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EAS 550/STRATEGY 566: Systems Thinking for Sustainable Development

Lab 4 Building stock and flow diagram with Vensim

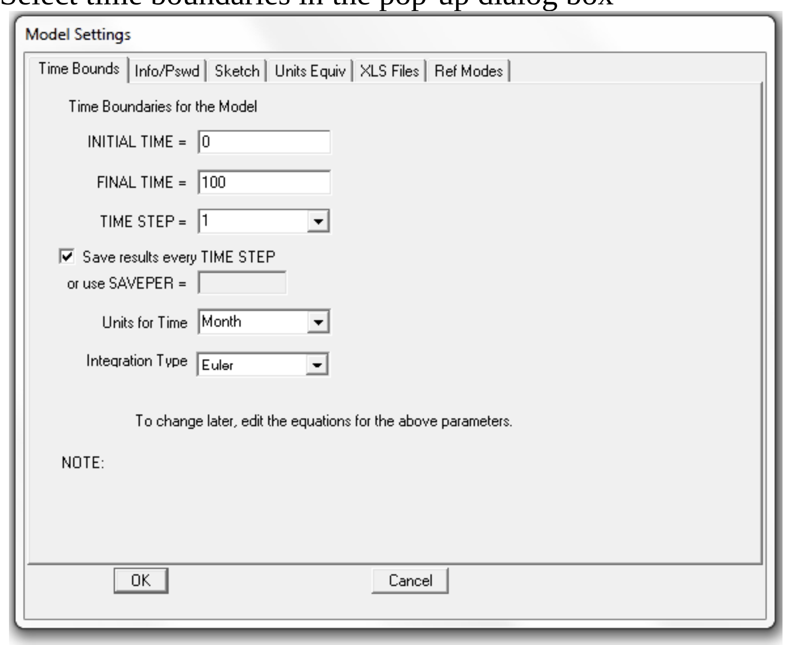
Instructions:

Download Vensim PLE: You can go to the following website to download Vensim PLE for your personal use: http://vensim.com/free-download/

- Two versions of Vensim PLE are available: Windows version and Macintosh version. Select the one that is compatible with your computer. This illustration is based on the Windows version, but functions in the Macintosh version are similar.

Getting started with Vensim PLE:

- Open Vensim PLE
- Go to **File → New Model**
- Select time boundaries in the pop-up dialog box



In this model, select the following time boundaries, then click **OK** or hit return.
Initial time = 1998
Final time = 2008
Time step = 0.25
Units for time = Year
Integration type = Euler

- To give your model a name, go to **File → Save As**, enter "Influenza Prevalence" and click **OK**. Vensim PLE should automatically supply the .mdl extension. If not, select this extension from the drop-down menu.

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Develop the stock and flow diagram:

- Add a stock - click on the 

button in the sketch tools bar, and click again in the desired place within the work space. Type the word “Prevalence of Influenza” in the pop-up text box and then hit return.

- Add an inflow – click on the 

button in the sketch tools bar. Then click once to the left of the “Prevalence of Influenza” stock, move the cursor and click again inside the “Prevalence of Influenza” stock. If you do it correctly, the stock should blacken. In the pop-up text box, type **Incidences** and hit return.

- Add an outflow – again click on the 

button in the sketch tools bar. Then click first inside the “Prevalence” stock, move the cursor, and click again to the right of the stock. In the pop-up text box, type **Deaths** and hit return.

- Add a variable – click on the 

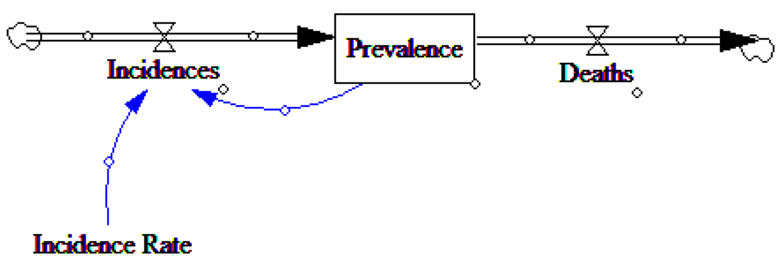
button in the sketch tools bar and click again in the desired place within the workspace. Type the word “Incidence rate” in the pop-up text box and then hit return.
- Add an arrow showing **Incidences** is dependent on **Prevalence of Influenza** and

  Incidence rate – click on the 

button in the sketch tools bar. Then click first inside the “Prevalence” stock, move the cursor, and click again on **Incidences**. Do the same to connect **Incidence rate** with **Incidences**. You can adjust the position of the arrow by dragging the small circle in the middle of the arrow or the arrowhead.

