Introduction to System Dynamics Modeling
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Lecture – 23.3
Testing System Dynamics Models
Testing System Dynamics Models: Example 3

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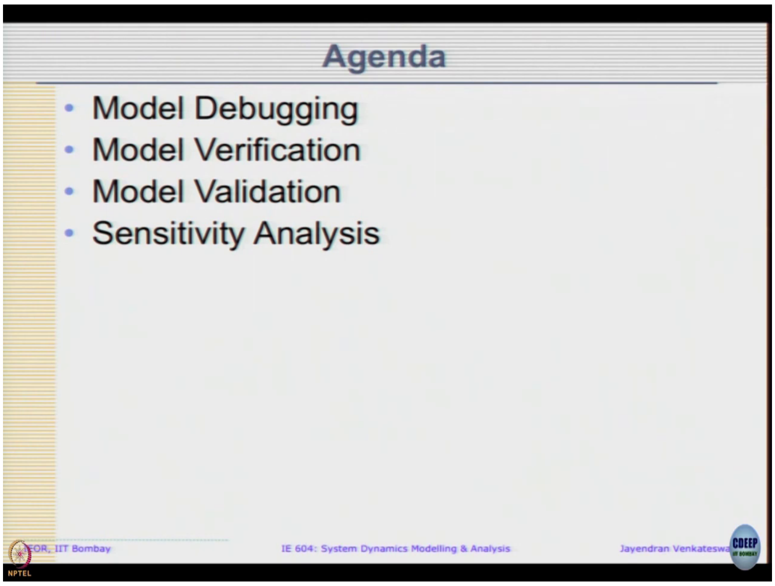

Today, we will briefly look at testing of SD model. Today's agenda, we will cover a few topics or other concept of testing of SD models, you can start with Model Debugging, Model Verification, Model Validation and Sensitivity Analysis these are broad topic that we look at when you think about model testing . So, why do you want to do model testing?

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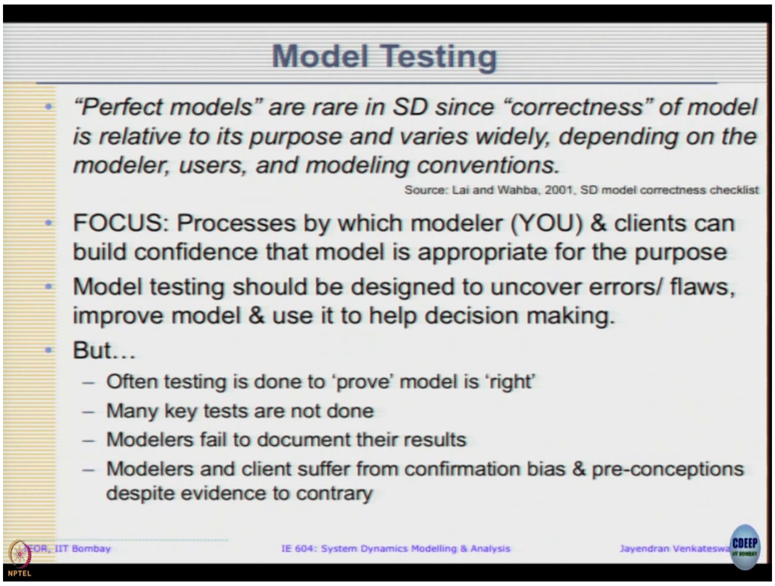

The perfect models are going to be difficult in the case of SD since correctness of model is related to the purpose and varies widely depending on the modular user as well as the modeling conventions. However, we need to build confidence of the model that we have built. So, that we can gain useful insight as well as present our findings appropriate to the purpose on hand. So, this is what we want to do. So, we going to test our model.

So, we can build a confidence on a model. So, that we can have some belief in the result and (Refer Time: 01:30) In model testing, we should be designed so, that we can uncover the various flaws or errors that we do in the modeling. Some are pretty straightforward if it is programming kind of errors, but logical errors are little more difficult and we can use it to improve the model to make it better.

However, we do testing to prove model is a right rather than try to uncover what is a right model; we will come to that later. So, then key test need not be done modelers fail to document result that is nothing new. It is been there for edges then OSC started competitions documentation is always be an issue and modulus and clients of a confirmation bias and preconceptions despite evidence to the contrary sometimes you do not want the results to show what you want to or you not happy with the results it shows.

So, expect the model to be wrong. So, we need to address these things systematically. We will start with a few basic steps and go ahead look at how to validate the model etcetera ok. So, the first step towards is model debugging, we already had an introduction to it last class some time ago there we are looked at a model description and try to uncover the various errors within the model you already had made experience of that.

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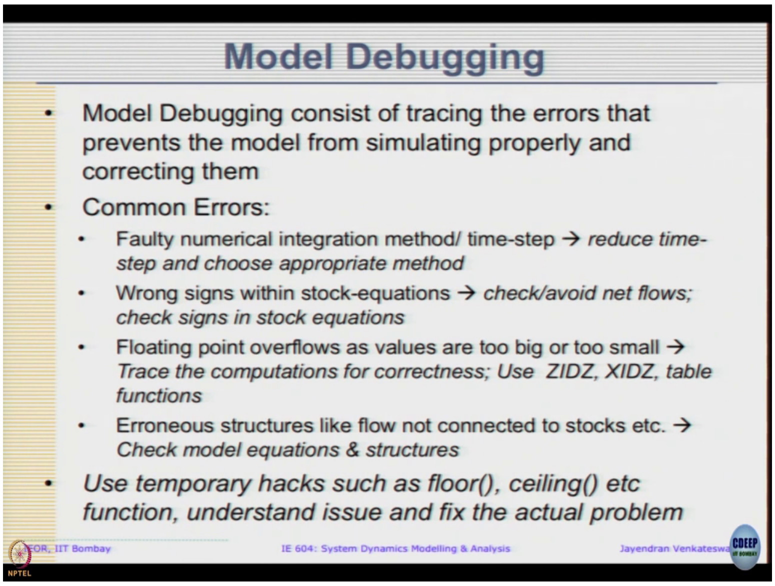

What you want to do is debug the model consists of tracing the errors that prevents the model from simulating properly and correcting them it is pretty basic step. The common errors or some of it are as follows faulty numerical integration method time step is being used. So, one way to counter it is reduce the time step and choose an appropriate method. So, what is written above on the right side of this arrow indicates how we have to counter that flow.

Like if you have to use Runge Kutta method, we used Arced method, Euler method or the time step is too large to get a reduce the time step which is now appropriate time step. So, that we can simulate it properly. Wrong sings within stock equations one get avoid is to check and avoid the net flows many times we end up instead of inflow and outflow explicitly, we can actually moderate as a net inflow. So, we do a net inflow, then we are be careful of the signs.

So, that the model stimulates correctly. Floating point overflows as values are too big or too small or we end up dividing by 0 only with avoid check that is to trace the computation figure out at what point the error occurs look at the table of values and correct the model to see whether that is did that large value is it realistic or not.

There are functions in Vensim like ZIDZ or XIDZ. So, this is when you divide by 0 what is the value to return. So, instead of returning, when you divide anything by 0 it will be indeterminate to avoid that this XIDZ and ZIDZ can be used you can look it up in Vensim help and you divide by 0, then what should it return? It should return 1 or it should return some 0.

What should it return that we have to specify and Vensim supports that. So, maybe that may be required if indeed division by 0 occurs or check out the table function, this your is extra politics more than what you desire it to be next especially in extreme. In that case, then we need to give the value such that it extrapolates correctly.

So, two types of errors one is a warning, that the competition is beyond the table function; that means, extrapolating some cases it may be other is floating per the errors or it actually need by dividing by 0 or due to some error in computations is getting a large value that we need to fix. So, in any simulator and we get an error, then there is something you need to fix. And there could be error in the structure itself like flows are not connected to stocks, a drawing was not proper etcetera. So, for these you need to check the model equations and the structures directly.

So, now, we can use temporary hacks such as floor function or ceiling function or look at a separate part of the sub model of the entire model to see understand issue and fix the actual problem that is actually occurring within the model. So, that is a broad steps about debugging. Closely related debugging is this model verification overall, we what we want and a answer is this question I will build the model correctly.

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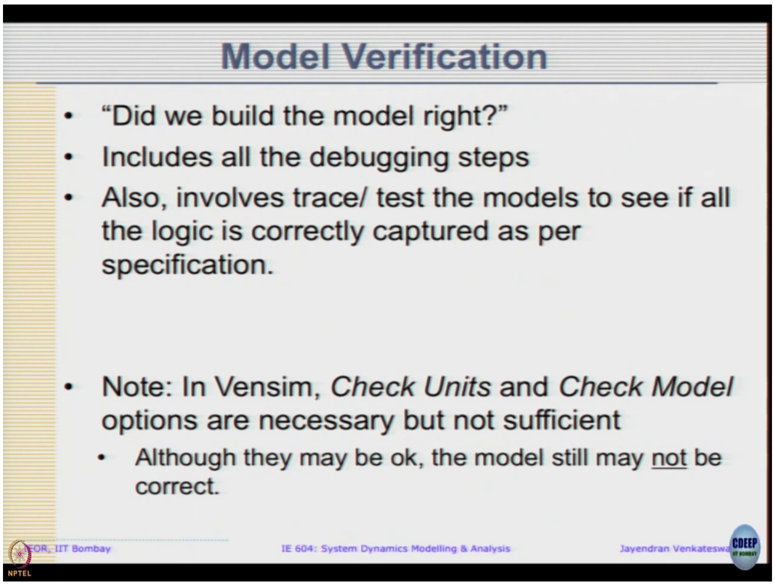

It includes all the debugging steps, but also goes beyond to trace it and test the model to see of the all the logic is correctly model I am captured as per the specification. So, this is what we want to do. So, that in trace what we call this model verification. So, model verification starts with basic debugging and goes a little beyond that one also.

We have few tools in Vensim itself, one of it two of it we have already used this check units and check model. They are necessary, but not sufficient; that means, even if you do the model and click check units, it says units are fine still there could be errors inside the model based on what values are giving what connections you were giving there could still be errors in the model. So, they are necessary, but not sufficient. So, we need to actually check for correctness beyond what we see here.

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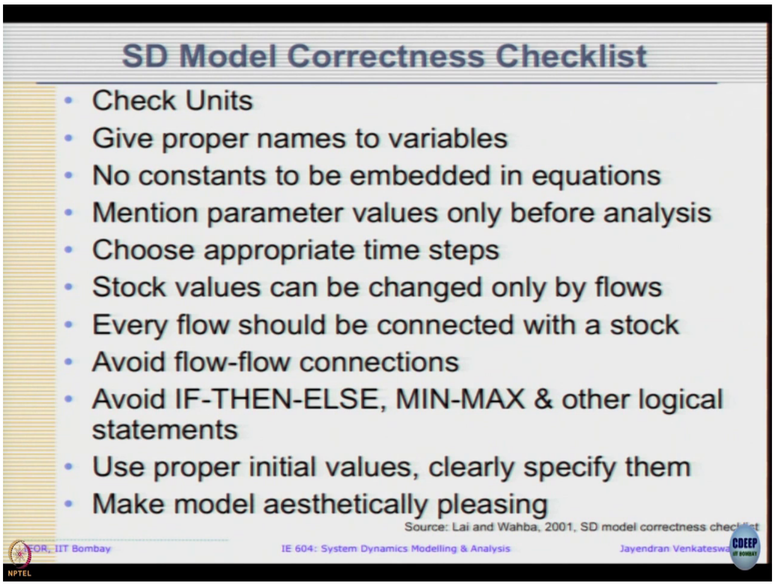

Various people are come up with various checklists that we can go through to see if the model is correct. First is to check units and see if proper names are given to the variables or it makes sense to us. No constants are embedded in the equations. We should try to mention the parameter values only before the analysis, choosing appropriate time steps, stock values can be changed only by flows, every flow should be connected with a stock, we should try to avoid flow connections.

So, try to avoid if then else and min max and other logical statement as much as possible, but problem entails and we need to include it. Else and intuits proper initial values and clearly specify them. So, that model can start at dynamic equilibrium and lastly popular one is to make model aesthetically pleasing, when we as organically grow the model we will find that it is looking quite complex.

But finally, it has few presented to an external audience how do we make it aesthetically pleasing. So, one easy way is to use curved arrows instead of straight lines, because it is a little more pleasing than straight lines and sharp lines. So, this is also quite important.

So, some of these things may seem quite obvious that we ought to do, but many times in our case we do not do that, because its it seems too trivial for us to worry about, but unfortunately that is the one which ends up causing the errors or causing the various issues in our actual model. So, the one way or rather the only way to ensure, we are doing proper debugging and proper verification is to practice.

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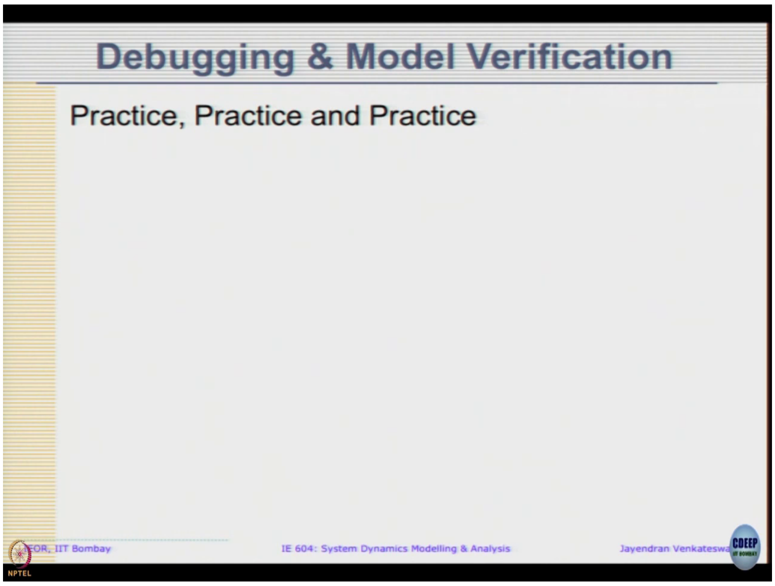

So, that is what we are going to do today, we are going to take up a few models and try to practice the debugging. In fact this time what we are going to do is, I am going to lead the debugging that is I am going to read the description point you to different things. So, it you can observe and follow even if you are not able to catch up in the model my suggestion is you go back and look at this video again to see how I am impressing through the model.

So, that we can also follow the similar steps. So, typically, how I go about checking the model is what I am going to go through. So, let us and for. So, we have three examples, we are going to do today's class, reach how example the model with errors is already online you can download them from model and when each scenario comes, we can try to open the model and see whether it confirms with our understanding that ok. I hope I will remember to mention all the points that I am going to check, but let us see.

Again these are only some of the cases that you are going to see. So, it is important for you to practices other kind of models actually make some mistakes; at least some say for example, from exam point of view, we may not get exact same errors. So, there may be any other form of combinations I try to give as many examples as possible.

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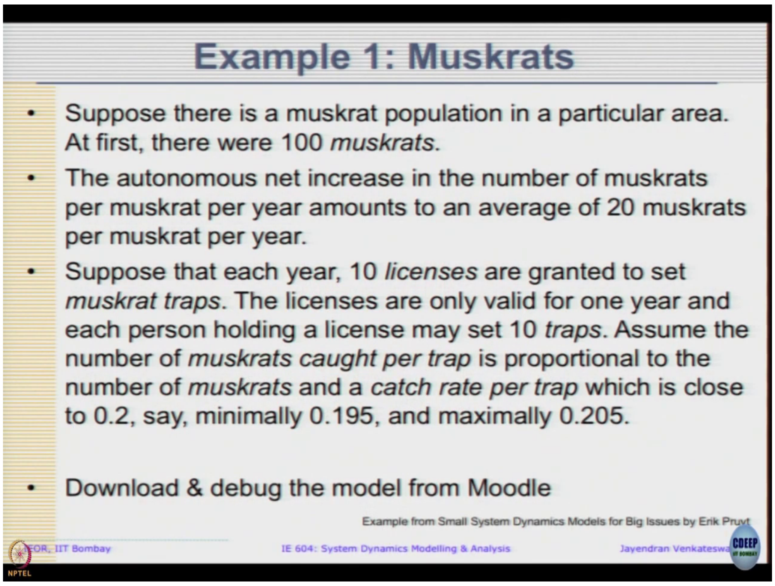

So, let us see the first is let us just understand the model no need to look at the Vensim model yet we have time for it. So, very simple model there is something called as muskrats, it is like a big large rodent section native of north America and invasive species in large parts of Europe and north Asia that is regions near Russia and stuff.

