Guided Study Program in System Dynamics

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

Solutions to Assignment #2
Monday, October 5, 1998

Reading Assignment:

Read refer to Road Maps 1: A Guide to Learning System Dynamics (D-4501-4) and read the following papers from Road Maps 1:

- *Simulating Hamlet in the Classroom (D-4540-1)*
- *System Dynamics Meets the Press, an excerpt from The Global Citizen (D-4143-1)*
- *Counterintuitive Behavior of Social Systems (D-4468-1)*

Exercises:

As in Assignment #1, each of the following questions should be answered with one or more short paragraphs. Again, there are no right or wrong answers. We are trying to help you understand the principles covered in the readings by identifying the presence of dynamic systems in your everyday life.

1. Simulating Hamlet in the Classroom

In this paper, Pamela Hopkins selected a series of character relationships and analyzed their feedback behavior. Choose a literary work from the following list and identify a feedback system. Justify your choice and identify positive and negative feedback. If you feel you are not familiar enough with any of these works, feel free to write about one of your choice.

- *Jane Austen: Pride and Prejudice*
- *Jane Austen: Sense and Sensibility*
- *Albert Camus: The Plague*
- *Charles Dickens: Tale of Two Cities*
- *Jack Engelhard: Indecent Proposal*
- *William Golding: Lord of the Flies*
- *Nathaniel Hawthorne: The Scarlet Letter*

- *James Joyce: Dubliners*
- *Ken Kesey: One Flew Over the Cuckoo's Nest*
- *Jerome D. Salinger: Catcher in the Rye*
- *William Shakespeare: Romeo and Juliet*
- *William Shakespeare: Macbeth*
- *Stendhal: The Red and the Black*
- *Lev Tolstoy: War and Peace*
- *Mark Twain: The Adventures of Huckleberry Finn*
- *Alice Walker: The Color Purple*

My choice is *Animal Farm* by George Orwell. I chose this particular literary work because it clearly shows how power can harm others and also illustrates many system notes. On one hand there is animals' wish for better quality of life, and on the other is Napoleon's wish for more power. The main events at the animal farm are:

- takeover of Animal Farm from Jones by animals led by pigs: Napoleon and Snowball
- better quality of life at the Animal Farm at the beginning
- fight for power between Napoleon and Snowball in which Napoleon wins
- Napoleon starts to gain control and more power over animals while quality of life decreases
- Napoleon and other pigs start to behave like humans, and quality of life at the Animal Farm is worse than at the beginning

Positive and negative feedback loops that have shaped the destiny of Animal Farm can be identified. There is a **positive feedback loop of power**. Napoleon gained power over other animals through violence, knowledge, and wealth. At first he chased away Snowball, and secretly raised dangerous dogs. This gave him power through violence, which he used again when he killed alleged traitors (chickens and goats). Very soon sheep, cats, other pigs and dogs started to please Napoleon. Other animals unfortunately did not have very good memory and knowledge, so Napoleon with his toadies could make them believe what ever he said. At the end Napoleon and other pigs started to act completely as Jones used to behave. They lived in a house, walked on two legs and drank beer and whiskey, at the expense of other animals.

On the other hand, there is also a **negative feedback loop of quality of life**, which is represented by Benjamin, the donkey that was skeptical about improvement of life at the beginning and that claimed that life will always be miserable. Quality of life at the Animal Farm at first improved, but as Napoleon gained power over animals their quality of life decreased, and at the end it was worse than at the beginning. Napoleon's main advantage was that he increased his power slowly, step by step. Other animals did not have very good memory, so he could convince them of everything he wanted if he did it after enough time. Because of their bad memory, animals were not able to recognize Napoleon's intentions, and he easily manipulated them. It is possible that animals will start new revolution against Napoleon and other pigs, and their quality of life will again rise. But, probably a new leader will emerge from the new revolution that will start to use power to harm other animals and their quality of life will again decrease.

A model could be used to:
- analyze a variety of possible responses of the other animals to Napoleon's behavior,
- see what would happen if Snowball was a leader instead of Napoleon,
- compare what would happen if Jones was a different person, and
- predict how would animals react if Napoleon was not so patient in increasing his power.

