





Chapter 1

Modeling with Vensim

Vensim is a visual modeling tool that allows you to represent **dynamic systems** in a flow chart atmosphere. Here are some of the key things to keep in mind:

- Populations are represented with Box Variables created using the Box Variable Icon .
- Change is represented with thick Rate Arrows created using the Flow Icon .
- Parameters are represented with Auxiliary Variables created using the Auxiliary Variable Icon .
- All population variables and parameters that are involved in the formula for change must be linked to the Rate Arrow with thin blue arrows created using the Arrow Icon .


1.1 Developing a Population Model in Vensim

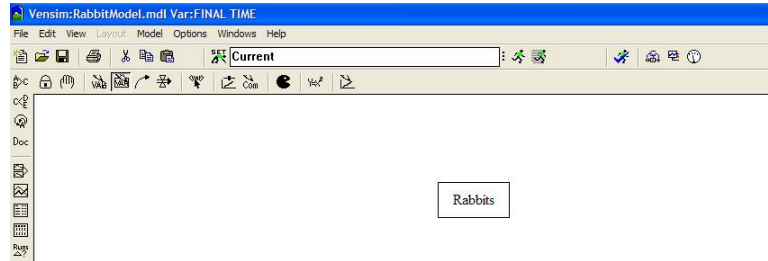
In order to illustrate how Vensim can be used to represent dynamical systems, we'll start by looking at a simple population model: the growth of a rabbit population. We assume that the only factors effecting the number of rabbits are natural births and natural deaths, where we have fixed birth and death rates. We do not consider nutritional resources, space, competition, predators, etc.


Figure 1.1 is a Vensim diagram that illustrates this simple rabbit population model, with fixed birth and death rates. Thus, change due to births is given by $(\text{BirthRate} * \text{NumberOfRabbits})$ and change due to deaths is given by $(\text{DeathRate} * \text{NumberOfRabbits})$. Next we'll create this model in Vensim and use it to generate graphs of the rabbit population.

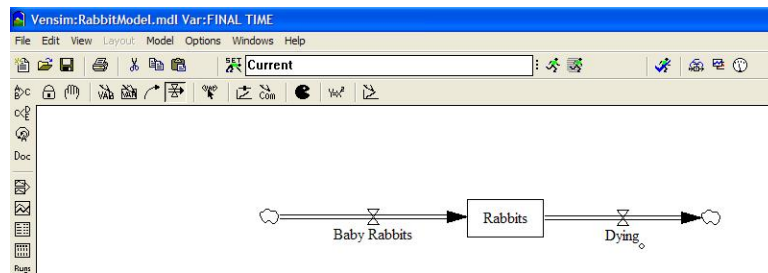
1.1.1 Creating the Flow Chart


As we've seen in Figure 1.1, we can think of the dynamics or change in our population as “flows” into or out of a population. These rates of change are represented by the thick Rate Arrows in the illustration. Each population (variable) is represented by a Box Variable in the flow chart, and parameters are represented by an Auxiliary Variables (dots). Dependence of the rates of change or “flows” on parameter and variable values are illustrated by connecting the auxiliary variables and/or population variables to the flows through arrows using thin blue arrows. Recall that our number of new rabbits is determined by multiplying the birth rate (auxiliary variable) and current number of rabbits (population variable). We can create this flow chart by proceeding with the following steps.

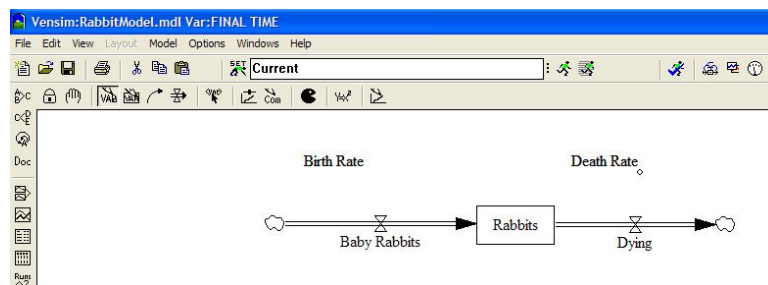
1. Begin by opening Vensim, which can be found by going to the Start Menu, selecting All Programs, then selecting Vensim. This will bring up a window with toolbars at the top and a white area (worksheet) for the majority of the space.
2. Put a box variable in the worksheet by clicking on the box icon variable  a single time, moving to the worksheet and clicking once where you want to place the box. This will bring up a narrow rectangular box where you are to type the name for the variable, such as “Rabbits”. Hit enter when you are done.