So, let us go with this suppose there is a muskrats population area initially there were 100 muskrats. So, as and when we read the description, we needed visually not visually what can I say? We need to imagine how the model is going to look like? As soon we use a term like population muskrats population area is 100 muskrats. So, terms that are you could be a stock. So, look at the population.

So, maybe its a stock. So, let us picture that autonomous net increase in that number of muskrats per muskrat per year amongst an average of 20 muskrats per muskrat per year. So, let me just talking about some net increase in the muskrat population. So, this must this should be a flow that is going into the muskrat stock ok.

Then suppose that each year, then license are granted to set muskrat traps. These licenses are valid only for one year and each person holding a license may set 10 traps, assuming the number of muskrats caught per trap is proportional to the number of muskrats and catch rate per trap which is close to 0.2. So, minimally 0.195 maximally 0.205. So, this is only description given. So, this so, the second part since, we already talking about net flow, the second part may be something referring with how much is removed from the population. So, this must be the out flow within the model.

Explicitly as you can see there is nothing about birth and death that is given, but if you carefully observe the description, there is; a word net given this could mean there is something about birth and death that is happening. In spite of that an average of 20 muskrat per muskrat is increasing. So, that is what the description that is given. So, now, you need to download and debug this model sometimes, when you open the model it talks about scaling and preferred is 100 percent. So, you get the exact same size.

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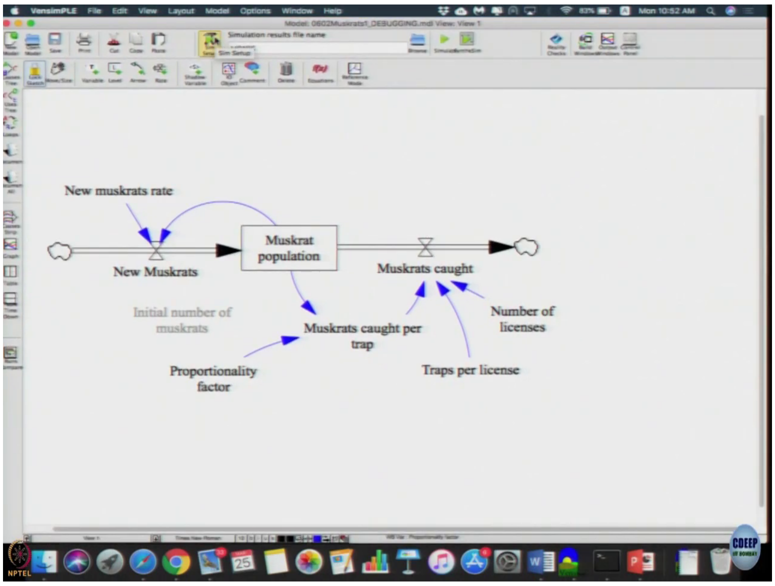

This is a model that you will see. First is the first step is you look at the structure right. So, we imagined there is some muskrat population, some new muskrats come in and some muskrats is getting caught. So, they removed from the population, see description is not fully complete, but given the description you can assume that the muskrat is caught and terminated and not just caught and released back into the population.

So, there are some reasonable assumptions to make. There are some variables like, how much muskrat is caught per trap, how many tracks per license, how many number of licenses, it seems kind of structurally ok. The next we can try to do is look at the model and say check units, units seems to be model check model, model also seems to be. Then, we can quickly trace through the equations. So, new muskrat was about 20 muskrat per muskrat per year right.

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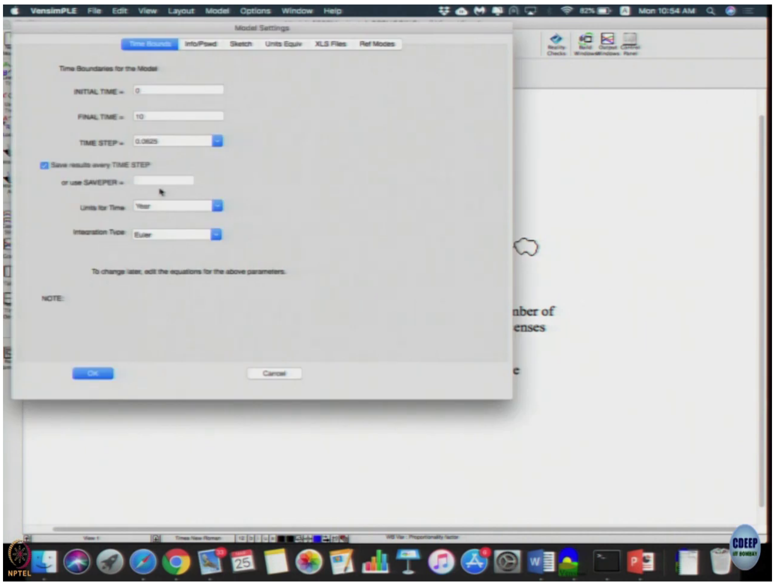

So, before, we going to that we can actually look at model settings to look at what is a time units first try to you see that ok. All the description were in years and we have time units also in years and let us look at this side time step 0.0625 Euler’s method. So, is fine is reasonable quite low, but let us see we do not know since it have an impact. So, let us looks the equations you just move the mouse whatever the units pops up below that, you can see units seems actually be fine.

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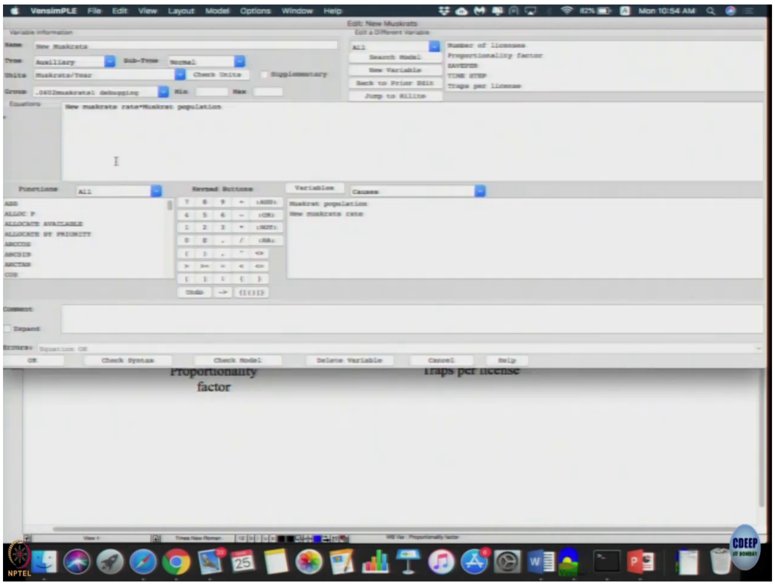

To open it which is new muskrat in to muskrat population a new muskrat rate is about 20 which is consistent with what numbers we have. See any change in constants is not that big a issue it is need to ensure that it is fairly accurate.

Units that is a bigger problem. So, muskrat population should be roughly the muskrat caught per trap into the proportionality factor as per the description and number caught should be number of licenses into number of tasks per license multiplied by number of muskrat per trap that should logically give us the number of muskrats caught.

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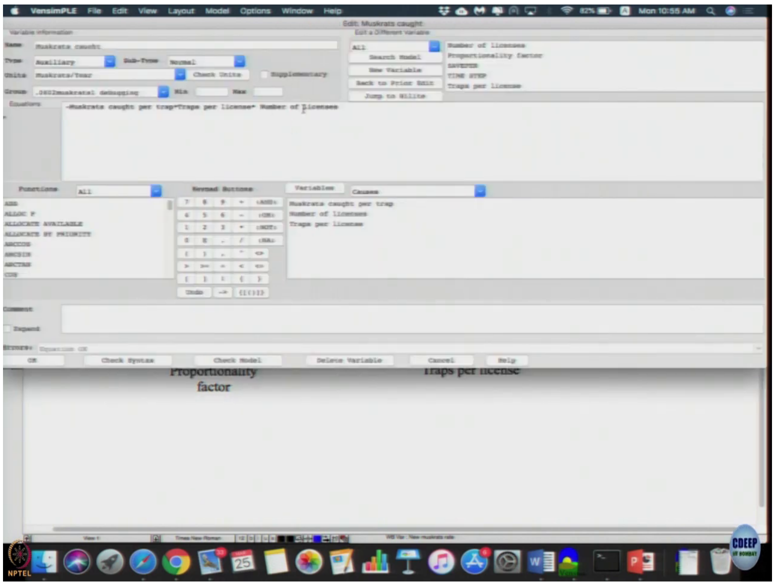

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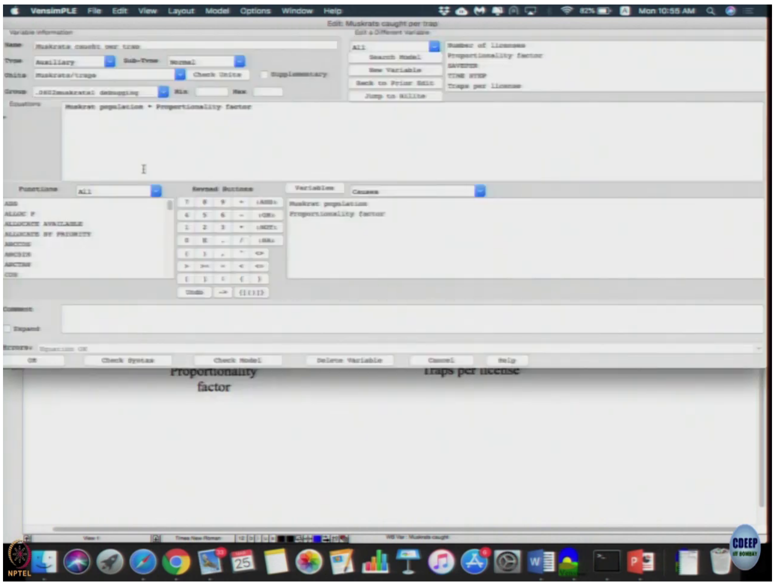
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Traps per license

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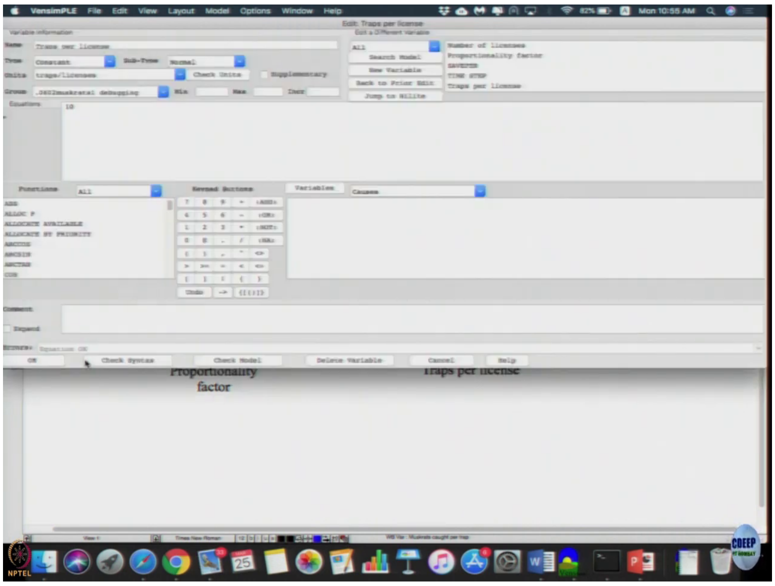

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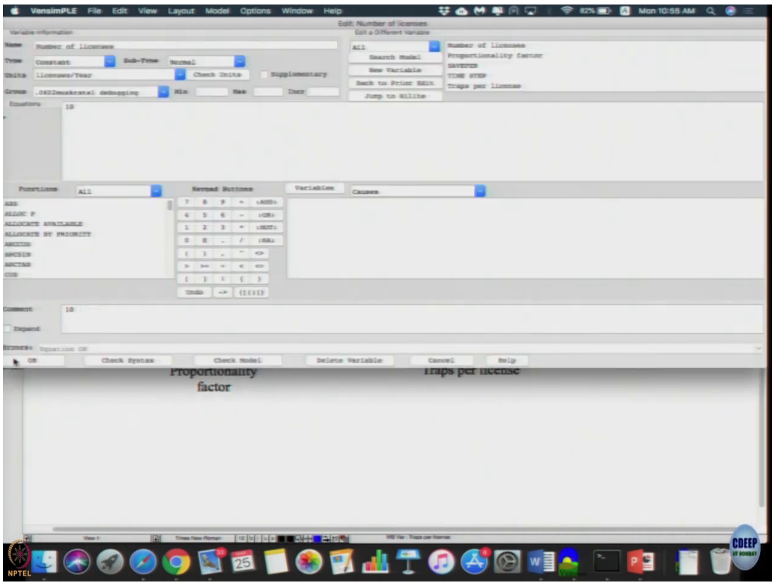

So, which is a product of all three muskrat caught is the proportionality factor. Trap per license is 10 number of license is 10 which is roughly the what the description as said. 10 and 10 traps proportionality constant is 0.195 on this taken hear 0.195 so, minimally it is here right. So, seems ok, let us just stimulate it; that means, let us see if there is errors over write yes ok

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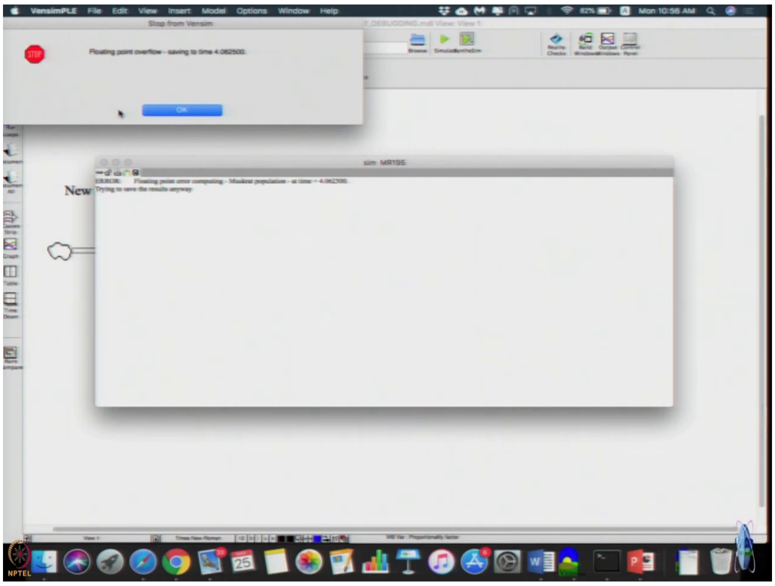

To get this errors floating point overflow, there is an error and error says floating point error computing muskrat population at time 4.06 a simulation run length of 10 years at around 4.06 itself is getting a floating point error trying to say results anyway.

