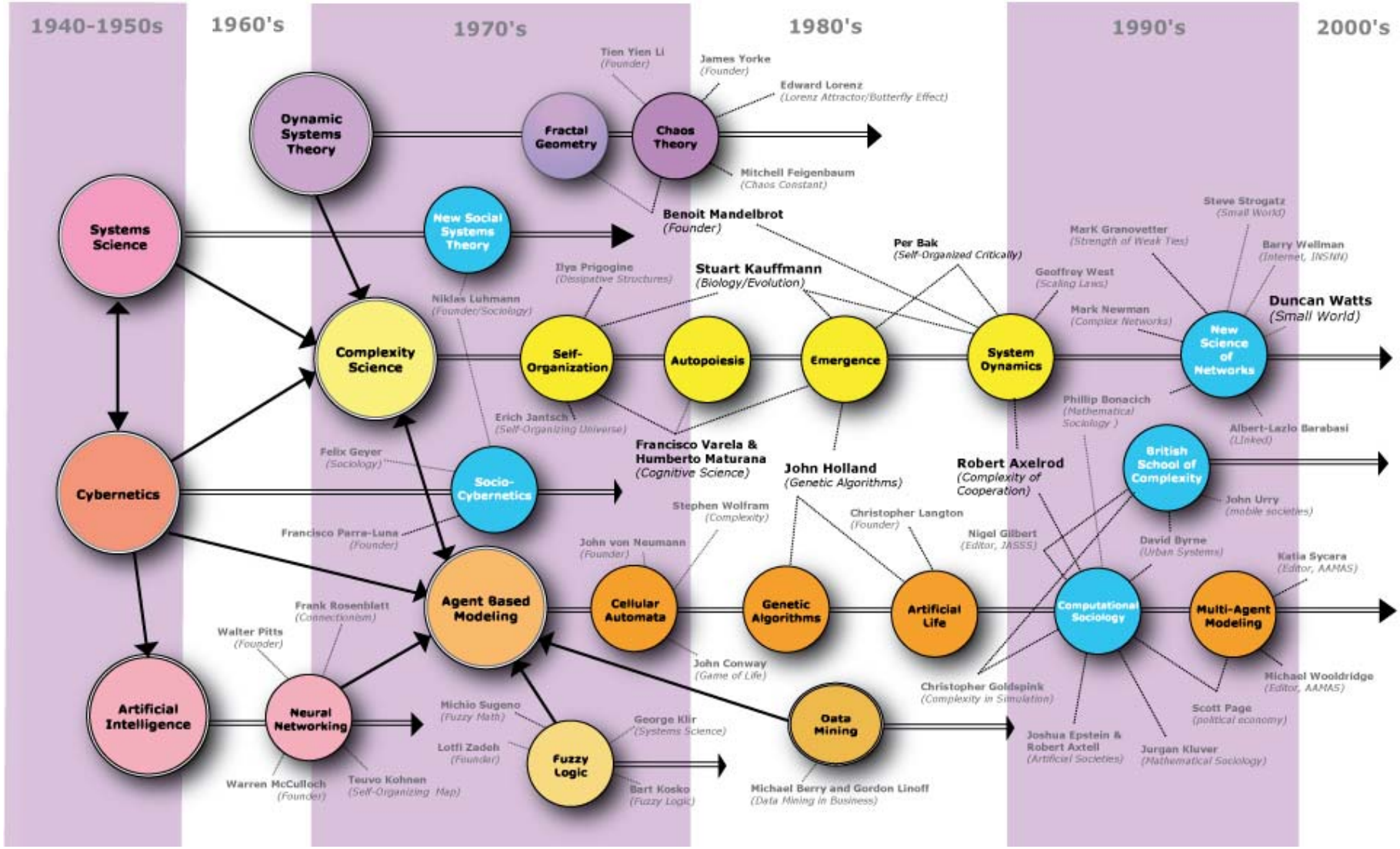
System Dynamics

"An approach to understanding the behaviour of complex systems over time. It deals with internal feedback loops and time delays that affect the behaviour of the entire system. What makes using system dynamics different from other approaches to studying complex systems is the use of feedback loops and stocks and flows. These elements help describe how even seemingly simple systems display baffling nonlinearity." (Wikipedia, 2014)

System Science(s): Study of systems



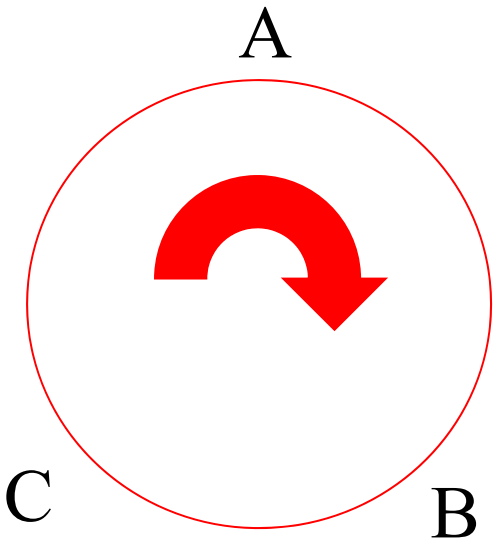
Linear Causality

A → B → C

A: Cause

B: Effect

Circular Causality



Feedback: shows how actions can reinforce (positive feedback) or counteract (balance through negative feedback) each other

Variables are organized in a circle or loop of cause-effect relationship called a "feedback process"

