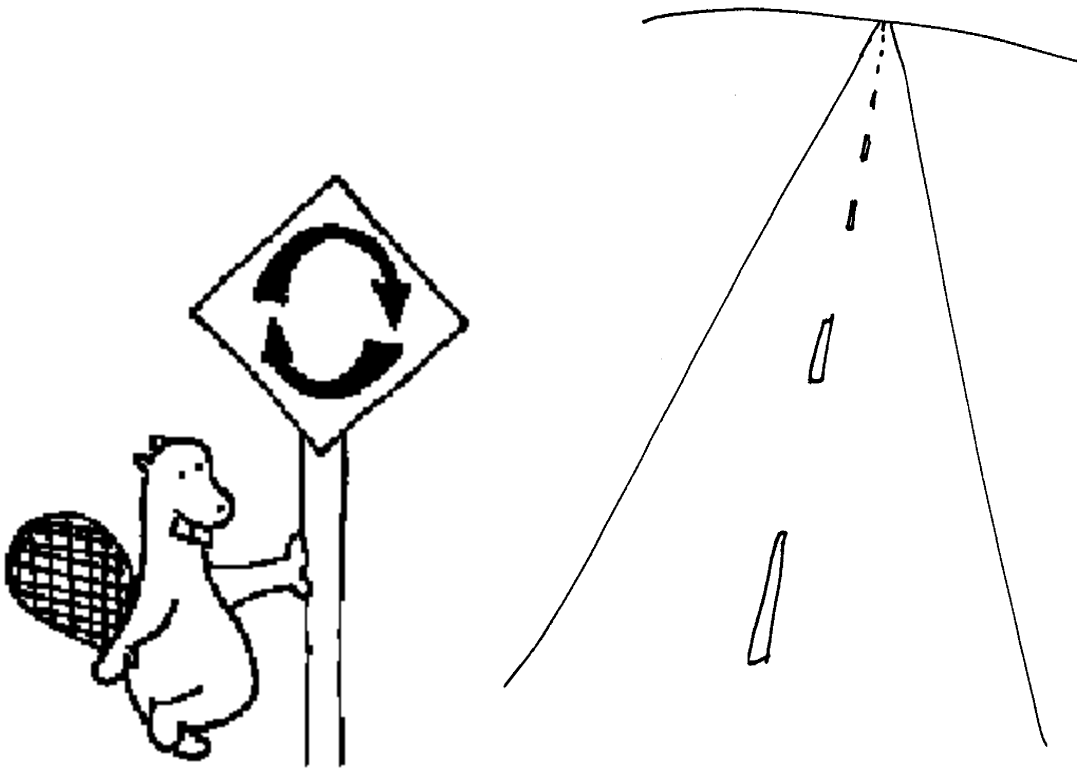
Road Maps 0

A Guide to Learning System Dynamics



System Dynamics in Education Project

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System Dynamics in Education Project
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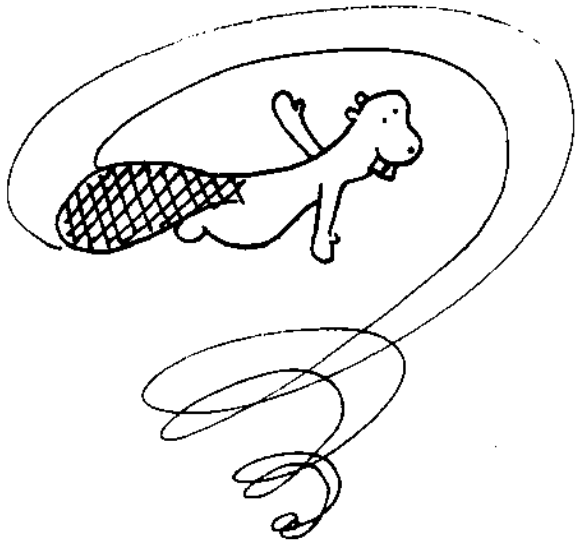
Welcome to Road Maps!

Many books and thousands of papers cover the field of system dynamics. With all of these resources available, it is difficult to know where to begin learning about system dynamics. The System Dynamics in Education Project at MIT is putting together Road Maps to help sort through this vast library of books and papers. Road Maps is a series of self-study guides that use modeling exercises and selected literature to provide a resource for learning about the principles and practices of system dynamics. In its present form, Road Maps is not meant to be a teaching curriculum for classroom use.

The Spiral Learning Approach

A new concept is usually not fully mastered after reading about it only once. Also, learning usually involves building one's understanding up from one level to a higher level. For this reason, Road Maps utilizes a spiral learning approach, in which each new concept is repeatedly reinforced in successive chapters. This repetition moves upward along a spiral as more advanced concepts build upon basic ones.

In constructing this spiral, Road Maps has been divided into chapters. The end of each chapter marks the completion of a particular subset of concepts, with the next chapter building on the material just learned. Each chapter comes as a separate document so the reader can request them as needed.



Organization

The Road Maps series begins with **Road Maps One**, which introduces the concepts of causal loops and circular feedback in systems. In addition, some of the applications and history of system dynamics are presented.

Road Maps Two takes you through your first system dynamics models, introducing computer simulation and the concept and methods of graphical integration. Two basic elements of system dynamics models, the stock and flow, are presented. You will need a computer and STELLA™ or Vensim™ software for this and subsequent chapters of Road Maps.

Road Maps Three presents two of the most common structures in system dynamics: the first-order positive and negative feedback loops. Systems exhibiting exponential growth and decay are examined, and the idea of loop dominance in systems is introduced

Road Maps Four introduces generic structures and discusses the use of computer simulation games in teaching system dynamics. After playing the *Fish Banks* game, you will construct a model of the scenario and learn about the tragedy of the commons. Using your computer model, you will simulate and analyze several policies for this system.