The story also explains in very illustrative manner some of the System Notes from *Systems 1: An Introduction to System Thinking*. For example it shows that:
- good intentions are not enough
- there are no simple solutions-Boxer was a hard working horse with good personality who could help animals to get rid of Napoleon, but his solution to all problems was to work harder and to believe everything that Napoleon said
- every solution creates new problems-instead of being abused by Jones, animals were abused by Napoleon; in addition, they did not have seed, fertilizer…
- competition is often cooperation in disguise-Napoleon was at first sight competing with other farmers (Frederick and Pilkington), but he was actually in cooperation with them
- don't be a boiled frog-Napoleon did not gain power over animals all at once, but he introduced different changes slowly during several years

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Hester Prynne, Roger Chillingworth, Rev. Dimmesdale, and the townspeople comprise a feedback system in *The Scarlet Letter*. Hawthorne uses feedback to develop plot, characters, and themes in this novel. Three themes seem especially obvious:
- The power of hidden guilt to destroy-especially the righteous.
- Public confession can lead to self-acceptance and, thereafter, to healing, personal freedom, and acceptance by the same unaccepting public.
- Seeking revenge may destroy the seeker rather than the object of the revenge.

(Is this story appropriate with today's headlines - OR WHAT!)

These themes are developed through the characters making choices that after a time feed back into the original choice. Rev. Dimmesdale is caught in two positive feedback structures. As his guilt grows so do the illnesses (both mental and physical) that afflict him. As these become worse, his ability to make choices also deteriorates, and Chillingworth's influence over him grows stronger, causing Dimmesdale's health to worsen even more. The second positive feedback structure also builds from his health. As his health deteriorates, his ability to empathize and relate to his parishioners increases. His reputation increases but so does his sense of guilt, which feeds back to his health, causing it to deteriorate even faster.

One negative feedback structure for Hester Prynne builds from her feelings of guilt. As her shame is made public and she withdraws from the town (both emotionally and physically), her sense of self and strength of character grow. This growth allows her to deal with the initial guilt she felt and she was able to put the guilt into an appropriate

perspective, ignore taunts from others, raise her child well and help others. As these happen, the public's perspective of her changes and she, in some fashion, is accepted by the community that rejected her. This, in turn, diminishes Hester's guilt.

Roger Chillingworth, in a series of reinforcing decisions, becomes more and more evil. As his desire for revenge increases, his actions towards and influence over the minister also increase, causing Dimmesdale's guilt to increase. Finally, a balancing feedback that Hester triggers takes over this descent into evil. As her strength of character grows, she confronts Chillingworth and tells Dimmesdale the truth concerning their relationship. Dimmesdale then gains the strength to break the influence Chillingworth has over him, and before his death is able to free himself from guilt.

The central beliefs of the people led to the structures of laws and punishments that provide the framework for the story. In an effort to control behavior, the scaffold and the scarlet letter are used to expose unwanted behavior and to do so through public humiliation. This negative feedback structure says that as unwanted behavior is identified and public humiliation is increased, the amount of unwanted behavior is decreased. This structure is so fundamental to the novel that the scaffold appears at the strategic points in the plot. The scaffold surfaces at the beginning when Hester first receives her punishment (and the story/feedback is set in motion), resurfaces in the middle when the minister's guilt forces him to ascend the scaffold during the night, and is the scene of the final revelation when all three ascend the scaffold together. Each time, the scaffold becomes the focus, all four key characters are present and the influence of each on the other becomes more apparent.

I chose an essay written by George Orwell called *Shooting an Elephant*. This essay is about a British police officer stationed in Burma. He hates his job, thinks imperialism is an evil thing, and is hated by the natives of the village. One day he is informed that a "tame" elephant has temporarily gone mad and is tearing up the village, and they want him to do something about it. He takes his rifle knowing it cannot kill an elephant but thinks he can use it to scare the elephant out of the village. While looking for the elephant, he comes across a villager who has been killed by the elephant and sends someone for a more serious gun that could kill the elephant. The villagers get excited seeing him with this gun and follow to watch him kill the elephant. When he finds the elephant, it has "calmed down" and is eating peacefully in a field outside the village. He then must make the decision to kill the elephant or wait for the owner to return. With the whole village standing behind him, waiting for him to shoot, he kills the elephant "solely to avoid looking like a fool."