- If needed, you can change of the names of stocks or flows – hit the 

button in the sketch tools bar. Now your model should look like this:



Specify equations for the model:

- To begin writing equations, click on the 

button in the sketch tools bar. The variables in your diagram will become highlighted. A highlighted variable indicates the equation for that variable is incomplete.
- Click on **Incidence rate**, the following dialog box will pop up. Enter the unit of measure in the text field to the right of the word **Units**. In this model, the unit for incidence rate is

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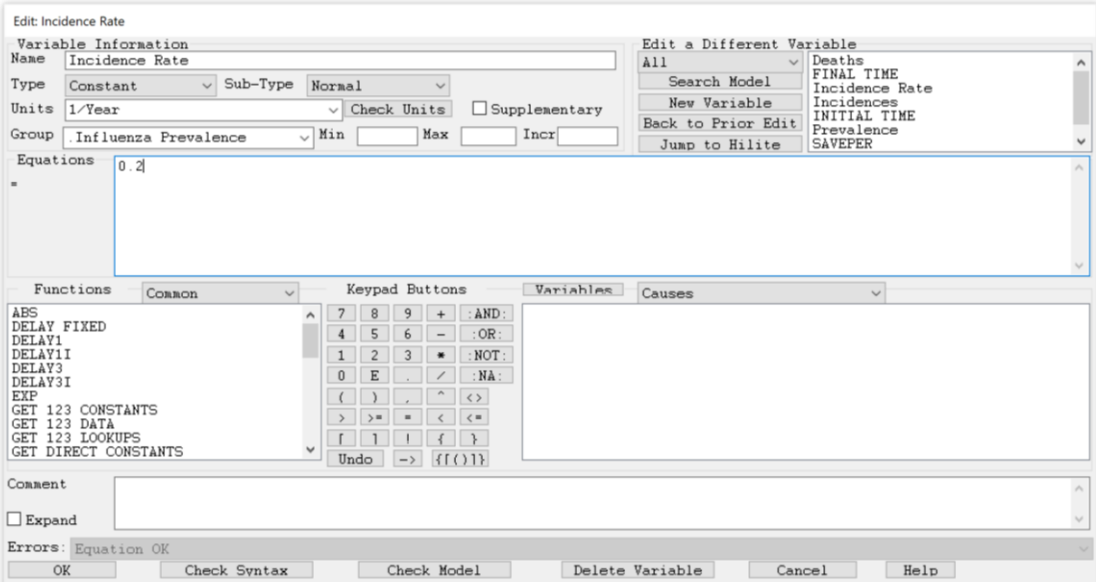
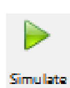
1/year. Write an equation for **Incidence rate**. In this model, incidence rate is a constant. Put 0.2 in the **Equations** box. Vensim PLE does not recognize 20%. Click **OK**.



- Click on **Incidences**. Similarly, enter the unit of measure in the **Units** box. In this model, the unit for incidences is million/year. "Prevalence of Influenza" and "Incidence rate" should already be shown in the **Variables Causes** box based on the structure of your model. Click on "Prevalence of Influenza", and it will show in the **Equations** box. Put "*" behind "Prevalence of Influenza" and click on "Incidence rate". Now the equation shows that **Incidences** is a product of **Prevalence of Influenza** and **Incidence rate**. Click **OK**.
- Similarly, set **Deaths** to 2.5 million/year.
- The last highlighted box is the prevalence stock. Click on it, and put in 33.4 in the **Initial Value** box, and million in the **Units** box.
- Check units – go to **Model** → **Units Check**. If it gives an error message, then go back, change and recheck your units, until it says "**Units are OK.**".

