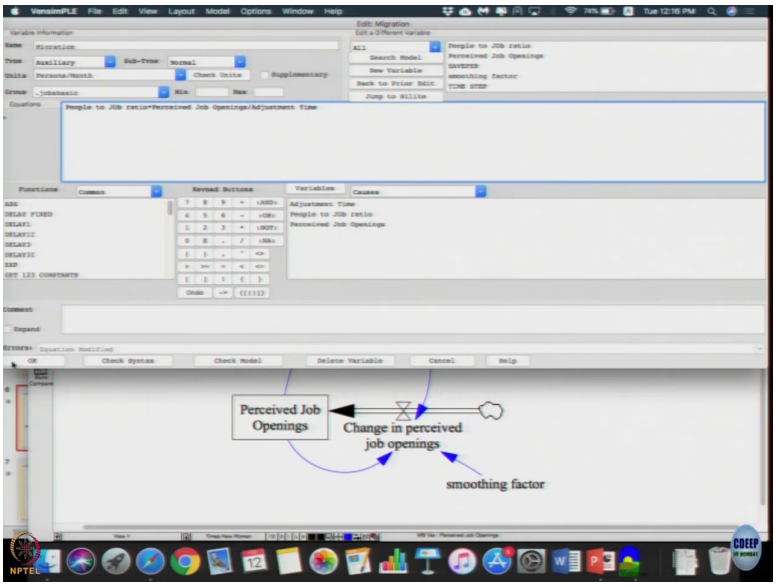

And migration does not react to job openings, it reacts to perceived job openings. So, equation you have upgraded perceived job openings into people to job ratio divided by adjustment time.

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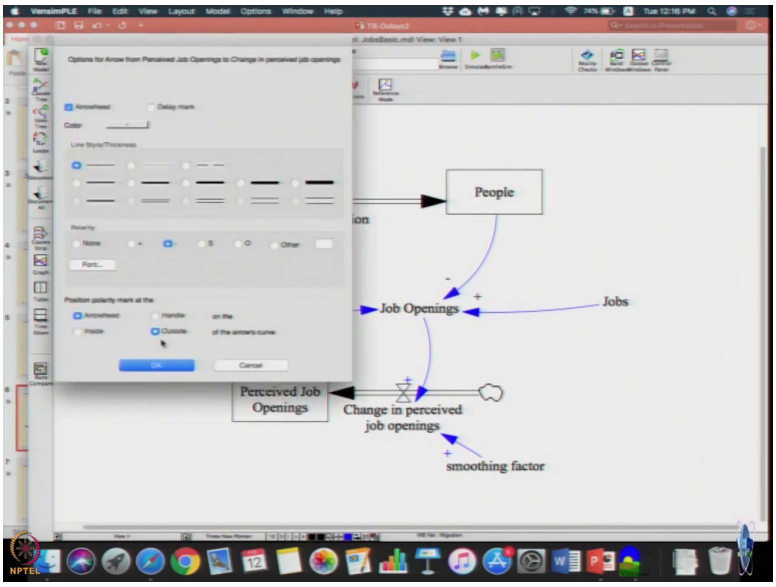

So, and equations for this (Refer Time: 03:26) plus plus minus plus; you can see it.

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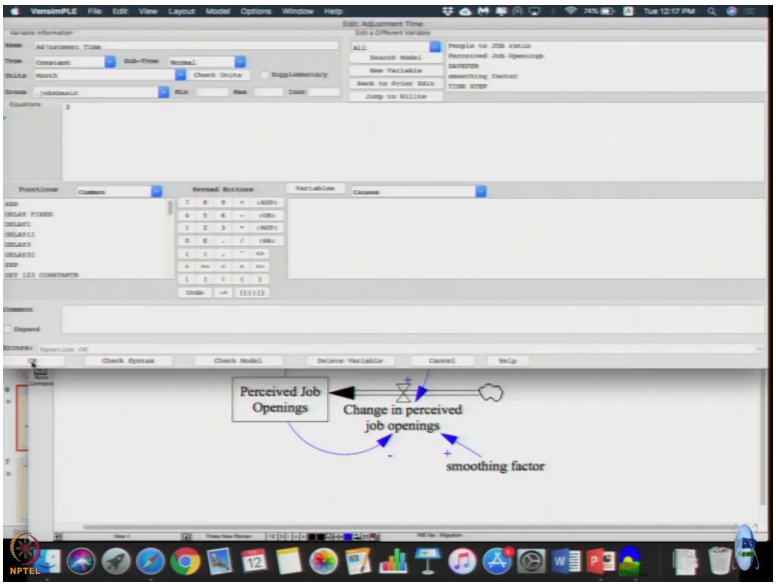

So, now you have two stocks in the system; the system this is a delay because adjustment time we have taken as 2; that means, after 2 months is average time it takes for people to move; so that is the time it take to move. Now, we are putting additional thing called as additional information delay where with job opening information is received later and then based on the perceived job openings people migrate and people migrate, (Refer Time: 04:24) jobs.

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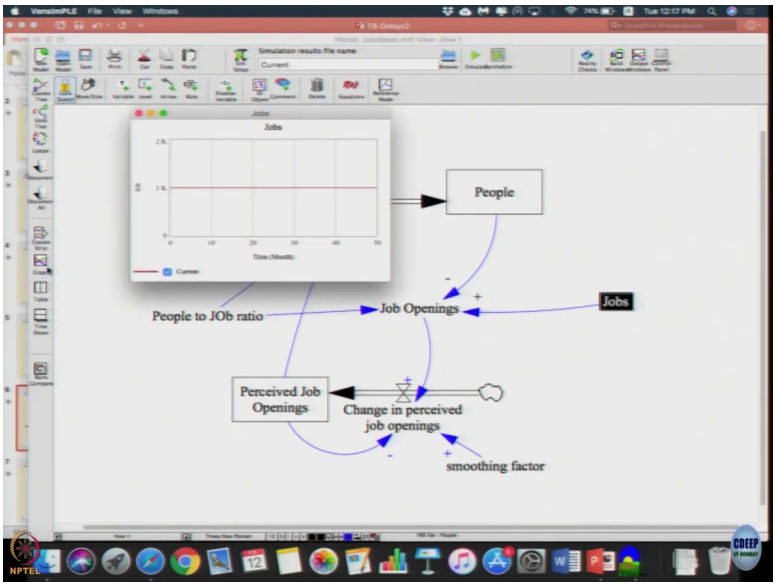

Now, let us simulate this; let us overwrite now see let us look at people, again just to clarify we go to jobs job is same constant at 1000, there is no change in jobs; job was again at 1000.

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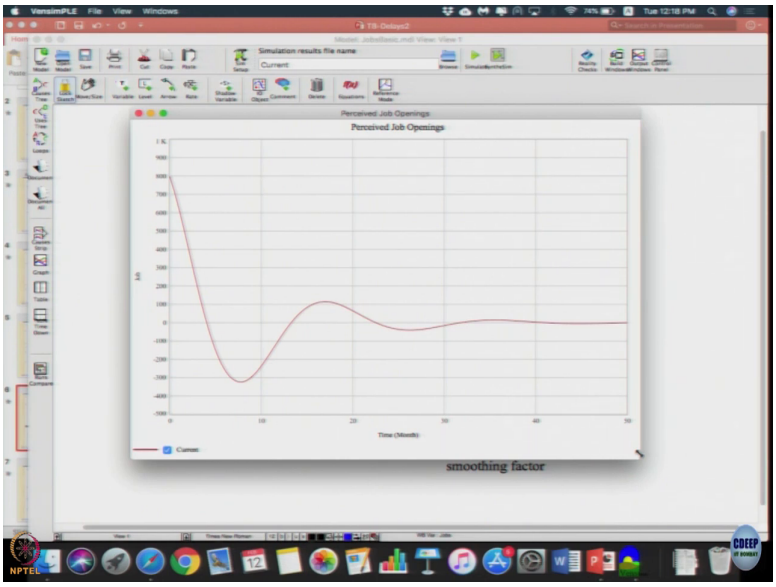

The perceived job openings is still fluctuating; in this case, it did not react; if it was only a first order delay; then from initial value of perceived job opening was 1000 and then it has to..

