



SYSTEM DYNAMICS 101

FAMES

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System Dynamics Overview

- System dynamics:
 - a way of thinking
 - a modeling tool
- Basic SD premise:
 - “Policy resistance” can be anticipated through systems thinking.
 - SD facilitates systems thinking by model construction and visualization of the modeled system behavior.

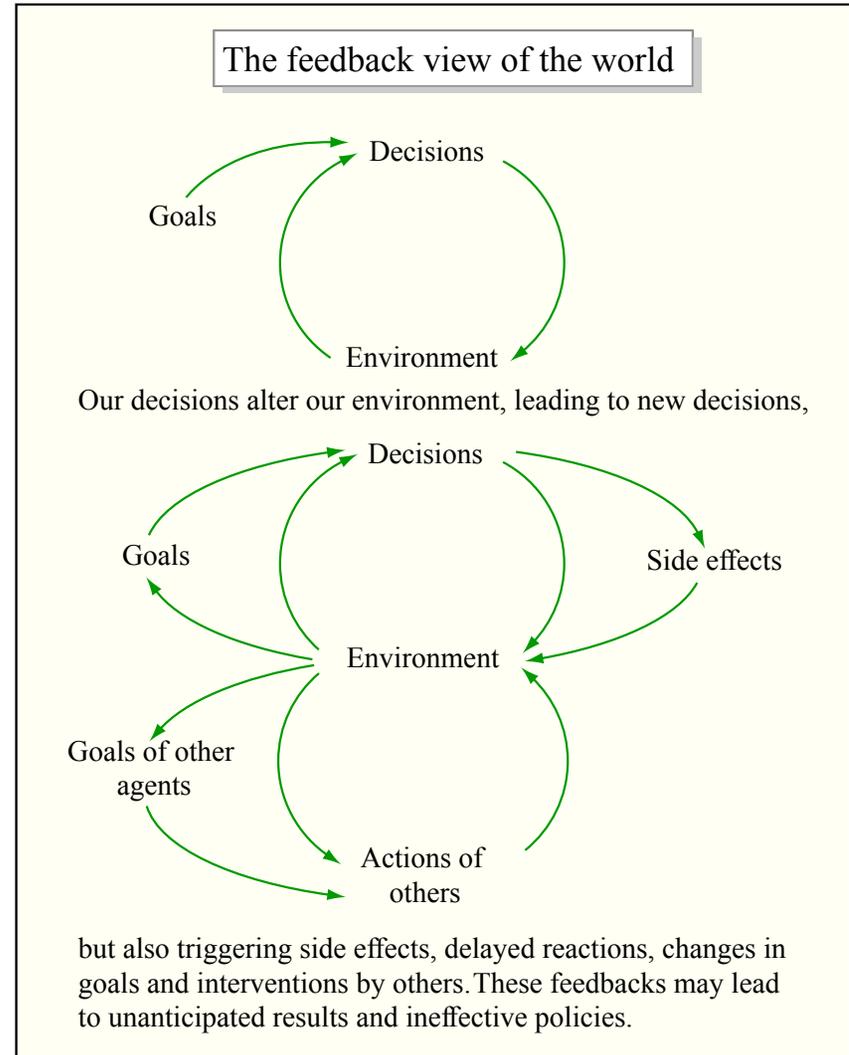
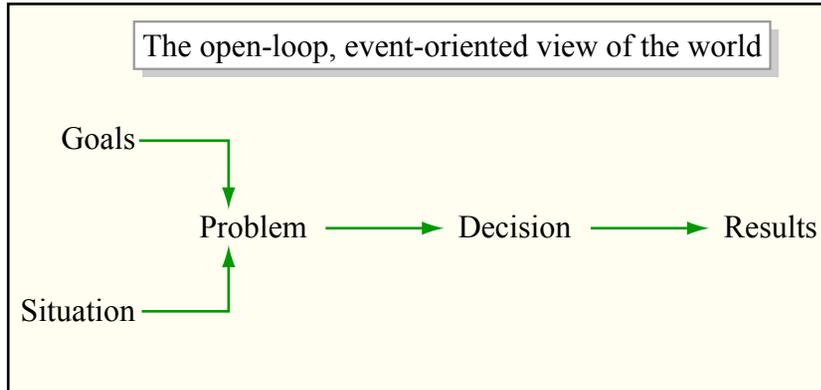


Policy Resistance

- A definition: unanticipated effects of well-intentioned solutions.
 - Related to behavioral complexity.
- Some examples:
 - Antibiotics and drug-resistant strains.
 - Fire suppression and forest fires.
 - Proliferation of taxis in San Diego.
 - California's deregulation of electricity markets.
- Can you think of others?