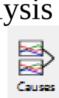
Simulation:

- To run a simulation, click on the 

button. Vensim PLE may ask you if you want to overwrite the "current" dataset. Clicking on yes will overwrite the "current dataset" displayed in the box to the left of the simulate button. Selecting no will allow you to create a different dataset.

- To see a strip graph, first select a stock or a flow, then click on the 

button on the analysis tools bar.

- The 

button displays a strip graph of the currently selected variable, along with graphs of all the variables that determine the value of the selected variable.

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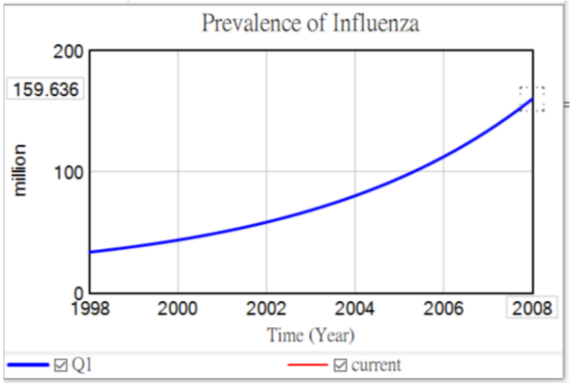
QUESTION 1: What is the prevalence of influenza in 2008?

The Prevalence in influenza in 2008 is 159.636 million.

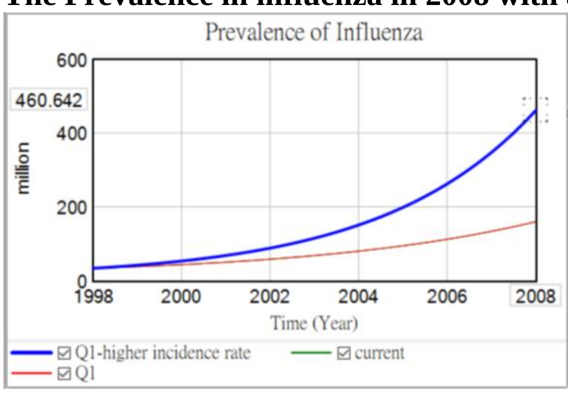


- Change the **Incidence rate** to 0.3, and simulate the model again. Save the new simulation with the name "higher incidence rate" (Do not overwrite the "current" dataset). Click the 

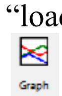
button.

QUESTION 2: Save and insert the new graph of **Prevalence of Influenza** vs. time below and explain the change.

The Prevalence in influenza in 2008 with a higher incidence rate is 460.642 million.



The difference between the prevalence of influenza of the two models become greater as time increases since we have a higher incidence rate of 30% comparing to the previous 20%. The higher incidence rate causes slopes that are steeper than the original one.

- Go to **Control Panel → Datasets**, you are able to remove the "current" dataset from "loaded – info…" by double clicking it. Remove the "current" dataset. Go back and click the 

button again.

QUESTION 3: Which line appears in the graph? Save and insert the new graph below.

The higher incidence rate model appears in the graph because we took away the original model.

