A System Dynamics Glossary

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accumulation (integration): the collection of some quantity over time. Examples of accumulation include water in a bathtub, savings in a bank account, inventory. An accumulator is also referred to as a stock or level.

aggregation: the grouping of numerous distinct system components into one variable. Aggregation is done for simplicity when the grouping generates the same behavior of interest as representing the components separately.

aging chain – a sequence of stocks connected by conserved flows in which the stocks depict the contents of the chain in different conditions or locations and the contents move in one direction along the aging chain.

amplification – an increase in the magnitude of variances from an average value, typically as in oscillations. Also a system response that is greater than is seemingly implied by input causes. Amplification occurs in information-feedback systems when policies adjust levels to values that change with varying flow rates. It is associated with delays, order/inventory processes and forecasting.

archetype: see system archetype

asymptotic growth/decay: goal-seeking behavior produced by negative feedback. The stock of the system moves towards the goal, slowing down as it approaches the goal. (Roadmaps Glossary, n.d.)

auxiliary variable (converter) – a variable that is not a flow and is capable of changing its value instantaneously.

balancing feedback loop – a feedback loop in which the resultant effect of the causal links over time tends to limit or constrain the movement of variables. Balancing loops seek equilibrium, trying to bring stocks to a desired state and keep them there. Also called a negative, compensating, goal-seeking or controlling feedback loop.

behavior mode – a shape, a dynamic pattern of the values of a system component over time

behavior over time graph: A system dynamics tool that shows how certain variables change over time. Several variables can appear on the same graph for comparison. Time is shown along the horizontal axis and the sizes of the variables are shown in the vertical dimension.

boom and bust cycle: See overshoot and collapse

boundary (system boundary): a border enclosing the parts of system structure needed to generate the behavior of interest. The system boundary excludes all components not relevant to the problem behavior of concern.

bounded rationality - the theory that human decision making is rational only insofar as the rational solution does not require calculations or mental efforts that exceed cognitive limitations. Bounded rationality is a characteristic of human decision-making that often impacts system performance.

calibration – the process of setting model parameter values to reflect an actual case or hypothetical conditions of interest

causal – a driving or influencing relationship between two variables, in contrast to pure correlations, when things happen close in space or time but one does not drive or influence the other one

causal link – an arrow in a causal loop diagram or system structure diagram that describes a relationship between two variables with the direction of causality and the direction of impact (same direction or opposite directions). Delays in the influence of the driving variable on the driven variable can also be shown on the causal link.

causal loop diagram: a conceptual system dynamics tool which represents a closed loop of cause-effect linkages (causal links) as a diagram which is intended to capture how the variables interrelate. Causal loop diagrams identify and label feedback loops to facilitate dynamic reasoning and formal modeling.

causal link polarity: Typically a positive (+) or negative (-) sign that indicates the direction of impact of the driving variable on the driven variable. Positive polarity indicates that the impacted variable moves in the same direction (increase or decrease) as the driving variable. Negative polarity indicates that the impacted variable moves in the opposite direction (increase or decrease) as the driving variable. Positive link polarity is some times indicated with the letter "S" (variables move in the *same* direction) and negative link polarity indicated with the letter "O" (variables move in *opposite* directions).

closed system: a system that functions without the influences of exogenous variables. The system internally generates the values of all the variables through time, completely by their interactions.

cloud: An infinite source or sink in a system dynamics model. An origin or ending place of a flow that is outside the boundary of the system. A cloud represents an unrepresented input or output stock of the system that is inconsequential to its behavior of interest.

co-flow – a stock and flow structure that mimics a primary stock and flow structure in which the co-flow structure models an attribute or characteristic of the contents of the primary structure

compensating feedback – a negative feedback structure that typically undercuts the intended effects of a policy . Also see policy resistance.

computation interval – see solution interval

connector: the links in a model that carry information from one element to another element. That information may take the form of a constant, an algebraic relationship, or a graphical

relationship. Information flows through connectors to auxiliary variables or flows (rates), but not to stocks.

conserved materials – contents of a model that are not, or are assumed to not, be created or destroyed within the model boundary

computation interval: See solution interval

conserved flow : a flow that moves a quantity of material between two or more distinct stocks so that the total amount of material in the related part of the system is unchanged. The total amount of material is divided among the stocks. In contrast, non-conserved flows flow from or to a cloud that has no limit in the quantity it can supply or absorb.

