Is Velocity Stock or Flow?

A Note on Model Formulation

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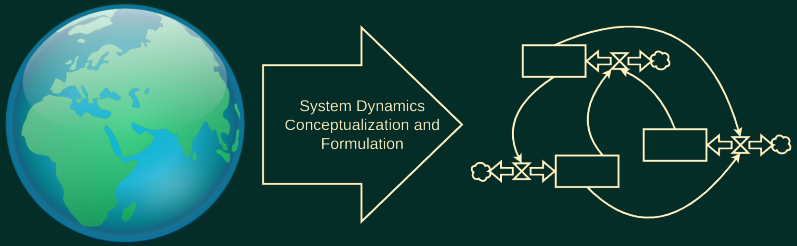
Elegance of system dynamics

Interconnecting feedback loops form any system. But at a lower hierarchy, each feedback loop contains a substructure. There are two fundamental types of variable elements within each loop – the levels, and the rates. Both are necessary. The two are sufficient [Forrester, 1971, sec. 4.3].



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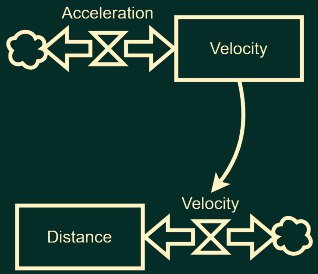
- a flow [Forrester, 1999] . . . but modeled as a stock [Forrester, 2009, p. 14]
- modeled both as stock AND flow [Hannon and Ruth, 2001, p. 364] [Glass-Husain, 1991, p. 33], and [Bossel, 2007a, p. 115]



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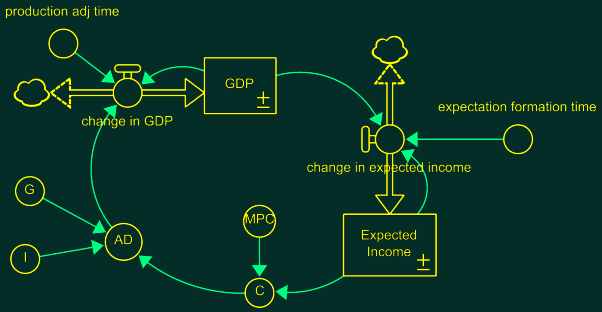
- GDP modeled as stock [Sterman, 2000, p. 719], [Bossel, 2007b, p. 103]



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  - No, units "do not indicate whether the variable is a level or a rate" [Forrester, 1971, sec. 4.3].
  - No, "[u]nits are no help in selecting level variables" [Richardson and Pugh III, 1981, p. 177].

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3. Facilitate quality control of models through formal assessment tools e.g. SDM-Doc [Martinez-Moyano, 2012]
4. Help standardization of modeling processes

Flows

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- "policy statements" driving a stream of "decisions" or "actions" [Forrester, 1971, sec. 4.4]

Stocks

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- "accumulation over time, a storage device for material, energy, or information" [Richardson and Pugh III, 1981, 176]

Snapshot test

[I]magine that all activity in a system is brought to rest. Only the level variables would remain and be observable. In a stationary system, all action would be frozen but all levels would continue to exist. A tree would stop growing, but the level of its accumulated height would be visible. In a factory, activity would have stopped, but the levels representing a number of employees, work in progress, capital equipment, and bank balance would be measurable. The more intangible levels would likewise remain – employee morale, company reputation, and quality of the product. Current instantaneous sales rate would have disappeared, but the knowledge of average sales rate for the past year would remain as a system-level [Forrester, 1971, sec. 4.3].

Redefining stocks

New definition:

- Storage for material, energy, information, resources, or individuals that accumulates the effects of decisions and actions and preserves and represents parts of the system's history.

Redefining the snapshot test

Imagine stopping time in the system, freezing all flows instantaneously, as if one took an all encompassing photograph of the system capturing intangible and invisible characteristics as well as physical processes. The potential level variables are those that still exist and have meaning in the snapshot. One would still be able to measure the extent of accumulations even if time were stopped, while flows would be stilled, perhaps visible in the photograph but not measurable [Richardson and Pugh III, 1981, pp. 176-7].

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Suggested measure (based on [Forrester, 1971, sec. 4.3]):

- To measure the variable of interest, do we need to measure other variable(s)?
  - Yes –> flow
  - No –> stock

Checking units of measure

The units of measure can help you distinguish stocks from flows. Stocks are usually a quantity such as widgets of inventory, people employed, or Yen in an account. The associated flows must be measured in the same units per time period [Sterman, 2000, p. 198].

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Suggested measure:

- Does the variable's unit of measure includes any time unit in its denominator?
  - Yes –> ???
  - No –> Stock

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1. Is the variable an accumulation?
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3. Does measurement need +2 points in time?
   - Yes –> Flow –> Stop
   - No / not sure –> Continue
4. Does measurement need other variables?
   - Yes –> Flow –> Stop
   - No –> Stock –> Stop
   - Not sure –> More research needed –> Stop

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- Developed an improved method for stock-flow identification
  - one single procedural package
  - more accurate and robust identification
  - basis for future improvements
- Preliminary tests for many different variables, more tests due
- Should develop a public, live repository to list all variables and their type

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Thank You!