Guided Study Program in System Dynamics

System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management[1]

Assignment #24

Assigned on: Friday, April 23, 1999

Due by: Monday, May 3, 1999
12:00 PM (Noon)[2]
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
Save solutions with the filename XYZ-S24.doc
(where XYZ are your initials)

Reading Assignment:

Please download the following paper from http://sysdyn.mit.edu/gsp98/

- Generic Structures: Exponential Material Delays, by Stephanie Albin (D-4614-E)

Also read the following:

- *Industrial Dynamics*,[3] by Jay W. Forrester, Chapter 9

[2] 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.
[3] Forrester, Jay W., 1961. *Industrial Dynamics.* Waltham, MA: Pegasus Communications. 464 pp.

Exercises:

1. Generic Structures: Exponential Material Delays and Industrial Dynamics, Chapter 9: Representing Delays

Please read the paper and work through the exercises. Then read the chapter and answer the following questions:

A. Tom has just created a new consulting company and hired five consulting rookies. Given that a rookie needs to be trained for an average of eight months before she becomes experienced, how many of the five rookies will become experienced consultants after 12 months? In your assignment solutions document, please include the model diagram, documented equations, and a graph of model behavior.
Hint 1: Although all rookies are hired at once, their transition into experienced workers should not be viewed as a discrete process (that is, in eight months, all five workers will suddenly become experienced). Consultants do not suddenly and discontinuously go from inexperienced rookies to experienced consultants. There is a gradual transition in the tasks that they can do, so their gaining experience is a continuous process.
Hint 2: Model the hiring decision as a pulse of 5 workers at time 0.

B. Because Tom did not realize the long time delay between hiring consultants and training them, he was unable to work on enough consulting projects, and his company went bankrupt. Tom therefore decides to start another company, but this time, he at first recruits 60 workers who already have consulting experience and do not need to be trained. He knows, however, that about six of his workers will retire or quit the company every year, so he makes a decision to also hire six rookies every year. What happens to the number of experienced consultants? Why? Again, in your assignment solutions document, please include the model diagram, documented equations, and a graph of model behavior.
Hint: You may wish to change the time horizon over which you simulate the model.

C. Tom now realizes that instead of having a constant retiring rate of 6 workers, a constant fraction, approximately 10%, of his consultants leave the company every year. Reformulate the retiring rate equation to reflect this situation. How does the model behavior change compared to part B? In your assignment solutions document, please include the model diagram, documented equations, and a graph of model behavior.
Hint: Again, you may want to increase the time horizon of your model.

2. Independent Modeling Exercise

As you may have heard, in September 1998, an MIT freshman died of acute alcohol intoxication. An article in the MIT Observer clarified the science behind the effects of alcohol poisoning. The following paragraphs are excerpts taken from that article.

"Alcohol is a depressant: it slows down the transmission of neural activity, which in turn lowers blood pressure, decreases heart rate, and slows down breathing. In the case

of acute alcohol intoxication, or alcohol poisoning, the imbiber's heart stops and he ceases to breathe. As he suffocates, the bloodstream carries less oxygen to the brain, and brain cells die. According to Professor of Toxicology Peter Dedon, when someone drinks alcohol, it descends into the intestines where it is absorbed into the bloodstream and body water and into the liver. In the liver, alcohol is first metabolized by alcohol dehydrogenase into acetaldehyde and then metabolized into non-toxic acetic acid, commonly known as vinegar. The liver is only able to metabolize approximately 7 grams of alcohol every hour. In the meantime, the alcohol in the bloodstream and body water reacts with receptors in the brain to slow down the transmission of impulses across neurons. [...]

"The delayed transmission of neural activity affects trained behavior and learning. It amplifies emotions, loosens inhibitions, and causes feelings of euphoria. These symptoms are characteristic of the "buzz" commonly experienced after a few drinks, when the blood alcohol content reaches approximately 0.02 grams of alcohol per deciliter of blood. As the level of alcohol in the bloodstream continues to rise, however, the mid-brain also becomes affected. In the mid-brain area, the retarded neural activity brings about a loss of motor coordination and dulls responses to external stimuli. These symptoms translate into a loss of coordination, delayed reflex time, and clouded judgment. The State of Massachusetts defines a person with a blood alcohol content of 0.08 grams per deciliter or more to be "legally drunk." As the blood alcohol content continues to increase, the drinker begins to slur his speech and has difficulty swallowing. The epiglottic closure and the constricting muscles that protect the airway become sluggish. At the same time, the alcohol activates a center in the brain which stimulates vomiting. Alcohol irritating the lining of the stomach will also induce vomiting. A drinker is then at risk to die from aspiration: inhaling his own vomit. If inhaled, the bacteria in the oral cavity may cause an acute infection in the respiratory system, particulate matter may block the victim's airways, and the highly-acidic gastric contents of the stomach may sear the lungs with a chemical burn. Drinkers will typically loose consciousness when their blood alcohol content reaches approximately 0.15 grams per deciliter. At that point, they are particularly at risk of suffering from aspiration. The use of alcohol also becomes deadly when the abated neural activity begins to affect the medulla, the inner core of the brain. There the sedative begins to affect body temperature, blood pressure, heartbeat, and breathing. Alcohol not only slows down the muscles that control breathing, but also inhibits the body's response to the carbon dioxide, so a victim of acute alcohol poisoning will not realize that he is suffocating. Half of the people whose blood alcohol content exceeds the lethal level of 0.40 grams per deciliter will die.