Feedback Processes

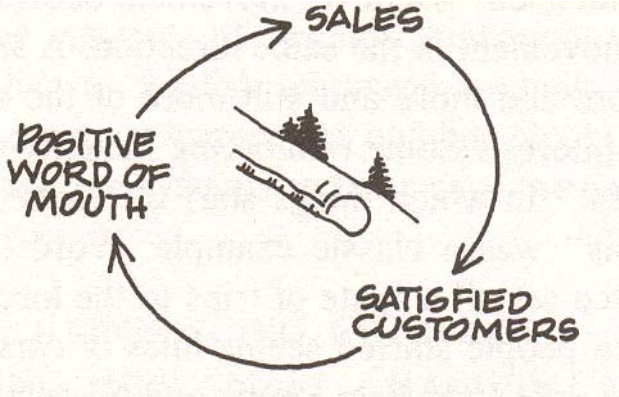
Reinforcing (R) or Amplifying

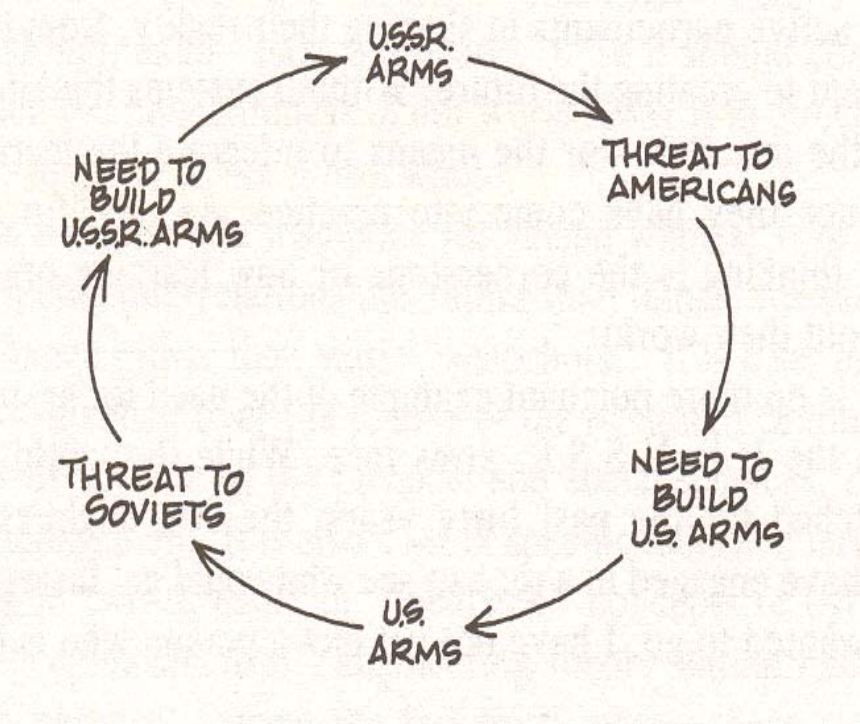
- Cause dramatic growth or collapse
- Amplifies change
- Snowballing effect
- Make something greater or less
- Accelerating growth or decline
- “Vicious cycles”, “self fulfilling prophecies”, “Virtuous cycles”

Balancing (B) or Stabilizing

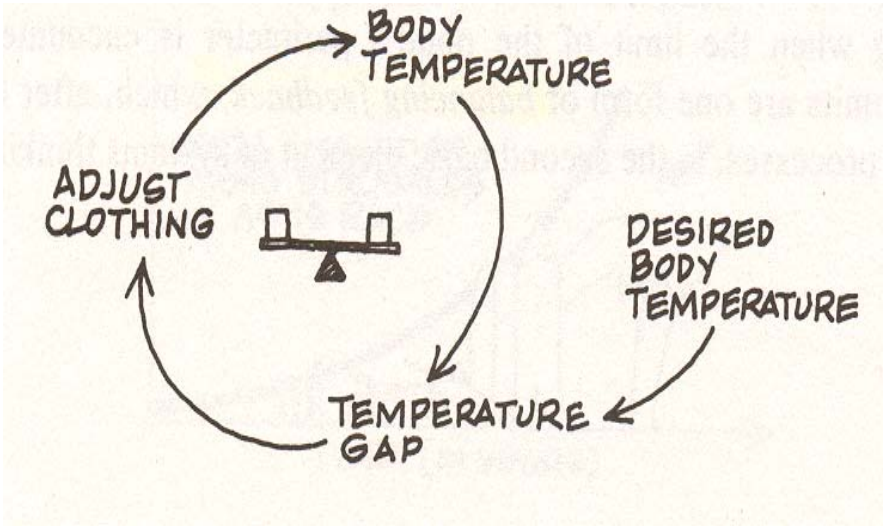
- Operates when there is a goal oriented behavior (implicit or explicit)
- Keep things under control
- Limit dramatic growth
- Ensure that systems fulfills its purpose
- Seeks equilibrium and stability
- Self correction to keep goal or target