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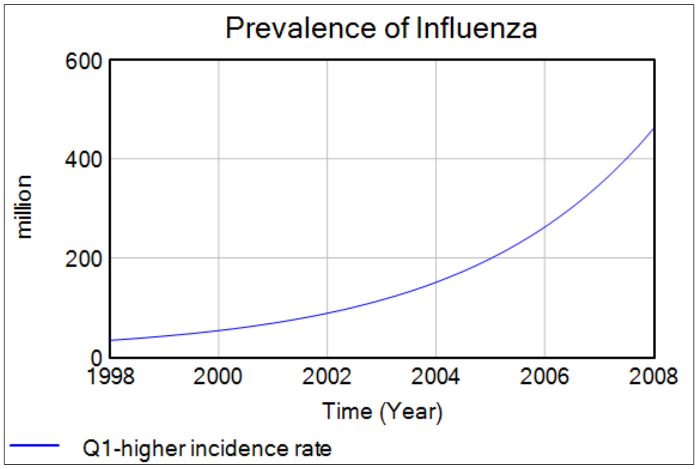
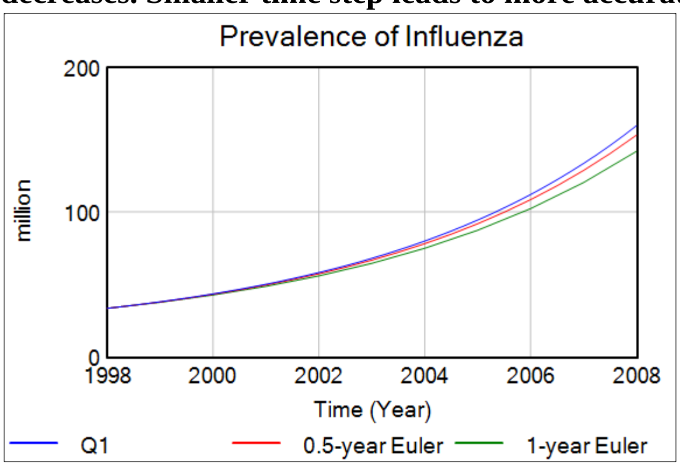


- Now change the **Incidence rate** back to 0.2. Then go to **Model → Settings**, change the time step to 1 year, and everything else remains the same. Simulate the model again and save the new simulation with the name "1-year Euler". Then change the time step to 0.5 year, and everything else remains the same. Simulate the model and save the new simulation with the name "0.5-year Euler". Make a graph of **Prevalence of Influenza** that shows the "current" dataset, the "1-year Euler" dataset, and the "0.5-year Euler" dataset.

QUESTION 4: Insert the graph below. What is the relationship between time step and the accuracy of the simulation results?

I renamed the "current" model to "Q1."
When the time step increases from 0.25 to 0.5 to 1, the accuracy of the simulation results decreases. Smaller time step leads to more accurate simulation results.



- Use the **Incidence rate** of 0.2, time step of 1 year, now change the integration type to "**RK4 Auto**". Simulate the model again and save the new simulation with the name "1-year RK4". Make a graph of **Prevalence of Influenza** that shows the "1-year Euler" dataset and the "1-year RK4" dataset only.

QUESTION 5: Insert the graph below. Which integration type do you think is more accurate?

RK4 is more accurate because it takes a weighted average of four different approximations.

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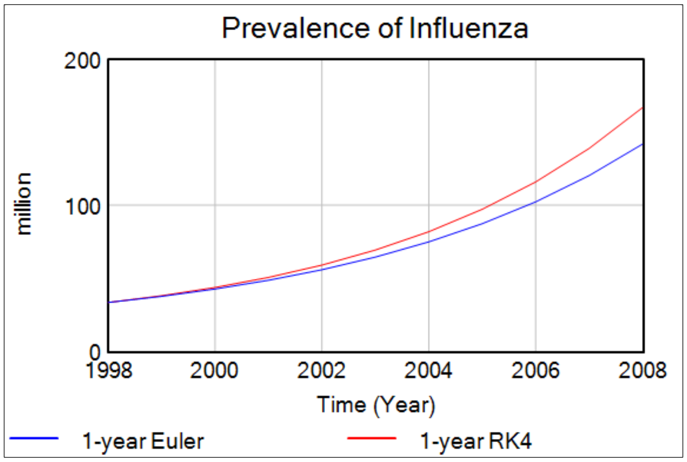
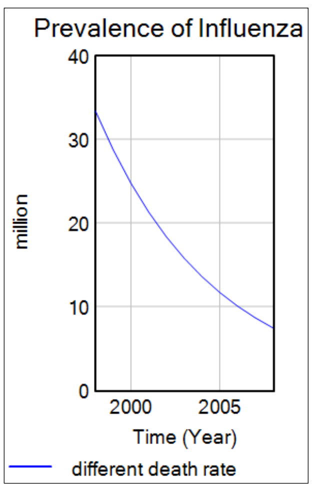


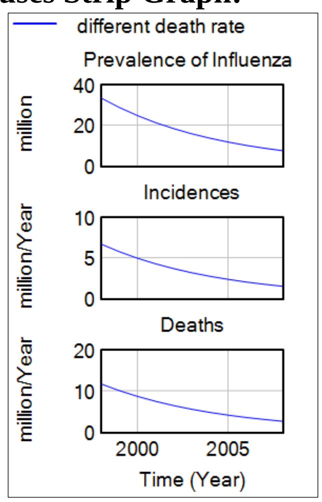
- What if the death rate is 35% of the prevalence (Incidence rate is still 20% of the prevalence)? Change the model structure to reflect the new death rate and run your model again.

QUESTION 6: Provide the new strip graph and causes strip graph for prevalence below.

Strip Graph:



Causes Strip Graph:



Different System Model:

In the late 1800s and early 1900s, the metropolitan area of Boston expanded rapidly. Because of the soaring population, water supplies from Lake Cochituate, Mystic Lakes, and Sudbury River can no longer satisfy the growing needs. Starting in 1897, a new reservoir was being constructed. This reservoir is known as the Wachusett Reservoir today. When the construction was completed in 1908, the Wachusett Reservoir was the largest public water supply reservoir in the world at the time. It has a total capacity of 65 billion gallons and is able to satisfy the water needs of an additional 350 thousand people. The population in Boston was around 600 thousand in 1908, and it was still growing very quickly with a birth rate of 3.98% (of the population) per year and a death rate of 1.72% (of the population) per year. The city managers were worried that even the supplies from the Wachusett Reservoir might run out in the future, requiring additional water sources. Consultants were hired who could help them determine if they need to worry

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about the adequacy of water supply in the next 50 years. Please show your analysis and answer the following questions with sufficient proof to support your argument.

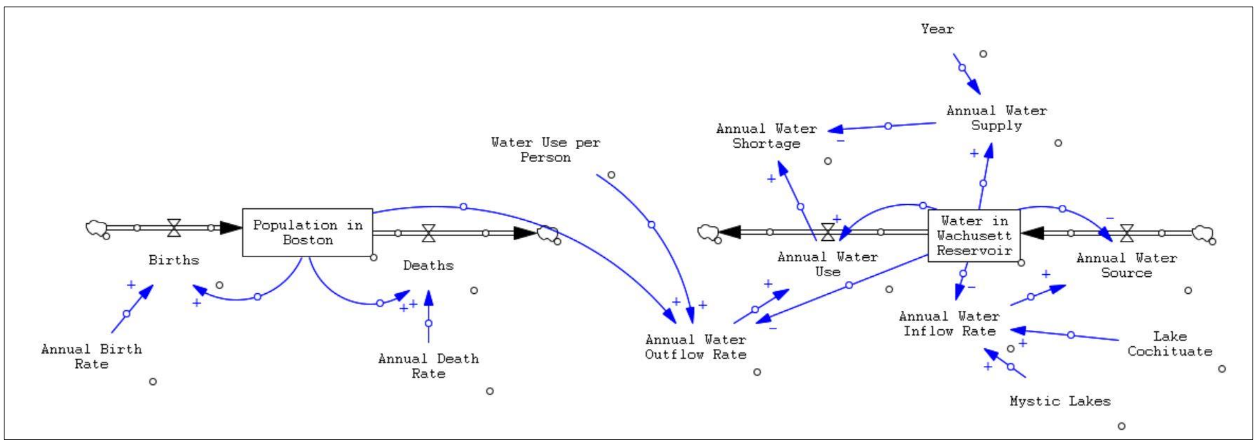
1. Insert an image of your system model.
2. When do they need the additional water sources in place?
3. If you were the environmental consultant, what would you suggest to the city managers?