"Medical director and professor of medicine Dr. Arnold Weinberg emphasizes that the effects of alcohol will vary from person to person. The effects of alcohol depend on the concentration of alcohol in the body, so people with large body mass have a higher tolerance because the alcohol they intake dilutes over their entire mass. Alcohol distributes into blood and body water, not into fat. Women typically have a greater fat to non-fat ratio, so the alcohol they intake does not distribute as well, its concentration in their body fluid is higher, and they are more susceptible to the effects of alcohol.

"An empty stomach will increase the effects of intoxication because it will enable the alcohol to rapidly move through the stomach to the small intestines, where it is absorbed

into the bloodstream and body water. Foods high in fat content, like cheese, will retard the absorption of alcohol. Carbonated drinks like beer and champagne, on the other hand, hasten the absorption of alcohol.

"Alcohol and medication are not a good mix. In the liver, alcohol inhibits the P-450 microensemble enzyme system which is in charge of degrading other drugs, like medication.

"The effects of alcohol on the body are also determined by the speed at which a person drinks. The enzymes in the liver can only metabolize, or degrade, on average 7 grams of alcohol every hour. By drinking alcohol over an extended period of time, the body has the time to digest the alcohol, rendering it harmless, instead of allowing it to build up. The chronic consumption of alcohol will, in the long run, increase the body's metabolism. The increased metabolism allows chronic drinkers to build up a tolerance to alcohol."

In this exercise, we will study the effect of alcohol on different people in different situations. We will build a model to contrast the effects over time of:

- social drinking versus binge drinking
- men drinking versus women drinking
- novice drinkers versus seasoned drinkers
- drinking on a full stomach versus drinking on an empty stomach

A. Use the above excerpts to conceptualize and formulate an alcohol consumption model. If you are feeling particularly courageous, try to make the model entirely on your own. If you would like some guidance, please refer to the following hints:

- The two important accumulations in the model are the quantity of alcohol in the stomach and the quantity of alcohol in the blood.
- Alcohol travels from the stomach to the blood when it passes through the small intestines and into the bloodstream. On average, it takes between 10 minutes to half an hour to absorb alcohol into the bloodstream. The more food in the stomach, the longer before the alcohol is absorbed.
- As long as there is alcohol in the blood, the liver metabolizes alcohol at a constant rate.
- Blood is measured in deciliters, alcohol is measured in grams
- When the blood alcohol content rises to approximately 0.15 grams per deciliter, the drinker passes out. Once the drinker becomes unconscious, he stops drinking.
- The average student has about 420 deciliters of body water (blood) in his body.

In your assignment solutions document, please include the model diagram, documented equations, a graph of model behavior, and graphs of table functions.

B. When Andrew has dinner with his family at Le Bouchon, his favorite French bistro, he drinks on average three five-ounce glasses of wine over the course of a five hour evening. Each glass contains approximately 20 grams of alcohol. When Steve drinks with his fraternity buddies, he drinks three 12-ounce cans of cheap beer every hour. Each

can has approximately 20 grams of alcohol. When Ian goes out bar hopping, he drinks five 1.5-ounce shots of hard liquor every hour. Each shot has approximately 20 grams of alcohol.

Simulate the model and compare and contrast what happens to Andrew, Steve, and Ian over the course of 5 hours. Include graphs and analyses of the behavior you observe. Clearly label the values of the parameters that you change for each scenario.
Hint: To formulate the drinking patterns for each person, you may want to use the current value of time in the simulation.

C. Ian takes his girlfriend, Ellen, to a bar. She has very low alcohol tolerance. Ellen's volume of body water is half Ian's volume of body water, so she feels the effects of alcohol twice as strongly as Ian does.

Simulate the model and compare and contrast what happens to Ian and Ellen over the course of 5 hours, assuming that Ellen's drinking pattern is the same as Ian's. Include graphs and analyses of the behavior you observe. Clearly label the values of the parameters that you change for each scenario.

D. Steve's little brother comes to visit Steve in college over spring break. Steve is a seasoned drinker. He metabolizes 12 grams of alcohol every hour. Steve's little brother, however, has hardly ever touched alcohol. He only metabolizes seven grams of alcohol every hour.

Simulate the model and compare and contrast what happens to Steve and his little brother over the course of 5 hours, assuming that Steve's little brother has the same drinking pattern as Steve. Include graphs and analyses of the behavior you observe. Clearly label the values of the parameters that you change for each scenario.

E. What is safer? To drink on a full stomach or an empty stomach? Run four different scenarios, comparing and contrasting what happens to both Andrew and Ian when drinking on both full and empty stomachs. Include graphs for each scenario you run. What conclusions can you draw?