I can see several feedback loops in this system. The most apparent is a positive loop made up of the "need to kill the elephant," the excitement of the villagers, and his desire to not look like a fool. As he searched for the elephant, more and more excited villagers followed him to witness the shooting. The more excited they became, the more he felt he had to shoot the elephant. This loop climaxed in the shooting of a quiet, peaceful elephant for the sole purpose of not looking foolish.

A negative loop in this system could be looking at the actions of the elephant in regards to the "need to kill the elephant." When the elephant was ravaging the village,

the "need to kill" increased, but as the elephant "calmed down" this negated the "need" and neutralized the situation.

2. *System Dynamics Meets the Press, an excerpt from The Global Citizen*

In this paper, Donella Meadows listed a number of common assumptions of the current social paradigm. Choose three out of the assumptions listed on pages 4 and 5, and think of an example that demonstrates the assumption. Discuss why the assumption about that example may not hold. Elaborate on the effects of making a false assumption in the particular situation.

All growth is good-and possible. There are no effective limits to growth: The success of every country is nowadays measured by growth of GNP (Gross National Product). It seems obvious that if country produces more goods, invests more, spends more on products and services, and exports more, it is also more successful. On the other hand, GNP stimulates endless production of products that are actually not needed. GNP includes buying of weapons and bombs and destruction of forests. The concept of GNP does not distinguish what is good and what is bad-it just states that more is better.

All growth is good: The tourism industry development in Spain during the 60's and 70's advocated precisely that. The Mediterranean coastline nearly disappeared under the weight of rows of 15-floor buildings right by the beach. Everything was OK if it meant increasing the housing capacity.

The uncontrolled urban growth led to overcrowding and lack of facilities and services and, in general, to a decline of the quality of the tourism attracted and to a crisis of the whole sector.

There is an "away" to throw things to: My reuse company provides me with containers so I can throw things away. Every Wednesday I put my garbage and recycle items on the sidewalk for pickup, and sometime during the day the garbage truck removes my garbage. The garbage is gone.

It is so easy to assume that when the garbage leaves my home it must be gone and is no longer my problem. The saying "out of sight, out of mind" holds true here. The fact is it never is gone and will always be part of a problem that society must deal with in one form or another.

When I was a child, garbage was burned. When we burned the garbage it appeared to be "gone" but actually was just transformed into air pollution. Authorities then took action to reduce pollution. It was decided to separate garbage from items that could be recycled. Items such as cans, bottles, yard waste, plastic, and newspapers could be recycled into other products and the rest added to landfills. Again, nothing is gone. All we have done is move it to another place or transform it into another product.

Results can be measured by effort expended: One of the current worries of the Spanish Education authorities is the fact that most Spaniards finish compulsory school

with a low level in foreign languages. To solve the problem they keep increasing the number of school years in which studying a foreign language is compulsory.

They have now decided that, beginning this school year, the teaching of foreign languages is going to start at pre-school levels (3 years old). The thing is that learning a language does not depend only on the time you spend studying it, there are many other factors to consider. One of the more important factors is the proficiency of the teacher both in terms of language knowledge and in terms of knowing how to facilitate students' learning.

In the Spanish state school system most pre-school teachers have received training in how to teach pre-schoolers but have little to none preparation in foreign languages, especially in oral foreign languages, which is the only thing you can teach a pre-schooler who can't read. This means that what those pre-schoolers are going to get from the 'extra effort' is inaccurate pronunciation learning.

People are disconnected from nature: A false assumption found in the current social paradigm and reinforced in the economics discipline is the notion that "people are disconnected from nature." Economists exclude nature from important roles in most macroeconomic models. This false assumption is pushed to an extreme within economics by assuming that "people are disconnected from each other." This assumption is deeply embedded in the methodology of neoclassical economics with its emphasis on the behavior of self-interested, atomistic economic agents. Indeed the notion of *homo economicus* views rational behavior as that which supports the self-interest of the individual. The consequence of such an approach is the denial of social connectedness as an inherent aspect of human nature. This reductionist thinking is blind to the kind of insights one finds in a systems thinking approach. It is therefore not surprising that economists consistently fall short in their efforts to understand and make appropriate recommendations for real-world social problems.

