INTRODUCTION TO SYSTEMS ANALYSIS AND SYSTEM DYNAMICS

MAVA
FONDATION POUR LA NATURE

SAVi Sustainable Asset Valuation

IISD
International Institute for Sustainable Development

Glossary

- **System Dynamics:** a methodology to create descriptive models that focus on the identification of causal relations influencing the creation and evolution of the issues being investigated. Its main pillars are feedback loops, delays and nonlinearity through the explicit representation of stocks and flows.
- **Stock and flow variables:** a *stock* variable represents accumulation and is measured at one specific time. A *flow* variable is the rate of change of the stock and is measured over an interval of time.
- **Feedback loop:** "*Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself*" (Roberts et al., 1983).
- **Scenarios:** expectations about possible future events. Consequently, scenario analysis is a speculative exercise in which several future development alternatives are identified, explained, and analyzed for discussion on what may cause them and the consequences these future paths may have on our system (e.g., a country, or a business).
- **Intervention:** any instrument (e.g. policy or investment) utilized to influence the behavior of the system.

Glossary

- **Methodology:** the underlying body of knowledge for the creation of different types of simulation models. It includes theoretical foundations for the approach, and often encompasses both qualitative and quantitative analyzes and instruments.
- **Simulation model:** a model is simplification of reality, a representation of how the system works, and an analysis of (system) structure and data. A quantitative model is built using one or more specific methodologies, with their strengths and weaknesses.
- **Vertical/horizontal disaggregation of models:** vertically disaggregated models represent a high degree of sectoral detail; horizontal models instead include several sectors and the linkages existing among them (with a lesser degree of detail for each of the sectors represented).
- **Model transparency:** a transparent model is one for which equations are available and easily accessible and it is possible to directly relate structure to behavior (i.e., numerical results).
- **Model validation:** the process of deciding whether the structure (i.e., equations) and behavior (i.e., numerical results) are acceptable as descriptions of the underlying functioning mechanisms of the system and data.

Systems Thinking (ST)

"Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static 'snapshots'...Today systems thinking is needed more than ever because we are becoming overwhelmed by complexity.

Perhaps for the first time in history, humankind has the capacity to create more ***information*** *than anyone can absorb, greater* ***interdependency*** *than anyone can manage, accelerate* ***change*** *faster than anyone's ability to keep pace."*

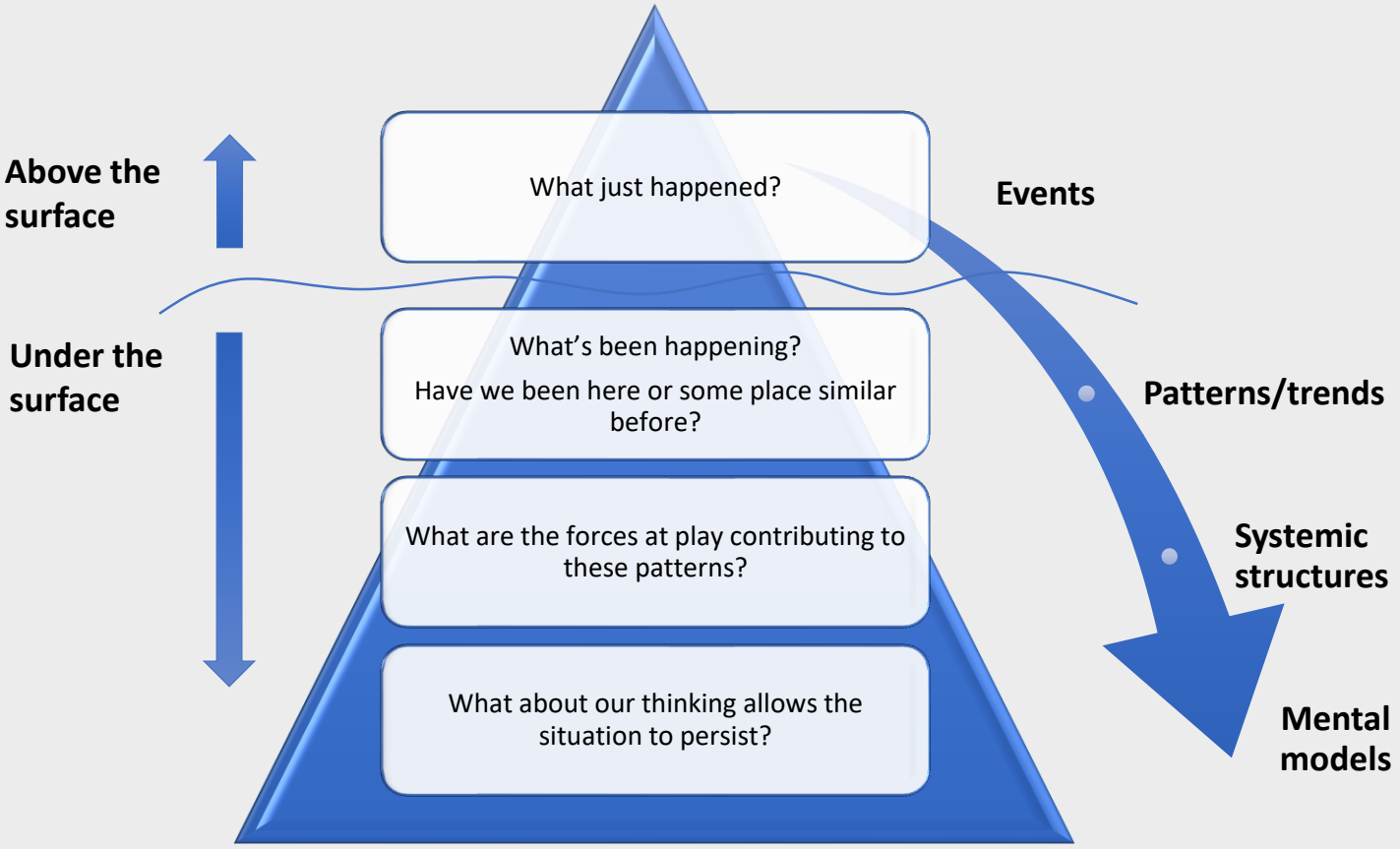
- Peter Senge, *The Fifth Discipline*

Systems Thinking (ST)

- An approach for developing models to promote our understanding of:
  - Events,
  - Patterns of behavior resulting in the events, and
  - The underlying structure responsible for the patterns of behavior.