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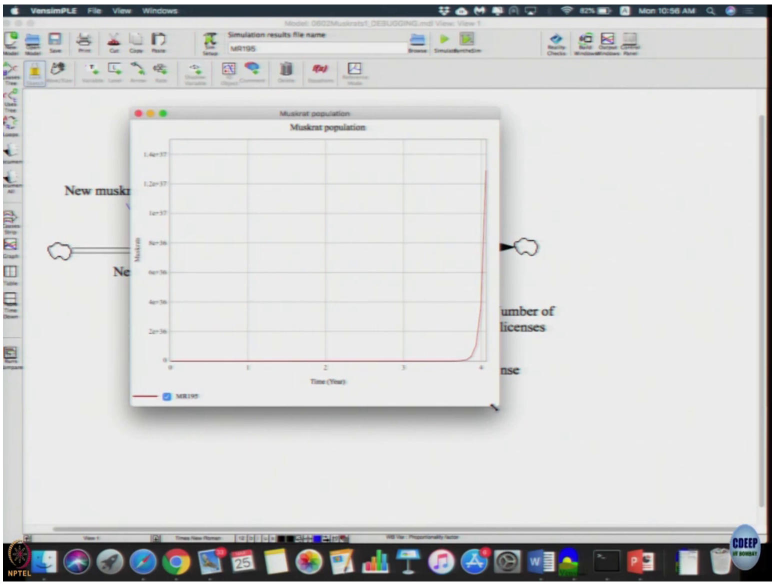

So, let us click close it let us see the graph. Graph is growing how is a graph growing? Know seems to be growing hyper exponential difference exponential means, it has to have doubling time which is constant here it is growing hyper exponentially much more than what it has to be right. So, there must be some error that is one and two actually, if you look at it there is a positive feedback system it has keep increasing, but this is the negative feedback system so, it has to decrease right

So only descriptions it can have its exponential growth, exponential decay or equilibrium in flow and out flow is equal right. This system cannot have an exponential hyper exponential growth, but hyper exponential growth your proportionality constant or a new muskrat rate or something has to keep reducing or keep increasing.

Number of new muskrats should increase a proportional rate should keep decrease, none of the proportionality constants are changing. Here the proportionality constant is 0195, 10 right.

So, none of the constants are changing correct. So, hyper exponential growth should not occur. So, just try to follow my steps. so, but still muskrat population is changing.

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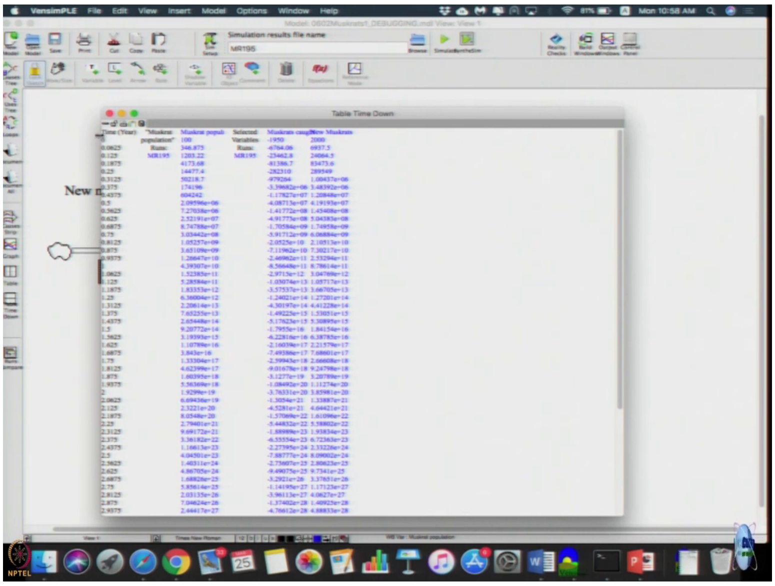

If you look at that population is just increasing all the way and what affects the population? Population affected by both these flows. So, let us include that also in the table. I click the time down table. Here muskrat population and then suddenly you find that. New muskrats are 2000 new muskrats first period is 2000 which make sense 20 into 100 2000. Number caught is 0.195 into 10 into 10 it should be 1950 which is fine, but it is minus 1950 let us look at it what is happening there?

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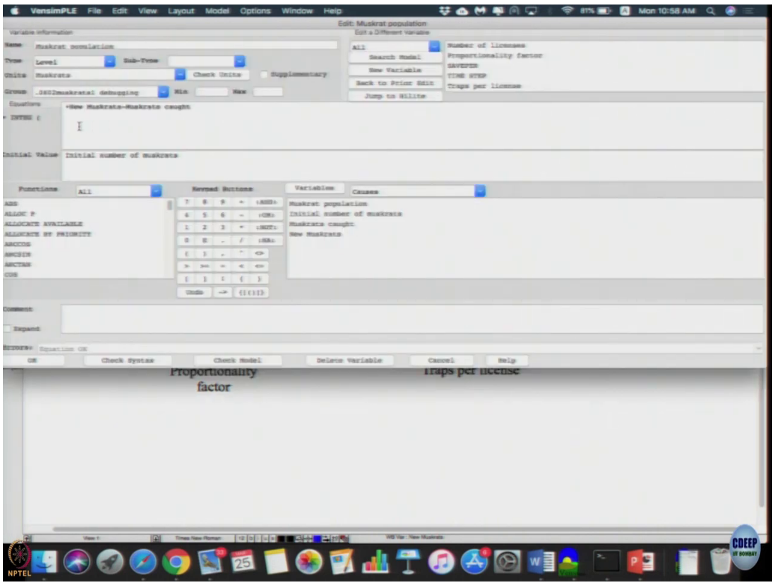

Let us looks at the population here this new muskrat minus muskrat caught inflow minus outflow this is fine just look at muskrat caught.

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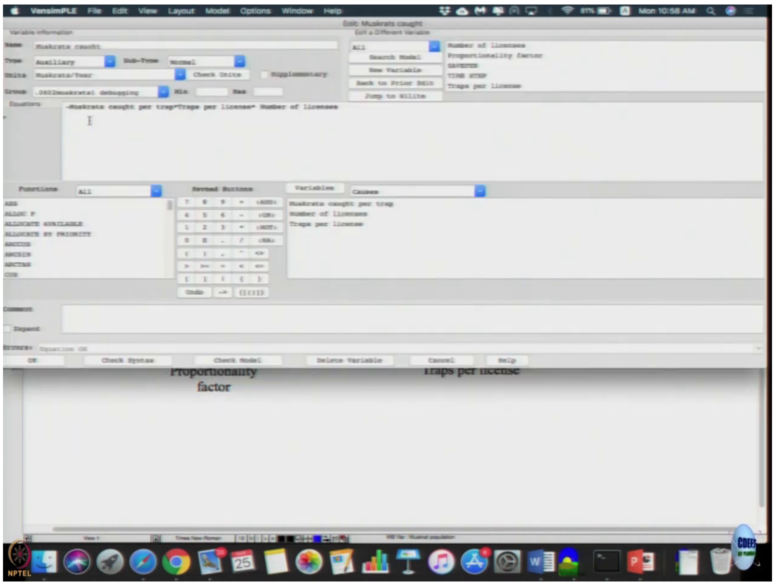

It is minus muskrat caught per trap into this. So, this minus should not be there because its minus and then, we already in compute in the stocks if minus of minus so, it became plus. So, stock value started increasing more than it odd 2. So, let us remove this minus sign. Let us click that is on the model, we did not get any errors, when we run it this time.

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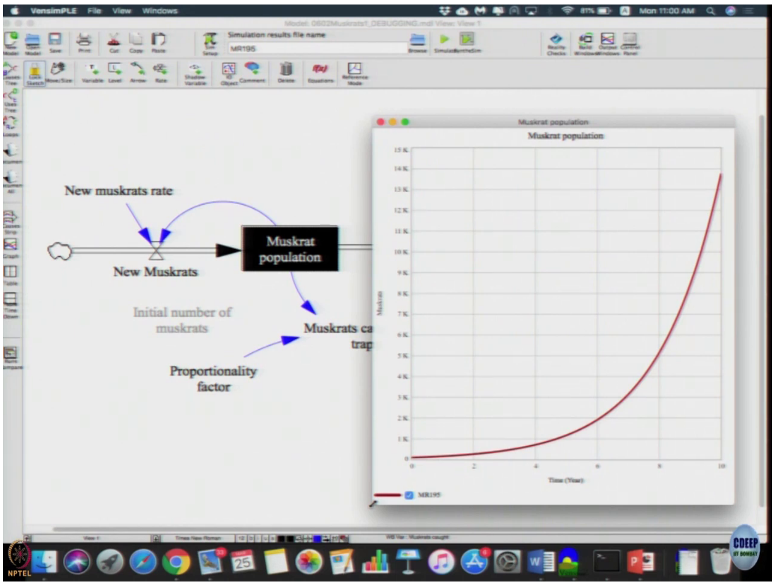

Still, we are getting exponential growth this is fine, but at least doubling time is you can check it doubling time should remain constant. So, this looks reasonable for this kind of errors. It does not seem to be any other errors using the model, but these kind of small bugs also can weep into the model.

So, even though in united it did use some results it did not make logical sense expectation is we actually look at the result and then, we try to see how we can understand the dynamics and see whether the model inherently can cause it right, but if we move to sensitivity analysis in other concepts also, we will end up using these models itself. So, save the what can I say this version of the model ok.

Now, you may not still be done, it says catch rate per trap this 0.2 minimum 0.195 to maximum 0.25, we can logically see for example, muskrat population is 100 and this is 20, new muskrats is 100 into 20 2000. So, instead of proportionality factor in 0.195, if it is 0.2, then we get 0.2 into 10 into 10 into 1000 which will also be equal to 2000 correct in that case, we need to get a straight line. So, we can check if the model is actually producing all the behaviors as for a expectation.

So, if it is anything beyond 0.2 then what should it be it should be have exponential decay. So, we can check with the model actually producing all the behaviors only then it is a completely verified model.

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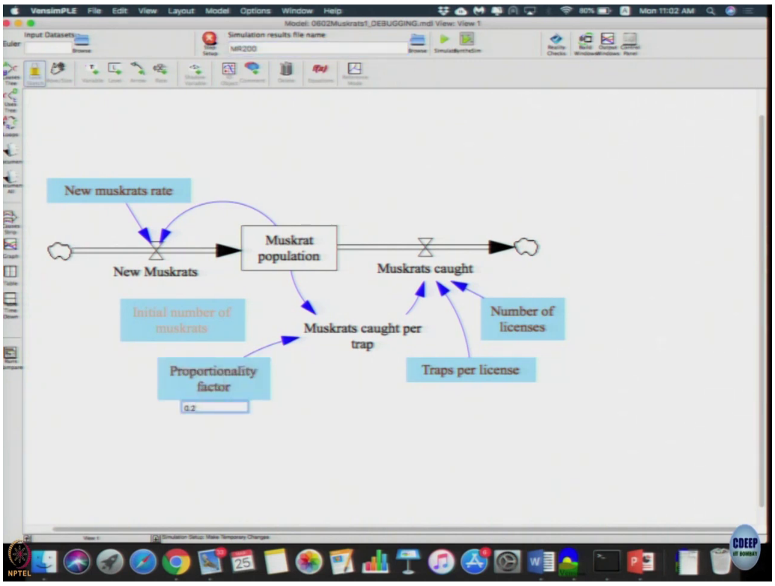

So, one way to do is without see changing the model as let us instead of MR 195 I am going to write 200 click sim setup click proportionality factor and write 0.2 its h let us stop it. Now, let us do muskrat population I just stopped here fine (Refer Time: 22:41) setup now we will do it. So, MR 200 let us change it.

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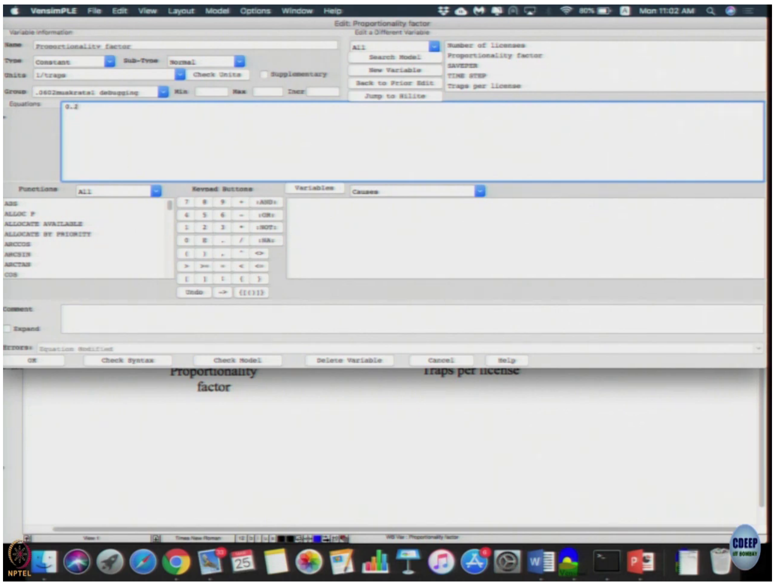

Let us go to the proportionality factor, I just make it 0.2 to play.

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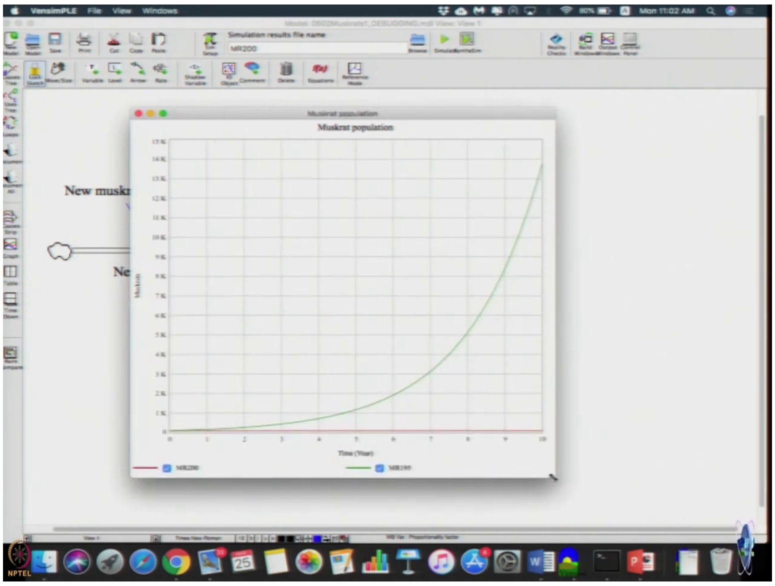

Now, actually we get two graphs one is a small red line in the bottom is actually being constant and the other is increasing the exponential, you can change it to 205 as a simulation file result name and change the proportionality factor to 0.205 click run.

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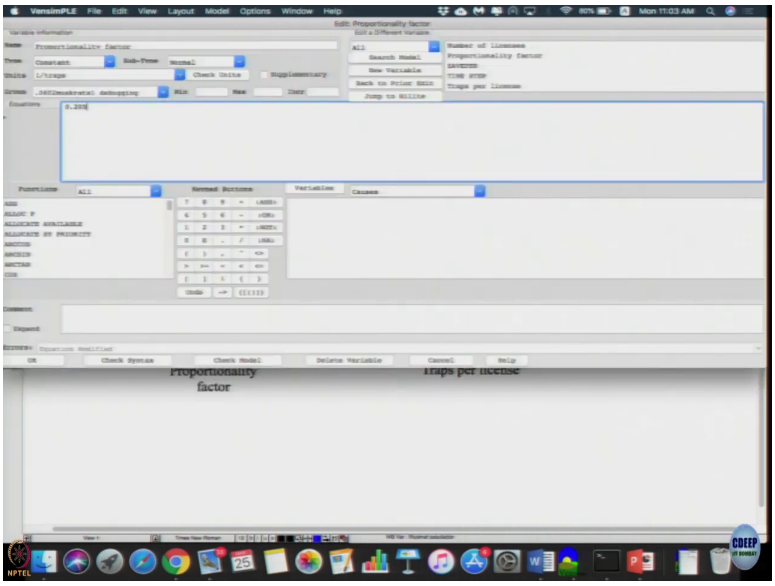

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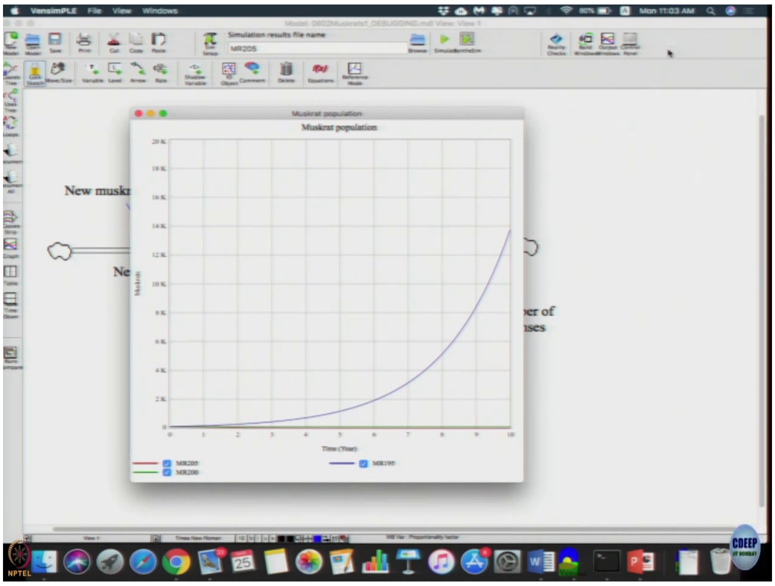

Now, if you do the caught the population. So, did it difficult to discern here I have exponential growth and the other one is supposed to be exponential decay, but I can make it out from here.