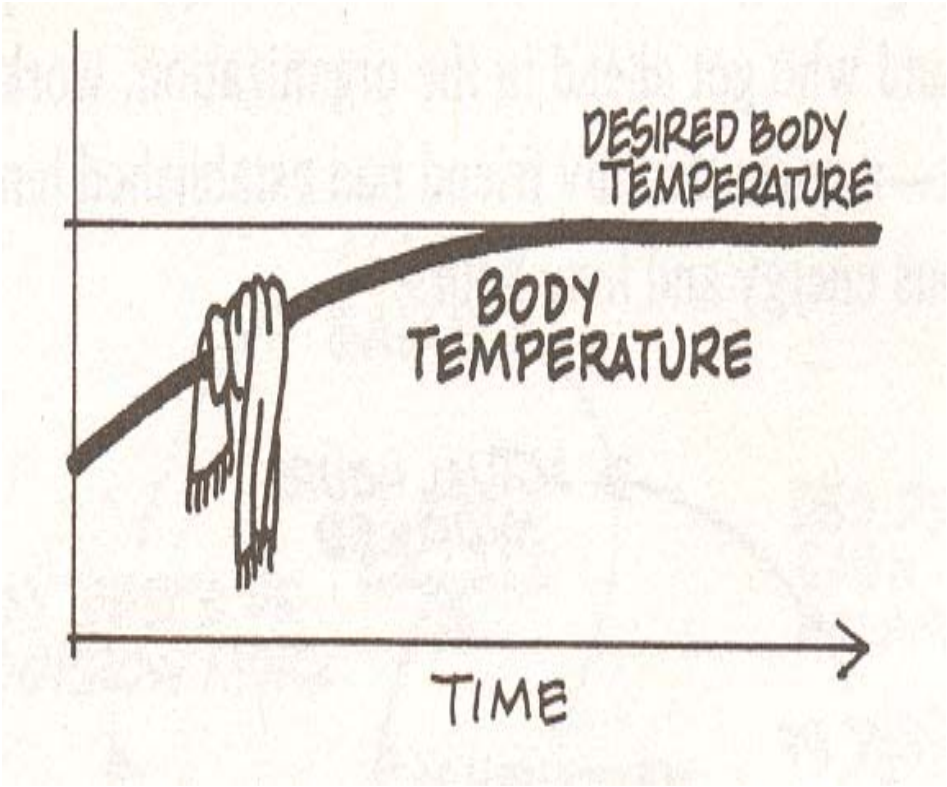
Reinforcing Feedback



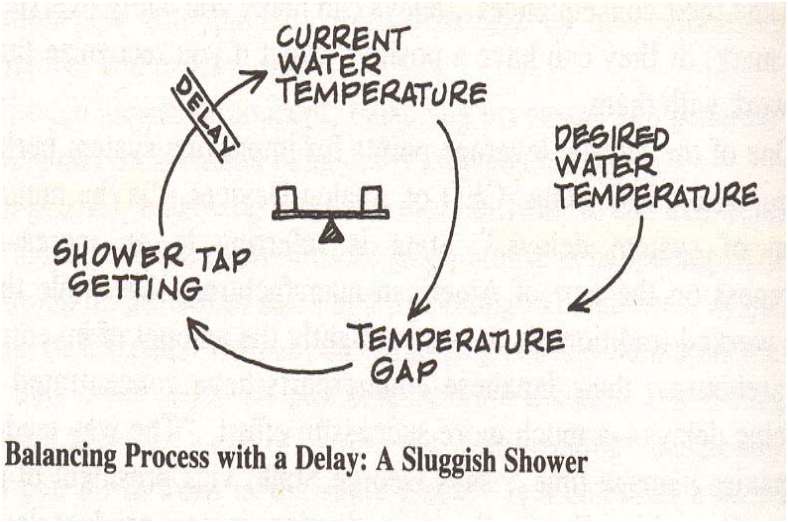


Balancing Feedback