It is only through our **understanding** of the **underlying structure** that we will be able to **identify** the most appropriate **leverage points** to effect **change** within the system.

Systems Thinking and System Dynamics



Events, Patterns, Systemic Structures and Mental Models

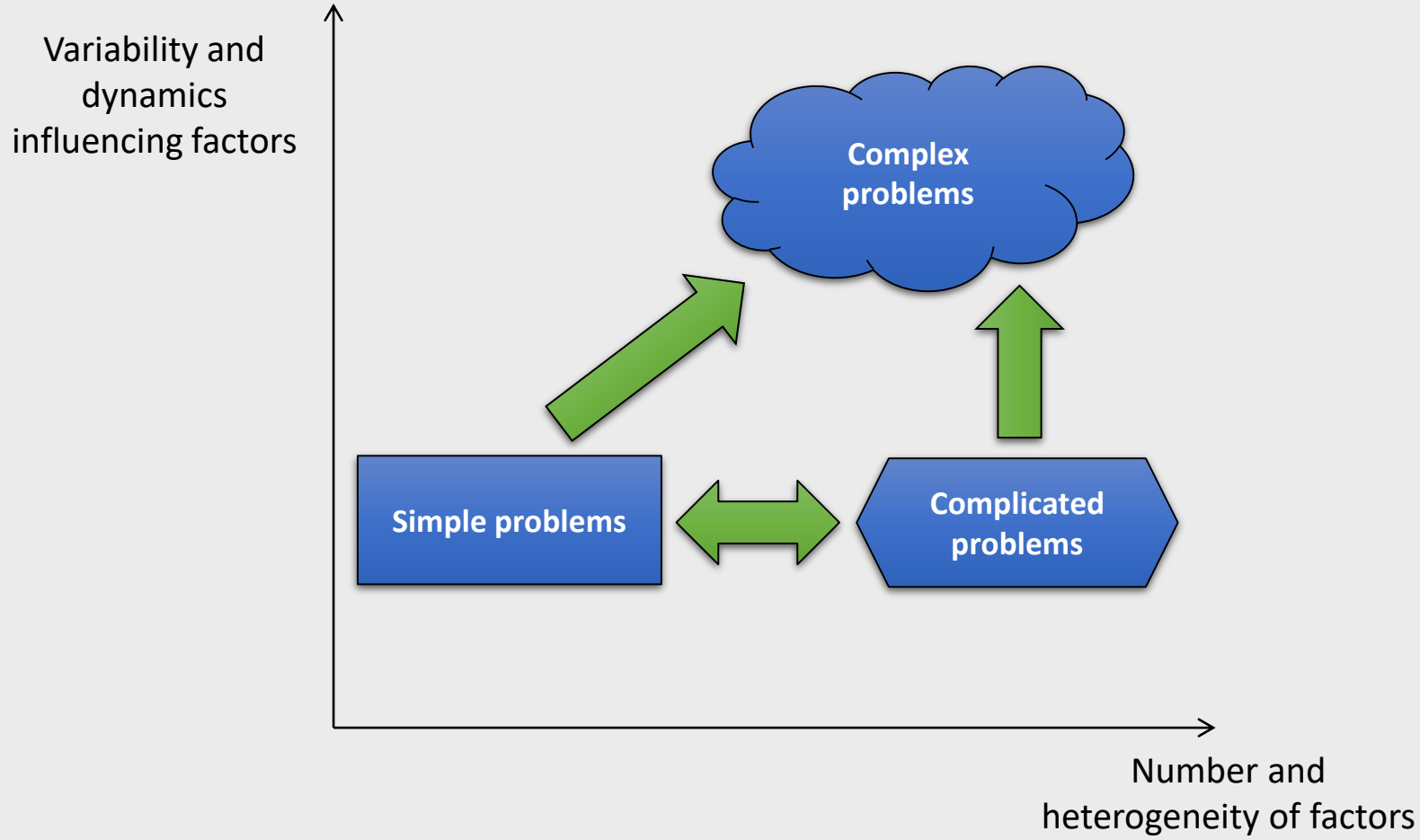
- **Events.** Information from different sources generally report events. What happened, where, when, who was involved, etc. This information is a snapshot of reality and only touches the surface of what happened. It is like a tip of an iceberg!
- **Patterns**. Documentaries start examining trends and patterns of events and data. This provides a richer picture of reality and give more insight to the story – observing fluctuations of stock market on quarterly basis
- **Systemic structures.** It is not common to read reports of how patterns or trends relate or affect one another. This is a deeper level of understanding that show how different factors interplay. The critical issue is how to understand how these factors interact
- **Mental models**. Deeper level of thinking that hardly comes out of surface. This is the 'mental model' of individuals and organizations that influence why things work the way they do.
- Mental models reflect the beliefs, values and assumptions that we personally hold and provide the underlying reasons for doing things the way we do.

When should we use Systems Thinking?