SD as a way of thinking: Exposing mindsets



Figures by MIT OpenCourseWare, adapted from Sterman.

Source: Sterman 2002



Some drivers of policy resistance:

- Time-delays
- Non-linearities
- Feedback



Shower: a metaphor and the origin of SD

- Achieving the right temperature is a control problem: there are **delays** in the system even if uncertainty is removed.
- Other control problems: driving, flying a plane. Humans and machines can learn to anticipate and adjust to short term feedback delays.
- The modeling part of SD originates from control theory and servomechanism design.
- Jay Forrester in the 1950s at MIT was the first to adapt those ideas to policy applications.



Folding a paper

- Fold a paper of 0.1 mm thickness
- How thick does it become if you fold it ~45 times?
 - $<0.5\text{m}$
 - 1 m
 - 100 m
 - $>100\text{ m}$

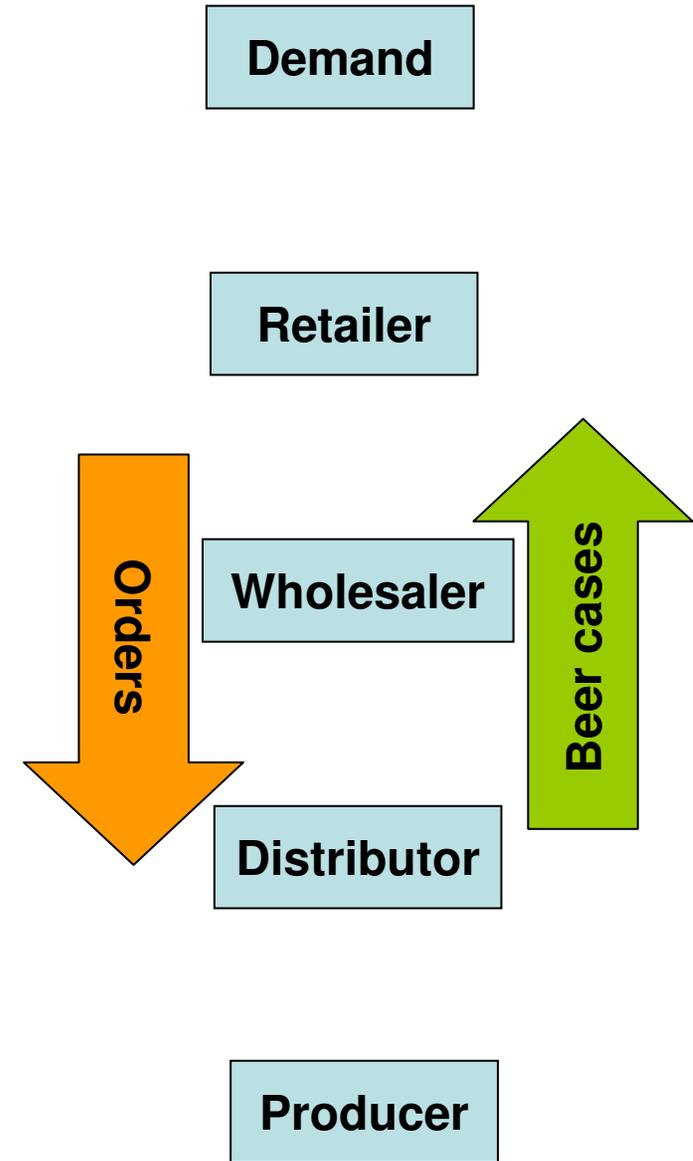
Human brains are not adapted to deal with **non-linearities**.



Beer games

Feedback: (coupling of action and reaction – usually several stakeholders are involved).

