Guided Study Program in System Dynamics

System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management

Assignment #3

Reading Assignment:

Read the following sections from "Vensim PLE: User's Guide, Version 3.0":

- Section 2: The Vensim PLE User Interface
- Section 6: Building a Simulation Model

The Vensim PLE User's Guide can be downloaded in pdf format from:

http://www.vensim.com/download.html

Please refer to Road Maps 2: A Guide to Learning System Dynamics (D-4502-4) and read the following papers from Road Maps 2:

- The First Step (D-4694)
- Beginner Modeling Exercises (D-4347-6)

Exercises:

In this assignment, you will build several models using Vensim PLE. The purpose of the assignment, however, is not only to increase your familiarity with Vensim PLE, but also to demonstrate some important ideas and principles of system dynamics.

1. The First Step

A. *The First Step* (D-4694) was written using the STELLA II simulation software, so you will need to make the necessary adjustments for Vensim PLE. Because all papers in Road Maps use STELLA II, you should make sure you know how to make the conversion between STELLA II and Vensim PLE models and equations. We recommend that you take the time now to read section 2 of the Vensim PLE User's Guide: *The Vensim PLE User Interface* (pp. 7-14). The section reviews the main features of the software.

B. Then turn to section 6 of the Vensim PLE User's Guide: *Building a Simulation Model* (pp. 53-64). Section 6 builds a population model similar to that presented in *The First Step*, using Vensim PLE. Browse through *Building a Simulation Model*. Refer back to the chapter if you have any problems making the models described in *The First Step*. If you still are having difficulties, please contact us as soon as possible.

C. Please read *The First Step*, building all of the models and running all of the simulations as you go along. In your assignment solutions document, please include the following:

- the model diagram as in Figure 17 and the model equations
- the graph of the model behavior as in Figures 21, 23, 26, and 27
- the model diagram as in Figure 32 and the model equations
- the graph of the model behavior as in Figures 33 and 35

2. Beginner Modeling Exercises

A. Please read *Beginner Modeling Exercises* (D-4347-6), answer all the questions and build all the models in Vensim PLE.

In your assignment solutions document, please include the following:

- for either the skunk population model or the landfills model, include the model diagram, the model equations, and a graph of the model behavior
- choose two of the remaining 12 models and include the model diagram, the model equations, and a graph of the model behavior for each of the two models

B. Think of two other simple systems that one could model as a stock with an inflow and/or outflow. For each of them, please include the following:

- short description of the system
- list of variables and their identification as stocks or flows
- model diagram
- model equations, including documentation and units
- graph of model behavior

3. Independent modeling exercise

A. Imagine a small forest of fir trees, located deep in the Pacific Northwest. The forest contains 1000 trees, half of which are still saplings. The other half have already grown to be tall, towering trees. Over the course of each year, the locals chop down, on average, 10 of the tall trees. Every year the third graders in Miss Pringle's class plant 10 young saplings in the forest and carefully watch them grow. Miss Pringle tells her class that it will take their saplings 50 years to grow to resemble the older trees.

This exercise will guide you through the steps to make a simple model of the forest, in order to understand how the distribution of trees in the forest changes over time. Our model will contain the elements listed below; identify each element as either stock, flow, or constant, and label its units. Then take each stock and determine its inflows and outflows.

- mature trees
- planting
- time for saplings to mature
- saplings
- harvesting
- maturing

B. Using Vensim PLE, combine the elements to represent the structure of the system.

C. Using the description of the system provided in part A, define the equations for each flow. Then supply the constants and initial values. Remember to document all equations. In your assignment solutions document, include the model diagram and documented equations. *(Hint: If there are N saplings in a forest and saplings need M years to mature, then N/M of the saplings mature each year.)*

D. Before you simulate a model, it is often useful to first make a general sketch of the behavior that you expect to see. The best way to make the sketch is to draw a horizontal time axis and a vertical axis for the key variables (the stocks in the model, for example). Then trace what you expect would be the general behavior of each variable (growth, growth followed by a collapse, decay, oscillations, etc.). Give a general idea of the time horizon (will your model be valid over a period of hours, months, years, or centuries?).

Identify any critical points (the peak before a collapse, or an inflection point between exponential growth and asymptotic growth, for instance), and try to approximate at which time they would occur. Such sketches are called "reference modes." After you have drawn some reference modes, you can simulate the model. If the behavior that the model generates differs from the behavior you predicted, then you know that there must be an inconsistency in either the model you formulated or your mental model.

Draw reference modes for the stocks in the forest model. You do not need to include these in your assignment solutions document, but you do need to draw them in order to be able to answer the next question.

E. Simulate the model over 300 years. Include graphs of the behavior of all stocks in your assignment solutions document. Did the model generate the behavior you predicted? Why or why not?

F. As more and more people move to the Pacific Northwest to be closer to nature, the demand for firewood increases. Now the locals chop down five more trees each year. Miss Pringle, the third grade teacher, decides to compensate by planting five more saplings each year.

Make the necessary changes in the forest model to reflect the new scenario. In your assignment solutions document, include the documented equations that you changed.

Before running a simulation of the new scenario, draw reference modes for each stock in the model. Then simulate the model. In your assignment solutions document, include graphs of the behavior of all stocks.

Did the model generate the behavior that you predicted? In a paragraph, explain which aspects of the forest system, reflected in the model, combined to produce the behavior observed in the new scenario. What lessons can you draw from these observations?