Business Dynamics summary

1 Learning in and about complex systems

Complex dynamics systems

1. Tools to elicit and represent the mental models we should about the nature of difficult problems
2. Formal models and simulation methods to test and improve our mental models, design new policies, and practice new skills
3. Methods to sharpen scientific reasoning skills, improve group processes and overcome defensive routines for individuals/teams

Policy resistance arises because we often do not understand the full range of feedbacks operating in the system. Side effects are a sign that our understanding of the system is narrow and flawed.

Decisions alter the environment, leading to new decisions, but also triggering side effects, delayed reactions, changes in goals and interventions by others. These feedbacks may lead to unanticipated results and ineffective policies.

Positive feedback: positive loops are self-reinforcing, if one gets bigger other gets bigger (R).

Negative feedback: negative loops are self-correcting. They counteract change. B for denoting a balancing feedback.

3 The Modelling Process

Exogenous variables are independent → arising from without (outside the boundary of the model), exogenous explanations are no explanations. Number of exogenous should be small.

Endogenous variables are dependent → arising from within

Endogenous focus: formulate a dynamic hypothesis that explains the dynamics as endogenous consequences of the feedback structure.

Dynamics hypothesis: working theory of how the problem arose, it guides modelling efforts by focusing on certain structures.

4 Structure and Behavior of Dynamic Systems

Exponential growth: from positive (self-reinforcing) feedback.

Goal seeking: negative loops seek equilibrium, negative feedback loops act to bring the state of the system in line with a goal.

Oscillation: by negative feedback loops with corrective actions. The state of the system constantly overshoots its goal state, reverses, then undershoots, and so on. Damped is also option.
Can occur if there are delays in at least one of the links in a negative loop

S-shaped growth: first exponential, then gradually slows to an equilibrium.
Carrying capacity: number of organisms it can support and is determined by the resources available in the environment and the resource requirements. If this is approached the net increase rate must decline.
1. Negative loops must not include any significant time delays.

2. Carrying capacity must be fixed.
→ interaction of the positive and negative loops must be nonlinear.

S-shaped growth with overshoot: if there are time delays in the negative loops → osciallte around the carrying capacity

Overshoot and collapse: no fixed carrying capacity

5 Causal Loop Diagrams

Loop positive or negative? → if negative links even loop is positive
if negative links is odd loop is negative

6 Stocks and Flows

Stocks are accumulations, they characterize the state of the system and generate the info upon which actions are based.
Stocks accumulate (integrate) their inflows less their outflows. The rate of change of a stock is the total inflow less the total outflow. Stock/flow map corresponds to a system of integral/differential equations.

Measurable quantities at a given time are stocks, flows are not measurable at a given time. Stock in units, flows units per time period.

7 Dynamics of Stocks and Flows

Net rate of change of a stock is the sum of all its inflows less the sum of all its outflows. Stocks accumulate the net rate of change. Stocks integrate their net flows, the net flow is the derivative of the stock.

A stock is in equilibrium when it is unchanging. The net rate must be 0. Dynamic equilibrium: still changing, but same in and outflow. Static equilibrium: all flows of a stock are 0.

Differentiation: the calculation of the net rate of change of a stock from its trajectory.

Process of accumulation is the same as integration. The amount added to a stock in any period is equal to the area swept out by the net rate of change in the stock over that period.

8 Closing the Loop: Dynamics of Simple Structures

First order system: one stock.
Linear first-order systems can generate exponential growth and goal-seeking behavior.

Nonlinearity in first-order systems causes shifts in the dominant loops → s-shaped e.g.

Phase plot: a graph showing how the net rate of change of a stock is related to the stock itself.

Linear systems: rate equations are linear combi's of the state variables and any exogenous inputs.

Quantity increases by the same absolute amount per time period, while exponential growth doubles the quantity in a fixed period of time.

The rule of 70 is used to determine the number of years it takes for a variable to double by dividing the number 70 by the variable's growth rate.

First-order linear positive feedback systems generate exponential growth. First-order negative feedback systems generate goal-seeking behavior.

In real systems there must be shifts in feedback loop dominance and therefore there must be important nonlinearities in all real systems.

Linear analysis remains an important tool. Often a system is close to linear in a certain neighborhood and can be usefully analysed by linearization, that is by approximating the nonlinear rate equations at a particular operating point with the best linear approximation.

Positive feedback dominates whenever the rate of change of the state variable is increasing in the state variable that is as long as the slope of the net rate of change as a function of the state variable is positive. Negative feedback dominates whenever the net rate of change is decreasing in the state variable that is as long as the slope of the net rate is negative.

Nonlinear first-order systems can never oscillate no matter the form of the nonlinearity.

First-order linear negative feedback systems generate exponential decay to a goal. The decay is characterized by the half-life, the time required for the gap between the state of the system and the goal to be cut in half.

9 S-Shaped Growth: Epidemics, Innovation Diffusion, and the Growth of New Products

S-shaped growth arises through nonlinear interaction of positive and negative feedback loops.

13 Modelling Decision Making

Fractional increase rate
R=gS
g increase rate

Fractional decrease rate
R= dS = S/L
d decrease rate
L average life time for the stock

Adjustment to a goal → negative feedback
R=(S*-S)/AT
S* desired state
S actual state
AT adjustment time, average time to close the gap

14 Formulating Nonlinear Relationships

Table functions
Effect X on Y = Table for Effect of X on Y (X)

16 Tools for Modelling Dynamic Systems

TREND function