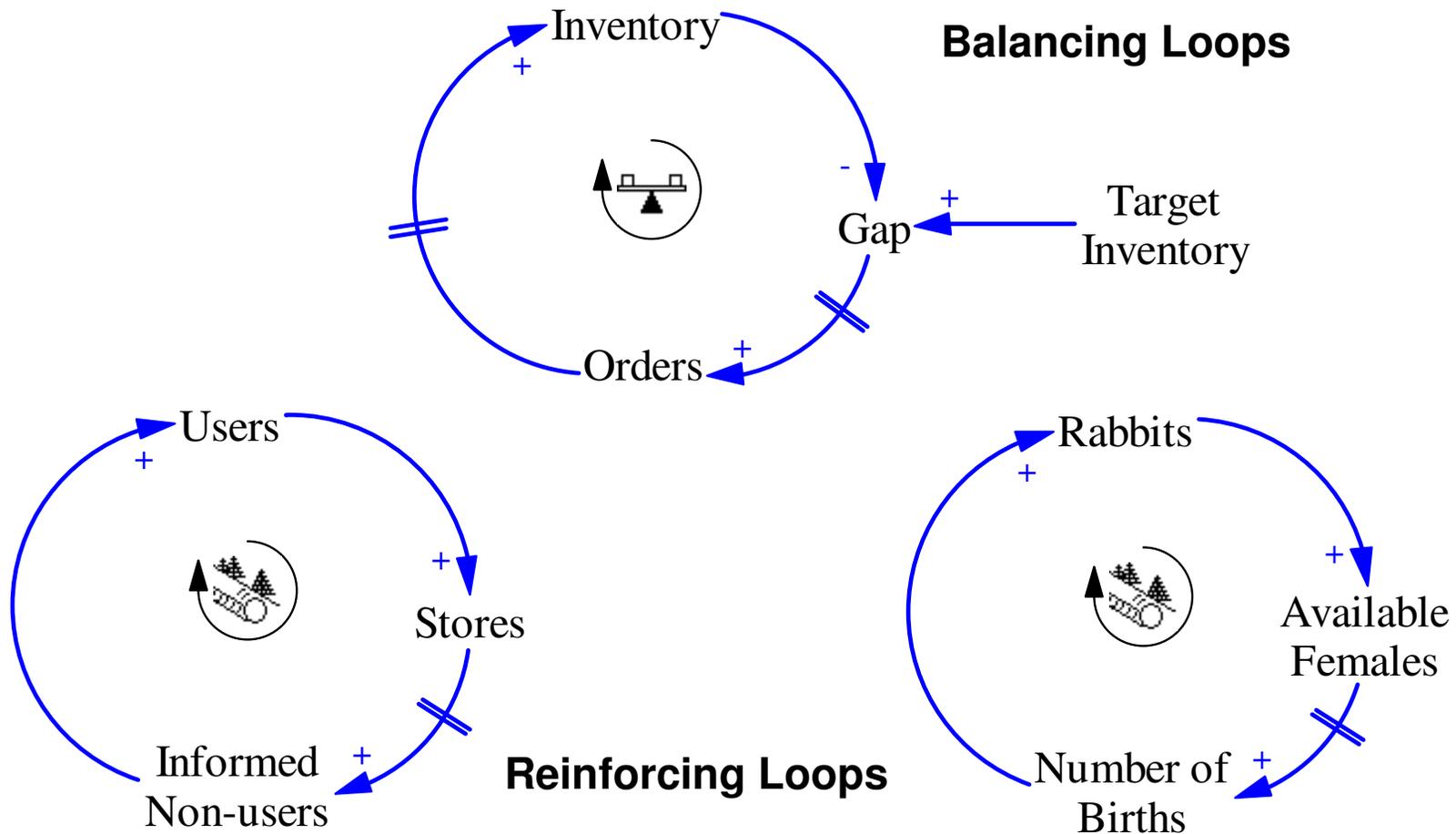
What is the plausible *reference mode*?