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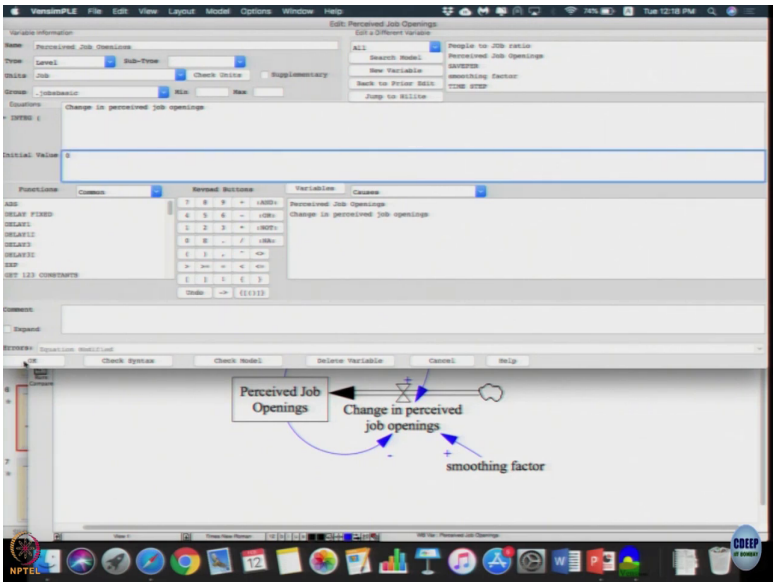

Was an 800 ok; let me, let us make the perceived job openings 0, let us assume there is no jobs initially; now let me simulate it again ok.

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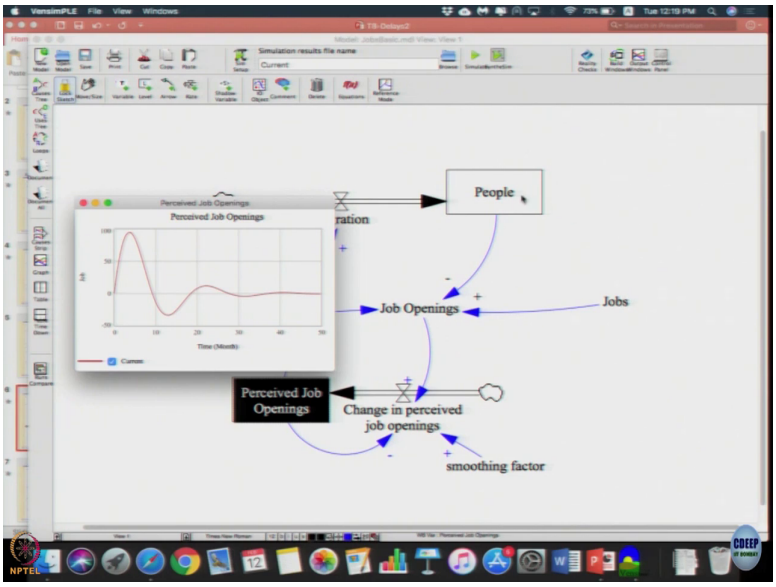

So initially it was 0 and then when additional 200 jobs came about; there is a time 0 came about additional 200 jobs. So, initial people was 800, jobs was 1000; so when it change. So, immediately started to increase, but it did not saturate at to fill the gap, it started fluctuating let us see why. Because, if it is only a first order system, it cannot fluctuate we know that it has to smoothly reach the target, we just simulated for demand right the same behavior we need to expect.