3. Next add two flow arrows, one going from the left of the Rabbit box, into the box, and one going from the Rabbit box out to the right. To do this
 - (a) Click once on the flow icon , then come to the worksheet,
 - (b) Click once to the left of the Rabbit box to identify where to start the arrow, then
 - (c) Click once in the box, indicating where to end the arrow. This will cause another rectangular name box to pop up. Type in a name for this flow, such as “Baby Rabbits”.
 - (d) Click once in the box to start the second arrow, then
 - (e) Click once to the right of the box to end the arrow. Type in a name for this last flow, such as “Dying”.



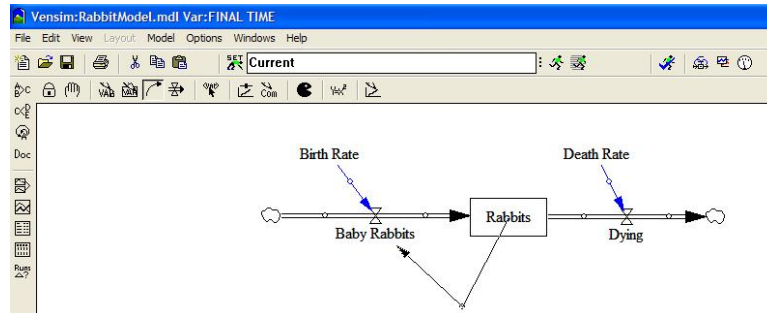
4. Now we add auxiliary variables for the birth and death rates. To do this
 - (a) Click once on the auxiliary variable icon .
 - (b) Click in the worksheet where you want to place your parameter. This will cause a rectangular name box to pop up. Type in the name for the parameter then hit enter.
 - (c) Repeat the above steps to add the death rate parameter.



5. To finish our flow chart, we must add our connector arrows. Direction is important here, they must start on the parameter or box variable TO THE FLOW PIPE. To add the connector arrows from the parameters:


- (a) Click once on the arrow icon , then come to the worksheet.
- (b) Click once on the birth rate parameter, then
- (c) Click once on the Baby Rabbits flow pipe to finish the arrow.
- (d) Repeat this process, connecting the Death Rate to the Dying flow pipe.

To add connector arrows from the Rabbits box to the flow pipes, do the same thing, but it helps to make an INTERMEDIATE CLICK someplace above or below the pipe to make the arrow bend.



1.1.2 Adding Equations to the Model

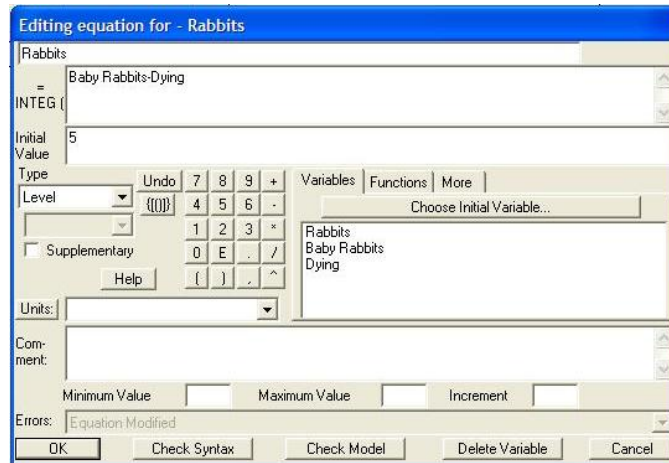
After we have the flow chart created, we still need to specify the formulas that relate the parameters and population variables to the rates of change. We also need to establish initial values of the populations as well as the values of the parameters involved in the model. To do this, simply follow the steps given below.

1. To add the equations to model, click on the $Y = x^2$ button . This will cause all of the parameters and variables to become highlighted until their formulas are filled in.
2. Click on the Birth Rate parameter. This will bring up a box, like the one below. Fill in the value of birth rate in the large white rectangular box to the right of the equal sign. Suppose the birth rate is 15%, so type in the decimal equivalent of 0.15 and hit enter.



3. Repeat this step with the Death Rate parameter, using 6% for the death rate.

- Click on the Rabbit box. This is where you will need to specify the INITIAL VALUE of the rabbit population. Assume we start our study with five rabbits in our population.



- Lastly, we fill in the formulas in the flow arrows.