Related Reading

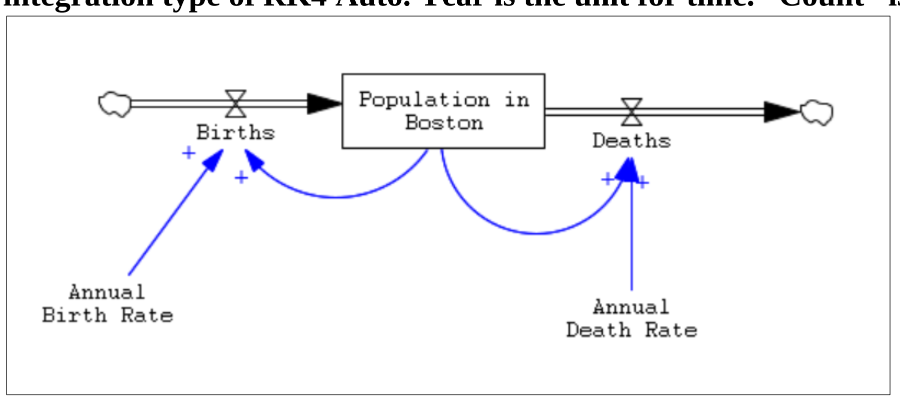
History of water supplies in Boston: http://www.mwra.state.ma.us/04water/html/hist1.htm

I built a model from 1908 to 1958 because $1908 + 50 = 1958$. I also set the time step to 0.25 and the integration type to RK4 Auto because I want the simulation results to be more accurate. Year is the unit for time.

For calculation, I assume that one gallon of water per year per person is needed. So the supply amount of water will be $65\ \textit{billion gallons}/\textit{year} + 350\ \textit{thousand gallons}/\textit{year} = 6500035000\ \textit{gallons}/\textit{year}$. In addition, the water is filled in 1908; thus, the initial value for 'Water in Wachusett Reservoir' is $30000000 * 365 + 10000000 * 365 = 14,600,000,000$, which is the aggregation of the annual amount of Lake Cochituate and Mystic Lakes.



I changed my model to a simplified one so that I can move forward and complete this lab report. This model is set to be from 1908 to 1958, with a time step of 0.25, and the integration type of RK4 Auto. Year is the unit for time. "Count" is the unit for population.



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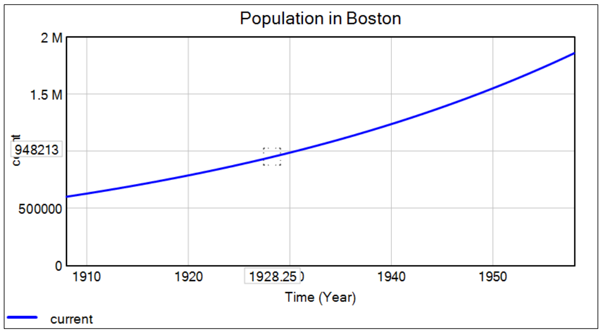

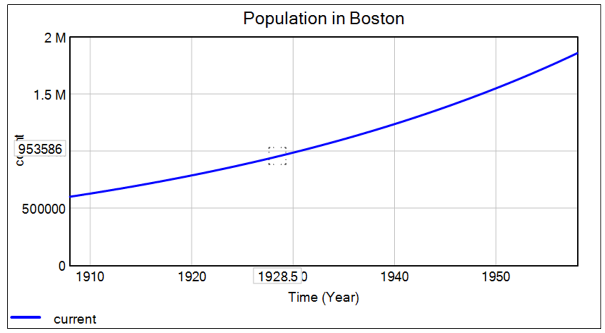

Midway through the year 1928, the population in metropolitan Boston would have exceeded $950000\ (\text{counts}) = 600000 + 350000$. This was when the city would need supplemental water sources.

If I were the environmental consultant, I might suggest the city managers to increase the water rates, so that the demand, which presumably turned out to be the amount of water use, will decrease due to the law of demand and supply. The main reason of making this suggestion was because I was not able to provide engineering-related advice such as constructing more reservoirs, which the public management team did within the next 30 years, that were both environmentally and socially sustainable. In addition, I would not like the city to develop more for sufficient water sources because this would also be non-environmentally sustainable. Nevertheless, the trade-offs from my recommendation of increasing the water rates included water becoming less affordable to more people, and that the public management team would either fire me, or lost in the next election because of this unfavorable decision to the civics.