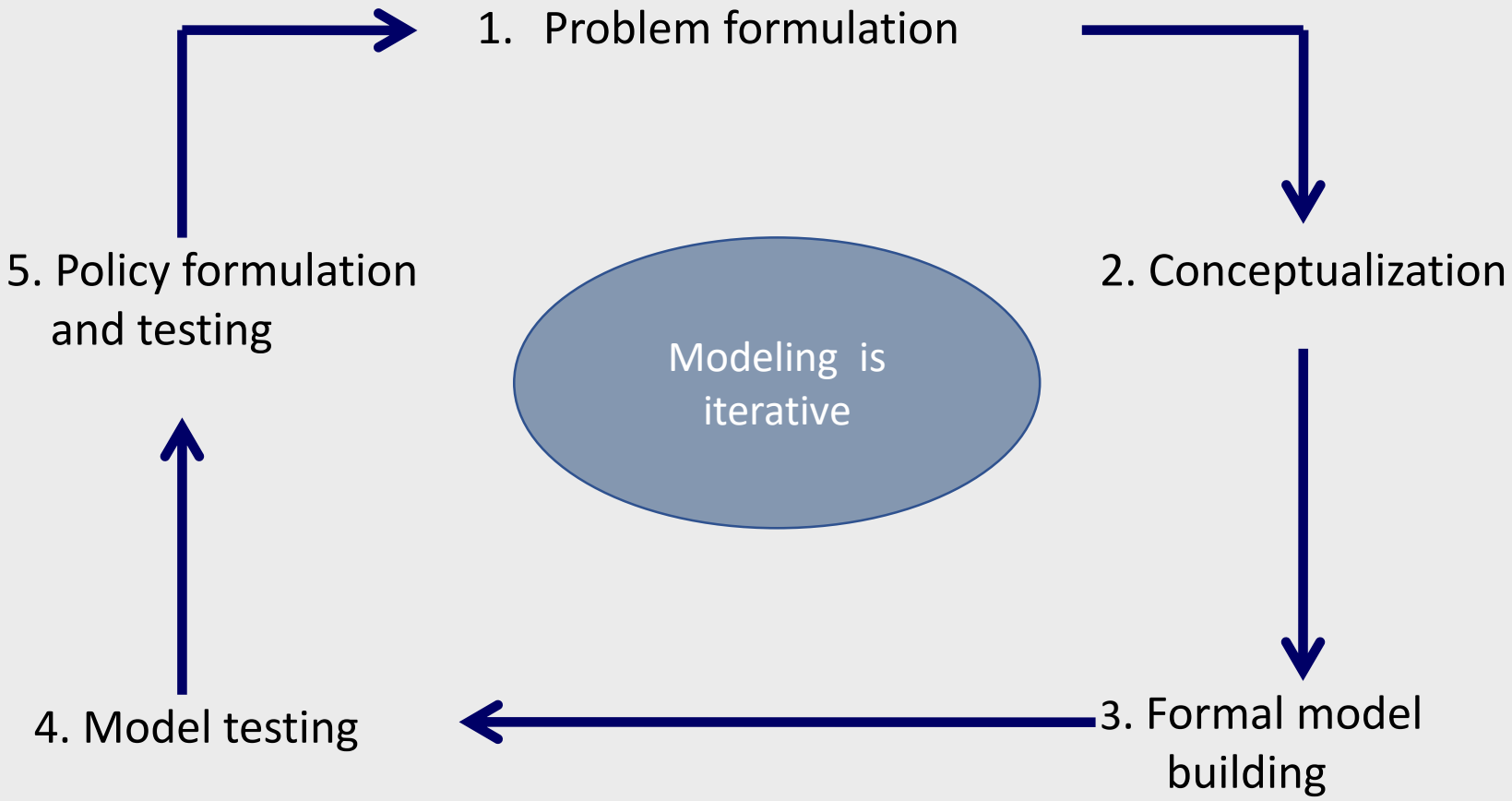
We should use systems thinking to address:

- Complex problems that involve helping many actors see the “big picture” and not just their part of it.
- Recurring problems or those that have been made worse by past attempts to fix them.
- Issues where an action affects (or is affected by) the environment surrounding the issue, either the natural environment or the competitive environment.
- Problems whose solutions are not obvious.