- Click on the Baby Rabbits flow. You'll see a rectangular space to type your equation for the calculation of the number of new rabbits to the right of the equal sign. Keep in mind that the number of new rabbits is given by

$$\text{Baby Rabbits} = \text{Birth Rate} * \text{Rabbits}$$

Rather than having to type the RIGHT SIDE OF THIS EQUATION in, and potentially mistyping, notice that there is a box containing the names of the parameters and variables connected to the pipe by the connecting arrows. Simply click on a name in that box and it will appear in your formula box.



- With your cursor in the rectangular box to the right of the equal sign, click once on the Birth Rate label, then type *, then click once on the Rabbits label and hit OK.
- In a similar fashion, click on the Dying flow and specify the formula for dying as



$$\text{Dying} = \text{Death Rate} * \text{Rabbits}$$

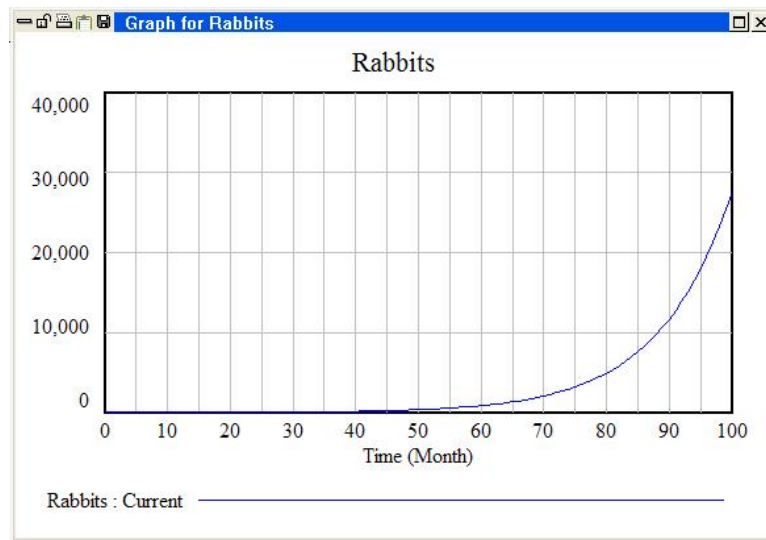
- Note, none of your variables, parameters, or flows should be highlighted once you've filled in all of the formulas.
- To make sure you've typed in everything correctly, go to the Model menu option and select Check Model option. If everything has been typed in correctly, you'll get an OK notice.

1.1.3 Running the Model

Running the Model Once


Now you're ready to "run" the model, i.e. allow the model to generate values of the population determined by these parameter values and dynamics. Once this data has been generated, it can be graphed and the model can be tweaked and rerun, allowing the user to verify and validate the model, then use it for making observations and predictions about the behavior of the system.

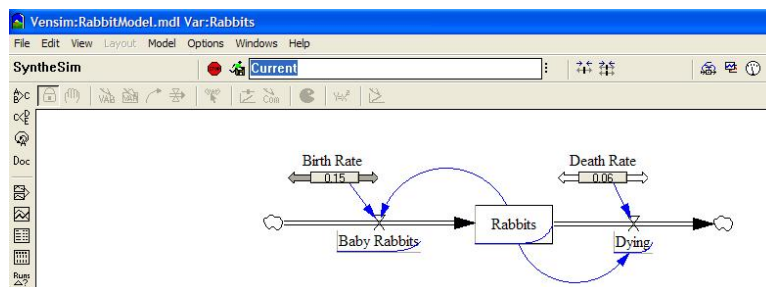
1. In order to run the model, click the Run Model button 
2. Next, click once on the Rabbits box to highlight it.
3. Then click on the Graph Icon on the left side of the window  to see a graph of the Rabbit population over time.




Running the Model in Simulation Mode

Rather than running the model with one set of parameter values, looking at your results, then adjusting your parameter values and rerunning the model, we can tweak the model while it's "running" and see the results of our changes immediately. To do this, we must be in *simulation mode*. Try it out!


1. In order to run the model in simulation mode, click the Run Simulation button . This will change the appearance of the model, putting slider bars over the parameter values.

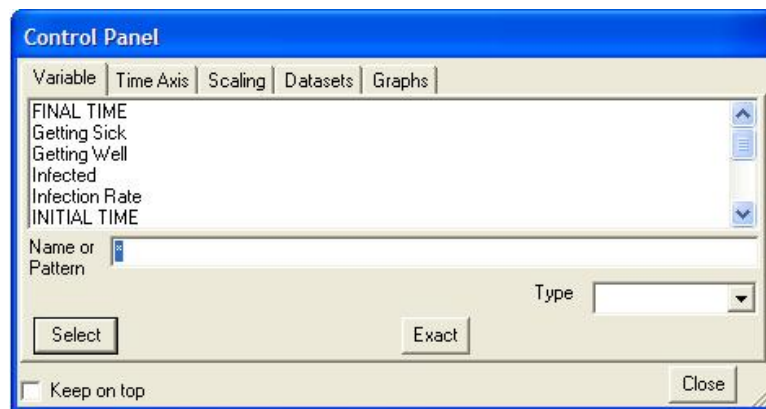


- As you move the slider bars, the parameter values adjust and you can instantly see the effects it has on the population value by looking at the sketch of the population graph displayed over the Rabbit box.
- To leave simulation mode, hit the Stop button .