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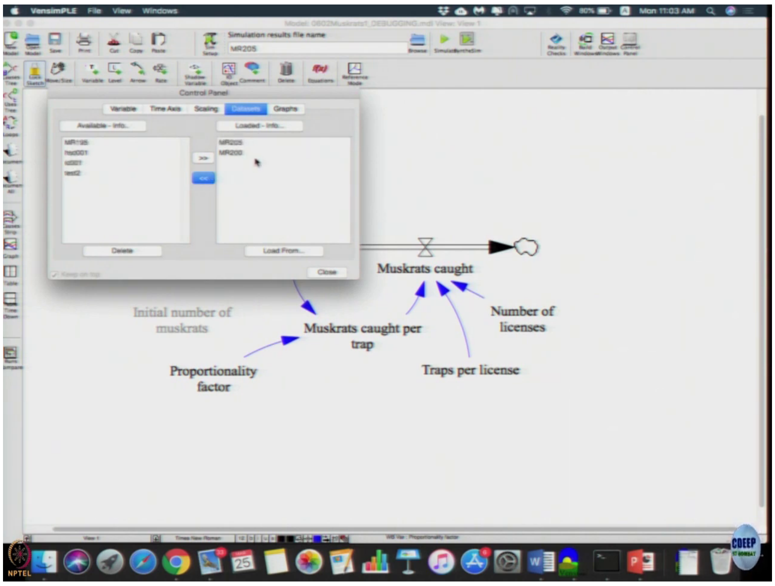

So, in that case you can just go to our control panel data sets remove the 195 data set 200 and 205 is what we have is it ok.

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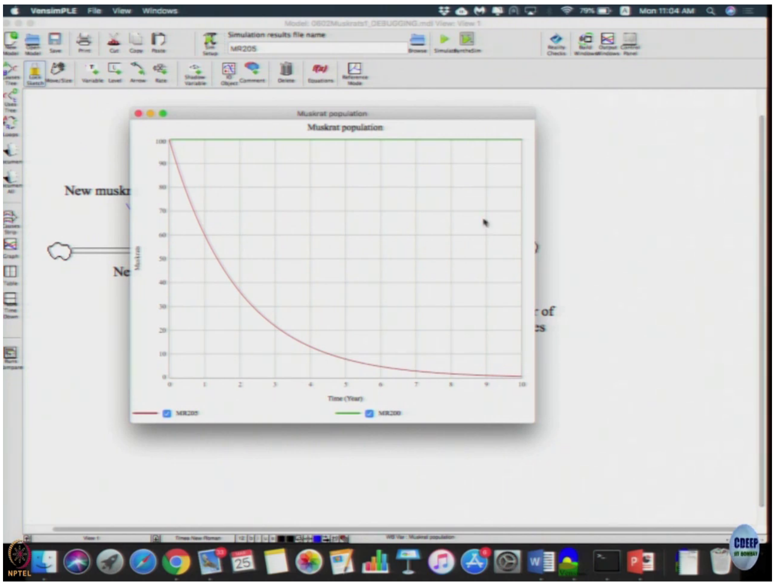

Look the graph now, you can get a constant line corresponding to proportionality constant as 0.2 an exponential decay, when if it corresponds to 0.205 it is exponential decay it is able to produce the results that we can expect from a first order system. So, model is verified which can use for further discussion and analysis just to quickly go over it. So, we have record how to go about it. So, we provides it its quite easy for you.

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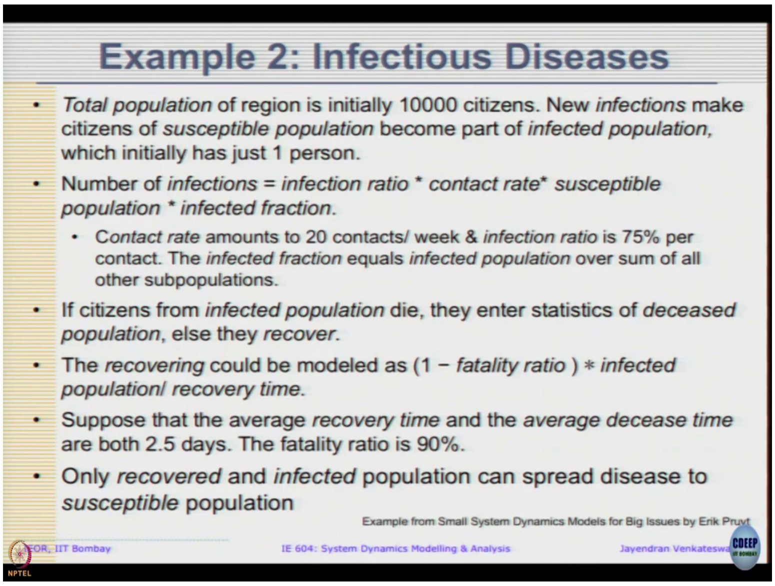

Let us look at example 2 this is model on infectious diseases total population region is initially 10000 citizens 10000 that. New infections make citizens of susceptible population become part of infected population which initially has just one person ok. So, then it is getting closer to the existing model that we already seen. The number of infections is infection ratio and contact and susceptible population infected population again the model is quite straight forward there.

And the values of contact rate is given and the infection rate values also given and the fractured infected equals infected population over some of all other sub populations. Let us see what are other subpopulations right now it is only susceptible infected. If citizen so, infected population die the enter statistics of deceased population else they recover ok. Now, it is interesting, now we have deceased population and recovered population. So, we have susceptible infected deceased and recovered.

The recovering could be modeled as 1 minus fatality ratio into infected population divided by the recovery time. So, how long it takes to recover to fix that. Suppose average recovery time and average decease time, there is average time it take to die are both two and a half days. The fatality ratio is 90 percent. Only recovered and infected population can spread disease to susceptible population ok. So that means, once people die they do not spread the disease.

So, assume they do not spread the disease further. So, only the susceptible and infected population spread the disease and even recovered also, I mean recovered infected spread the disease to the susceptible population. So, let us look at what the model says and see whether we can spot the errors in the model. Let us open this is non disease population. So, you can take it ok.

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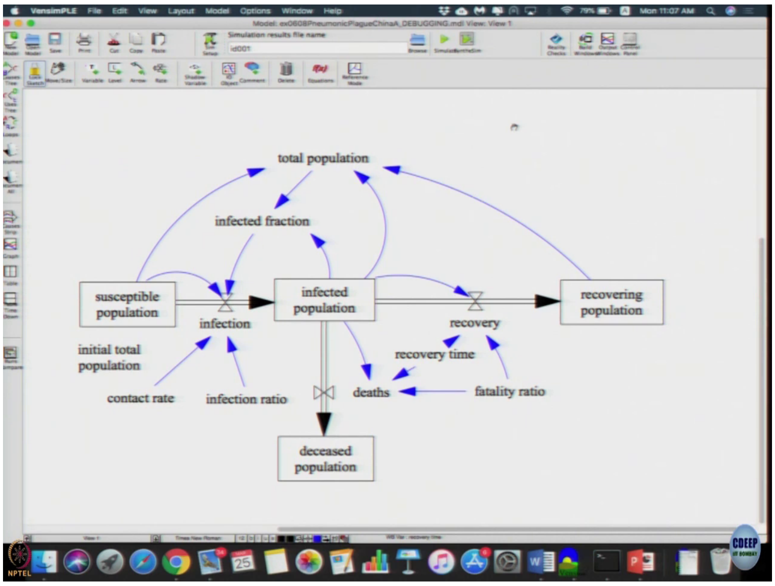

So, the susceptible population, infected population, recovering population deceased population find susceptible the flow seems to be make some logical sense infection moves them here, recovered moves them here and or here either one of the places. The infection was given as a product of contact rate infection ratio susceptible population infected fraction.

So, they are all seems to be connected there, infected fraction as given as a relation between this and this infected population total population so, that seems to be fine. Recovery different on infected population time and fatality ratio that seems to be connected fine that is also given the similar relation that seems to be fine let us quickly look at model settings.

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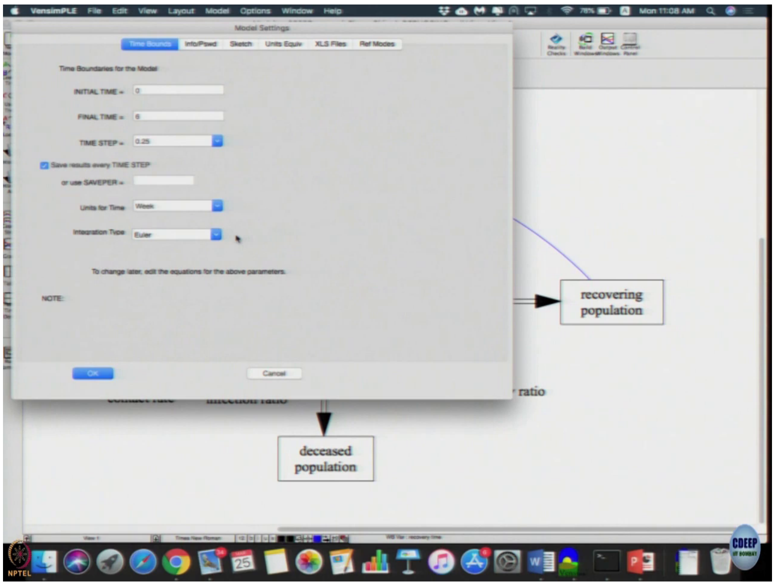

Final time 0.25 step v is time units is v ok.

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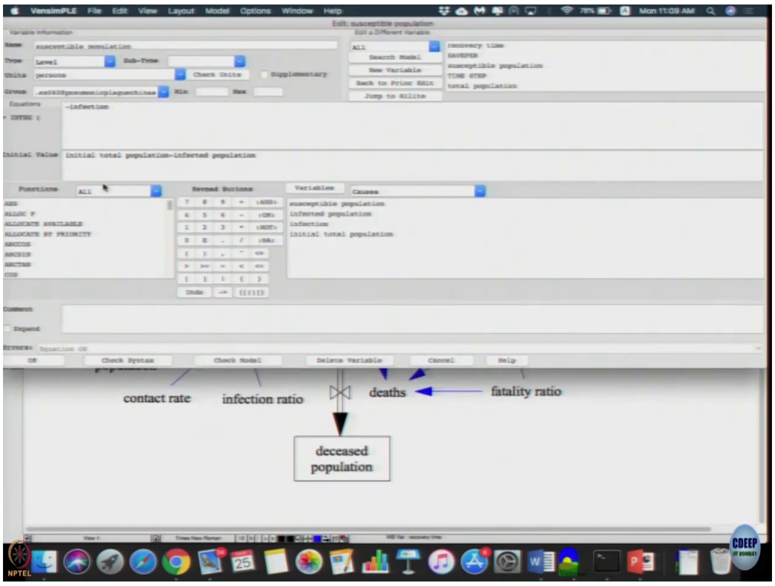

Quickly look at the equations susceptibility population is minus infection which is fine because there is only outflow there is no inflow here.

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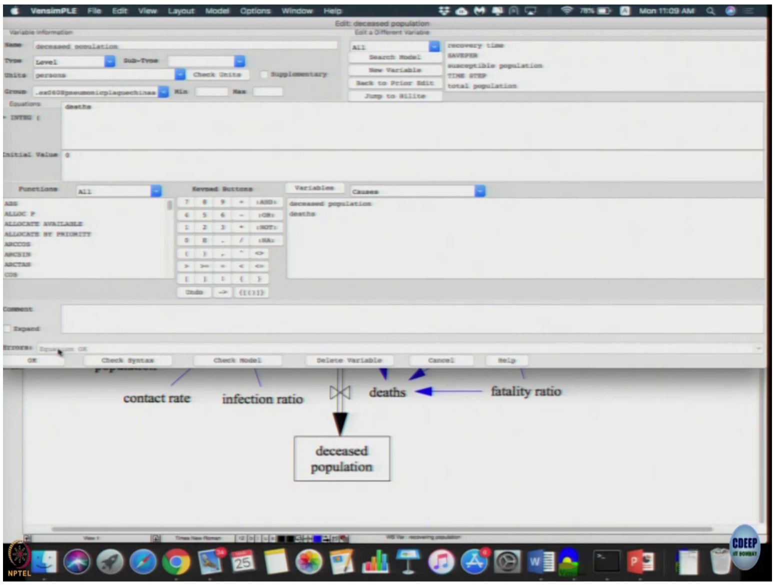

So, initial population initial total population is minus infected initial value. Initial total population is 10000 which is fine. Initial infected is 1 that is fine. The equation when infected is infection minus recovery minus death that is also fine flows are fine. Recovering population initial is 0 adds a recovery which is fine only inflows are there, deceased population again 0 just fine and deaths for plus which is fine.

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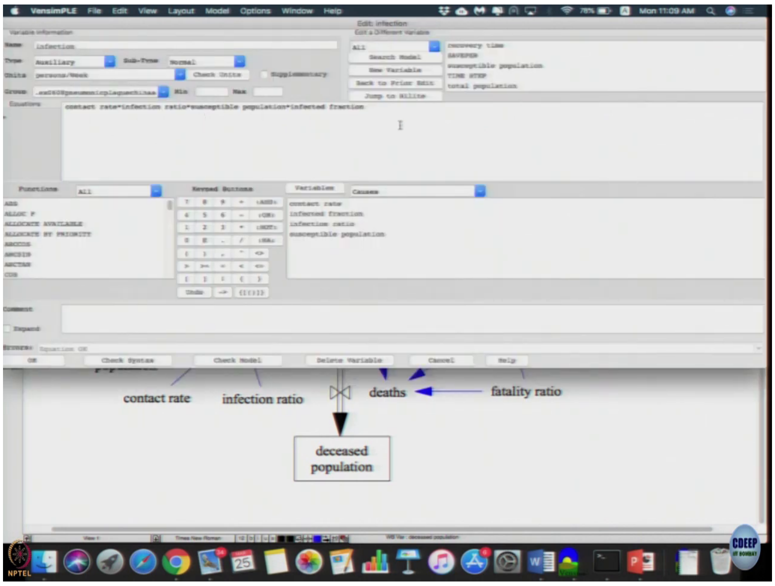

Infection is it is a product of all which is fine. Here you should be.