controlling feedback loop – See balancing feedback loop

conveyor: a type of stock that represents a space into which material flows and stays for a fixed amount of time, then exits. Its associated parameters determine transit time which represents how long material stays in the conveyor. Material that flows in at a given time is not mixed with material that had flowed in earlier — whatever entered first will also leave first.

counterintuitive behavior: a surprising result of policies devised to remedy a problem when a presumed solutions results in counter-productivity. Thus, as troubles increase, typically well-intentioned but flawed efforts are intensified, which reduce improvement or worsen the problem instead of improving conditions. Also see policy resistance.

cyclical behavior: See oscillation

dampening – a decrease in the magnitude of variances from an average value, typically in oscillations. Also a system response that is less than is seemingly implied by input causes.

decision function: a policy statement that determines how information is used to generate actions for managing the system. Also the algorithm used to transform incoming information into a stream of decisions over time.

delay: a phenomenon in which the effect of one variable on another does not occur immediately. A process by which the output lags behind its input in time.

delta time – see solution interval

dimensional analysis: A process that checks for unit consistency in equations.

disaggregation: the opposite of aggregation. Disaggregation is done to separate variables into components that do not have similar effects on system behavior. (Roadmaps Glossary, n.d.)

doubling time: the length of time it takes an exponentially growing quantity to double in size. Associated with exponential growth.

dynamic – changing over time

endogenous variable/view: internal, the opposite of exogenous. An endogenous view approaches a problem searching for its causes and cures within the system boundary. Endogenous variables affect and are affected by other system variables.

equilibrium: conditions in a dynamic system where the inflows and outflows of each stock balance each other, and the sizes of the levels cease to change.

equilibrium behavior – a behavior mode in which all stocks are at their equilibrium. Static equilibrium behavior occurs if flows are zero (so the contents of stocks do not change) over time. Dynamic equilibrium behavior occurs if flows are non-zero but they balance (so the contents of stocks change, but their levels stay constant) over time.

equilibrium conditions – a system structure and set of conditions (parameter values) that generates equilibrium behavior

exogenous variable/view: External, the opposite of endogenous. An exogenous view assumes that a system's behavior is dominated by the influence of outside events that are not part of the internal dynamics of the system. An exogenous variable is an outside (input) variable that affects but is not affected by the system.

exponential behavior – a behavior mode generated by a relationship in which the change in a variable (usually a stock) is proportional to the size of the variable itself

exponential decay – behavior that occurs when the rate of increase or decrease in a variable (usually a stock) is proportional to the size of the stock at that point in time, so as to slow down its rate of change. As the stock gets larger (smaller), its increase (decrease) occurs progressively slower. The speed of increase or decrease can be described with a half-life. Associated with negative feedback and tends to generate goal-seeking behavior.

exponential growth (or collapse): behavior that occurs when the rate of increase or decrease in a variable (usually a stock) is proportional to the size of the stock at that point in time, so as to accelerate its change. As the stock gets larger (smaller), its increase (decrease) occurs progressively faster. The speed of increase or decrease can be described with a doubling time. Associated with positive feedback.

feedback – when the effect of a causal impact comes back to influence the original cause of that effect. A feedback loop is an alternating sequence of variables and causal links that creates a closed ring of causal influences.

feedback loop polarity: a positive (+) or negative (-) sign that indicates whether a loop is a reinforcing (positive) feedback loop or a balancing (negative) feedback loop. Loop polarity is found by the algebraic product of all signs around a loop.

feedback system: a closed system consisting of feedback loop structures, closed paths of cause and effect. They can be a positive feedback system, a negative feedback system or most typically a combination of both.

first-order system: see order

flow (rate) – the movement of people or things between stocks within a system boundary or across the model boundary and thereby into or out of the system (through sinks and sources); changes in stocks over time. Flows represent activity, in contrast to stocks that represent the state of the system.

formalization – the creation of a model from a conceptual model which can be mathematically analyzed, solved or simulated

frequency of oscillation: a descriptive measure of oscillatory behavior. The number of cycles a system generates in a time unit. The inverse of the period of oscillation

generic structure: A structure that can be applied across different settings due to having the same fundamental underlying structures and relationships.

goal-seeking behavior – a behavior mode in which the system moves toward an equilibrium or target condition. The flow of the stock is typically modeled as a fraction of the difference between the equilibrium condition (or target) and the current condition. Therefore, farther the system is from the goal, the more it changes towards that goal and as it approaches the goal the increase or decrease slows down. Associated with negative feedback. See exponential behavior.