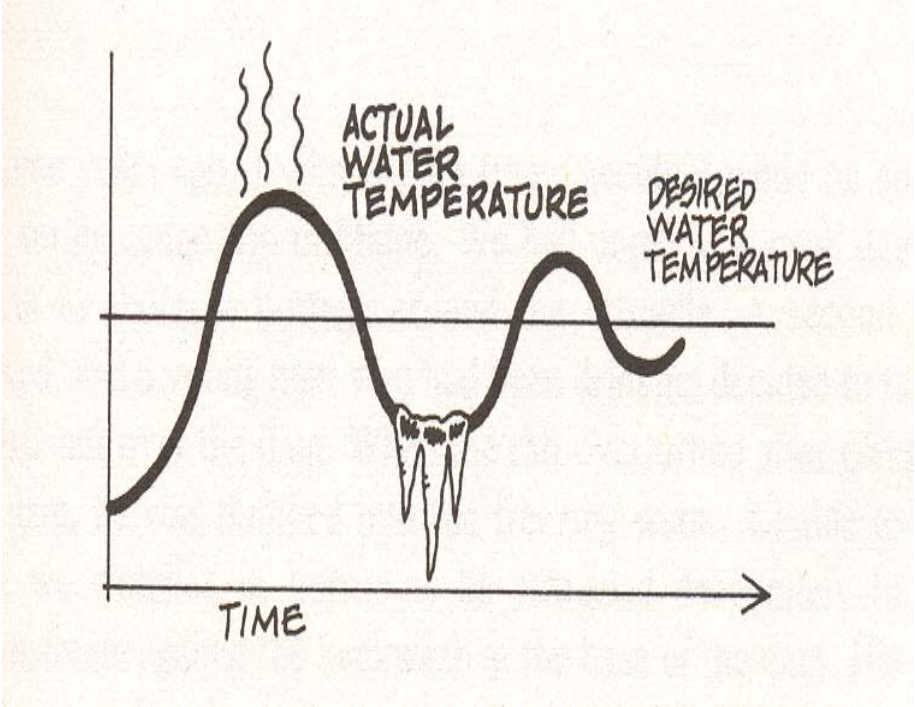




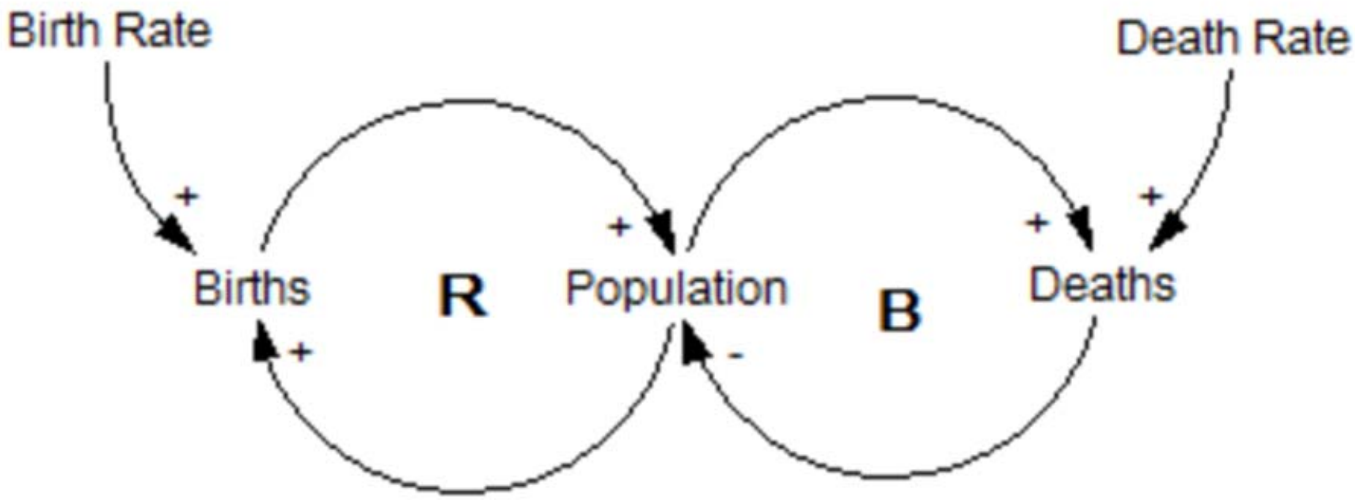
Delay = interruption between actions and their consequences