So, the only variable which also can keep changing can cause this behavior is not the jobs, but getting with difference between jobs in the people; that is second stock in the system.

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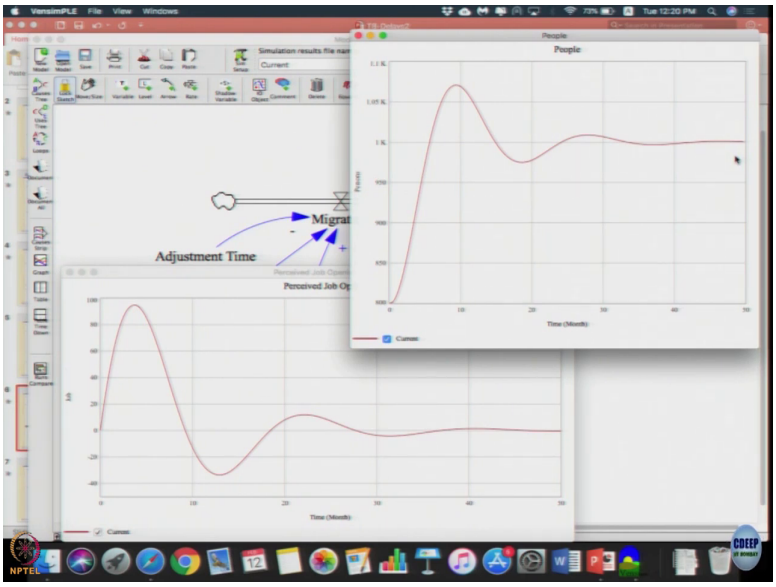

So, let us see the behavior of that; let me get all the output variables jobs, people; this is fine this. So this is a perceived job openings in the people. So, as soon as there are some jobs that are perceived, then people started to slowly come in. And as they started coming in you know because of the delays involved, it overshot the number of people in system overshot; that means, I have more people than the jobs.

So, then it try to compensate because the delays it overcompensated; again it fell down too much then it can take and then again it kind of fluctuate; fluctuated and then finally, damp finally, saturated at the or reach a steady state around 0 here and around 1000.

So, steady state values continue to be 1000. So, these kind of oscillation we call it as damped oscillations that oscillations are not consistent kind of damps. So, to get a system to oscillate we need minimum two stocks and just this information asked us to allows the system to first

exceed, then what it has to be the goal and then it overcompensates down and again it increases etcetera and slowly only it going to converge.

People end up choosing say mechanical unsafe; disciplines I do not know or might choose unsafe new disciplines.. So, this allows this so; that means, we can you just saw what happened right because of the small delay information, more people were there then the jobs available. So, more people are there jobs; less jobs are there then instead of migration, you can imagine migrating to that particular field a number of people are going to join there right. So, then again people overcompensate, then suddenly just more demand, system is going to fluctuate.

But in this case the delays were shot, we are adjustment time of 2 months and smoothing factor of 0.25, when reality is much smaller; this smoothing factors, adjustment time is much larger. So, these fluctuations are very large and there are more delays involved; we just had two forms of delay; one is migration delay, other is the perceived openings delay. We have so many other delays which is going to sustain the fluctuations for a really long time in the 50 years, 60 years, 100 years. So, that is a really really long time before it can actually reach whatever its carrying capacity is going to be..

Like here, we assumed this smoothing constant is gone, smoothing constant variable is constant, but that can also change. I can update it based on new information available; I am going to; I am going to decide to react quickly to the new information or not. So, that can be another factor which will again further cause more dynamics in the system, but now we are going to see real non-linear dynamics when we introduce two stocks.

