Guided Study Program in System Dynamics

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

Assignment #25

Assigned on: Friday, April 30, 1999

Due by: Monday, May 10, 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-S25.doc
(where XYZ are your initials)

Reading Assignment:

Please refer to Road Maps 8: A Guide to Learning System Dynamics (D-4508-1) and read the following paper from Road Maps 8:

- Oscillating Systems II: Sustained Oscillation by Kevin A. Agatstein (D-4602)

[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.

Exercises:

1. Oscillating Systems II: Sustained Oscillation

A. Please read the paper and build the academic performance model and the cleanliness of a dorm room model in Vensim. Simulate the models and explain the behavior that you observe. In your assignment solutions document, please include the model diagram, documented equations, and graphs of model behavior.

B. What is the effect of the following changes on the amplitude, the period, and the mean value of the sustained oscillations? Make each of the following changes individually, and explain the effect of each change on the behavior of the model. Relate your explanations to previous exercises on oscillation.

In the academic performance model:
- Increase the "NORMAL AMOUNT OF STUDYING" from 21 hours to 25 hours.
- Decrease the "NORMAL AMOUNT OF STUDYING" from 21 hours to 15 hours.
- Decrease Nan's "DESIRED GPA" from 3.5 GPA units to 3.0 GPA units.
- Decrease the initial value of "Current Grades" from 3.0 GPA units to 2.5 GPA units.

In the cleanliness of a dorm room model:
- Decrease the "dropping of dirty clothes" from 5 articles/day to 3 articles/day.
- Increase the "LAUNDRY ON FLOOR ACCEPTABLE TO ROOMMATE" from 3 to 5 articles of clothing.

C. The time lag between two oscillations is the time between a peak of one oscillation and the corresponding peak of the other. The phase shift between two oscillations is the time lag divided by the period.

In the academic performance model:
- What is the phase shift between the "change in hours of weekly studying" and the "Hours of Weekly Studying" in the academic performance model?
- What is the phase shift between the "Hours of Weekly Studying" and the "net improvement in grades"?
- What is the phase shift between the "net improvement in grades" and "Current Grades"?
- What is the phase shift between "Current Grades" and "change in hours of weekly studying"?

In the cleanliness of a dorm room model:
- What is the phase shift between "picking up laundry" and "Laundry on Floor" in the cleanliness of a dorm room model?
- What is the phase shift between "change in the daily complaints of my roommate" and "Daily Complaints of My Roommate"

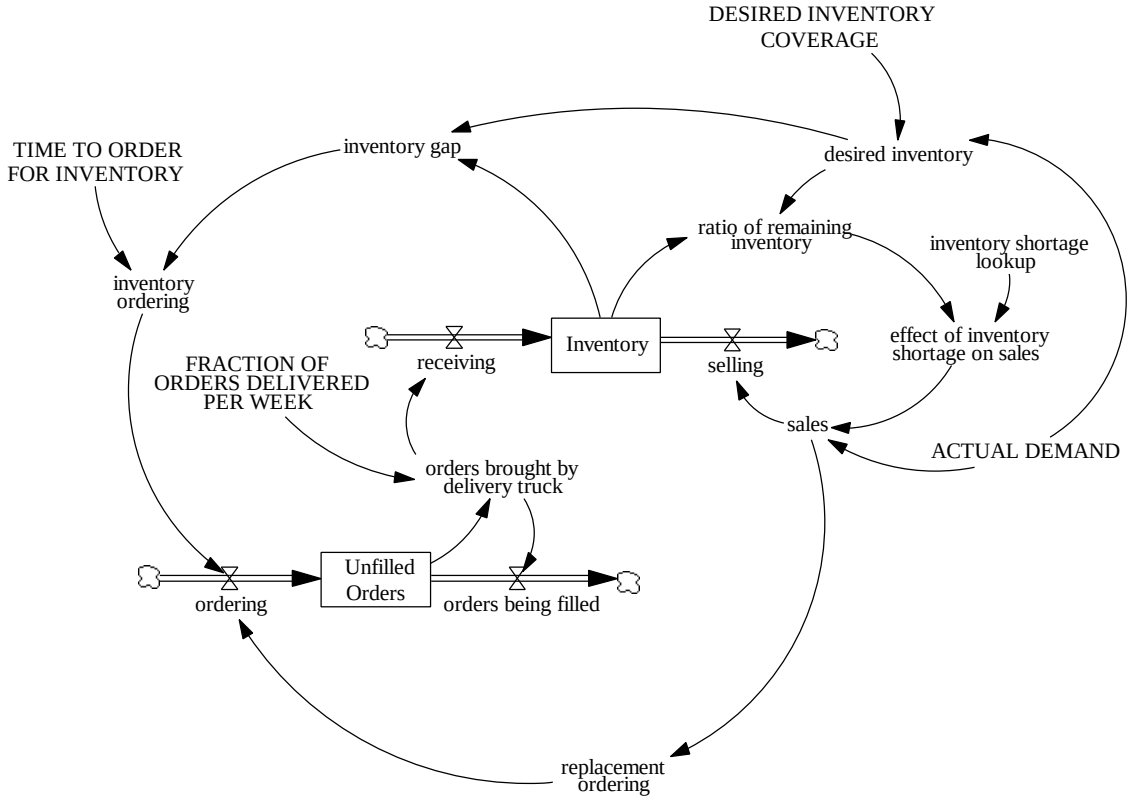
D. What is the sum of the phase shifts encountered by a signal traveling through the negative feedback loop of the academic performance model? What about for the cleanliness of a dorm room model? Can you make any generalizations about the relationship in the phase shift between a stock and its flow?