Understanding reality:
Dynamic and Detailed Complexity

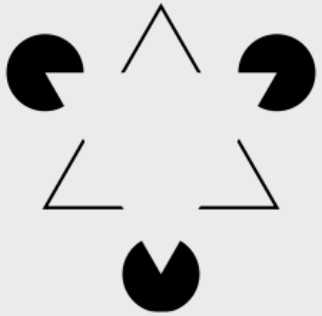


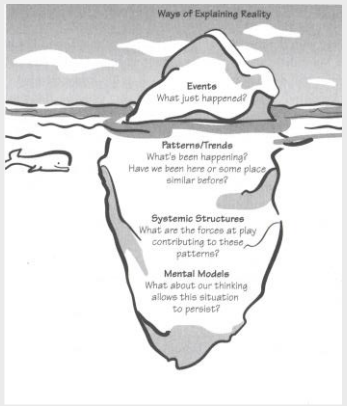
System Dynamics modelling process

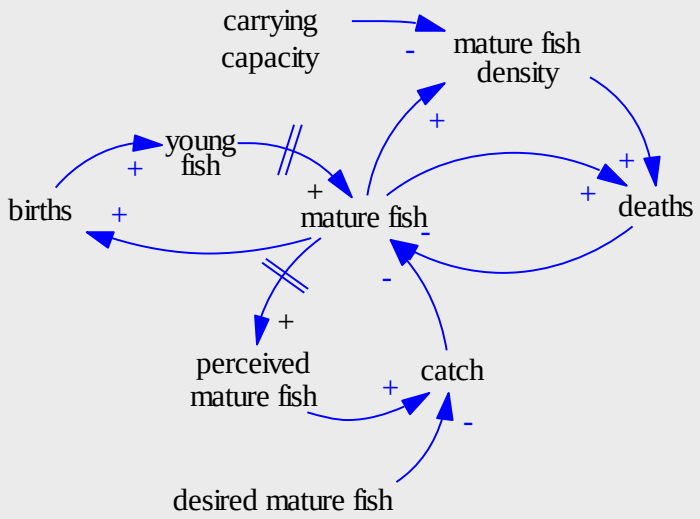


Systems Thinking and System Dynamics

- **Systems thinking** attempts to understand a whole system rather than its parts, utilized to identify the most effective leverage points to stimulate change within the system
- Created by Jay Forrester in the late 1950s at MIT, as the methodological foundation of "The Limits to Growth", **System Dynamics** is an integrated and quantitative (modeling) approach used to understand situations for (complex) real world issues to guide decision making over time for achieving sustainable long term solutions *(SD class, SPL – 2012)*.

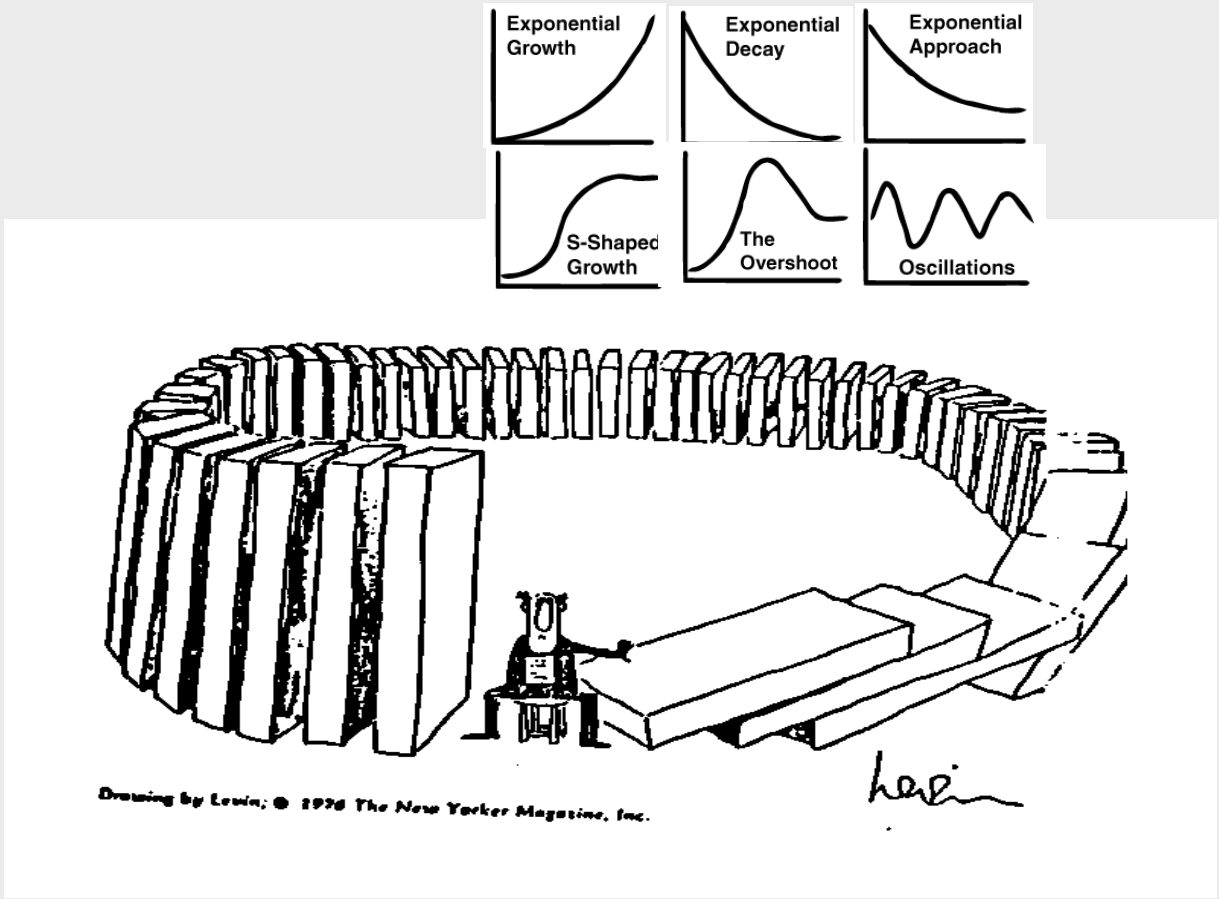






System Dynamics allows for…

- Understanding how structure leads to behavior (through causal relations, stocks and flows)
- Simulation across time scales (with semi-continuous runs, using differential equations)
- Disaggregated spatial assessments (with the possibility of using subscripts and GIS as inputs)
- Modeling across disciplines (integrating optimization and econometrics into a single model framework)



Causal Loop Diagram (CLD)

- Represent the feedback structure of systems
- Capture:
  - The hypotheses about the causes of dynamics
  - Mental models of individuals or teams
  - The important feedbacks driving the system
- Critical aspects:
  - Think in terms of cause-and-effect relationships
  - Focus on the feedback linkages among components of a system
  - Determine the appropriate boundaries for defining what to include in the CLD