graphical differentiation – the process of using graphs to determine and describe the net flows which impact a stock, based on the given changes in the stock over time; the compliment of graphical integration

graphical function: A graph that relates movement in one variable to movement in another. The input and output variables are placed on the axes of a graph, and the relation plotted. Often used to describe non-linear relationships.

graphical integration – the process of using graphs to determine and describe how a stock changes over time, based on the given dynamics of its flows

growth with overshoot – a behavior mode in which a system increases beyond its target or equilibrium condition and then decreases.

group model building – a methodology for building system dynamics computer models in which a group or team of people participate actively and simultaneously in building the model

half-life: the amount of time it takes for a stock to move halfway towards its goal. Associated with goal-seeking behavior. The half-life is the converse of doubling time in positive feedback.

high-leverage point – parts of a system where small changes can have very large impacts on system behavior and are therefore effective for focusing system design, management attention, and resources

homeostasis: the tendency of organisms to preserve their equilibrium conditions. Control through the operation of negative feedback loops — homeostasis is reached when the goal is attained and stable equilibrium achieved.

impulse: theoretically, a signal of zero duration but finite hight and area. Practically, in simulation models, a signal (flow) of specified area lasting for one solution interval and occurring at a specified time.

information delay – a delay that represents the gradual adjustment of perceptions or beliefs, or a gradually delayed impact of some variable on a flow or auxiliary variable.

integration: see accumulation

level – see stock–

limits to growth: a resource constraint, an external or internal limiting response to growth. An initial growth begins to slow and eventually come to a halt at the limit, and may even reverse itself and collapse. For instance, population growth is limited by space, water and resources essential for survival.

linear system: a system in which all relations between variables are mathematically linear. In such systems, the complete behavior can be found by superimposing different behavior modes without interacting with one another.

link polarity: see causal link polarity

Little's Law – the relationship among the size of a stock, the net flow into or out of the stock, and the average time material stays in the stock when the system is in equilibrium, if the contents of the stock are perfectly mixed. The size of the stock is the product of the net flow and the delay.

look-up function: see table function

loop dominance: a characteristic of feedback loops in which a loop is strong enough to determine the behavior mode of a part of the system. In a system with multiple loops, mathematical relations, magnitudes and algebraic signs of variables determine what kind of behavior is dominant at any given time. If the system exhibits exponential growth, then one or more positive loops most likely dominate. If the system exhibits goal seeking or asymptotic behavior one or more negative loops probably dominate.

loop polarity: see feedback loop polarity

material delay – a delay that captures the time delay in the flow of conserved material through a process. Also see conveyor.

mental model – a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing, or projected) whose structure is analogous to the perceived structure of that system. Mental models represent the relationships and assumptions about a system held in a person's mind. Mental models

are often quite valid in system structure, but frequently draw wrong conclusions about system behavior.

model boundary: see boundary

negative feedback: feedback that works to cancel deviations from a goal. In isolation or if dominant negative feedback generates goal-seeking behavior.

nonlinear relationship – a causal relationship between two variables in which the change in the impacted variable is not proportional to the change in the impacting variable. Nonlinearity implies threshold and saturation effects.

open-loop thinking: approaching a problem with an exogenous perspective, without applying the concept of feedback

order – the minimum number of state variables required to fully describe a system as modeled

oscillation: behavior exhibited by a second-order or higher-order system in which the stock value moves sinusoidally over time. Three types of oscillation include sustained, where the amplitude is always constant; expanding, where the amplitude increases over time; and dampened, where the amplitude decreases over time.

overshoot and collapse – a behavior mode in which a system increases beyond the equilibrium condition, often destroying its ability to sustain itself, and then collapses toward much below the equilibrium conditions

parameters: factors that describe relationships in a system and are considered constant, at least during the computation span of one model run.

path-dependence – a pattern of behavior in which small, events early in the history of a system determine the ultimate end state, even when all end states are equally likely at the beginning

period of oscillation: the time duration of each cycle in oscillatory behavior from the analogous part of one wave to another. The inverse of the frequency of oscillation

phase plot – a plot of the behavior of one endogenous system variable in relation to another endogenous system variable

pipeline delay – see conveyor

polarity: see causal link polarity or feedback loop polarity

policy analysis: analysis employed to evaluate policies to alleviate undesirable behaviors of a system. It allows the model-builder to compare how a system would react to different policies through simulation.