Casual loop diagrams

- A way to capture feedback





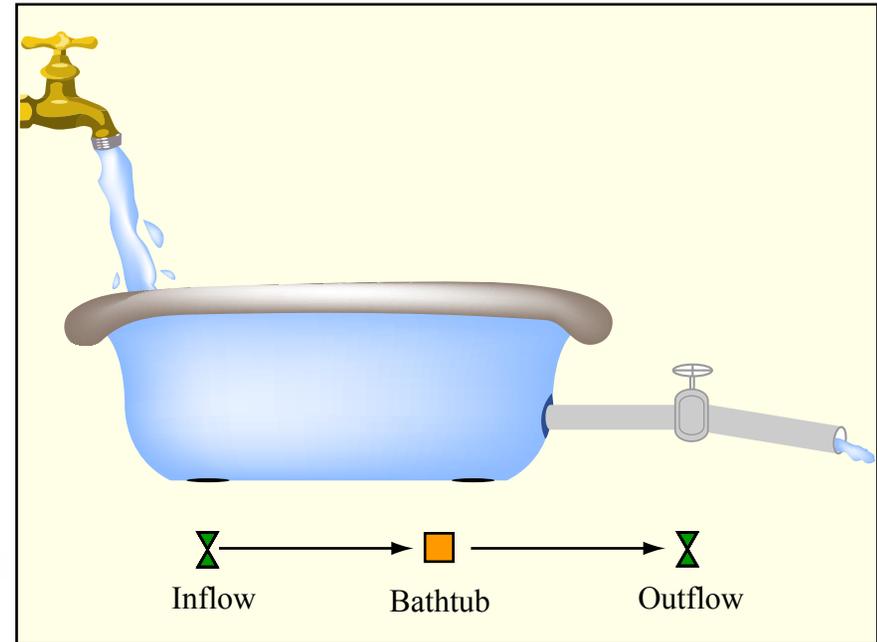
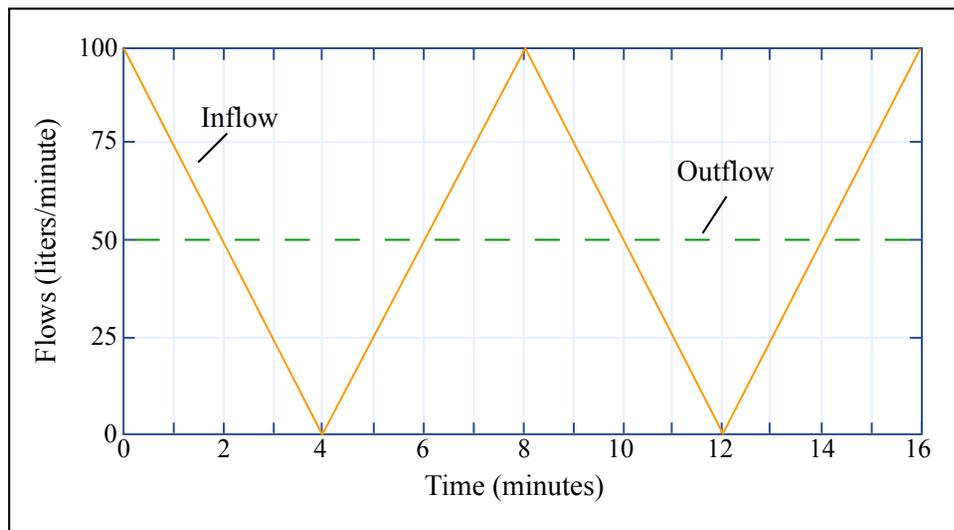
Causal Loops recap

- Unambiguous
 - Direction
 - Link polarity
- Tracing the loop to identify loop polarity
- Example:
 - price and revenue
- Example:
 - Attractiveness of market
 - Number of competitors
 - Price
 - Profits



Beyond causal loops: the mechanics

- Stocks
- Flows
- Integration



Figures by MIT OpenCourseWare, adapted from Sterman.

Source: Sterman 2002

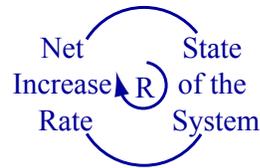
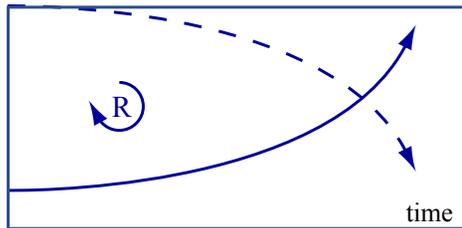
Assuming the initial quantity is 100lit. How does the “stock” (quantity of water) behave?



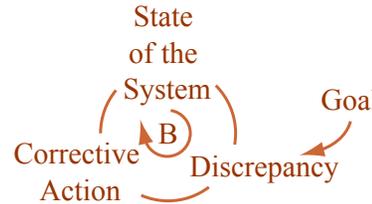
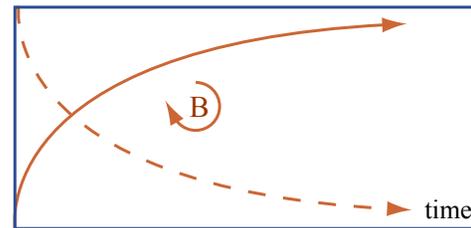
Fundamental Reference Modes

Linear Fundamental Modes

Exponential Growth
(1st Order)