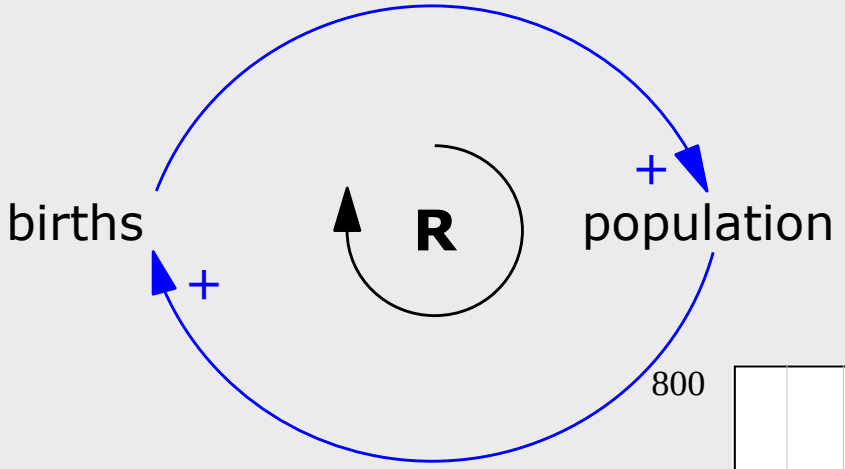
Reinforcing Loops

- Reinforcing loops tend to increase and amplify everything happening in the system
(i.e. action - reaction).

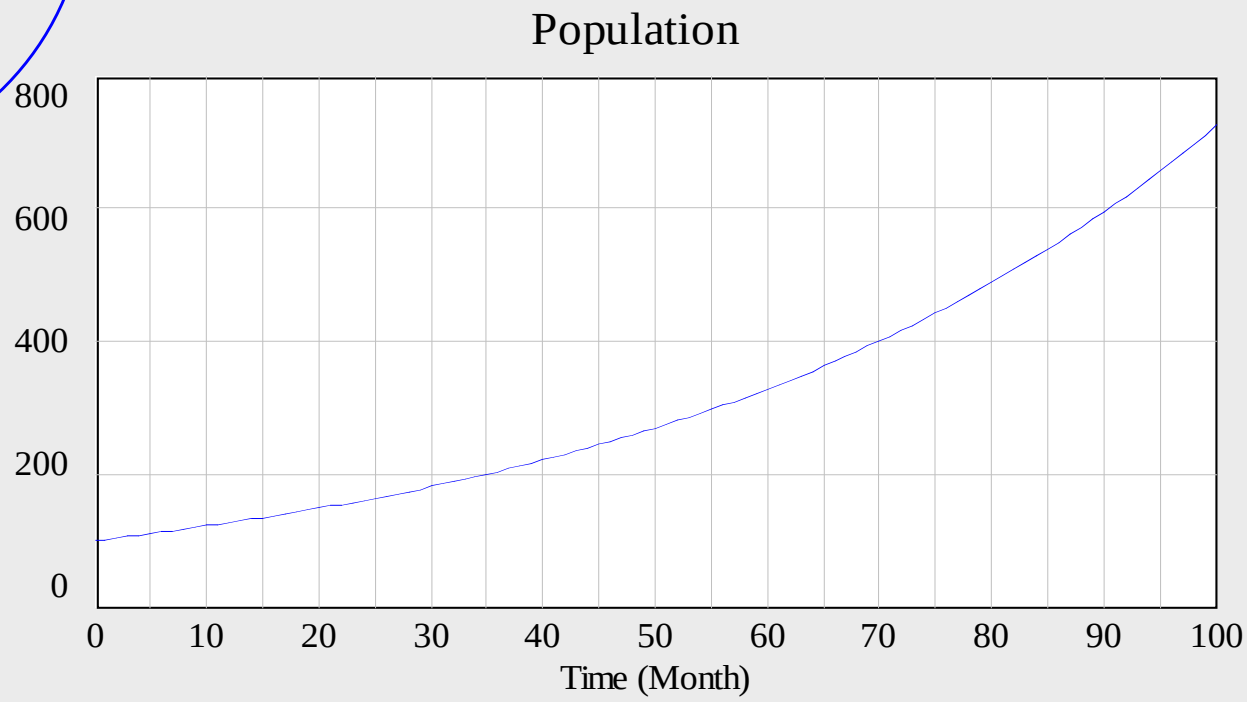
Example

- Fold a paper (0,1 mm) 42 times:
- What would be the final thickness of such paper?
- The result is a thickness larger than the distance between the Earth and the moon = 0,1*2^42 (43,980,465,111 cm = 439,804 Km)