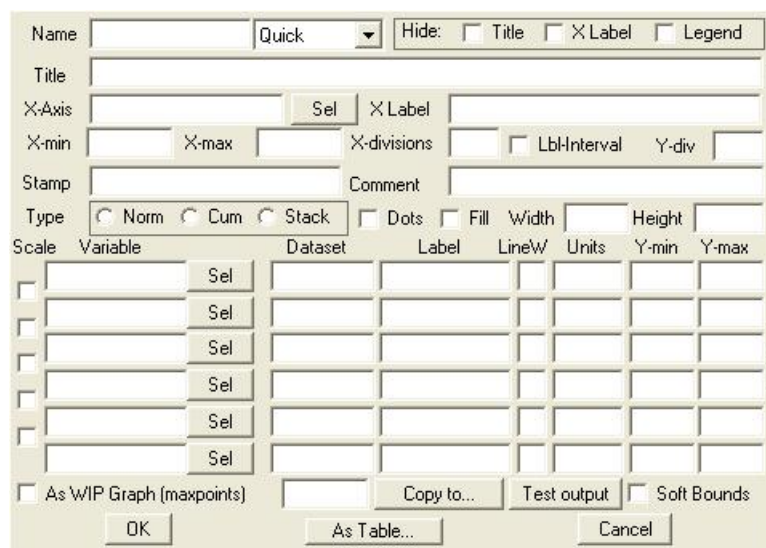
1.1.4 Creating a Graph

In addition to the graphs we get by clicking on the graph icon on the left side of the window, we can create graphs to our own specifications by using the Control Panel tool.

- In order create a graph of a single or multiple curves, click the Control Panel button . This will cause the Control Panel to pop up.




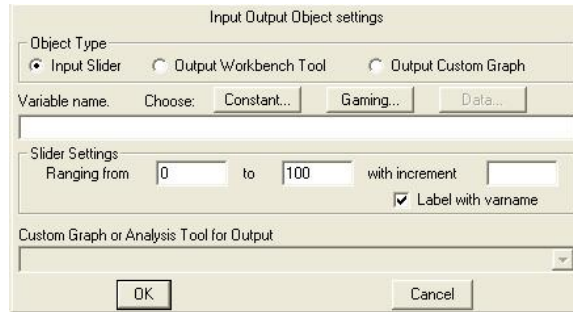
- Select the Graphs tab, then click on the New button option. This will bring up the Graph Menu:



- Give the graph a name to identify it, as well as a title.
- You can select your variable for the horizontal (independent) axis by clicking on the sel button and selecting from the variables in the problem.
- In a similar fashion, select the variables whose values you would like to plot along the vertical axis.

6. When you are done, click on the ok button.

7. Now click on the Input/Output Object Icon , then click in the location of your worksheet where you would like the graph to appear. This will cause the Input Output Settings box to appear.



8. Select the **Output custom graph** radial button, then select the name of the graph you just defined in steps 1 through 6 from the **Custom Graph or Analysis Tool** drop down window. Now, when you press the run button, you'll have a copy of your graph in the window. The graph will stay up if you are in Simulation Mode too, which helps you see the results of your parameter changes.

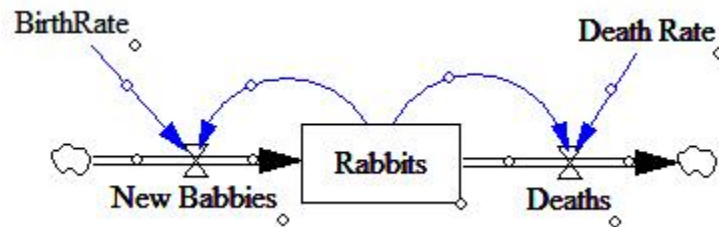


Figure 1.1: A Vensim flow chart illustrating the dynamics of the rabbit population. Arrows represent directional “flow”: rabbits are added to the population as baby rabbits (birth) and rabbits leave the population when they die.