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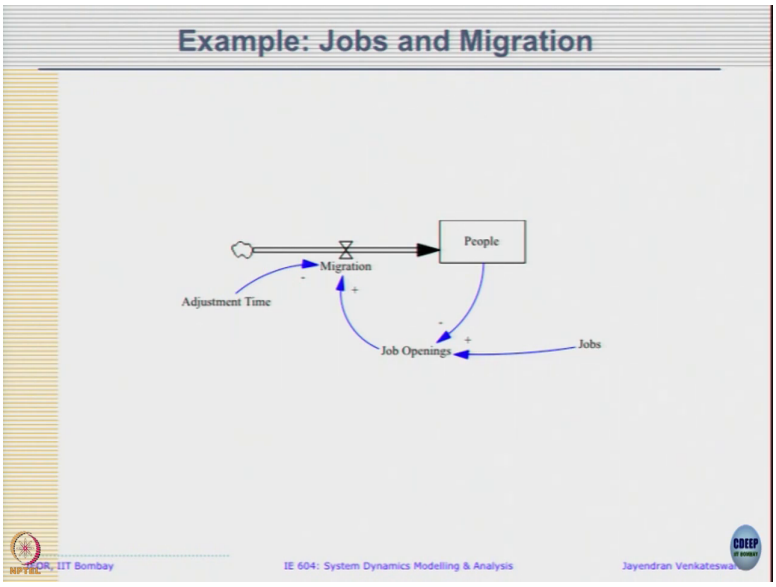

So, in model only the first model is there; this one is there. So, we have to make a dimensional consistent, then add the next stock and flow; only then you will be able to see the damped oscillations. So, we have to do it; it is not now, later. Now, higher order information delays what does it mean and how do you model it?

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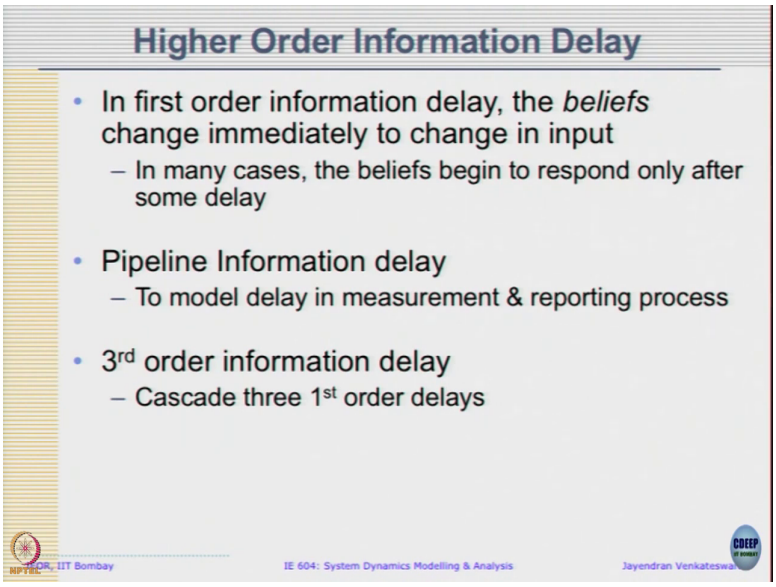

In first order delay, the beliefs change immediately on changes to input and higher delays it takes time for belief to change; it responds only after some delay. A simplest form of it is a pipeline information delay where if it is they are only going to report a measurement delay or reporting delay that values are not change; I am just going to communicate it then it is it can model it very similar to a pipeline material delay.. So, that information is conveyed, there is no change in information..

Let me just give example of the 3rd order information delay; the 3rd order information delay in the material delay what do you do? We had a 1st order material delay and we connected three in series to call it a 3rd order material delay right. In a similar concept, we will do a 3rd order information delay where we will cascade three 1st order information delay.