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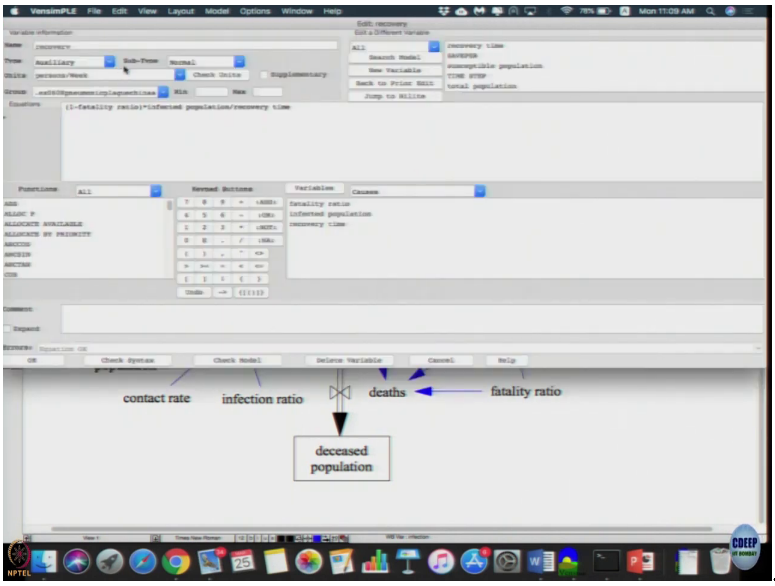

Recovery rate is 1 minus fatality ratio and infected population as recovery time that has a description given that is also fine. Deaths is infected in fatality ratio. So, those would not I recovered that is how it is model. So, that is a 1 minus fatality ratio is there.

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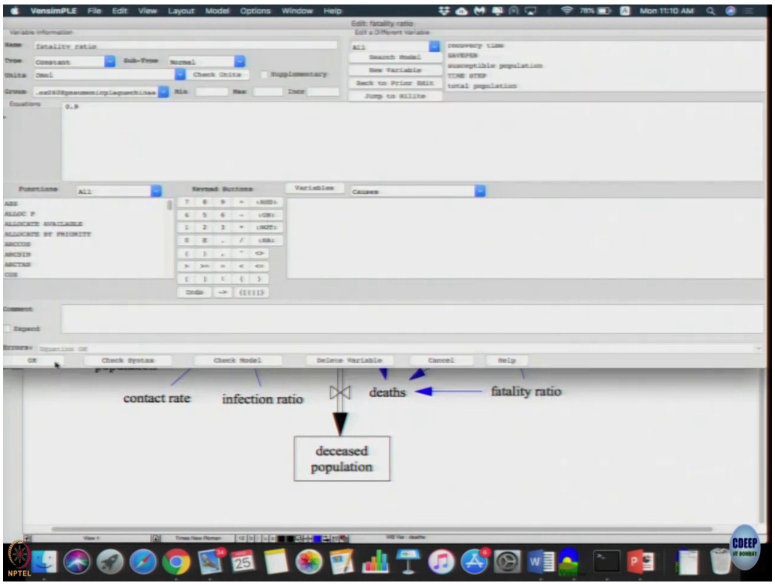

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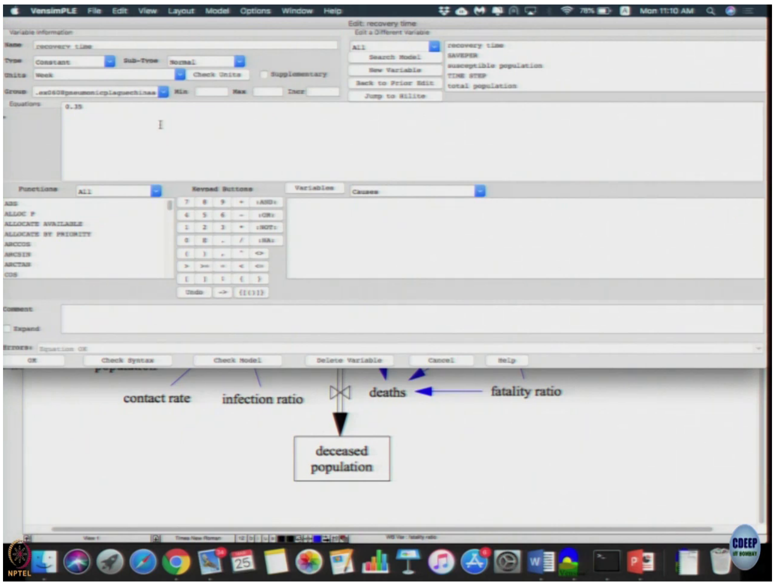

Fatality ratio as good as 0.9 which is fine ok. Recovery time was actually given as two and a half days it conveyed into weeks. So, 2 by 7 0.35 which is fine contact rate as given as 20 per person per week which is fine.

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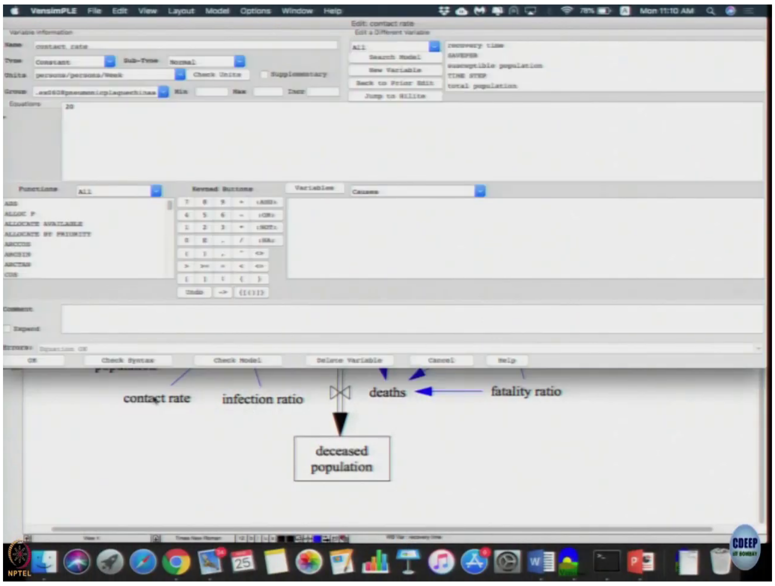

Infection ratios 0.75 which is fine which is what has given ok.

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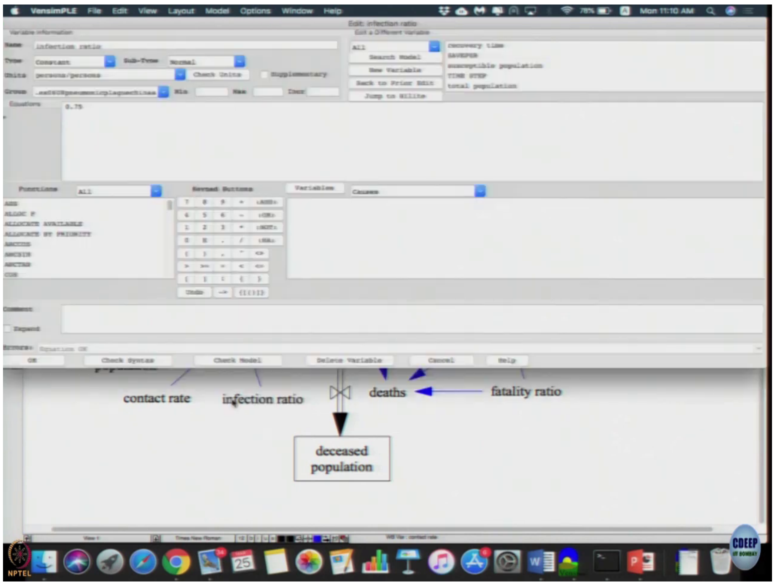

Model seem generally let us run it ok.

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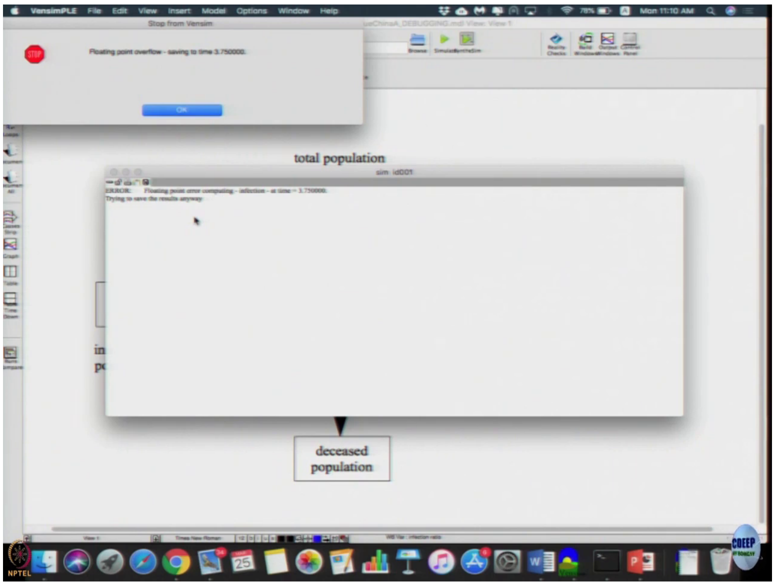

Again I am getting floating point error, 3.75, but model seems structurally let us see the recovery time was point recovery time was 0.35 per week right.

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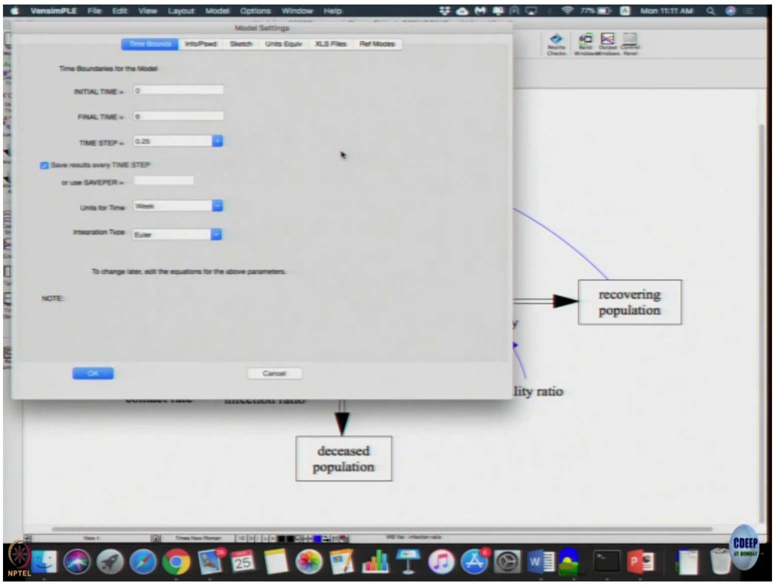

Let us go to model settings yeah, let us look at the time step here time step is 0.25 where in our case this smallest time step was 0.35 recovery time. Here it was 20 into 0.75. So, here the time step the smallest is 0.35 while here the time step uses 0.25. So, ideally we want time step which much lower than the smallest delay right. So, that could be a cause for unusual dynamics, we can actually look at the dynamics.

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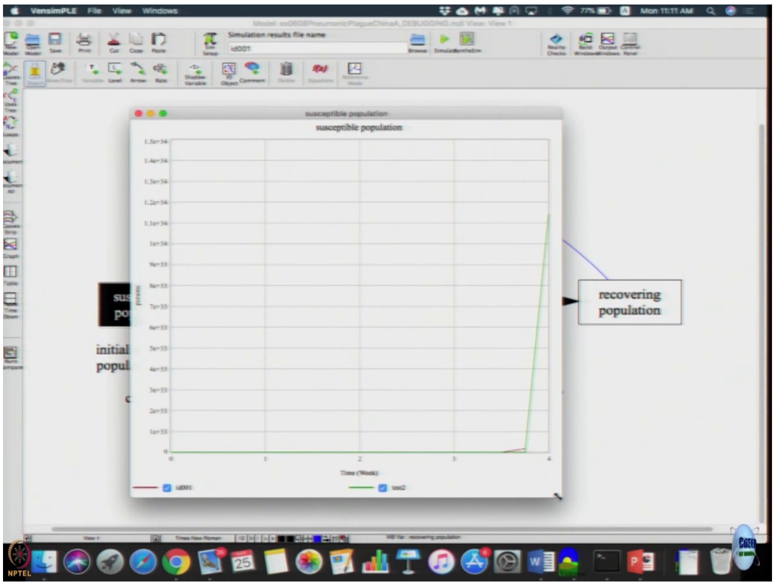

Let us look at infected population, it is just going negative large infected population or recovered population whole think just crashes and become negative susceptible population is increasing which also does not make any sense there is no inflows at it is increasing right. So, let us see whether time step is only issue here other seems switch the 0.25.

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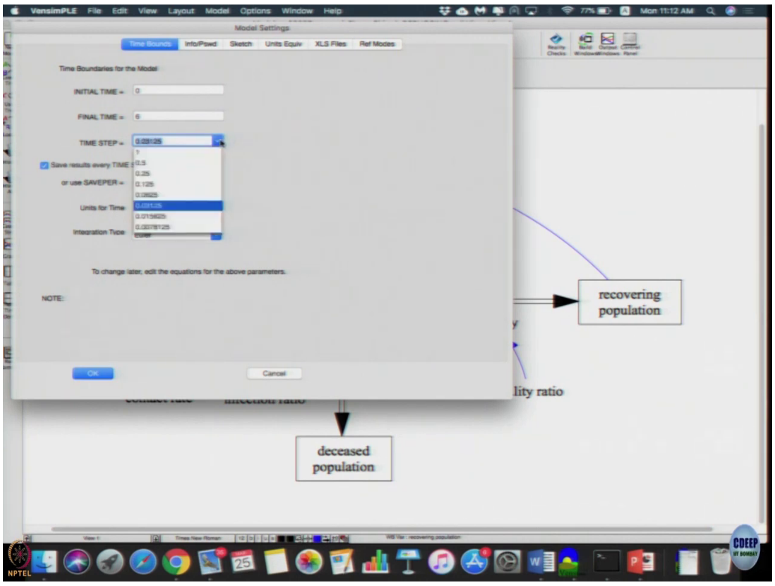

Let us go say 0.0315, let us try that, let us click ok, let us run it wait error stopped at least.

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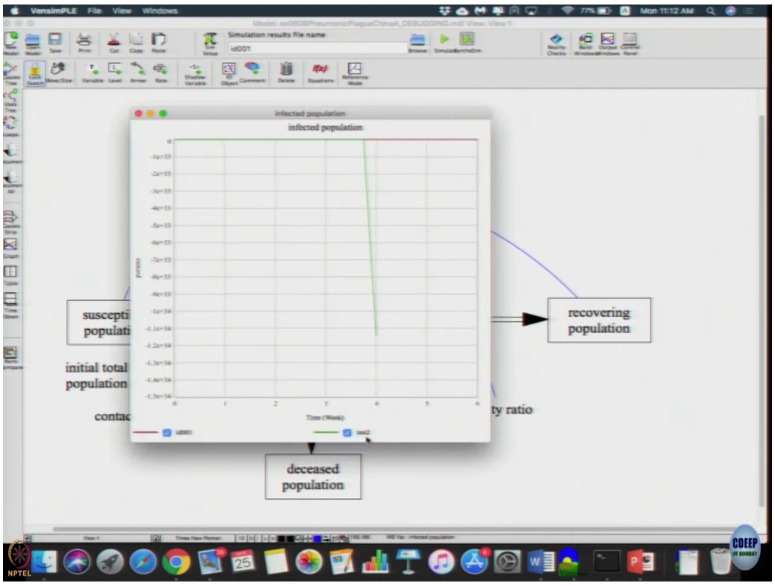

Let us look at infected population ok. Let me run it again.

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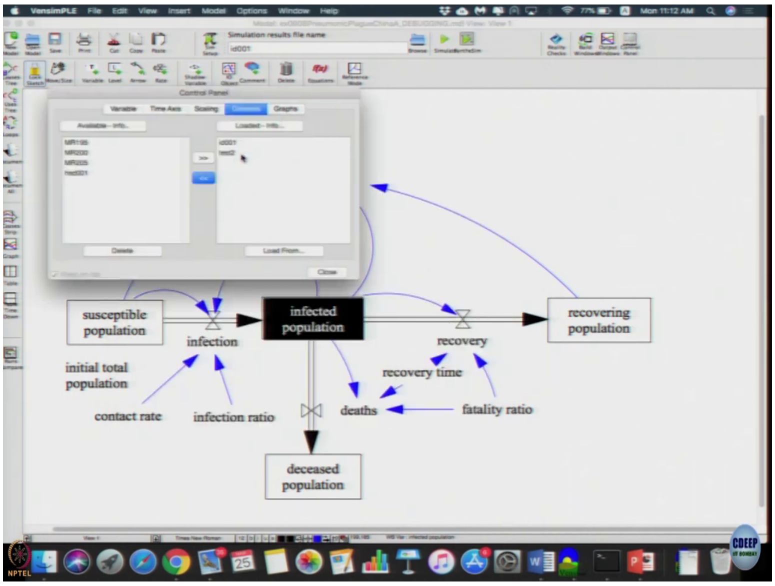

Just to let me get rid of the data set many some other data set test two which is loaded we just delete the test two id001 is what we need to see id001 ok.

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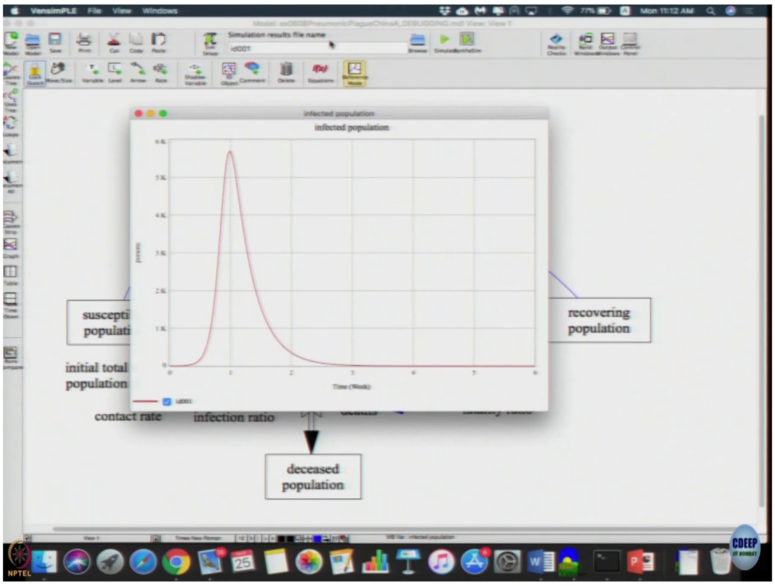

So, susceptible seems reasonable, I mean infected seems reasonable susceptible as to decrease and went to 0 that is also reasonable.

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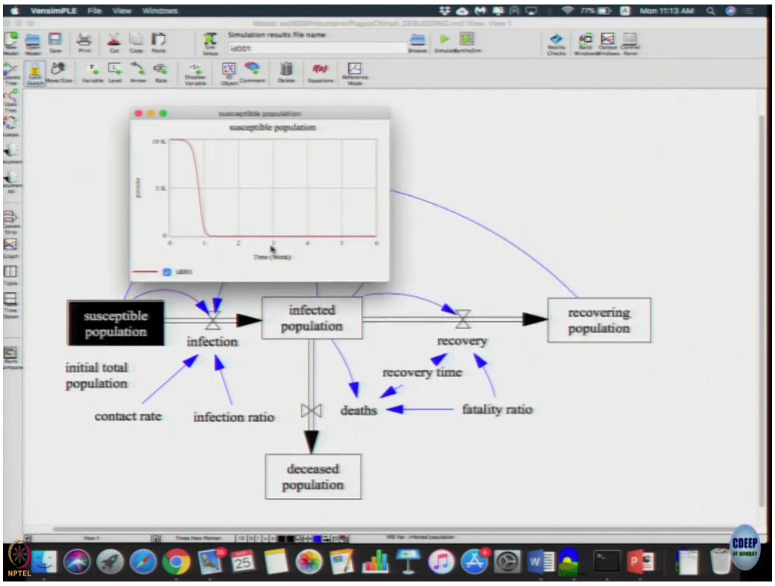

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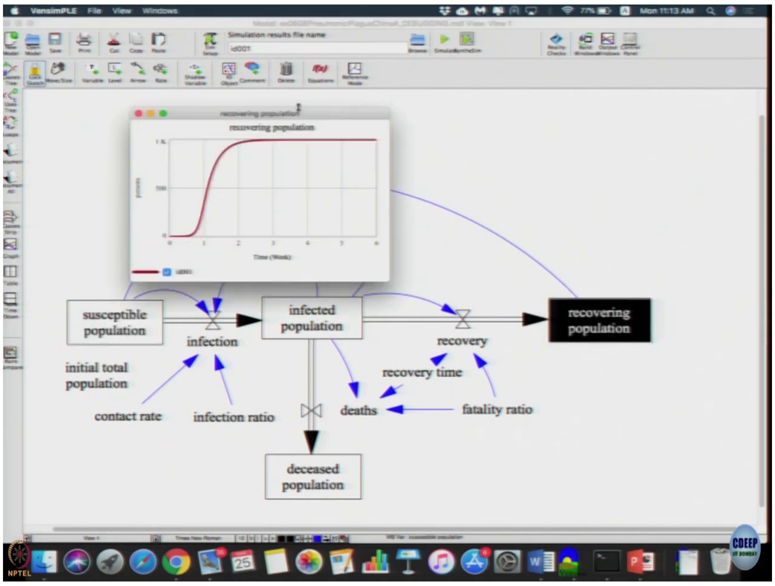

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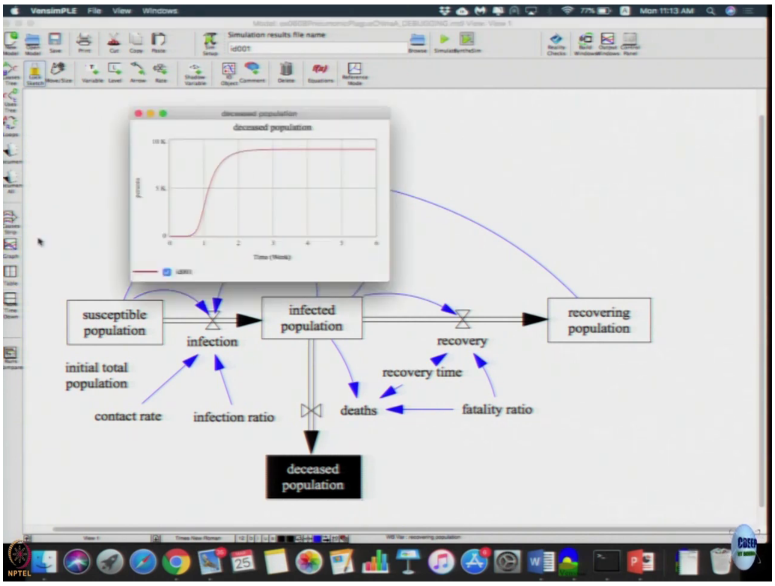

Recovering Graph showing classical shape growth that is a dynamics experts from this model deceased population again shows a shape growth, but 9000 people die and 1000 people recover that is because fatality ratio is 0.9 will that makes sense. So, this is the overall dynamics and this is only thing that seems to be error in this particular scenario ok. Questions in this case, when this case the main error was caused by incorrect simulation time step. So, one way to check, it is let us create a id002.

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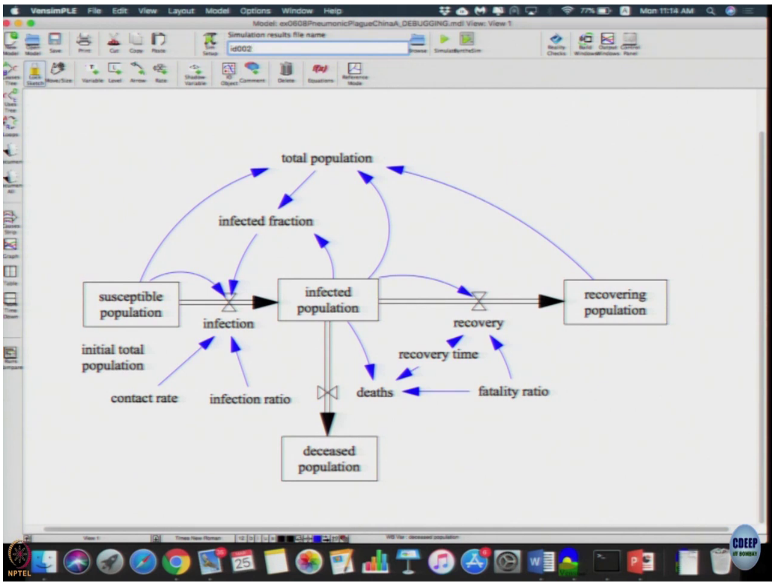

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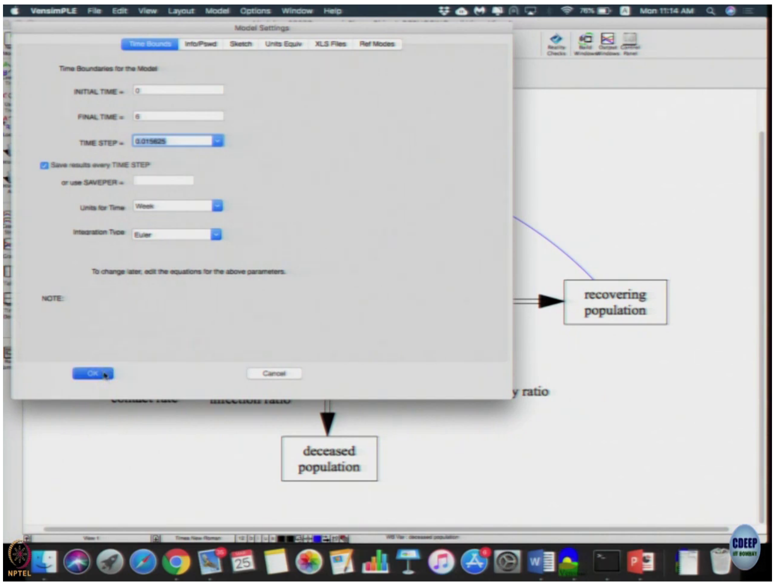

So, in this case I am going to change the simulation time step further down. 0.0156, we do not know what similar time step we choose. Let us choose another time step to see whether there is any difference in the curves. So, reduce the times to further let us stimulate again let us look at infected population.

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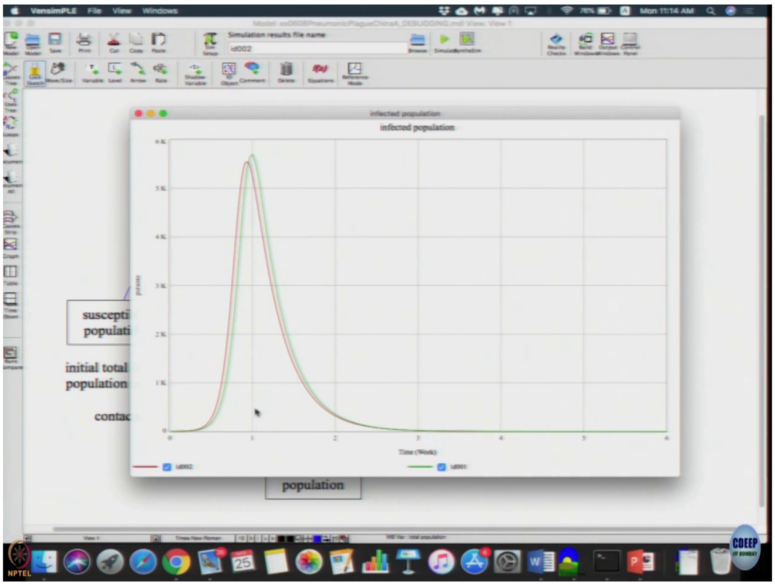

There is a difference; that means, still we need to choose a more appropriate time step such a way that we are getting a curve, where it should not keep changing. Whenever there is a change occurs; that means, you have to keep reducing until you get a time step where the change is almost nil. So, let us give one more let us give an id 3.

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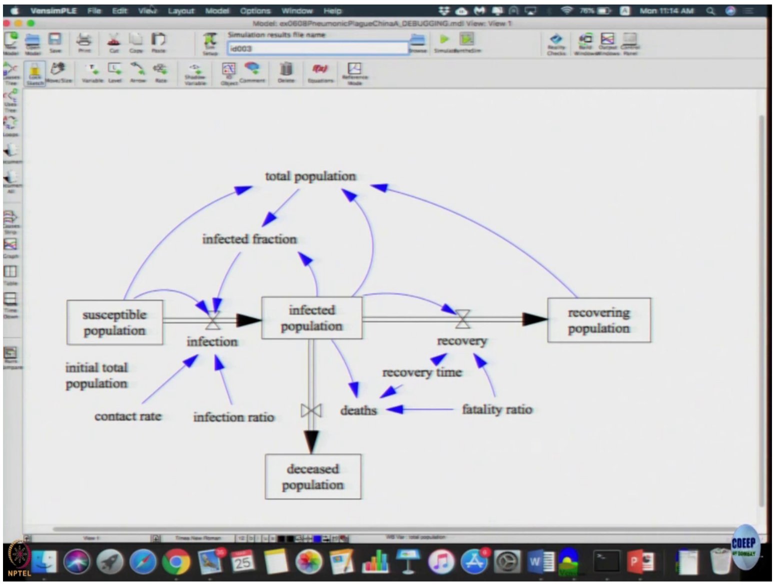

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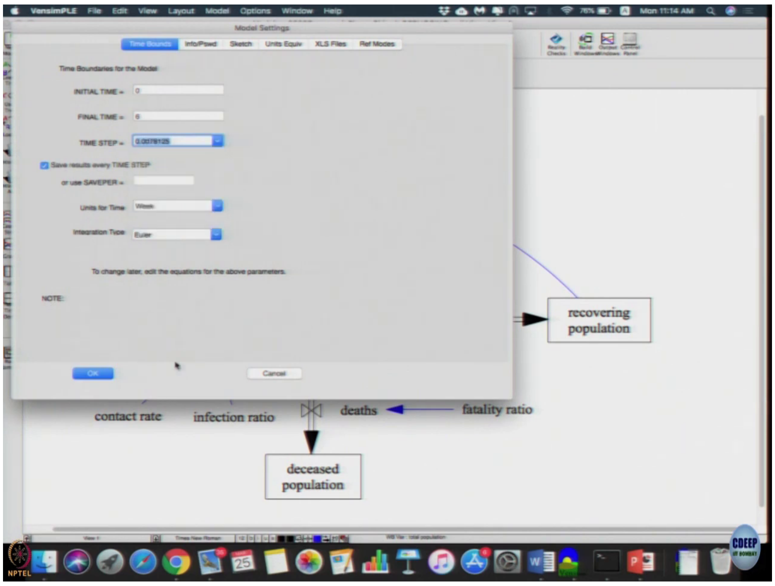

Let us look at settings that is further reduce it to smallest one possible at least in Euler method, let us run it.

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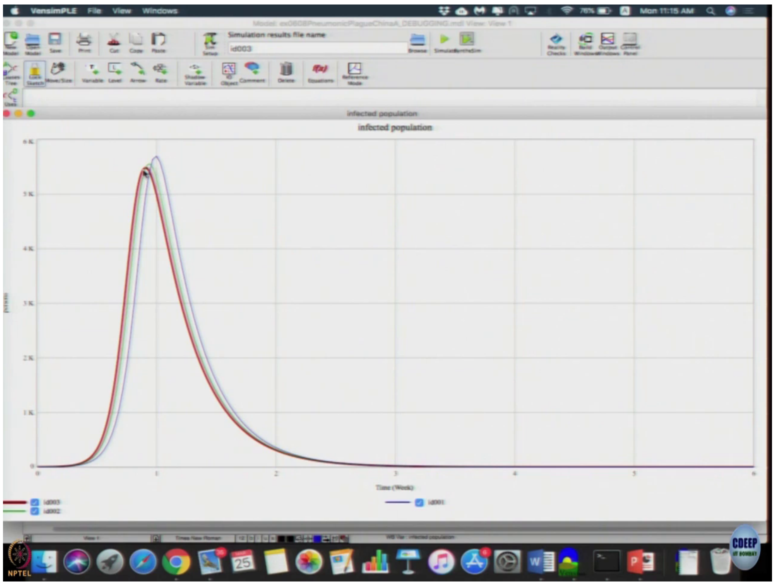

So, id 3 so, further small changes in the model. The first stimulation time step the second it was from point, what was it? From 0.3 to 0125 that is huge jump, there is further jump when we further reduce the time step. So, these kind of population dynamics or rather the infectious disease model, you should remember that the origins of the model came from not from the system dynamics community, but came from the epidemics modeling community who is differential equations to model. So, if you want higher accuracy to represent it better, then its good area to go for other integration types.