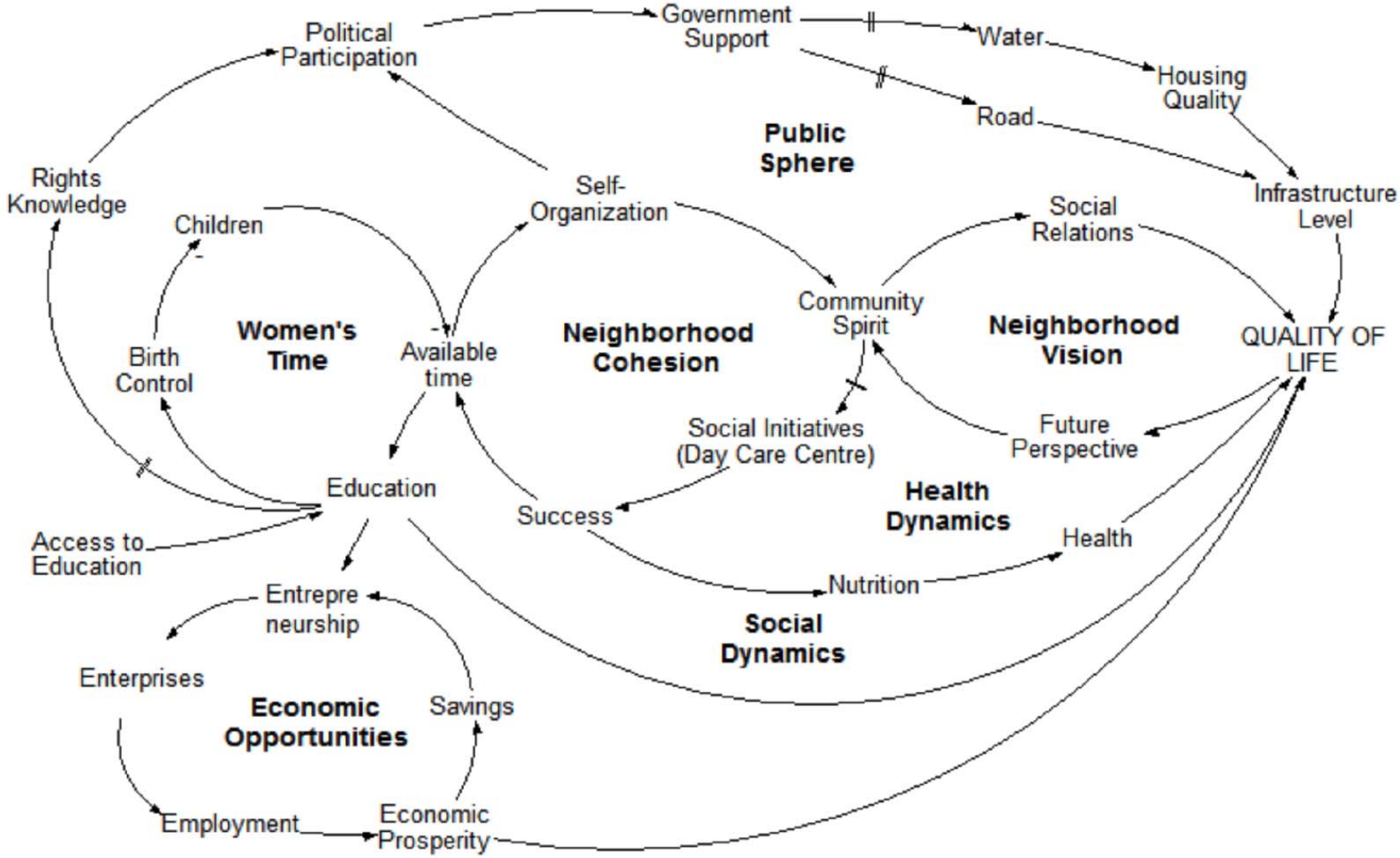


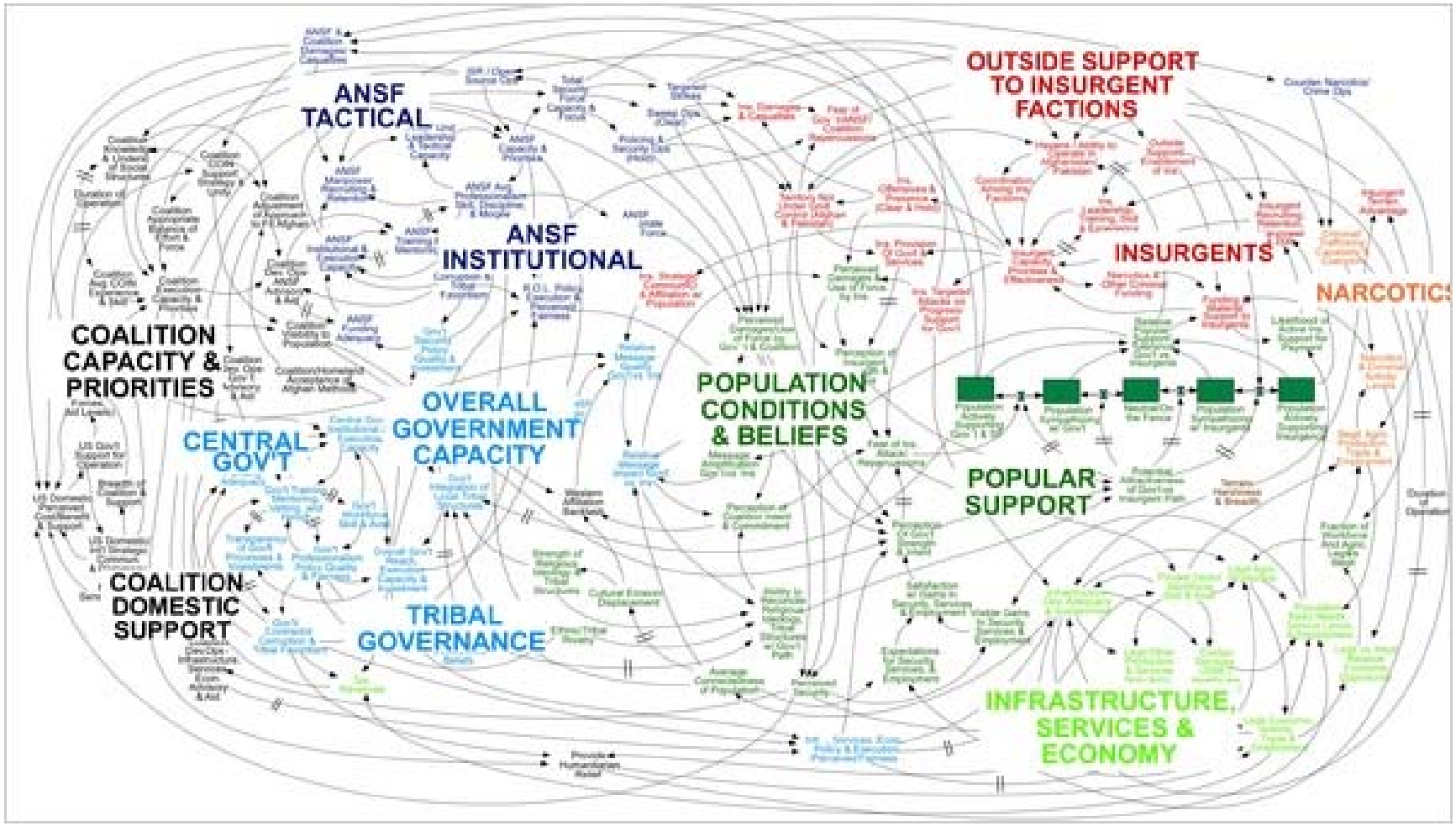
Balancing Process with a Delay: A Sluggish Shower



Causal Loop Diagrams (CLDs)

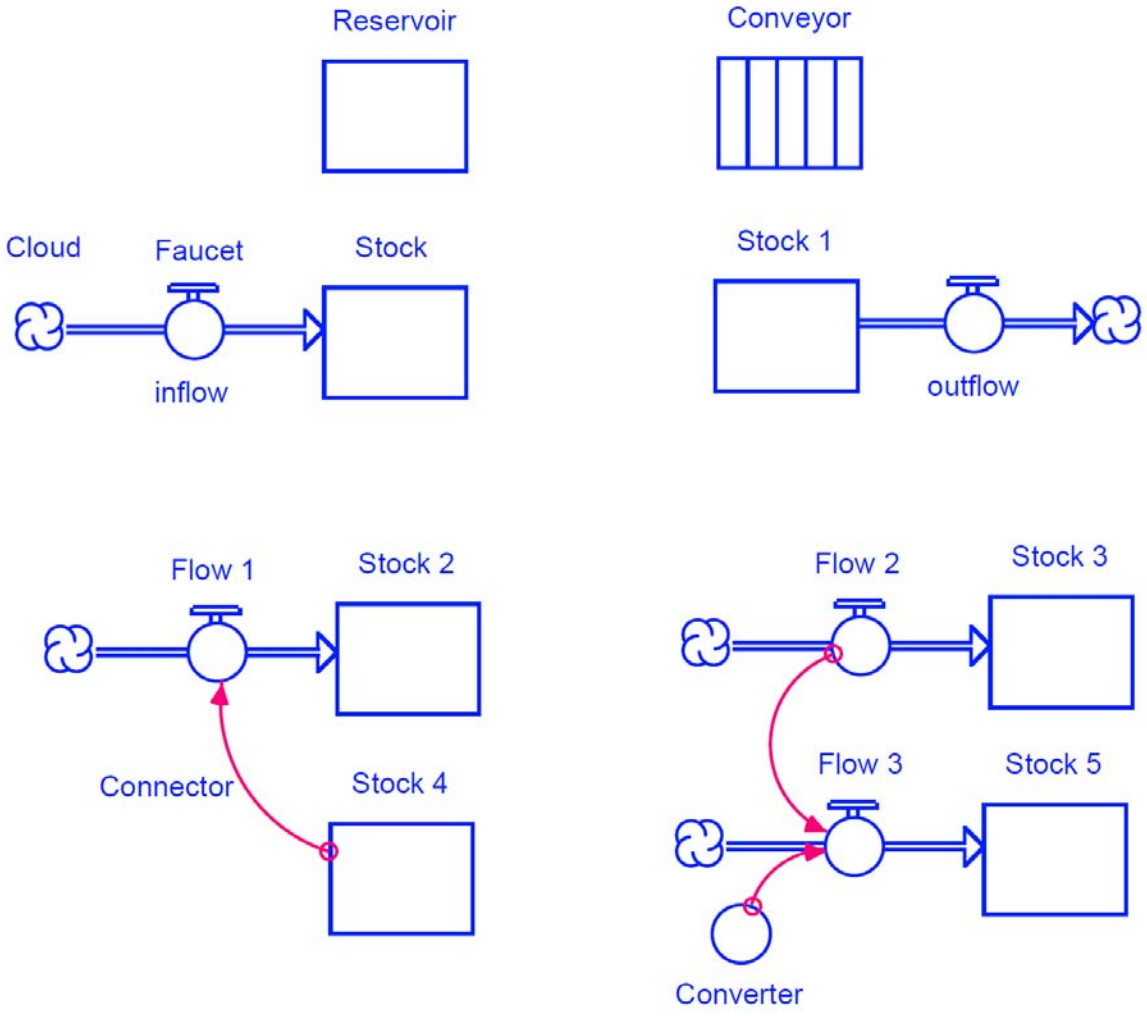


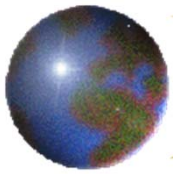

Political Participation
Government Support
Water
Housing Quality
Road
Public Sphere
Rights Knowledge
Self-Organization
Infrastructure Level
Children
Social Relations
Community Spirit
Women's Time
Neighborhood Cohesion
Neighborhood Vision
QUALITY OF LIFE
Birth Control
Available time
Social Initiatives (Day Care Centre)
Future Perspective
Education
Success
Health Dynamics
Access to Education
Health
Nutrition
Entrepreneurship
Social Dynamics
Enterprises
Economic Opportunities
Savings
Employment
Economic Prosperity



http://www.nytimes.com/2010/04/27/world/27powerpoint.html?_r=0

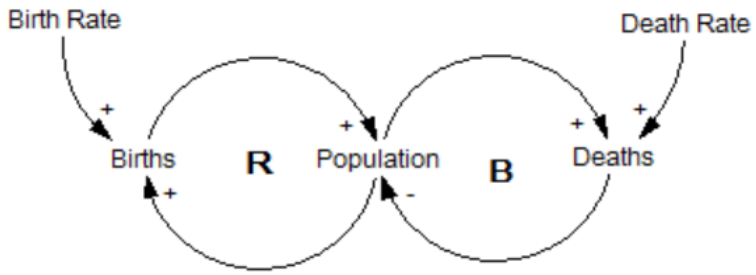
Stock and Flow Diagrams

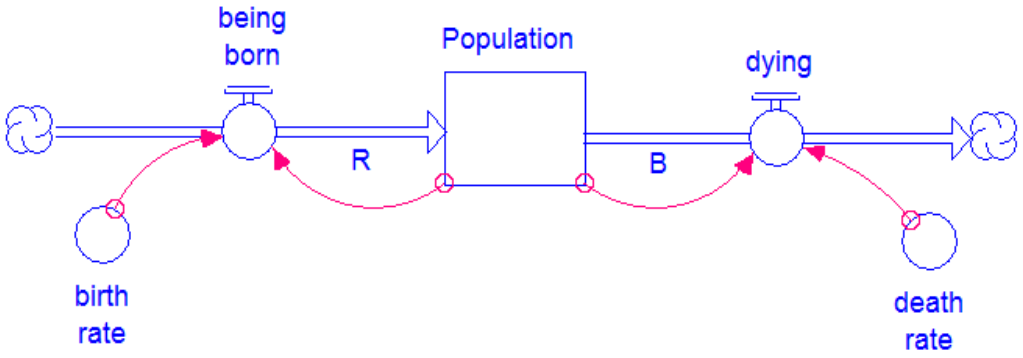




Flow and Stock

- Stock: Anything that accumulate and can be measured at one point in time (water in bathtub or behind a dam, population, wood in the forest, etc.)
- Flow: Anything that changes over time (number of births, inflation rate, etc.). Inflows and outflows
- Stock and flow obey laws of conservation and accumulation