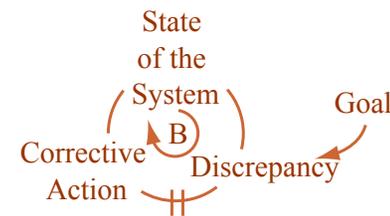
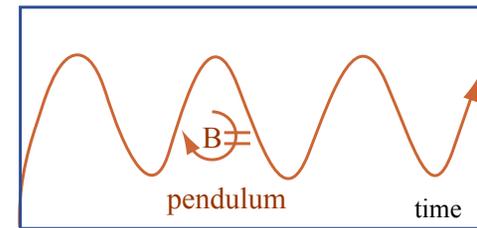


Goal Seeking / Exponential Smooth
(1st Order)



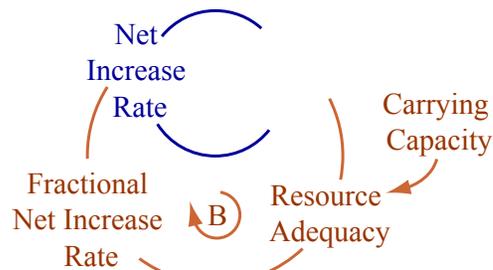
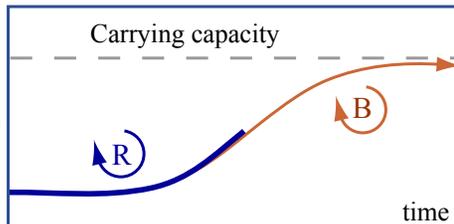
Oscillation

(2nd Order, delay = stock)

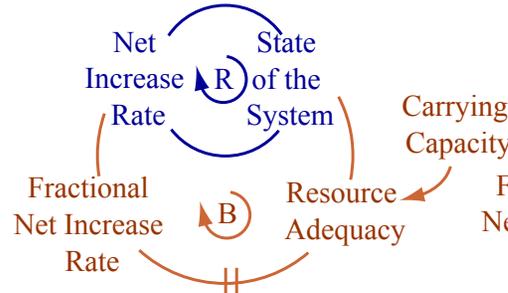
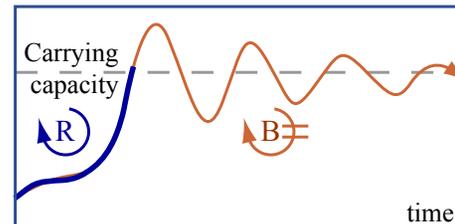


Nonlinear (Mode-Switching)

S-shaped Growth



S-shaped growth with Overshoot & Oscillation



Overshoot & Collapse

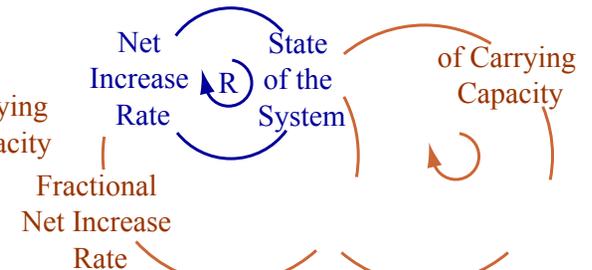
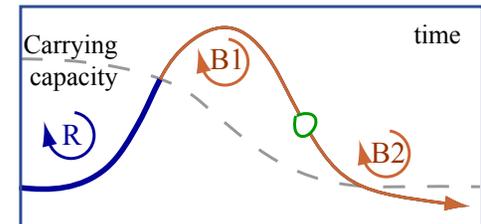


Figure by MIT OpenCourseWare, adapted from Piepenbrock and Sterman.

Source: Piepenbrock 2004, Sterman 2000





Brief Return to the Beer Game model

- Examining various behaviors



Traditional Model Testing: Validation, Verification, Accreditation

- Validation: the model structure reflects the real world accurately enough
- Verification: the model operates according to how it was designed
- Accreditation: the model is considered credible by the decision-makers

Methods:

Inspection

Historical data and forecasting / backcasting

Statistical testing



SD Modeling Process review

- Problem articulation
 - Purpose (why?)
 - Boundary selection (space + time)
 - Reference modes (expected behaviors)
- Formulating dynamic hypotheses
 - Endogenous explanation
- Testing and validation
- Policy Design and Evaluation