Road Maps Five probes the structure of system dynamics models, emphasizing some important features that you may not have noticed, and explains the spread of an epidemic. Road Maps Five also introduces testing for model validity in the system dynamics context. How do you know that your model is a good representation of the real system?

In **Road Maps Six**, the dynamics of economic supply and demand are explored and more modeling exercises are provided. Also, oscillatory systems are used to show the transferability of structures. More modeling exercises sharpen your modeling skills and develop intuition about systems.

Road Maps Seven presents some unexpected behaviors that can occur in higher-order positive feedback loops. It also points out mistakes commonly found in system dynamics models and provides more independent modeling exercises.

Road Maps Eight continues to improve your modeling skills by analyzing the first stage of the process of building a model: conceptualization, and by warning you against other mistakes commonly made in models. Road Maps Eight

also increases your understanding of oscillating systems and introduces sensitivity analysis.

Road Maps Nine explores the dynamics of credit card spending, illustrates how to correctly formulate table functions, and introduces the behavior known as overshoot and collapse. More graphical integration exercises develop your intuitive understanding of the process of graphical integration.

Road Maps Ten provides further instruction on how to build a model from scratch with exercises for the second step, formulation. There are a number of other papers in Road Maps Ten which will continue to build skill in working with system dynamics models and continue the reader's understanding of system dynamics principles.

Road Maps discusses the principles and characteristics of systems, explores the interrelationship between structure and behavior of dynamic models, provides guidelines for good modeling practice, and discusses the applications of system dynamics. From Road Maps One on, the spiral of learning returns to these primary areas several times by introducing more advanced material while building on fundamental concepts. After completing Road Maps, you should have a strong working knowledge of system dynamics, have developed intuition about the fundamental principles of systems and be ready to explore the application of system dynamics in any area of interest.

How to Use Road Maps

First, you need to determine where you should begin in Road Maps. Some readers have had more background in system dynamics than others. This introduction should help you find a good starting point in Road Maps.

Road Maps explores several topics in system dynamics through selected readings and exercises. Before each reading or exercise is a short description of the reading and its most important ideas. After each reading or exercise, we highlight the main ideas before moving on.

Each chapter in Road Maps contains readings that introduce and strengthen some of the basic concepts of system dynamics. Other readings focus on practicing the acquired skills through various exercises or simulation games. Most

of the chapters conclude with a prominent paper from the literature in the system dynamics field.

We present the fundamental concepts of system dynamics as *System Principles* in Road Maps. These principles are enclosed in boxes that highlight them from the rest of the text to emphasize their importance. The progression of system principles in Road Maps allows you to revisit each principle several times. Each time a principle is revised in Road Maps, you will build upon your previous understanding of the principle by learning something new about the principle. The system principles are the core of Road Maps around which the readings, exercises, and papers are built.

As part of the spiral learning approach that we use in Road Maps, many concepts will be briefly introduced early on and then explained later in greater detail. Road Maps contains a number of series of papers that are spread out over successive chapters. Each of these series focuses on a specific topic in system dynamics or the developing of a particular skill. The series start out with a simple paper, and progress to further develop the idea in subsequent chapters.

Things You'll Need for Road Maps

Modeling Software

In order to complete Road Maps Two and subsequent Road Maps, you will need to have access to modeling software. The Road Maps guides and most papers included in Road Maps were written with the use of STELLA II for the Macintosh. STELLA II is currently available for both the Macintosh and the Windows platforms. If you have any questions about STELLA, contact High Performance Systems (see Appendix). Ask about prices for educational use.

Vensim, Powersim, and DYNAMO are other software programs designed for building system dynamics models. Vensim is produced by Ventana Systems, which offers a free introductory version of its software, Vensim PLE, that can be downloaded off the World Wide Web. See the Appendix for more information about obtaining Vensim and Powersim.

Notice written June, 2000:

We have written a guide on how to use Vensim modeling software for each section of the Road Maps series that involves computer modeling. Each guide is

located in the back of the exercise document. When Chapters 1-9 of the Road Maps series were written, STELLA software was the most common beginner modeling program available. Now you may choose from a number of system dynamics modeling software packages. If you would like more information on Vensim, please go to http://www.vensim.com. A free version called Vensim PLE is located there.

For more detailed information on using Vensim software in the Road Maps series, please refer to the paper titled: "Vensim Guide (D-4856)" in the Appendix section at the end of Road Maps.

A Computer

To run the latest version of STELLA, STELLA 5.0, on a Macintosh, you will need an Apple Macintosh computer (68020 processor or higher) with at least 8 MB of RAM, a 12 MB hard disk and System 7.1 or higher. To run STELLA 5.0 for Windows you will need an IBM PC-compatible computer with a 486-class processor running Windows 3.1 or greater. You will need at least 8 MB RAM, a hard disk with a least 16 MB of free space. Previous versions of STELLA have similar requirements.

In either case, if you plan on continuing to model, it may be a good idea to have access to a computer with more memory, hard disk space and a faster processor.

Books

1) Goodman, Michael R, 1974. *Study Notes in System Dynamics*. Portland, Oregon: Pegasus Communications, 388 pp. (Road Maps 2 onwards)

2) Forrester, Jay W., 1969. *Urban Dynamics*. Portland, Oregon: Pegasus Communications, 285 pp. (Road Maps 3 onwards)

If you have any problems in getting the above three books, contact Pegasus Communications (see Appendix).

3) Meadows, Donella H., Dennis Meadows, Jorgen Randers, 1992.
Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future.
Post Mills, VT: Chelsea Green Publishing Co., 300 pp. (Road Maps 5)
To order a copy of this book, contact Chelsea Green Publishing Co. (see Appendix).

Good luck with Road Maps!

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