Birth Rate
Death Rate
+
+
+
+
Births
R
Population
B
Deaths
+
-

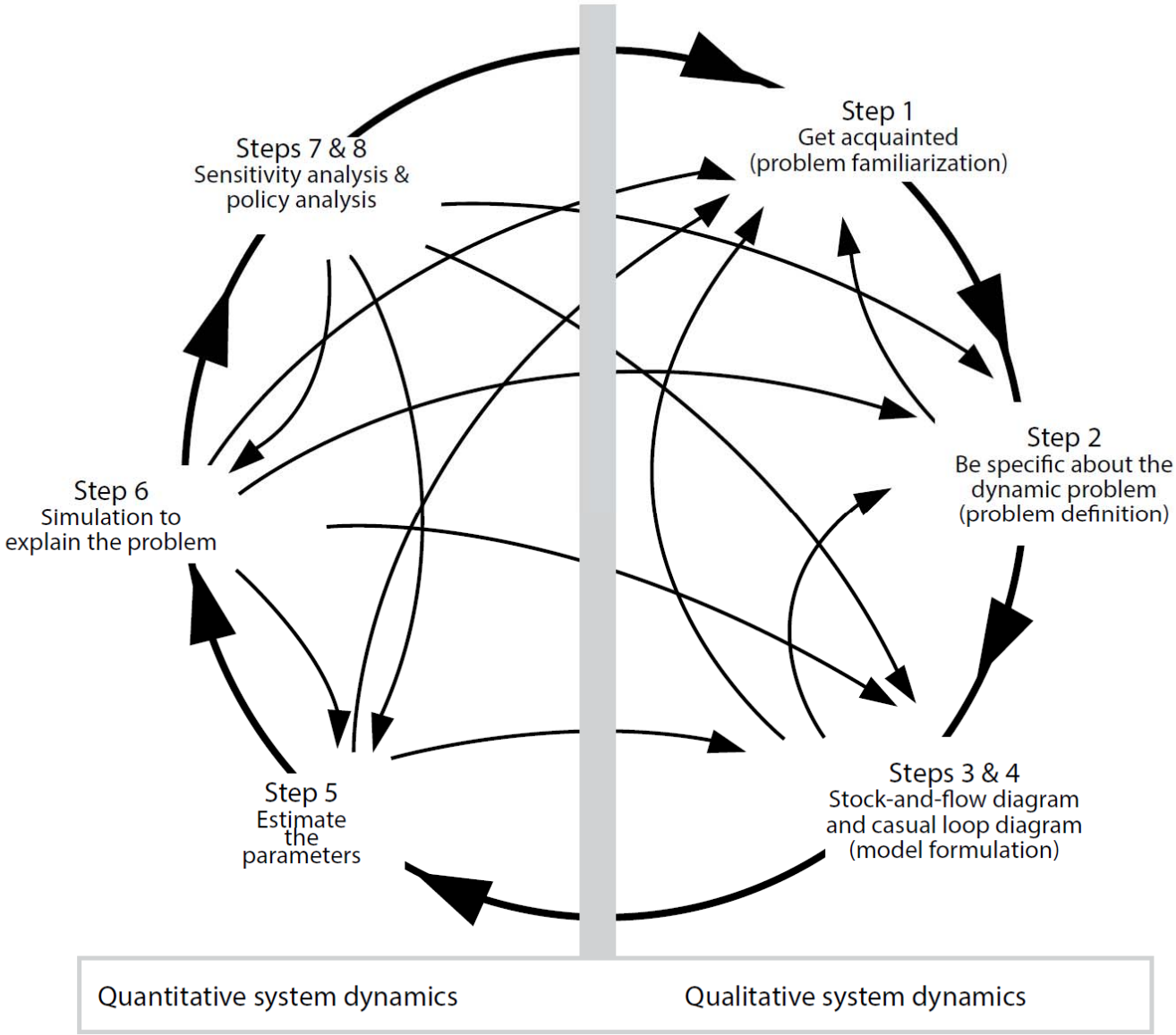

being
born
Population
dying
R
B
birth
rate
death
rate

	Tangible	Intangible
Stocks	Populations (male, female) Food Energy Resources Land Houses Labor (jobs) Trees Roads, traffic, vehicles Water, Pollutants Cash Cattle Equipment	Poverty or wealth Quality of life Happiness Health Hunger Quality Anger Satisfaction Confidence Morale Motivation Attractiveness Leadership
Flow	Hiring, lay-off Saving Producing Being born, dying Constructing Depreciating Being infected Adopting Earning, spending Pumping, recharging Evaporating, infiltrating	Learning Growing Becoming aware Contributing Leading Managing Changing behavior Liking, disliking Becoming sustainable Understanding Assuming

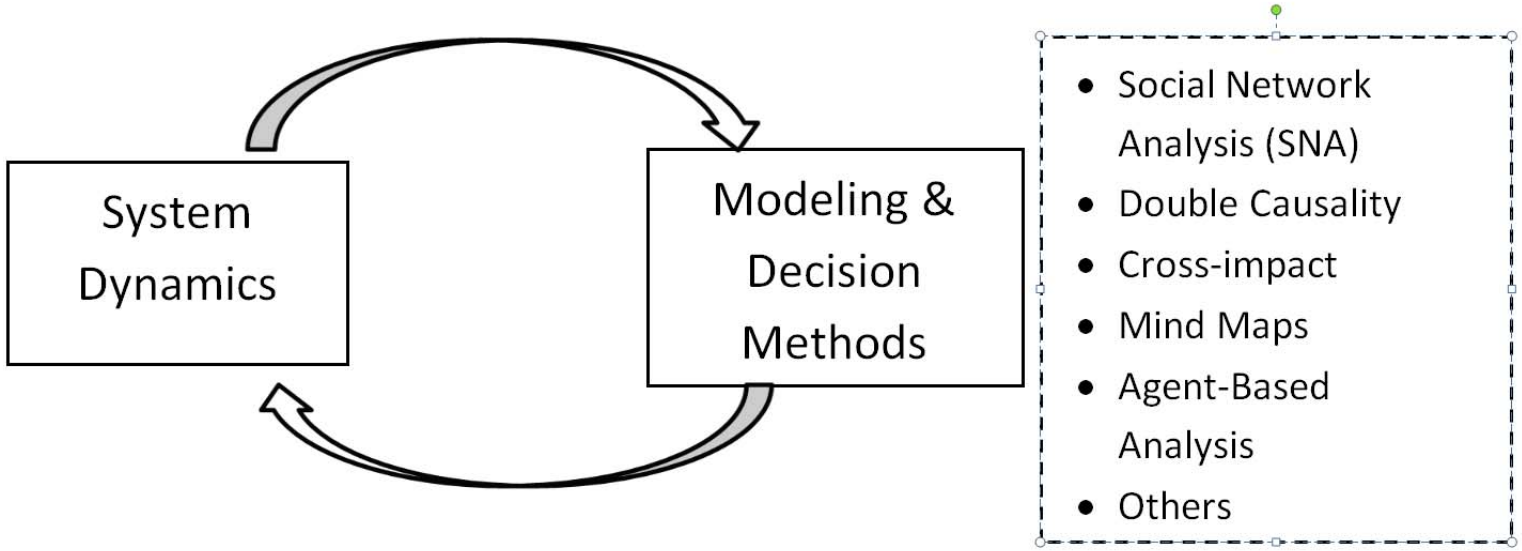
Using iThink or Stella

- Trademark of Isee systems (www.iseesystems.com)
- Introduction to Systems Thinking by Richmond (2004 a,b).
- Other SD software include Vensim and Powersim.