E. Can you think of another example of a system that exhibits sustained oscillations? What are the stocks in this system? Describe the negative feedback loop driving the oscillation.

2. Modeling Exercise

We are now returning to the Tea Pot, the well-loved Heavenly Seasonings Tea, and the new sensation: Strawberry-Kiwi Delight Tea.

Here is the model from assignment 21 in its final state:



The equations are:

Inventory = INTEG (receiving - selling, 12)
Units: crates
The number of crates of Heavenly Seasonings Tea in Richard's supply room.

receiving = ORDERS BROUGHT BY DELIVERY TRUCK
Units: crates/Week
The number of crates of Heavenly Seasongs tea that Richard receives from his supplier every week.

selling = sales
Units: crates/Week
The number of crates of Heavenly Seasonings tea that The Tea Pot sells to students every week.

sales = ACTUAL DEMAND * effect of inventory shortage on sales
Units: crates/Week
The number of crates of Heavenly Seasonings tea that Richard is able to sell.

ACTUAL DEMAND = 4
Units: crates/Week
The actual number of crates of Heavenly Seasonings tea that students want to buy.

effect of inventory shortage on sales = inventory shortage lookup (ratio of remaining inventory)
Units: dmnl
The effect of inventory shortage on sales is a function of the ratio of remaining inventory.

inventory shortage lookup ([(0,0) - (1,2)], (0,0), (0.05,0.3), (0.1,0.55), (0.15,0.75), (0.2,0.9), (0.25,0.97),(0.3,1),(1,1))
Units: dmnl
The inventory shortage lookup function reflects the fact that as the ratio of remaining inventory decreases, Richard sells less tea.

ratio of remaining inventory = Inventory / desired inventory
Units: dmnl
The ratio of the current inventory to the desired inventory.

desired inventory = ACTUAL DEMAND * DESIRED INVENTORY COVERAGE
Units: crates
The number of crates of Heavenly Seasonings tea that Richard would like to keep in his supply room.

DESIRED INVENTORY COVERAGE = 3
Units: Week
The number of weeks worth of demand for Heavenly Seasonings tea that Richard wants to keep in his supply room.

inventory gap = desired inventory - Inventory
Units: crates

The difference between Richard's desired inventory and the current inventory.

inventory ordering = inventory gap / TIME TO ORDER FOR INVENTORY
Units: crates/Week
The number of crates of Heavenly Seasonings tea that Richard orders every week to correct for an inventory gap.

TIME TO ORDER FOR INVENTORY = 2
Units: Week
The time it takes Richard to order tea to correct for an inventory gap.

Unfilled Orders = INTEG (ordering - orders being filled, 16)
Units: crates
The number of orders that Richard has placed with his supplier but has not yet received.

ordering = replacement ordering + inventory ordering
Units: crates/Week
The number of crates of Heavenly Seasonings tea that Richard orders from his supplier every week.

replacement ordering = sales
Units: crates/Week
The number of crates of Heavenly Seasonings tea that Richard has to order from his supplier every week to replace those that are sold to customers.

orders being filled = ORDERS BROUGHT BY DELIVERY TRUCK
Units: crates/Week
The number of orders that Richard has placed that are filled every week.

orders brought by delivery truck = Unfilled Orders * FRACTION OF ORDERS DELIVERED PER WEEK
Units: crates/Week
The number of crates of Heavenly Seasonings tea that Richard's supplier delivers to The Tea Pot every week.

FRACTION OF ORDERS DELIVERED PER WEEK = 0.25
Units: 1/Week
The fraction of unfilled orders that The Tea Pot receives every week.

Build the model as shown above and study any possible difference between this model and the model you built in assignment 21.

Step 1: Expected Demand

Right now, both unfilled orders and inventory undergo damped oscillations whenever actual demand changes slightly. The system oscillates because when Richard places his orders, he does not take into account the number of orders that he has placed but not yet received (the stock of "Unfilled Orders"). In effect, Richard is ignoring the long delay in the system between the time he places an order and the time he receives it. The long delay is due to the time for his supplier to receive his order and pass the order on to the manufacturer, the time for the manufacturer to change the production of tea, the time for the manufacturer to deliver the tea to Richard's supplier and the time for Richard's supplier to bring him the crates of tea. The number of orders that Richard has placed but not yet received is the amount of tea that is in the pipeline.

To compensate for the delay, Richard needs to plan ahead. He needs to try to predict his future demand so that he can place orders now for the sales four weeks from now, when the tea that he orders today arrives. How does Richard try to predict his future sales? Actual demand may fluctuate from day to day, but expected demand should not. Richard projects expected demand by smoothing actual demand over a period of four weeks. Then, instead of basing the desired level of inventory on the actual current demand, Richard determines his desired inventory based on the demand he expects.

A. Create a stock representing "Expected Demand." Formulate an equation for the change in expected demand. Do NOT use the SMOOTH function provided by Vensim. In your assignment solutions document, include the new model diagram and documented equations that you added or modified as a result of this revised formulation.

B. Consider the Strawberry Kiwi Delight scenario, in which actual demand is constant at 4.5 crates a week. Draw reference modes for the behavior of all stocks. Simulate the model under this scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Did you observe the behavior that you predicted? Why or why not?

C. Imagine a scenario in which the college students suddenly become antsy. They experiment with many different things, including a wide variety of herbal teas. Actual demand is four crates a week for ten weeks, then four and a half crates a week for ten weeks, then three crates for ten weeks, then two and a half crates for ten weeks, then four crates again for ten weeks. What is Richard's expected demand as actual demand fluctuates? Draw a reference mode and then simulate the model. In your assignment solutions document, include behavior graphs for all stocks. Did you observe the behavior that you predicted? Why or why not?

Step 2: Pipeline Ordering

Richard only receives orders four weeks after he places them (each week, he receives 25% of the orders he places). In order to be ready to sell tea four weeks from now,

Richard needs to have enough tea in the pipeline to cover his "Expected Demand" for the next four weeks.

A. Formulate an equation for the number of required orders in the pipeline. Convert the "FRACTION OF ORDERS DELIVERED PER WEEK" to "TIME TO RECEIVE ORDERS" and then use the parameter in two different places in the model. You may need to modify existing equations. Be sure to check for units errors before running the model. In your assignment solutions document, include the new model diagram and documented equations that you added or modified.

Richard now orders not only to replace the tea that he sells and maintain his desired inventory, but also to fill the pipeline with orders that he expects to need in the future. It takes him the same length of time to order for inventory as to order for pipeline correction. The pipeline gap is the difference between the current number of orders in the pipeline and the number of orders that need to be in the pipeline if Richard wants to be able to provide for his expected demand.

B. Add pipeline ordering to the model. In your assignment solutions document, include the new model diagram and documented equations that you added or modified.

C. Consider the base scenario, in which actual demand is constant at 4 crates a week. Draw reference modes for the behavior of all stocks. Simulate the model under the base scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Did you observe the behavior that you predicted? Why or why not?

D. Consider the Strawberry Kiwi Delight scenario, in which actual demand is constant at 4.5 crates a week. Draw reference modes for the behavior of all stocks. Simulate the model under this scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Did you observe the behavior that you predicted? Why or why not?

E. Consider the base scenario for the first ten weeks and then introduce the Strawberry Kiwi Delight flavor on the 10th week. Draw reference modes for the behavior of all stocks. Simulate the model under this scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Did you observe the behavior that you predicted? Why or why not?

F. Consider the scenario of the antsy college students. Actual demand is four crates a week for ten weeks, then four and a half crates a week for ten weeks, then three crates for ten weeks, then two and a half crates for ten weeks, then four crates again for ten weeks. Draw reference modes for the behavior of all stocks. Simulate the model under the base scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Did you observe the behavior that you predicted? Why or why not?

Step 3: Pipeline Recognition

Richard keeps good records of the orders he makes, and thus knows exactly how many orders are in the pipeline. Jim, who owns a competing tea shop, The Other Tea Pot, is not so organized. Thus, he tends to underestimate the number of orders in the pipeline. Jim's estimation error can be modeled using a pipeline recognition factor, which is a fraction between 0 and 1. For instance, if Jim thinks there are orders for 50 tea in the pipeline when in reality, 100 orders of tea are in the pipeline, his pipeline recognition factor would be 0.5.

A. Add the "PIPELINE RECOGNITION FACTOR" to the model, and reformulate the equation for pipeline gap to account for the "PIPELINE RECOGNITION FACTOR." In your assignment solutions document, include the new model diagram and documented equations that you added or modified.

B. Consider the Strawberry Kiwi Delight scenario. Set the "PIPELINE RECOGNITION FACTOR" to 0, and simulate the model under this scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Explain the behavior you observe. Which earlier-discussed scenario does this scenario mimic? What does a "PIPELINE RECOGNITION FACTOR" of 0 mean?

C. Again, consider the Strawberry Kiwi Delight scenario. Set the "PIPELINE RECOGNITION FACTOR" to 1, and simulate the model under this scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Explain the behavior you observe. Which earlier-discussed scenario does this scenario mimic? What does a "PIPELINE RECOGNITION FACTOR" of 1 mean?

D. Again, consider the Strawberry Kiwi Delight scenario. Set the "PIPELINE RECOGNITION FACTOR" to 0.75, and simulate the model under this scenario over a period of 50 weeks. In your assignment solutions document, include behavior graphs for all stocks. Explain the behavior you observe.