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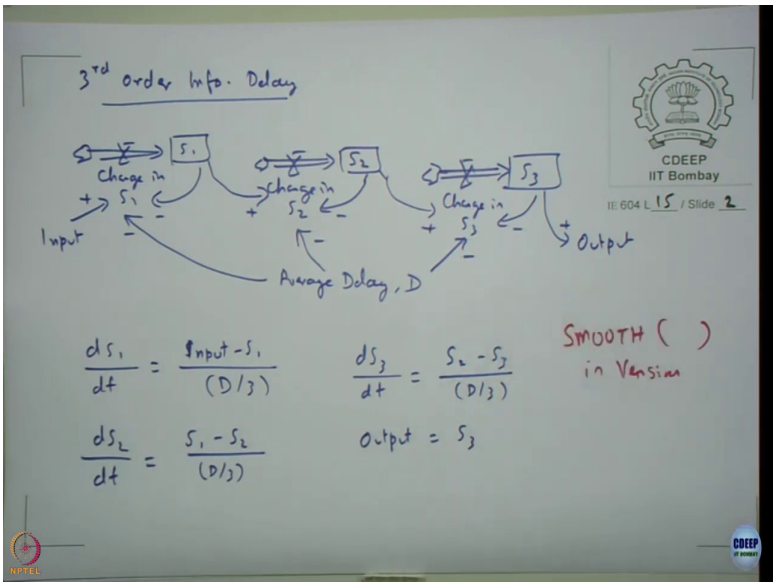

Let us do 3rd order information delay, let us define as stock S 1, change in S 1; let us take that as a input and let us take a average delay. So, this is the easiest right whatever input changes; this is the 1st order delay right just written in a drawn in a slightly different fashion, but it is nothing but a simple 1st order delay where your equation for d s 1 by d t is nothing, but input minus S 1 divided by D by; let us make it D by 3.

3rd order delay; I am going to divide the total average delay into 3 equal compartments. So, what our input minus S 1 is what I am changing. Now, when happens; when I want to start drawing the 2nd order and 3rd order; what I going to do is define another stock S 2, call it as change in S 2; change in S 2 is get affected by S 2 and information from S 1. So, it will d S 2 by d t; it is nothing, but S 1 minus S 2 divided by D by 3.

So, now if I increase my input initially assume input is equal to stock 1 equal to stock 2; let me finish it and then I will explain. Let us put a stock 3, let me have it as; change in S 3 plus minus average delay. Then I have final output plus and your d S 3 by d t; S 2 minus S 3 divided by D by 3 and your output is nothing, but this stock value S 3 ok.

So, what happens when I change my input? Assume input equal to stock S 1 equal to S 2 equal to S 3 equal to output. So, input is equal to output; system is steady state no change. Suppose, input changes by 1 unit; then based on the difference, first this stock changes; the next time period only this stock is going to change and reached a value change the value of new value of input and then this value is going to change; so this how we model the information delay.

Since again as you can see information is not conserved; suppose input increased from 0 to 10; the pulse input and then it became again 0, a time 1. Then this will increase; so based on average delay; it will increase a one third of it this will increase one third of this, this will increase one third of even that right. So, it is like almost like Chinese whispers; start with 1 and this make can maximum grow up to one third of it assume delay is now one third of based on the delay value and again it will go one third of that and then one third of that.

So, each time it will going to keep reducing a final output will be a third order delay of this input and just like we had what is the function delay and function in Vensim to model this in shortcut Vensim has something called as a smooth function in Vensim. In this smooth function, you can directly connect the input to the output and do the average delay; it will smooth the input based on the order of the delay and do the value of the output. You can play it with the examples already available in Vensim further smooth function to directly do that.

Because as you can see if you are going to model as a 5th order delay, just making all these stocks itself is going to make your model so complicated right; so that is when this smooth function helps. Most of the systems we deal with will be a first order delay like demand forecasting people use exponential smoothing. Very few cases we exclusively go for second

order delays and the other higher orders just because it is so difficult to comprehend once you start looking at higher order information delay..

So, it may be easier for us to explicitly model them; like we did in the previous example, we explicitly model, change in the perceived value and change in the migration separately may be easier for us to model that; so there is some physical relation.. So, there is physical context to the model that we are building ah, but in case in we are going to higher order delay is what is going to.