Reinforcing Loops



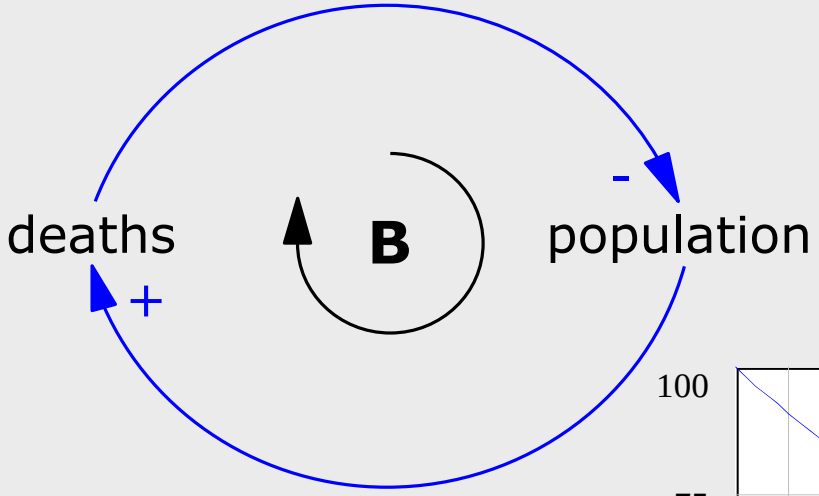
Self reinforcing

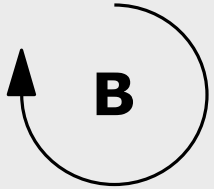


Balancing Loops

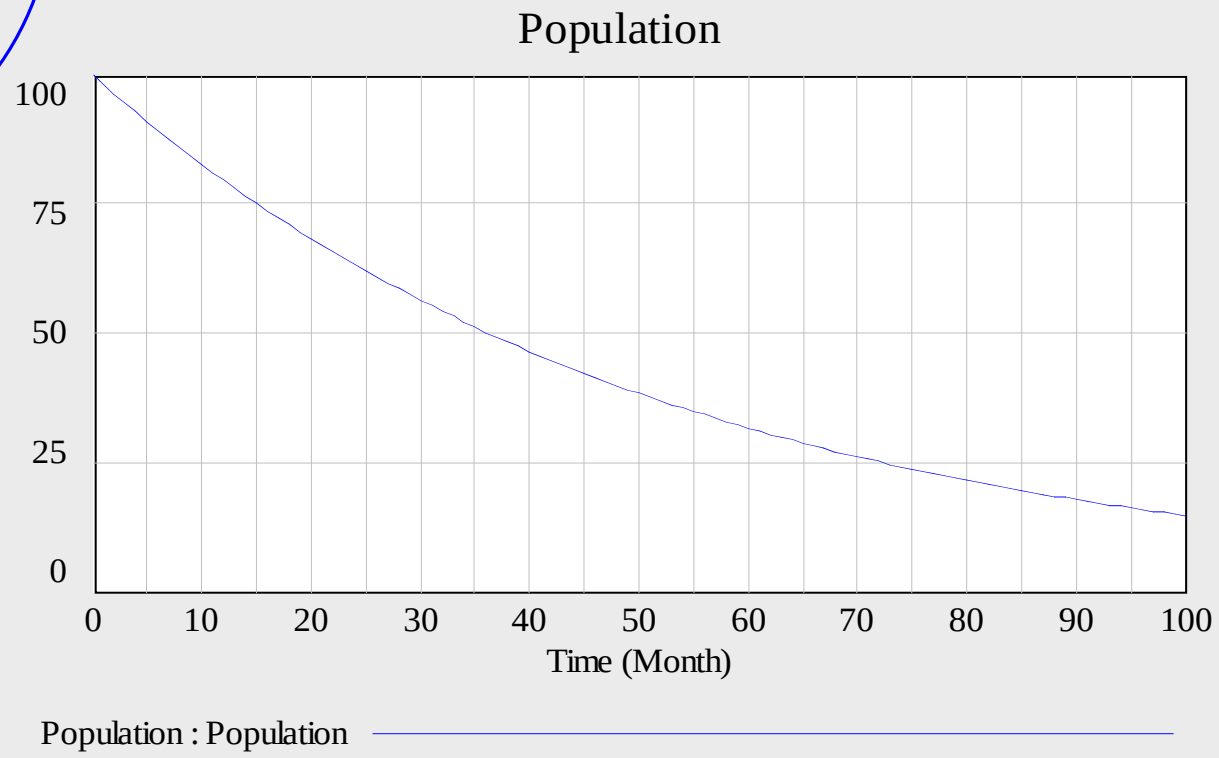
- Negative loops are counteractive and oppose change.
- Balancing loops represent a self-limiting process, which aims at finding balance and equilibrium.