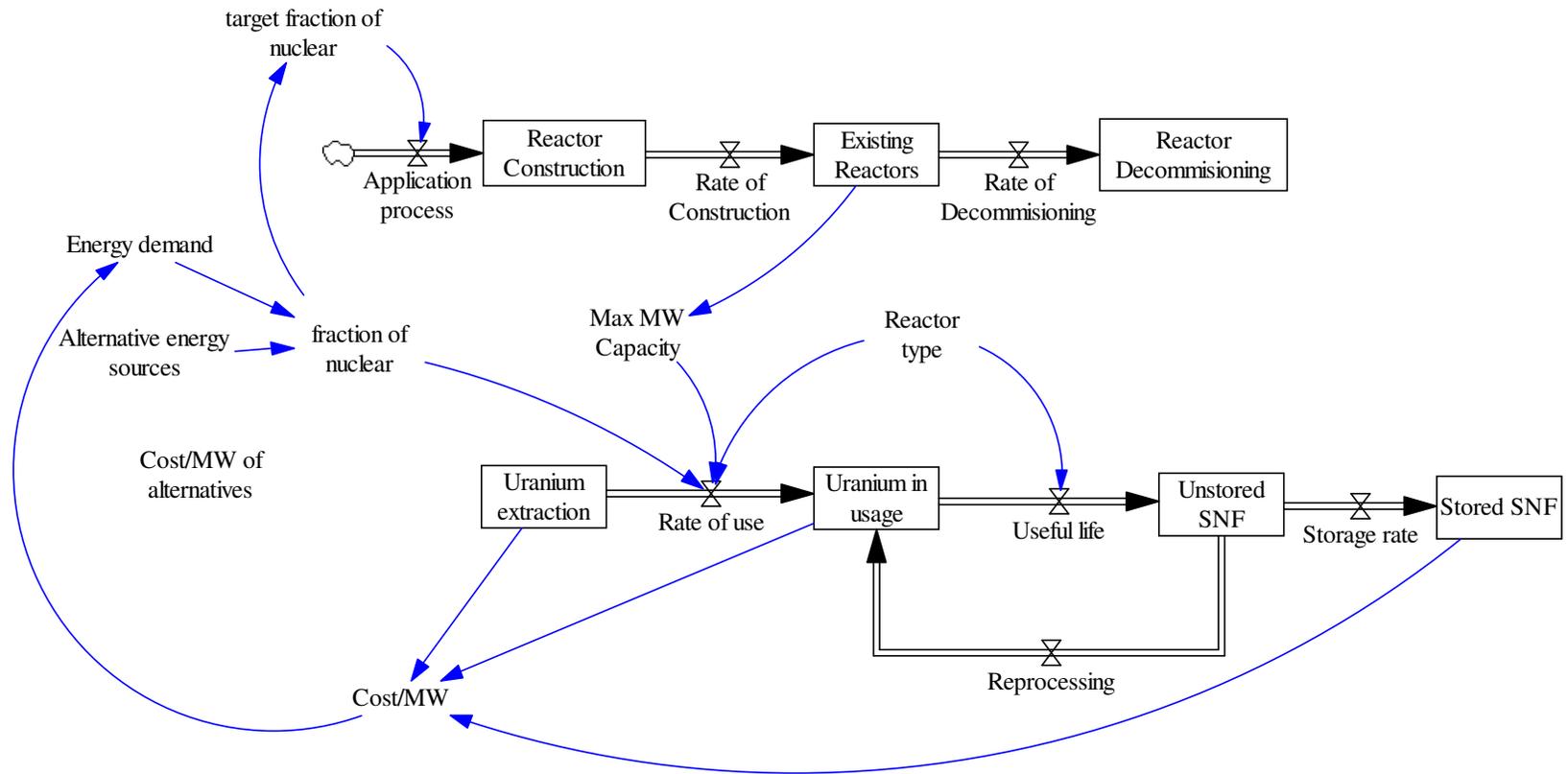


SD and the CLIOS Process

- SD is considered a tool in the CLIOS Process toolkit.
- SD as a way of thinking shares a lot of similarities with the CLIOS Process but it is not explicit with regard to the nested complexity.
- CLIOS Diagrams can be a good starting point for creating SD models.
- Preliminary SD models can be a good starting point for engaging stakeholders and making explicit their tacit knowledge.



Developing an SD model for SNF





Resources

Software:

Vensim, Stella, iThink.

Anylogic!

Books:

J. Sterman Business Dynamics

P. Senge The Fifth Discipline

Attached Papers



Back-up



Agenda

- Purpose of SD
- Origin of SD
- Mind-sets vs. SD
- SD Notation and terminology
- Applying SD thinking in SNF