System Dynamics Group
Sloan School of Management
Massachusetts Institute of Technology

Introduction to System Dynamics, 15.871
System Dynamics for Business Policy, 15.874
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Assignment 1

Problem Definition and Model Conceptualization*

Assigned: Thursday 4 September 2003; Due: Tuesday 16 September 2003
This is an individual assignment.

The design and evaluation of high-leverage policies demand a long-term, dynamic perspective. The analyst or manager must be able to characterize the strategic problem, including its current symptoms and history. The time horizon should be explicit and must be long enough to include possible side effects, delayed responses to policies, and other feedbacks. This assignment develops your ability to develop a *reference mode* that graphically characterizes patterns of problem behavior over time in various situations. The assignment also develops your skill in constructing *causal loop diagrams* that capture the feedback structure of the system, and your ability to relate the structure in a causal map to the problem behavior in the reference mode.

Problem definition involves both textual and graphical statements of problematic behavior. Conceptualization entails identifying feedback loops that are hypothesized to underlie observed patterns of system behavior. Model formulation is the process of moving from a theory of underlying structure to a fully specified mathematical model so that the theory can be tested. In this assignment, the skills involved in problem definition and model conceptualization are treated separately. Later assignments will bring these skills together with those of formulation and analysis to focus on a variety of strategic and operational problems.

How much should you hand in?

Use your judgment. Some words of wisdom:

"Be careful that you write accurately rather than much." —Erasmus

We don't give higher grades for longer write-ups.

"Often must you turn your stylus to erase, if you hope to write something worth a second reading." —Horace

Allow yourself time for revisions.

"What is written without effort is in general read without pleasure." —Samuel Johnson

And graded without pleasure.

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* Prepared by John Sterman, September 1999; revised January 2002, August 2003.

☛ denotes a tip to help you build the model or answer the question.

While your graphs and diagrams should be clear and legible, it is ***NOT*** necessary to create professional quality graphics. ***DO NOT*** spend your time creating artist-quality presentation graphics using fancy software. Use your time to think about the issues and develop your ideas. Use software to create the diagrams ***ONLY*** if it will boost your productivity. A legible handwritten diagram you had time to think about is preferable to a beautiful computer-generated diagram that took so much time to render you didn't have time to think deeply about its content.

A. Diagnosing the Causes of Policy Resistance *(5 points)*

Forest fires are in the news again. The year 2000 was the worst year for wildfire in the US in fifty years. 2002 was worse, with 7.9 million acres burned, an area larger than that of the states of Massachusetts and Rhode Island combined. The 2003 fire season is not yet over, but has again seen a number of devastating fires, and the US government estimates more than 190 million acres of public lands are at risk for catastrophic wildfire. The costs to state governments, the Forest Service, local residents and businesses are staggering, totaling well over $1 billion in 2002 alone. While the number of forest fires in the US has fallen in recent decades, both their size and severity have increased. Why is the policy of fire prevention/fire suppression failing, and, more importantly, what can be done?

A0. Read the article entitled "Another costly war that America can never win?" (*The Economist*, August 17, 2002), about the effects of last summer's forest fires in the Western US.

A1. Make a list of the most important variables or concepts characterizing the problem described in the article. Your list should be comprehensive but as short as possible (six or fewer). Aggregate similar concepts where possible (e.g. if you thought that each measure needed to fight fires was important, could you lump together the different types of measures into broader categories?).

A2. Drawing on the verbal description and analysis in the article, graph the behavior of the key variables you identified in (1). First, identify the time horizon over which the dynamics unfold. Do not be constrained by the publication date of the article or the range of data given in the story, but select a time period long enough to capture the dynamics of the critical variables, including their past development and enough of the future for the dynamics to play out. Next, sketch a graph showing the behavior over the time horizon for each variable. If two or more variables have the same units of measure, plot them on the same scales. Qualitative patterns are more important than numerical precision in the early stages of problem definition.

A3. Drawing on the article and your analysis above, create a causal loop diagram that captures the important feedback loops underlying the dynamics you described above. Your diagram should include the loops you believe are essential to understanding and explaining the dynamics, but should be simple enough to understand. Remember that your client cannot understand a diagram that includes everything. Be sure to identify the polarity of each link and loop. Make sure you capture both the loops that represent the intent of the historic policy of fire prevention/fire suppression, and the loops capturing the unintended 'side effects' of the policy.