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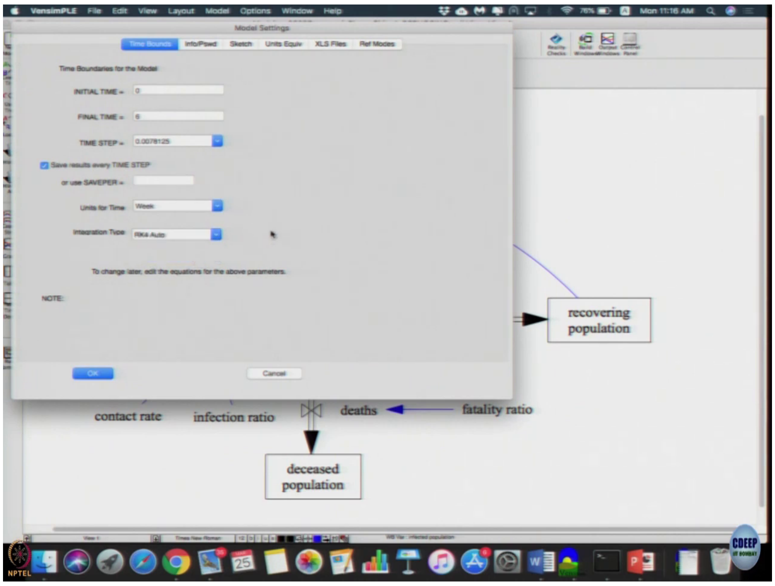

So, instead of Euler method a more powerful integration tool would be a Runge Kutta method those who did not because, then numerical methods will know that Runge Kuttas have a accuracy. So, let us just change it to rk 4 call it rk simulated let us see what happens.

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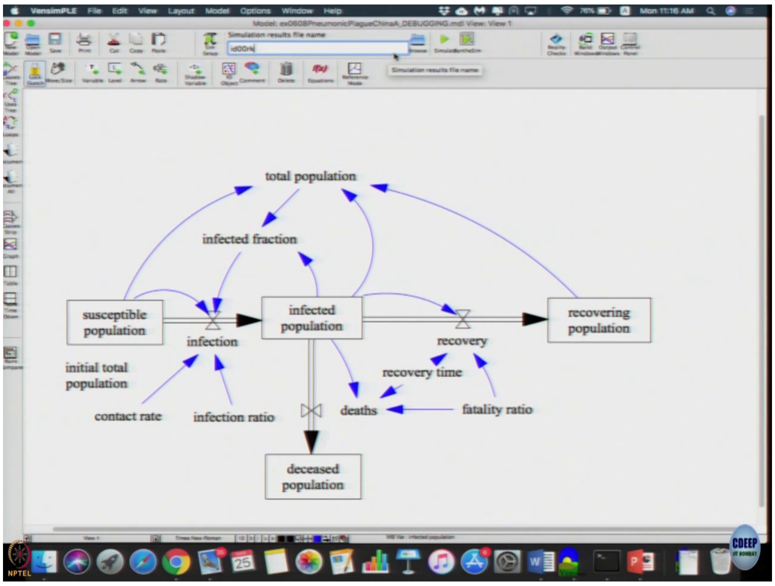

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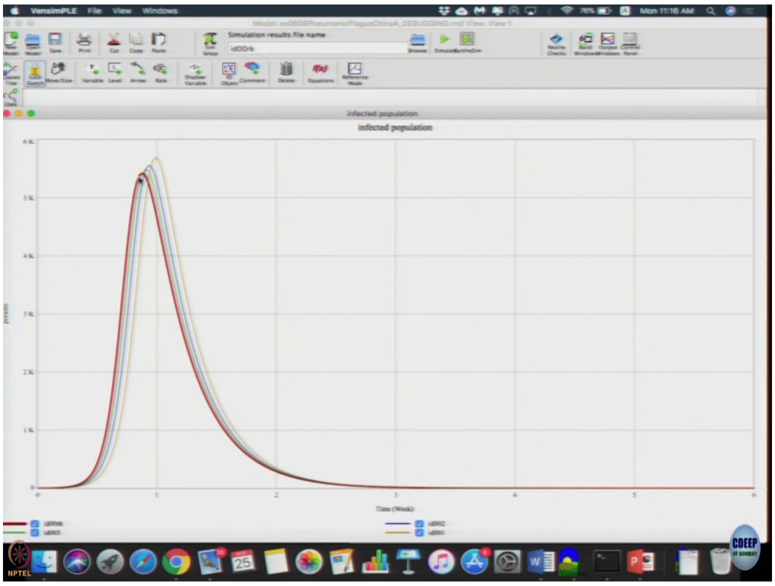

That gives us the most accurate results, just I will it seems to sell improve based on the earlier ones. So, in this particular case, you may want to prefer rk 4 methods and check weather different time scales also makes difference else will give the lowest time step where results does not change significant.

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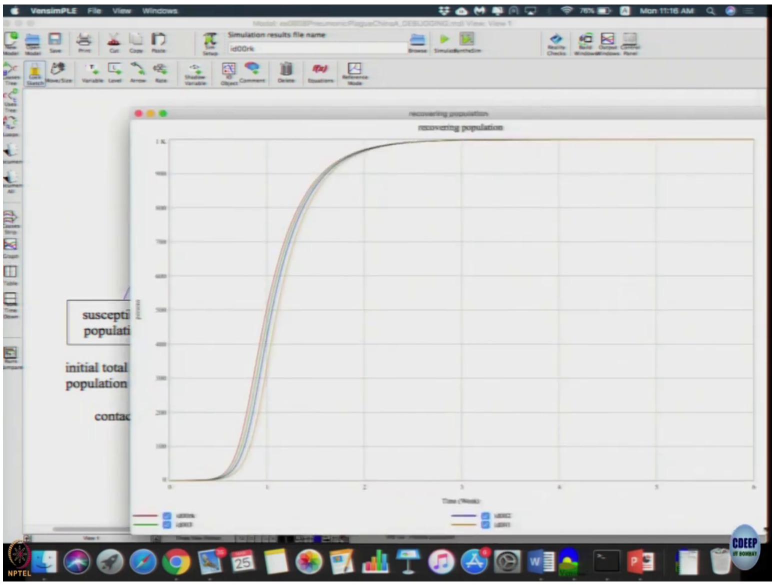

Let us look at the recovery population, these are things we relate to observe in the sense, where it its steady state values is exactly the same right. Steady state values what we are interested in, it does not matter what we use it all converts to the same 1000 as you can see right here, but the transient shape of the curve also does not change because actual dynamics does not change, but we are interested in highly more accurate results the trajectory changes a bit.

There is no large chain deviations in the dynamics, in this large deviation then it is a major error in your logic. So, you need to choose an appropriate time step, but once you get kind of similar results and then if you more and more accurate results it is you have better to have a smaller time step, but a better method of integration.

So, starting point is similar ending point is similar only the transient line which change. So, we saw two things one first one was a small error in the flow equation stock flow equation second one had a floating point error because of time steps selection. Let us look at third scenario and see what kind of errors it can have.

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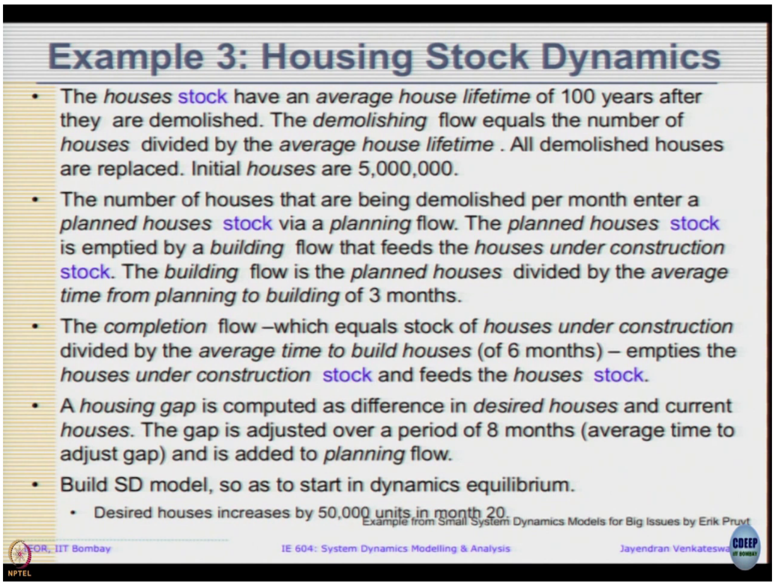

So, again, we highlighted a few variables housing stock dynamics houses have an average. So, completely different model imagine houses are built in a particular area. Housing stock of an average house lifetime of 100 years after they are demolished, the demolishing flow equals a number of houses divided by average house lifetime. So, if we imagine housing stock. So, highlighted all the stocks that is coming in and the description itself use a word stock, probably you should moderate as a stock right. You know demolishing means, it has to be an outflow all demolish houses are replaced initial houses are 5 million ok.

Number of houses that are demolished per month enter a planned houses stock via panning flow the word what is demolished? I am going to plan to build them again. The planning houses stock is empty by building flow that feeds the houses under construction; that means, land stock is going to feed into a housing under construction stock. The building flow is the planned house divided by average lifetime.

So, all seems to be a first order delay. Flow is stock divided by time that must be first order ok. The completion flow that is what our housing and the construction divided by the average time to built houses ok. Empty is a houses of stock I was just under construction stock and feeds to houses stock ok.

So, we have 3 stocks houses stock, planned houses stock and houses under construction stock. So, planned houses become houses under construction, house under construction become actual houses right. So, initially a plan more houses then I construct them, then after its being used its being demolished all has to be connected through flows. The housing gap is computed as difference in desired houses and current houses, the gap is adjusted over a period of 8 months average time to adjust gap is given as 8 month, then it is added to the planning flow.

So, apart from just rebuilding existing houses, they also want to planned to build as many as a desired number of houses. So, build the SD models as to start in dynamic equilibrium and then there is another condition given desire houses increases by 50000 units in month 20 ok. So, this is the is a very brief description, let us see what happens when the housing stock dynamics let us assume ok.

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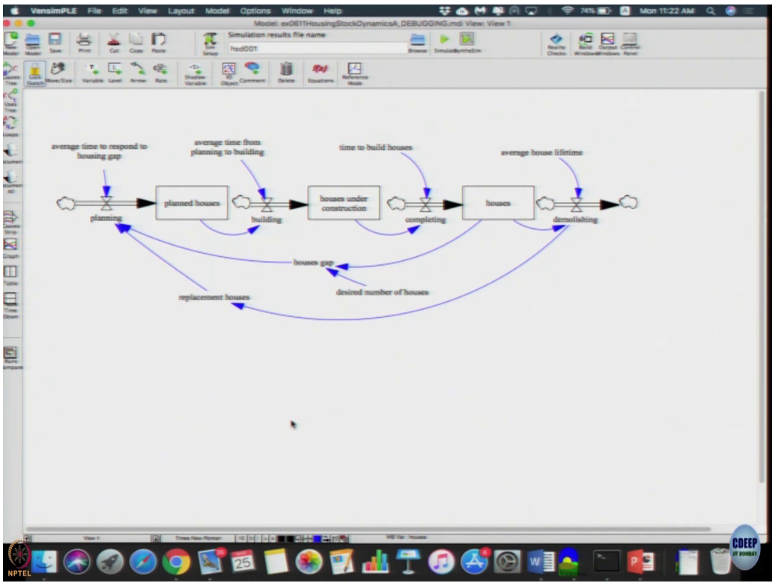

This is the housing stock, here three stocks and flows as soon as you open it becomes quite apparent that is something wrong flows are not being connected to stocks right. There is number of planed houses is no way it is going to reduce, the planning only will increases nothing decreasing it because as some houses being getting constructed then it has to decrease. So, it is become obvious that these flows as to be connected to the previous stock and as soon as they complete their houses under construction should also reduce.

But just likely please note that when I am clicking simulate model is still simulating, modeling does not care whether it is connected or not model will still be valid say if you guess say for example if you click these and plot there you getting some dynamics something is happening something is changing this is fine which is getting some large numbers good posture as well as negative, but that is an obvious one.

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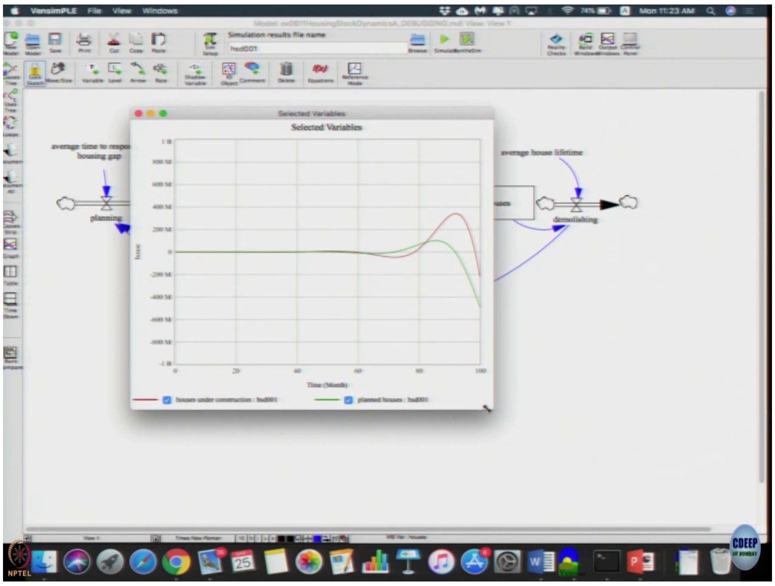

So, we can fix it first. So, let us get clicking this delete I am deleting this clicking the rate. So, this is done now, if I click equations the rate equation has to be changed, we go to planned houses that is already defined it inflow minus outflow.

