

# Guided Study Program in System Dynamics

System Dynamics in Education Project

System Dynamics Group

MIT Sloan School of Management<sup>1</sup>

## Assignment #27

Assigned on: Friday, May 21, 1999

Due by: Monday, June 7, 1999  
12:00 PM (Noon)<sup>2</sup>

WE WILL REVIEW THE RESPONSES ON MONDAY  
AFTERNOONS, BOSTON TIME.

LATE SUBMISSIONS WILL NOT RECEIVE FULL  
ATTENTION.

*Please email assignment solutions, questions, or comments to:*

*[gsp@sysdyn.mit.edu](mailto:gsp@sysdyn.mit.edu)*

*Save solutions with the filename XYZ-S27.doc*

*(where XYZ are your initials)*

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## Reading Assignment:

Please refer to Road Maps 9: A Guide to Learning System Dynamics (D-4508-1) and read the following papers from Road Maps 9:

- Generic Structures: Overshoot and Collapse, by Lucia Breierova (D-4480)
- A Skeptic's Guide to Computer Models, by John Sterman (D-4101-1)

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<sup>2</sup> The deadline is in United States Eastern Time, equivalent to Greenwich Mean Time minus 4 hours during US daylight savings time, and Greenwich Mean Time minus 5 hours for the rest of the year.

## **Exercises:**

### 1. Generic Structures: Overshoot and Collapse

A. Describe one or more systems that you think exhibit or may exhibit overshoot and collapse.

- What would be the variables in the system corresponding to the “stock” and “resource” of the generic structure?
- How does the “stock” deplete the “resource,” and why is the “loss fraction” of the “stock” dependent on the amount of “resource”?
- Is the “resource” renewable? If so, how does the renewal of the “resource” affect the system?
- Over what time horizon does the behavior of overshoot and collapse occur?
- Once the “stock” collapses, has all the “resource” been depleted? Why or why not?

If you have extra time, feel free to model the system that you described and submit your model.

B. Turn back to section 4, “Table Functions in the Generic Structure.” It is possible to generate the unrealistic behaviors of S-shaped growth or even exponential growth by simply altering one of the table functions. Which one of the table functions should be changed? How would you change the table function so that the model produces S-shaped growth, what assumptions would this change in the table function represent, and why are these assumptions unrealistic? What about for exponential growth?

*Hint: You may want to refer to Road Maps 9: Mistakes and Misunderstandings: Table Functions.*

### 2. Independent Exercise: Sensitivity analysis of table functions

In this exercise, you are going to explore the sensitivity of model behavior to changes in table functions. Before you tackle the exercises, please read the following introduction to the topic, taken from a paper in progress.

Table functions, also known as graphical functions, are useful tools for representing nonlinear relationships between variables in a model. The reasons for performing sensitivity analysis on table functions are similar to the reasons for testing the effects of changes in constant parameters. Table functions often express a modeler’s crucial assumptions about the relationship between two variables. A modeler should, therefore, simulate the model with alternative formulations of table functions to see how the model behavior changes under different assumptions. If sensitivity analysis shows that the model behavior is relatively insensitive to changes in the shape of a table function, then the modeler would not have to specify the table function with extreme precision in order to generate the observed behavior. Thus, the modeler can be more certain about the model’s behavior, since the behavior remains the same even if the table function changes

slightly. Sensitivity analysis also allows a modeler to better understand the dynamics of the system being modeled and to investigate the behavior under extreme assumptions.

Before exploring in detail how changes in table functions affect the behavior of a model, it is necessary to understand what table functions are and how they should be formulated.

A table function is a graphical tool used to model a causal, usually nonlinear relationship between two variables in a model. Table functions model relationships that would be difficult to specify in mathematical terms. For example, a time series (a function in which a variable's value changes with respect to time) can be incorporated into a model as a table function; however, exogenous time series should seldom be used in a system dynamics model. More frequently, a table function represents an *effect* of one variable on another variable. In such cases, the function is referred to as a *multiplier* because it multiplies a normal, or reference value of a variable. A normal value, defined by the modeler, represents the normal, or reference conditions of the system, in which the variable being multiplied by the multiplier is equal to its normal value.

If a table function is a multiplier, the input (the independent variable on the horizontal, or x-axis) as well as the output (the dependent variable on the vertical, or y-axis) of the table function must be dimensionless because a table function cannot change the units of one variable to the units of another variable. In addition, the table function should be robust; both the input and the output should be allowed to vary over their entire possible ranges.

When formulating a table function, several important characteristics of the function should be determined: slope, shape, reference points, and reference lines.

The *slope* of a table function represents the direction of the relationship between the variables. When the relationship is positive, so is the slope; an increase in the value of the independent variable causes an increase in the value of the dependent variable. A negative slope means that the relationship is negative; an increase in the value of the independent variable causes a decrease in the value of the dependent variable.

The *shape*, or curvature, of a table function shows the strengthening or weakening effect of the independent variable on the dependent variable. When the curve of the table function becomes steeper, the effect of the independent variable on the dependent variable is stronger. A weakening effect of the independent variable on the dependent variable is indicated by a flattening of the curve.

If the table function is a multiplier, it multiplies the normal value of a variable. In a multiplier, a *reference point* is a point for which the multiplier outputs the value of 1, so that the dependent variable is equal to its normal value. A value of 1 for the multiplier means that the independent variable has no effect on the dependent variable, which occurs under the normal conditions of the system.

A *reference line*, for example  $y = x$  (the dependent variable equals the independent variable), can help to identify reference conditions of the system as well as weakening and strengthening effects of the table function.

In addition, it is often helpful to determine the coordinates of the extreme values of the independent and dependent variables shown in the table, as well as the coordinates of the points where the independent variable is equal to 0 and to 1, and where the dependent variable is equal to 0 and to 1.

Now please work on the following problems:

A. Choose one of the four models presented in *Generic Structures: Overshoot and Collapse*. Build the model in Vensim PLE and simulate the base run, as presented in the paper. In your assignment solutions document, please include the model diagram, documented equations, and graphs of model behavior in the base run.

B. Conduct parameter sensitivity analysis on the model you chose in part A. In your assignment solutions document, include graphs to show the results, and summarize your findings.

C. In the model, identify the table function corresponding to the “effect of resource on consumption per unit of stock” table function from the generic structure. Characterize the slope, shape, reference point(s) and any other interesting characteristics of the function, and explain the modeler’s assumptions in formulating the table function. Describe any alternative assumptions that one might have about the relationship between the amount of resource and the consumption per unit of stock, and specify table functions corresponding each of those assumptions. For each specification of the table function, simulate the model, and submit a graph of the table function and a graph of the model behavior. Explain how and why the particular table function specification resulted in any observed changes in the behavior of the model.

D. Repeat part C for the table function corresponding to the “effect of resource on loss fraction” table function from the generic structure.

E. Summarize your findings from parts C and D. What would you conclude about the sensitivity of model behavior to changes in table functions?