A4. Briefly describe how the loops you identify in your causal map create the behavior you describe. In particular, use your diagram to explain the apparent paradox posed by the fact that, while there are fewer forest fires than ever before, forest fire damage continues to grow.

- ☛ A good explanation captures the causal relationships (feedbacks) that generate the behaviors in the reference mode. Your explanation should show how the loops interact to create the reference mode.

A5. Use your diagram to suggest a policy that can protect the forests, and the ecosystems and economies they support, better than the historic fire suppression policy. Explain why your policy would help using your causal diagram. What implementation issues do you see?

B. Using Feedback Structure to Analyze Policies *(5 points)*

Read and do the challenge "The Medigap Death Spiral" on p. 176. Answer questions 1 and 2 in the challenge. For question 3, identify other examples of adverse selection, but you do not need to map their feedback structure.

In developing your causal diagram for the medigap problem (question 1 in the challenge), you will find it helpful to first develop reference modes for other important variables besides those shown in Figure 5-29. To do so, follow these steps:

B1. Make a list of the most important variables or concepts characterizing the problem but not shown in Figure 5-29. Your list should be comprehensive but as short as possible (six or fewer). Aggregate similar concepts where possible (e.g., is it really necessary to represent the different types of medigap insurance?). Remember that you are attempting to communicate your ideas to a reader, not write "The Book of Lists."

B2. Use the description in the challenge and your own knowledge to graph the behavior of the key variables you identified in (a). First, identify the *time horizon* over which the dynamics unfold. Do not be constrained by the dates shown in Figure 5-29, but select a time period long enough to capture the dynamics of the critical variables, including their past development and enough of the future for the dynamics to play out. Next, sketch a graph showing the behavior for each variable over the time horizon you identified. If two or more variables have the same units of measure, plot them on the same scale (for example, show revenue and cost on the same graph so that the difference between them (profit) can be easily seen). Qualitative patterns are more important than numerical precision in the early stages of problem definition. Hand in your reference modes.

☛ To get your causal diagram started it may be useful to ask yourself "what is the insurers' rationale for raising premiums?" That is, what is the *intended rationality* or *intended outcome* of the decision to raise premiums? What problem is a rate increase supposed to solve? Represent that logic in your diagram (what type of loop usually represents attempts to solve a problem?). Having represented the intended outcomes, you can then capture some of the unintended effects of the decision.

General Hints:

- Before starting, be sure to do the assigned readings covering causal-loop diagrams.
- Your diagrams should include the loops essential to explaining the dynamics, but should be simple enough to understand. Remember that your client will not understand a diagram that includes everything.
- Each of your diagrams must fit comfortably and legibly on a single sheet of 8.5 x 11 paper.
- Be sure to follow the conventions and rules for causal diagrams and reference modes described in chapters 4 and 5. These include the following:

  Label the time horizon of graphs explicitly; provide units of measure and scales for the variables.

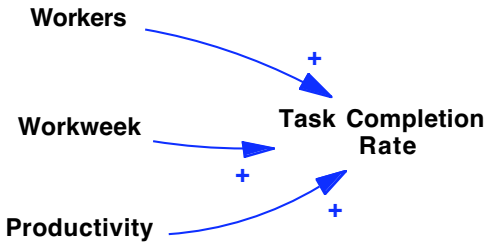
  Be sure to label the polarity of every link in your causal diagrams.

  Identify the polarity of the important loops.

  Give the important loops a meaningful name.

  Use variables with a clear sense of direction.

- *Operational thinking* and *dimensional consistency*: wherever possible, formulate your causal links so they capture operational realities—the basic definitions and physics—of the processes you seek to represent. The units of measure for the variables should, where possible, be obvious. In many cases, the equation for a key concept should be readily inferred from the causal diagram and units. For example, in a model of a work process, a good diagram of the determinants of the task completion rate would be:



Each variable has a clear sense of direction and obvious units of measure. From this information a reader can infer the equation for the Task Completion Rate:

Task Completion Rate = Workers * Workweek * Productivity
(Tasks/week) (People) * (Hours/Week) * (Tasks/Hour/Person)

Such a formulation is greatly preferable to this less operational version, in which the definitions and units for the variables are much less clear: