princ_systems

Systems Theory Principles

- stocks and flows
- now imagine those lines on a graph over time
- how do we describe those lines over time?
- then get into the math that describes those lines
  - but first, feedback. super prevalent in systems and complexity literature.

Stocks and Flows

Many organizational phenomena can be viewed as combinations of stocks and flows. Meadows [@meadows2009] provides a great explanation that we will repeat here:

> A stock is a store, a quantity, an accumulation of material or information that has built up over time. It may be the water in a bathtub, a population, the books in a bookstore, the wood in a tree, the money in a bank, your own self confidence. A stock does not have to be physical. Your reserve of good will toward others or your supply of hope that the world can be better are both stocks.
>
> Stocks change over time through the actions of flows. Flows are filling and draining, births and deaths, purchases and sales, growth and decay, deposits and withdrawals, successes and failures. A stock, then, is the present memory of the history of changing flows within the system (18).

Systems Theory Terms

Stocks and Flows

A stock is a store, a quantity, an accumulation of material or information that has built up over time. It may be the water in a bathtub, a population, the books in a bookstore, the wood in a tree, the money in a bank, your own self confidence. A stock does not have to be physical. Your reserve of good will toward others or your supply of hope that the world can be better are both stocks (meadows 18).

Stocks change over time through the actions of flows. Flows are filling and draining, births and deaths, purchases and sales, growth and decay, deposits and withdrawals, successes and failures. A stock, then, is the present memory of the history of changing flows within the system (meadows 18).

- As long as the sum of all inflows exceeds the sum of all outflows, the level of the stock will rise.
- As long as the sum of all outflows exceeds the sum of all inflows, the level of the stock will fall.
- If the sum of all outflows equals the sum of all inflows, the stock level will not change; it will be held in dynamic equilibrium at whatever level it happened to be when teh two sets of flows became equal (22).

A stock can be increased by decreasing its outflow rate as well as by increasing its inflow rate (22). Stocks generally change slowly, even when the flows into or out of them change suddenly. Therefore, stocks act as delays or buffers or shock absorbers in systems (23).

all 23 People often underestimate the inherent momentum of a stock. It takes a long time for populations to grow or stop growing, for wood to accumulate in a forest, for a reservoir to fill up, for a mine to be depleted. An economy cannot build up a large stock of functioning factories and highways and electric plants overnight, even if a lot of money is available. Once an economy has a lot of oil-burning furnaces and automobile engines, it cannot change quickly to furnaces and engines that burn on a different fuel, even if the price of oil suddenly changes. It has taken decades to accumulate the stratospheric pollutants that destroy the earth's ozone layer; it will take decades for those pollutants to be removed. Changes in stocks set the pace of the dynamics of the systems. Industrialization cannot proceed faster than the rate at which factories and machines can be constructed and the rate at which human beings can be educated to run and maintain them. Forests can't grow overnight. Once contaminates have accumulated in groundwater, they can be washed away only at the rate of groundwater turnover, which may take decades or even centuries. The time lags that come from slowly changing stocks can cause problems in systems, but they also can be sources of stability. Soil that has accumulated over centuries rarely erodes all at once. A population that has learned many skills doesn't forget them immediately. You can pump groundwater faster than the rate it recharges for a long time before the aquifier is drawn down far enough to be damaged. The time lags imposed by stocks allow room to maneuver, to experiment, and to revise policies that aren't working.

Stocks allow the inflows and outflows to be decoupled and to be independent and temporarily out of balance with each other (24).

Feedback Loops

meadows Balancing feedback loops are equilibrating or goal-seeking structures in systems and are both sources of stability and sources of resistance to change (30). Reinforcing feedback loops are self-enhancing, leading to exponential growth or to runaway collapses over time. They are found whenever a stock has the capacity to reinforce or reproduce itself (32).

Feedback loops are one or more links that eventually relate a variable to itself at a later point in time (Monge). Monge presents three common types of feedback loops. A self-loop is where a variable influences itself. A mutual causal loop represents the (nearly) simultaneous influence of two variables on each other. Finally, a standard loop represents the effects a variable has on itself through its influence on a chain of other variables.

Stability analysis is an important aspect of dynamic systems. Maruyama (1968) introduced to the social sciences the notions of deviation amplification and deviation counteraction to represent the influence that a feedback loop has on the initial variable. Deviation counteraction is a negative feedback loop where a magnitude of change in one direction in the initial variable leads in time through the feedback loop to an eventual change in the initial variable in the opposite direction. Thus, an increase in the magnitude of X will lead eventually to a decrease in X through the subsequent influence of the other variables in the loop. Since X has changed a second time, it causes the process to repeat. However, since X decreased this time but the loop is still negative, this decrease in X leads eventually to an increase in X. This is oscillatory behavior.

Deviation amplification represents a positive loop in which an initial change in a variable leads eventually to further changes in the variable in the same direction. Thus, an increase in the initial variable leads eventually to a further increase in the variable. Likewise, an initial decrease leads to a further decrease. It is of course important to find out where the system reaches stability. Blalock (1969) notes that stability is determined by the sign and magnitude of the product of the coefficients along the loop. Two general rules specify the type and stability of feedback. First, if the product of the coefficients is above zero, the feedback is positive; if below zero, the feedback is negative. Second, if the absolute value of the product is below one, the feedback is stable; if above one, the feedback is unstable (421).

Equilibrium

Continuity (Monge)

Does the variable have a consistent nonzero value through time? Zero represents the nonexistence of the variable. A continuous time variable, such as organizational climate, is typically viewed as one that always exists at some value (Joyce and Slocum, 1984). A discontinous-time variable, such as the payment of the monthly bonus in the Scanlon managagement process, is one that occurs, then does not have a value until it occurs again at the next month (Monge & Cozzens, 1987).

Magnitude (Monge)

The amount of the variable at each time point. Can be negative if the scale allows for it. Magnitude is eight units.

Rate of Change (Monge)

How fast the magnitude increases or decreases per one unit of time.

Trend (Monge)

The long term increase or decrease in the magnitude of a variable. Can be a positive or negative value. There is an upward trend of two units each time the variable occurs.

Periodicity (Monge) Cycles and Oscillations

The amount of time that transpires between the regular repeating of the values of the variable, controlling for trend. These are essentially cycles. Something happens every six time points.

Duration (Monge)

The length of time that a variable exists at some nonzero value (primarily for discontinuous time variables). How long a variable "lasts for." Duration of two time units.

Summary

In discontinous systems, rates of change are instant (think of a bar plot... the left line is an instant spike up to a value of 8). In continuous systems, rates of change would be "two units per time period." He also gets into a typology of causes and effects for a two state system: history, lag, rate of change, magnitude of change, and permanence of change (duration). These essentially overlap with what was discussed above, the difference is that you focus on them as a function of something else. X has a two unit change in magnitude that lasts for three time units (duration), and four time units later (lag) Y has a two unit change in magnitude that lasts for ten time units (duration).