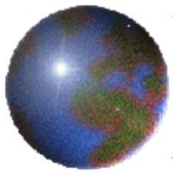
System Dynamics Modeling and Archetypes


Step 1
Get acquainted
(problem familiarization)
Step 2
Be specific about the
dynamic problem
(problem definition)
Steps 3 & 4
Stock-and-flow diagram
and casual loop diagram
(model formulation)
Step 5
Estimate
the
parameters
Step 6
Simulation to
explain the problem
Steps 7 & 8
Sensitivity analysis &
policy analysis
Quantitative system dynamics
Qualitative system dynamics

Mixed Modeling Methods

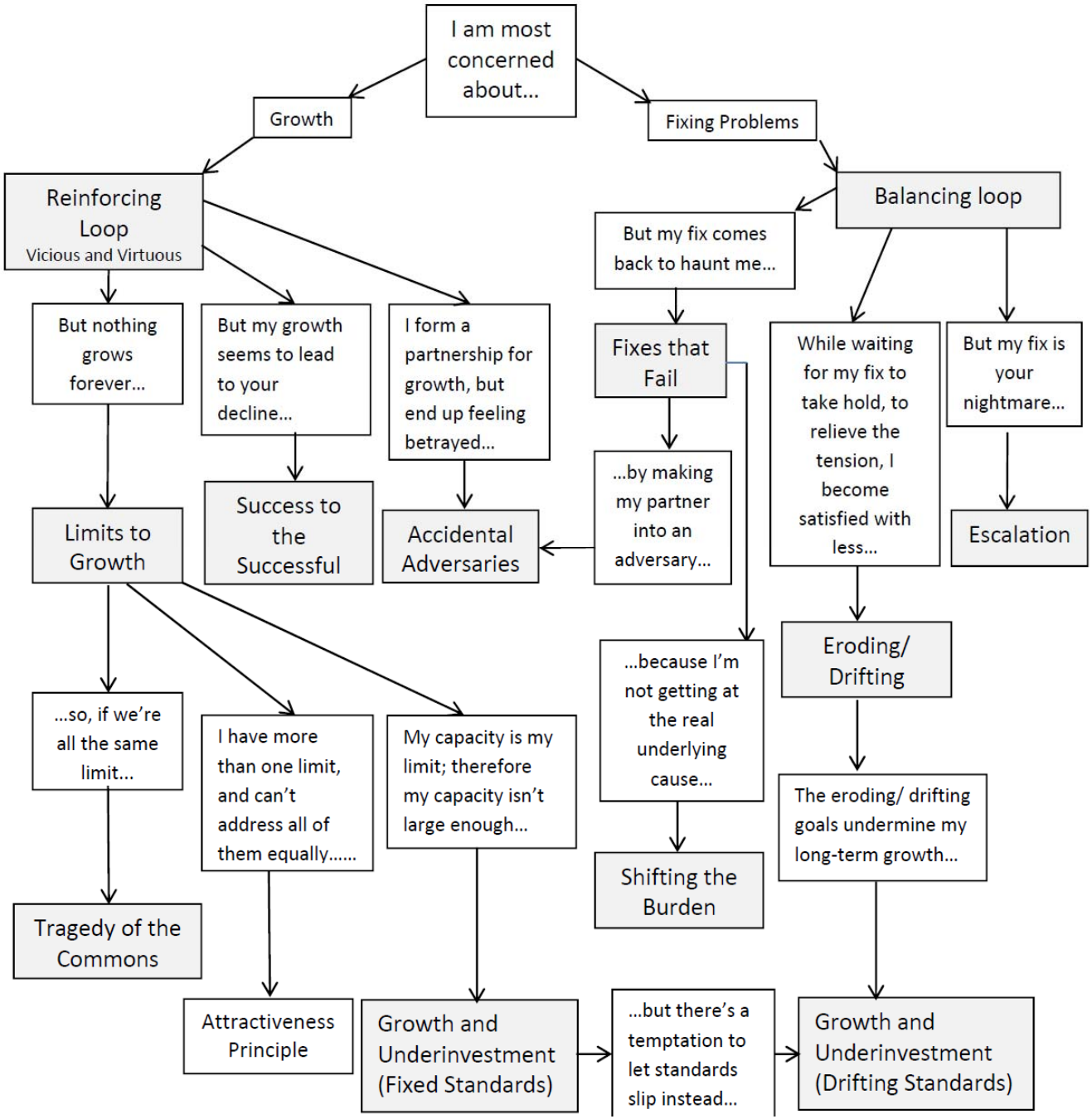


Why	• Why is a dynamic model constructed?
What	• What problem and behavior (reference mode) is being modeled and over what time frame and spatial scale? • What methods other than (or complimentary to) dynamic modeling can be used to model the problem? • What would happen if the problem were or were not addressed? • What solutions have been attempted in the past to address the problem and what were their outcomes? • What are the components of the problem being addressed and their connections? • What range of responses can be expected from the model?
How	• How will the model complement the traditional steps of project management? • How have the components of the model interacted in the past? • How will community members be involved in building, reviewing, and updating the model? • How will the model recommendations be presented to the community members?
Who	• Who is participating in developing the model (insiders and outsiders)?
When	• When should the model be integrated into project management? • When should the model be started, evaluated, modified, and updated?
Where	• Where should model development and community interaction take place (office, community)?



Systems Archetypes (archetypos = first of its kind)

- Limits to growth
- Fixes that backfire
- Shifting the burden
- Eroding goals
- Escalation
- Success to the successful
- Tragedy of the commons
- Growth and under-investment
- Balancing process with delay


I am most concerned about...
Growth
Fixing Problems
Reinforcing Loop
Vicious and Virtuous
Balancing loop
But my fix comes back to haunt me...
But nothing grows forever...
But my growth seems to lead to your decline...
I form a partnership for growth, but end up feeling betrayed...
Fixes that Fail
While waiting for my fix to take hold, to relieve the tension, I become satisfied with less...
But my fix is your nightmare...
Limits to Growth
Success to the Successful
Accidental Adversaries
...by making my partner into an adversary...
Escalation
...so, if we're all the same limit...
I have more than one limit, and can't address all of them equally.....
My capacity is my limit; therefore my capacity isn't large enough...
...because I'm not getting at the real underlying cause...
Eroding/ Drifting
Tragedy of the Commons
Shifting the Burden
The eroding/ drifting goals undermine my long-term growth...
Attractiveness Principle
Growth and Underinvestment (Fixed Standards)
...but there's a temptation to let standards slip instead...
Growth and Underinvestment (Drifting Standards)