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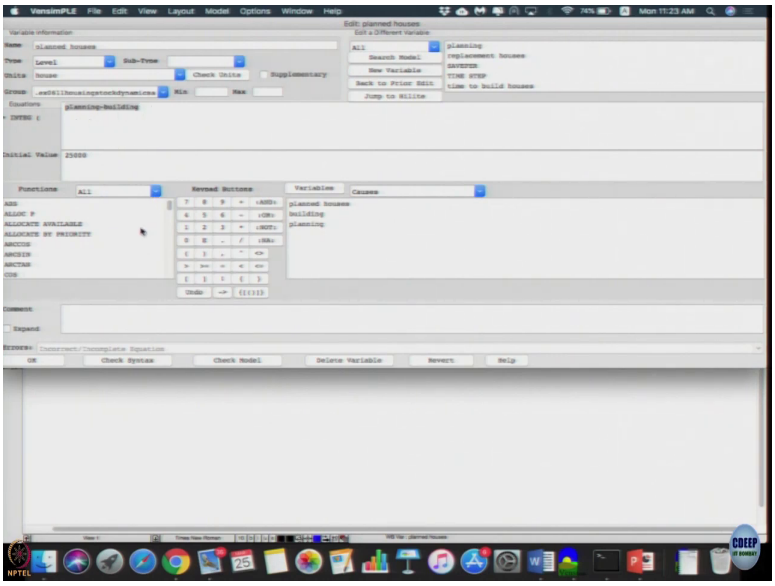

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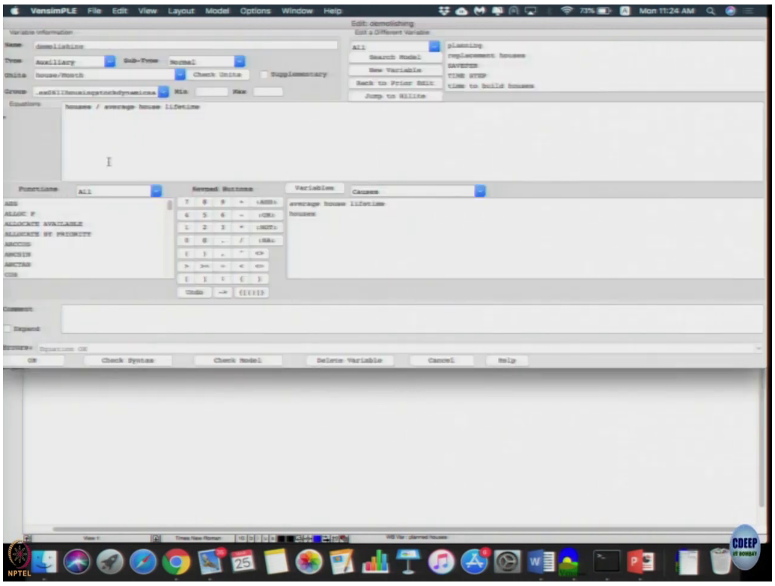

So, all you do is click ok, let the second one click third one click they all seem to be fine demolishing is this houses by average life, completing is houses by a time to build houses, building is planned divided by average time this is all fine and what was getting demolished has to be replaced plus where how there is gap in houses that also has to be planned for the planned equation includes replacement plus.

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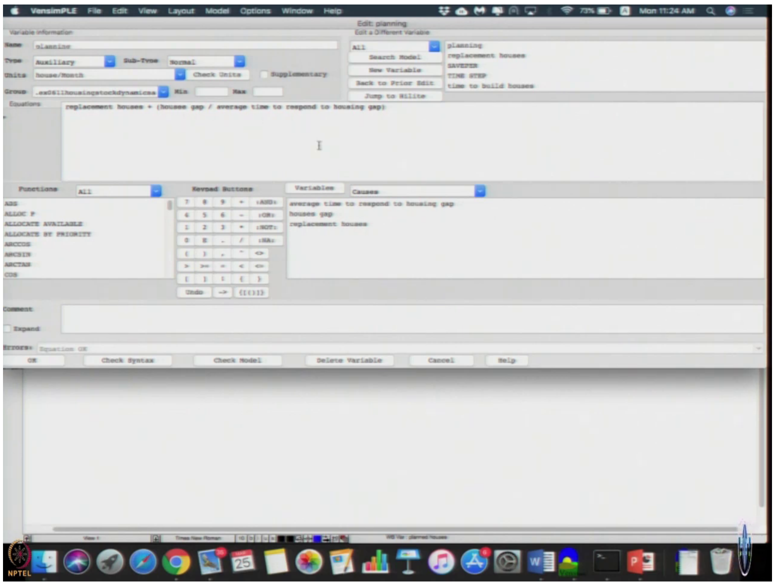

House gap by average time to respond housing gap which is also an another first order delay. So, both are captured model seems now reasonably completes. So, let us just simulate let us look at the houses.

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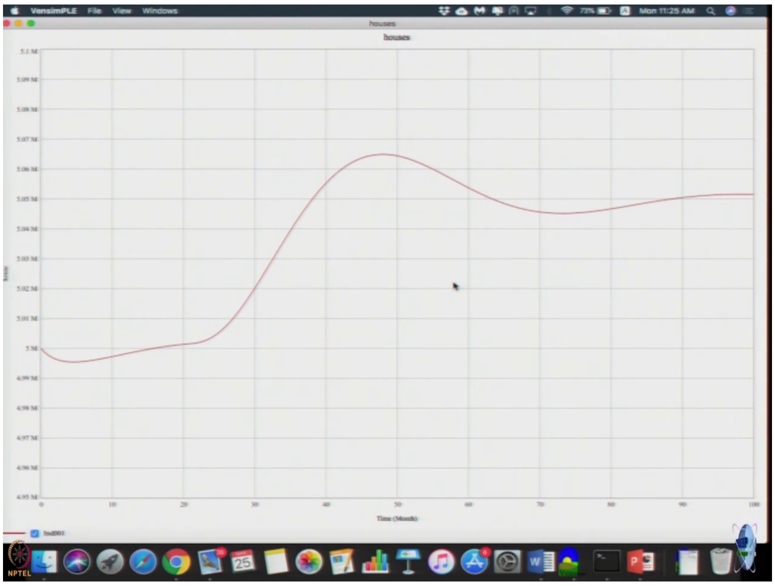

Its a kind of dynamics we get. So, one will show this is it ok? So, all changes was done is connected the flows to the stocks and we get this results ok.

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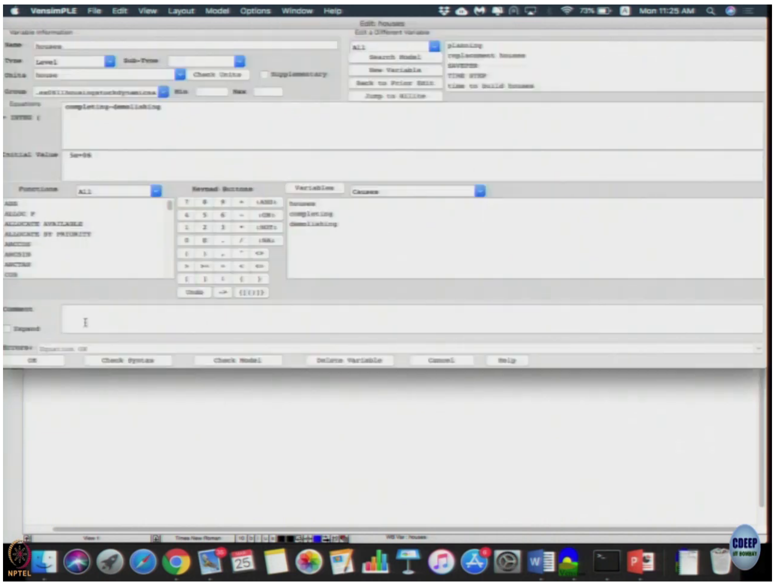

Again as I told you can practice it looking into the videos. So, now, the one condition that has given was the model was supposed to started dynamic equilibrium right and because also given the desired houses was 5 million plus step of 50000 at month 20. So, step function is given. So that means, my first 20 until time is 20, it should be flat, but here I am already seeing dynamics and time 0 or time 1itself; that means, model is not in dynamic equilibrium. So, what causes or not causes dynamic equilibrium, dynamic equilibrium initial value should be the same right.

So, when desired house is 50, desired house is initially 5 million houses also and 5 million. So, the housing gap is 0 that is not adding anything to planning right. Now, demolishing the initial value will be 5 million divided by average house lifetime which is given as just a minute let me see here average house lifetime is 100 years that is since that time unit is months, it is 1200 months which is ok.

So, its 5 million divided by 1200 is what is the demolishing rate correct. So, then that that much should be replaced every year correct. So, the inflow here will be 5 million divided by 1200 that is how much 5 million divided by 1200 4116.67.

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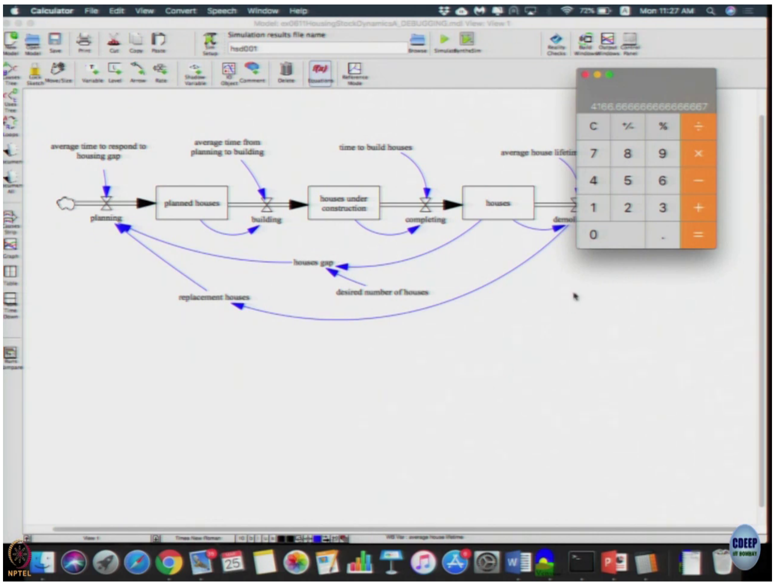

Now, if that is a inflow my outflow should be based on the average time it takes to built the average time it takes to build is 3 months per average time it goes from planning phase to starting construction phase. So, that must houses should be currently under plan. So, that must be so, that plans houses stock should be how much value? Initial value, we go with little slow, the plan number of houses number of houses in pipeline should be inflow rate time the duration. The duration is given in the average time planning to building multiplied by inflow rate; inflow rate is 4166 times 3 12500 right.

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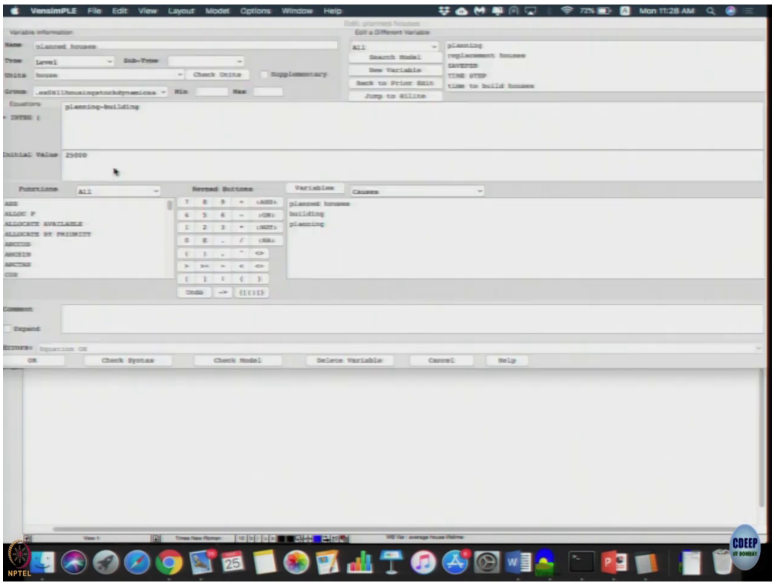

Let us see that 25000, let us constantly changing it 12500 and time to build houses is 6. In steady state, if my inflow here is 41 what does it 41666. So, this also has to be 41666 and this one also has to be 41666 41666 into time to build houses is 6.

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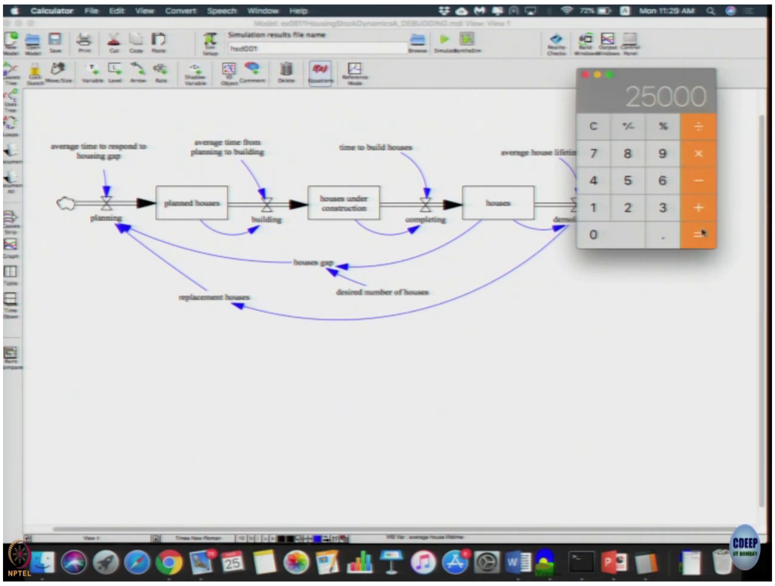

So, 41666 into 6 its 25000.

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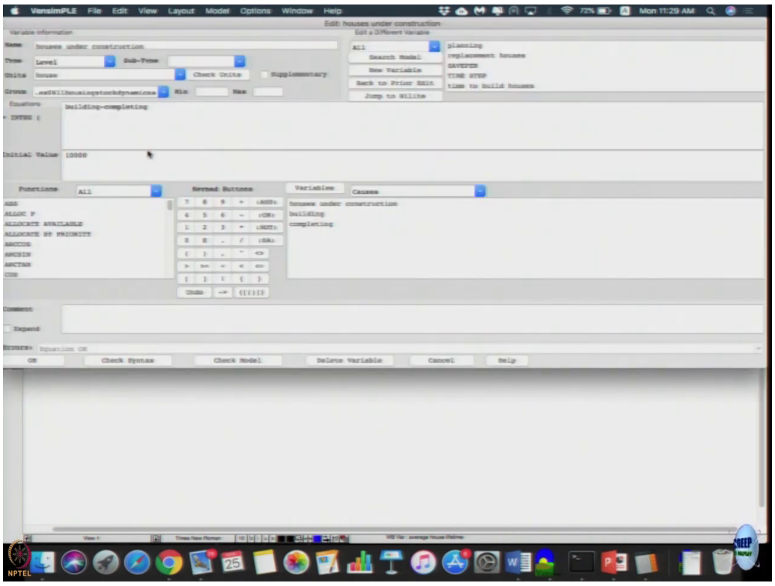

So, housing under construction should be 25000 this is 10000 let us just do it 25000 and this is 5 million this is 5 million which is fine.

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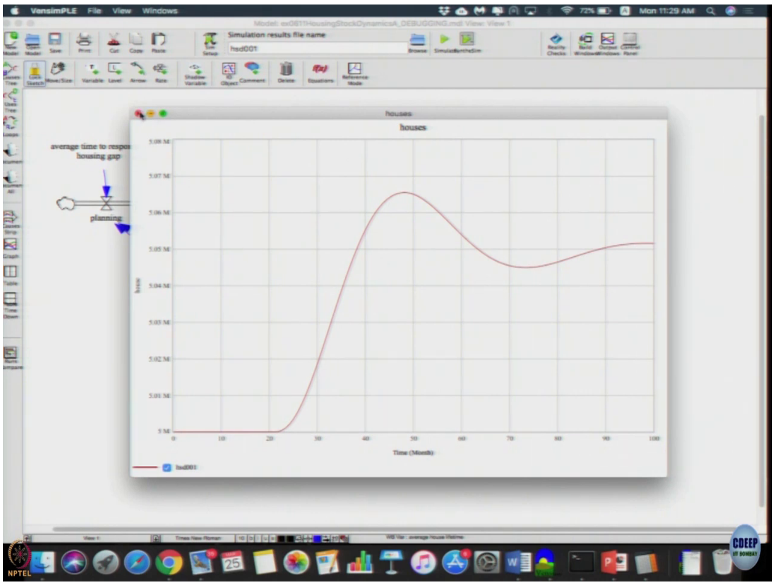

Now, let us simulate let us see the dynamics its starting in dynamic equilibrium; that means, dynamics seems for now. This model still not, but; however, these are constants inside it right. So, you think about and come tomorrow to see how I can replace all these constants with equations, we do not want to put constants here.

The problem with constant is now from say time to build houses, we knew it was 6. So, you multiply it directly or manually right. Suppose, how time to build houses increased to 7 months I can again go and check it. So, better way would be to see whether I can make it a equation. So, why did not you try that and we will continue that

Thank you, I will stop here.