Individuals cannot make any difference: This statement has been shown to be incorrect many time in history. Several examples: Napoleon, Hitler, Martin Luther King and many others. The fact is, that most significant eras were invoked by the monumental efforts of a single individual. In this day of modern communication the effects of a single individual can be even more pronounced.

The rational powers of human beings are superior to their intuitive powers or their moral powers: This assumption is reflected in the tendency for the public to express great concern over the quality of education in math and the sciences but never to express such concerns about education in humanities and the arts. Comparisons in the press of the performance of American students with that of students from other nations invariably relate to subjects associated with the rational and analytical qualities of mind, and initiatives by state legislatures to improve education frequently result from such comparisons. The study of literature is generally seen as important only insofar as it serves the utilitarian purpose of teaching reading and writing, and the study of the arts is often regarded as little more than recreation. What is ignored is the importance of arts and humanities in developing the synthetic powers of mind that allow children to learn to make sense of their world-to put the pieces together. Children who are trained in

reasoning and analysis exclusively may not develop the ability to think critically, to recognize irony and anomaly, and to deal with complexity and ambiguity.

Failure to nurture the creative (synthetic) powers of mind addressed by the arts and humanities can leave citizens ill-equipped to make the best use of the knowledge they gain from analysis and reason. In the wake of the industrial revolution of the late 18th century, P. B. Shelley, in his "Defense of Poetry" (a term he used in a broad sense to refer to all kinds of creative, synthetic thought), discussed this problem, saying:

> "We have more moral, political, and historical wisdom than we know how to reduce into practice. We have more scientific and economical knowledge than can be accommodated to the just distribution of the produce which it multiplies. The poetry in these systems of thought is concealed by the accumulation of facts and calculating processes. … We want the creative faculty to imagine that which we know; we want the generous impulse to act that which we imagine… Our calculations have outrun conception; we have eaten more than we can digest. The cultivation of those sciences which have enlarged the limits of the empire of man over the external world has, for want of the poetical faculty, proportionally circumscribed those of the internal world, and man, having enslaved the elements, remains himself a slave. To what but a cultivation of the mechanical arts in a degree disproportioned to the presence of the creative faculty, which is the basis of all knowledge, is to be attributed the abuse of all invention for abridging and combining labor to the exasperation of the inequality of Mankind?"

In our own age, dominated as it is by technology, the synthetic, creative, intuitive powers of mind that can help us gain perspective on the meaning of our machinery are even more needed.

3. Counterintuitive Behavior of Social Systems

A. On page 6, Counterintuitive Behavior of Social Systems listed four common programs of improving the depressed nature of the central city: busing the unemployed to the suburbs, implementing a training program, providing financial aid (government subsidies) to depressed cities, and constructing low-cost housing. Only the fourth was discussed in detail. Choose one of the other three and discuss why it may lead to counterintuitive behavior.

Busing the unemployed to the suburbs has the potential to generate counterintuitive results in at least two ways. First, like the construction of low-income housing, a busing program could be expected to attract more individuals to the inner city thereby exacerbating the unemployment problem. This is particularly likely if the people attracted by the program tend to be unskilled laborers. A second counterproductive consequence is the attitudinal backlash commonly associated with affirmative action programs. Programs that create the appearance of "special treatment" for low-income, inner-city residents (often disproportionately minority populations) are likely to generate

greater animosity against those disadvantaged groups the programs are intended to benefit.

Implementing a training program: As with the housing problem, job-training programs may attract more people to the area. Only a small proportion can be trained, and this may not be enough to offset jobs needed by those immigrating to seek training. This immigration can increase competition for available jobs and may increase rather than decrease the unemployment rate.

The training itself does not increase the number of jobs. People who have gone through he training program and still have no jobs will be likely to be more discontented. If the jobs are not identified in advance it is also possible that job training may not be appropriate.

In this type of climate businesses may be forced to fund training or accept improperly trained trainees. This could be an incentive for business to leave the area thus lowering the availability of jobs.

Providing financial aid (government subsidies) to depressed cities may lead to counterintuitive behavior through a number of ways. First, increased financial aid can be viewed as the equivalent of gifts to cities. These gifts then serve as positive reinforcements or rewards for the city officials, whether or not they are doing a good job. Second, dependence on financial aid creates a disincentive for city officials and residents to seek out more sustainable funding sources. Third, depressed cities that possess inadequate resources to maintain a high quality of life for their residents are inappropriately propped up by financial aid. This illusion gives a false impression to potential residents who decide to move to the city, based in part on the intervening effects of the aid. So as a result of the aid, more people move to the city, thus compounding the strain on resources and financial aid.