policy resistance – where policies are delayed, diluted, or defeated by the unforeseen reactions of various factors and feedbacks in the system

positive feedback: a reinforcing loop which produces exponential growth or collapse. Change in one direction results in more and more change in the same direction.

positive feedback loop – see reinforcing feedback loop

ramp function: a common input variable that changes linearly over time.

rate – see flow

reinforcing feedback loop – a feedback loop in which the sum effect of the causal links over time tends to strengthen (reinforce) the movement of variable values in a single direction due to positive feedback.

sensitivity analysis: analysis used to determine how responsive the model outputs are to changes in specific parameters, or policies, or structures. If the behavior of a model changes drastically, that suggests a critically important factor, or high sensitivity. Conversely, if a large change results in little change in behavior, that factor is not likely to be central to the dynamics in question, that is, it shows low sensitivity.

simulation – the generation of the behavior of a system with a model of the system structure, either using a mental model or a formal computer model.

smoothing: filtering out short-term noise-like fluctuations in a time series to detect underlying, significant patterns.

solution interval (computation interval, delta time, time step): The amount of time between successive computer calculations in a formal model

S-shaped growth: growth that exhibits behavior like the shape of the letter "S." It grows exponentially initially, then slows down and approaches its maximum value. S shaped growth is endogenously caused by a shift in loop dominance from positive to negative feedback.

stability (stable behavior): behavior in which the system returns to equilibrium conditions after being disturbed or remains within specified limits. In an unstable system or region, a disturbance is amplified, leading to increased growth, collapse or oscillation.

stable equilibrium – a system structure and condition (set of parameter values) in which, if the system is moved away from the equilibrium conditions, the system tends to return to those conditions. Also see unstable equilibrium

stasis – see equilibrium behavior

state variable: see stock

static – not changing over time; constant

steady-state behavior: a behavior pattern that is repetitive or constant over time and in which the behavior in one time period is of the same nature as any other period.

step input: An input (usually for testing purposes) that suddenly changes and then remains at the new value.

Stock (level): an accumulation of people or things in a specific location or with a specific condition in a system. An element of a system that accumulates or drains over time. Stocks are the memory of a system and are only affected by flows.

stock and flow diagram – a graphic depiction of the stocks and flows in a system and how they are connected

structural diagram: see system structure diagram

structure: see system structure

system: a collection of parts that interact in a meaningful way to function as a whole.

system archetype – an integrated feedback structure, resulting behavior mode or modes, and a story of how the structure can create the behavior modes, so as to describe a common problem and potential solutions

system boundary: see boundary

system structure – the way in which system elements are organized or interrelated. The totality of feedback loops, stocks, flows and time delays in the system. The building blocks and connections of a system.

system structure diagram – a combination of a causal loop diagram and a stock and flow diagram that depicts a system's stocks, flows, and feedback in a single picture

systems thinking – the use of conceptual system models and other tools to improve the understanding of how the feedback, delays, and management policies in a system's structure generate the system's behavior over time. Systems thinking does not use computer simulation. Systems thinking involves 1) seeing interrelationships (feedback loops) instead of linear cause-effect chains, and 2) seeking processes of change over time rather than snapshots. Systems thinking helps people see things on three levels: events, patterns of behavior, and system structure.

table function – a numeric table version of a graphical

time series – a table of values or graphical plot of a system variable over a period of time, often used to identify behavior modes. Also see behavior over time graph.

time step – see solution interval

transferable structure: see generic structure

transient behavior - a dynamic response that does not persist. Temporary, short term behavior, typically between equilibrium conditions

unstable behavior – behavior over time that does not converge to an equilibrium or remain within specified limits.

unstable equilibrium – a system structure and conditions (set of parameter values) in which, if the system is moved away from the equilibrium condition, the system tends to move farther away from the equilibrium condition. Also see stable equilibrium.

validation – the process of developing confidence in a model's usefulness, performed with tests of model structure similarity to actual structures, simulated behaviors that reflect the behaviors of the system modeled, and ultimately impacts of the model results on actual systems and problems

validity: a model's suitability for a particular purpose. A model is valid if it accomplishes what is expected of it, as demonstrated by structure and behavior tests

vicious cycle: a reinforcing, amplifying structure that yields undesirable results.

virtuous cycle: a reinforcing, amplifying structure that yields desirable results.

Supporting Sources

Zhu, H. And others. 1995. Road Maps Glossary. D-4498, MIT System Dynamics Group Literature Collection. www.systemdynamics.org/mit-sdgroup-literature-collection