Balancing Loops

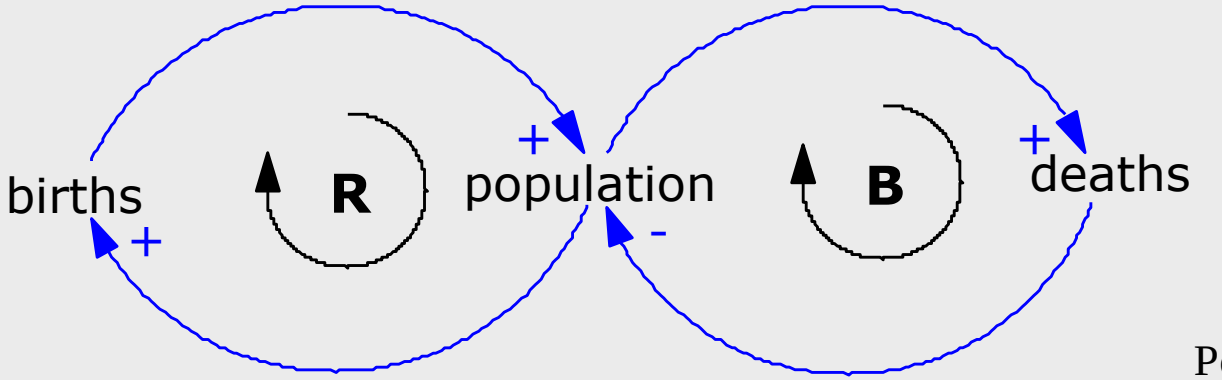


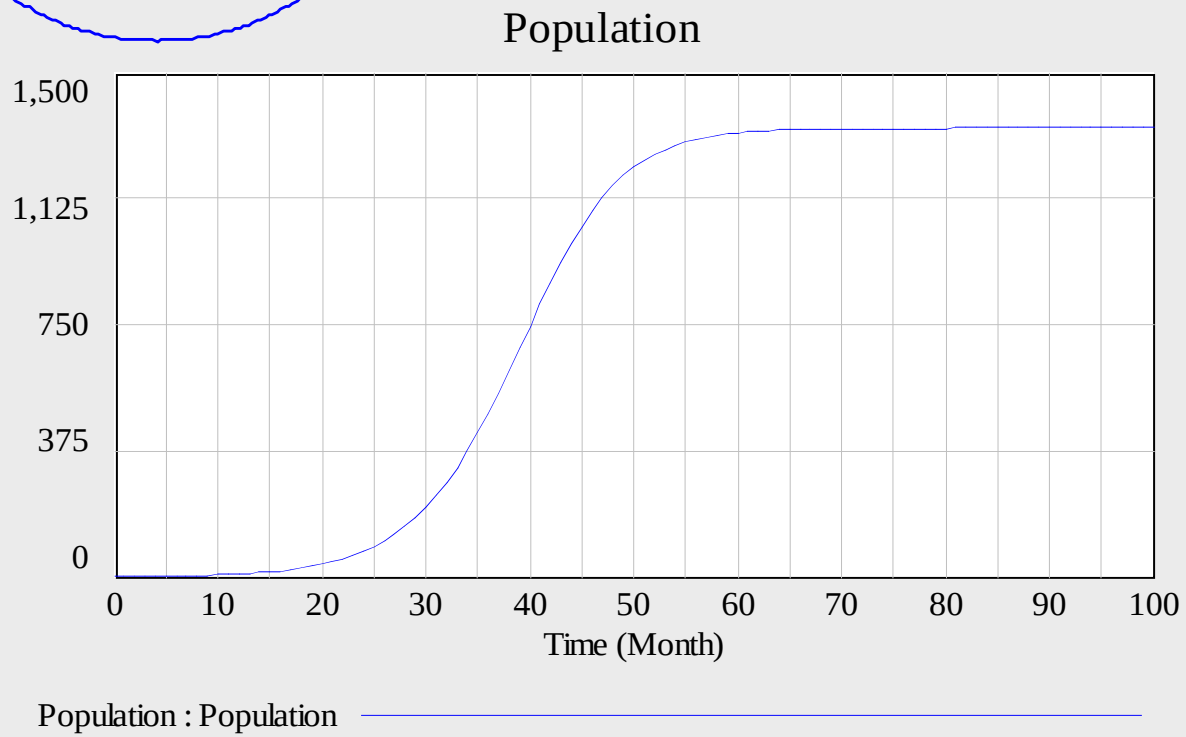


Self balancing

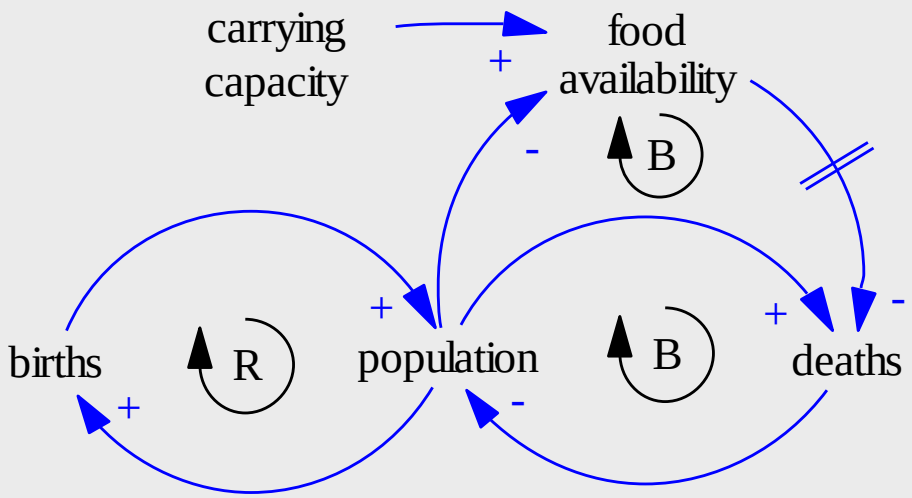


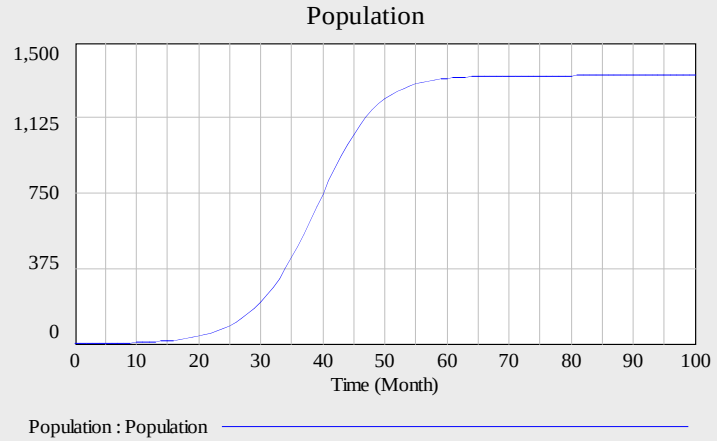
Combining Feedback Loops

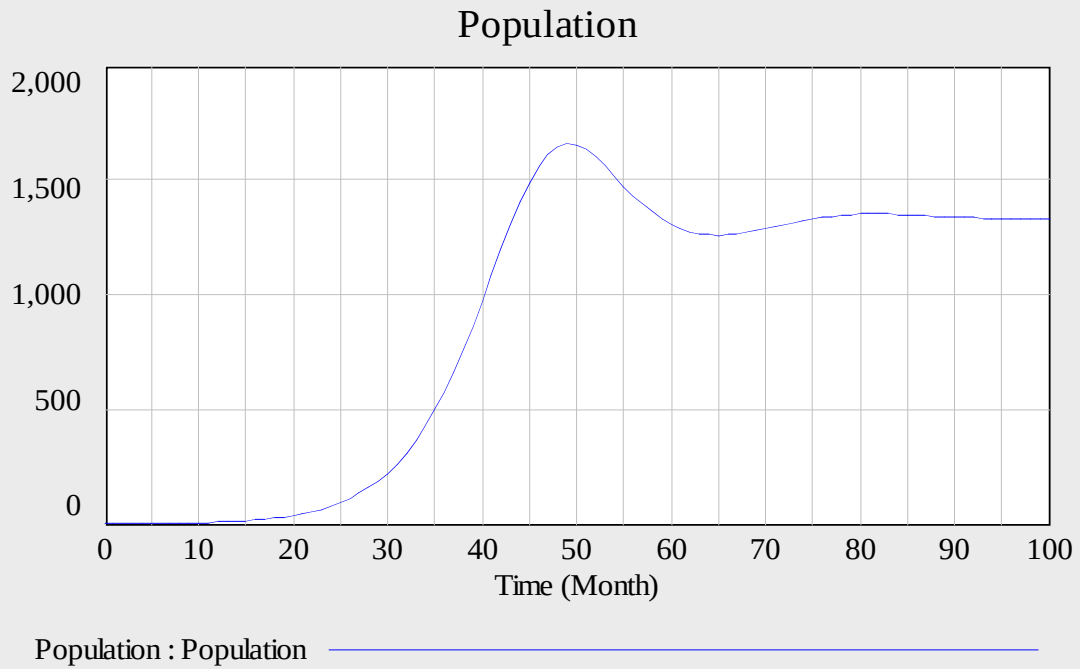




Feedback Loops and Delays



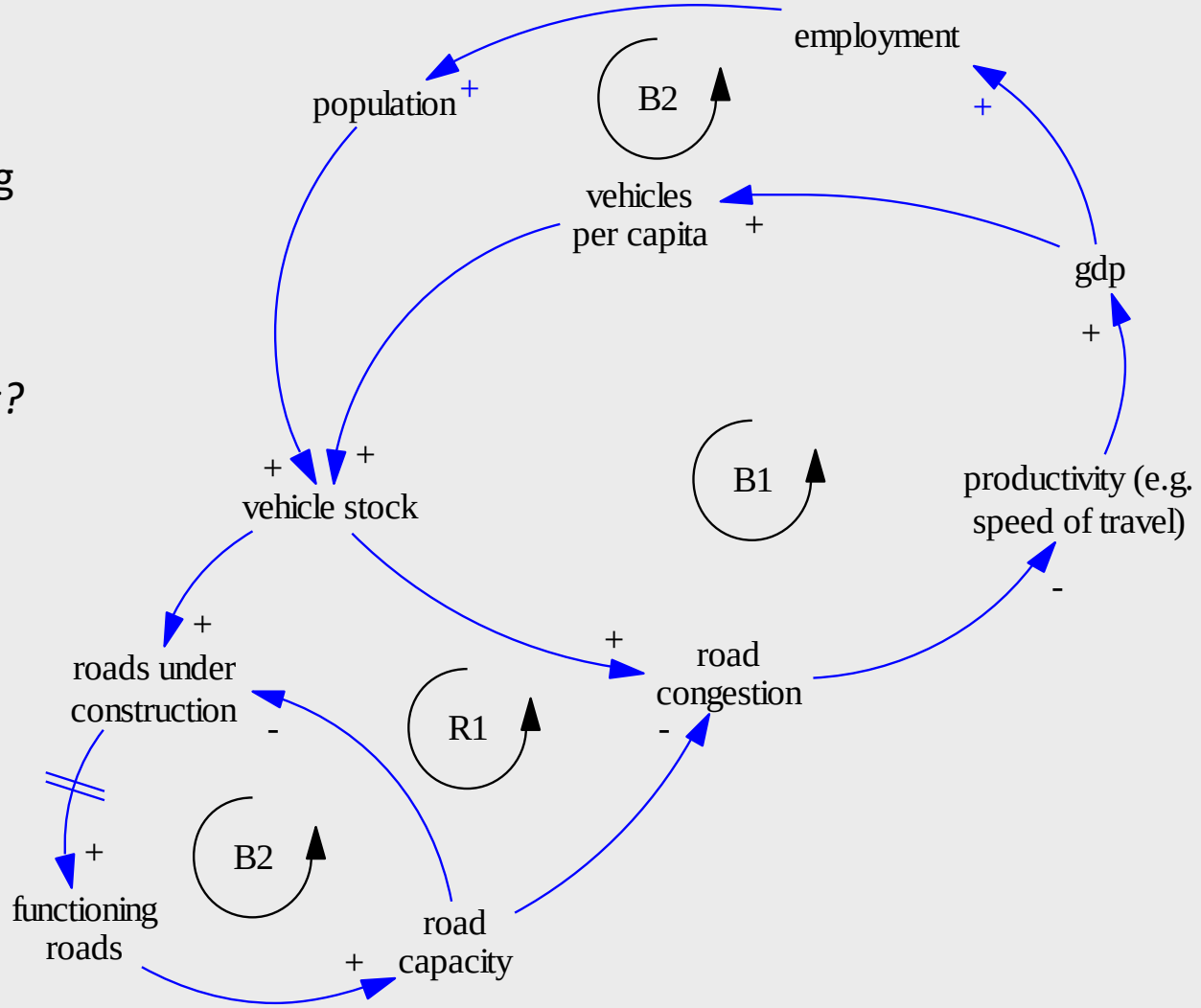




Why feedback? To pick more effective interventions

Should we still aim at strengthening reinforcing loops?

How do we define *Sustainable Communities?*



System Dynamics and SAVi

- System dynamics modelling is used in the Sustainable Asset Valuation (SAVi) methodology to assess the impact of infrastructure projects or policies across:
  - Dimensions of development
  - Sectors
  - Economic actors
  - Over time and in its geographical location

- We built the Causal Loop Diagram together with the users of the SAVi applications to create ownership and to capture all local dynamics and knowledge. Each SAVi application is therefore customized and integrates different sources of knowledge.

SAVi Sustainable Asset Valuation

System Dynamics and SAVi

- For detailed CLDs of the SAVi models per asset type, please visit Module 1 – SAVi Models.

Thank you!

- For more information, please contact:

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