B. In 1905 the Kaibab plateau was an isolated region in which two populations, deer and wolves, have lived for years. The wolves, the predators, fed on the deer, the prey, which in turn nourished itself by eating the grass that grew on the plateau. In 1905, however, authorities decided that they wanted to increase the deer population by protecting it from the wolves. They offered a bounty for the hide of each wolf any hunter would eliminate.

You have just read a paper on the counterintuitive behavior of systems. Can you think of any side effects that the authorities may have over-looked when planning their bounty policy? Using the logic described in the paper, can you suggest what might actually have happened to the deer population on the Kaibab plateau?

There are a couple of things the authorities overlooked when they established the bounty on wolves on the Kaibab plateau. First, it is fairly well known the wolves and deer need each other to stay healthy. These two populations have been living together for probably thousands of years keeping a balance between deer, wolves, and food available. By eliminating one of the populations, the wolves, the other two would be in jeopardy. With the wolves gone, the deer would flourish for awhile giving the desired goal of

increasing the deer population. Since there is a limit to the available grass on the plateau, the increased deer population would eventually exhaust the source and begin to starve. Without the wolves to weed out the sick and weak, diseases would spread through the deer population reducing the size of the herd to even smaller numbers than before the bounty. I think this can be summed up with a sentence from Counterintuitive Behavior of Social Systems: "A policy that produced improvement in the short run is usually one that degrades a system in the long run."

C. Counterintuitive Behavior of Social Systems *was written in 1971. Industrialization, population growth and technological advancement have progressed at record rates in the two and a half decades that have since passed. What factors might have changed between 1971 and 1998 to compound the behavior described in this paper?*

While many of the trends in the various sectors of global models have done very well in recent decades, the contention that we are on an unsustainable path remains valid. Natural resource constraints appear to be less of a problem than initially anticipated; however, as Forrester predicts in his paper, when the symptoms are addressed in one part of the system the troubles often move elsewhere. In this case we seem to be poisoning the planet faster than depleting it of non-renewable resources. One example of this can be found in the shift in thinking regarding fossil fuel consumption in the U.S. As a consequence of the energy crises of the 1970s, many Americans purchased fuel-efficient cars and reduced interstate speed limits and mandated improved average fuel efficiency levels in new cars. Today, largely as a result of a perception that the fossil fuel problem has "gone away," speed limits are rising across rural parts of the U.S. (75 miles per hour in many western states), and fuel consumption has increased dramatically (one study found a 40% increase in fuel consumption by automobiles, trucks, and buses in the U.S. from 1970 to 1988.) Consumers have also acquired a strong interest in gas-guzzling sport utility vehicles. This growing interest in vehicles classified as "light trucks" has provided a loophole for circumventing efforts to raise average fuel efficiency levels. Increases in consumption patterns put greater pressure on a finite system and result in higher pollution levels. Indeed, Forrester's predictions of overshoot and collapse seem even more applicable today than they did twenty-five years ago.

An increase in the belief in the style of technology, namely, the belief in the single fix to a problem, is rooted in the concept of progress, our ignorance, and the belief that as technology increased in 1998 it was automatically prepared to handle certain social problems with greater and greater effectiveness. This increased faith is due to the fact that we are surrounded by technology, even more than in 1971, and by solutions to our problems that are more technology based. Secondly, the growth of large technological corporations and their business approaches to the solutions of a greater and greater range of problems increases our faith in the use of technology. As Neil Postman writes, we are becoming a technopolis. I am not necessarily convinced as to the total value of this approach. We can see its failure in the well-known problems with which we are all familiar: Asia, Russia, Bosnia, etc.; the list goes on.

Computers and the vastly expanded capacity of communications play a role in greatly increasing the range of influence of corporations and government for various activities and solving all problems. The speed of deployment of technology is much faster now, whether for war, as in Desert Storm, or more "benign" activities such as satellite communications, major dam projects, use of fertilizers for farming, greater public works projects, etc.