An Introduction to System Dynamics

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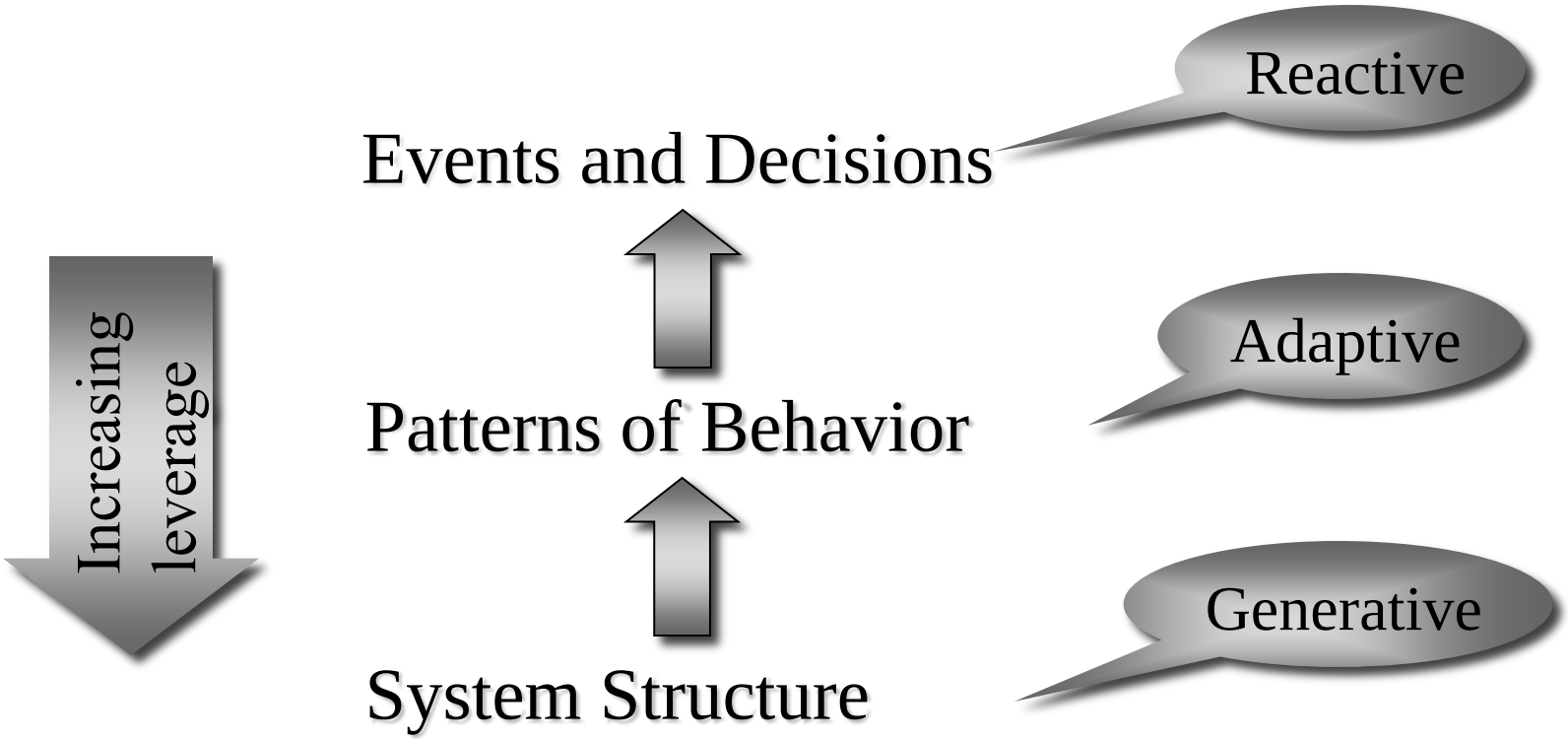
A Systems Perspective



“Distancing...”

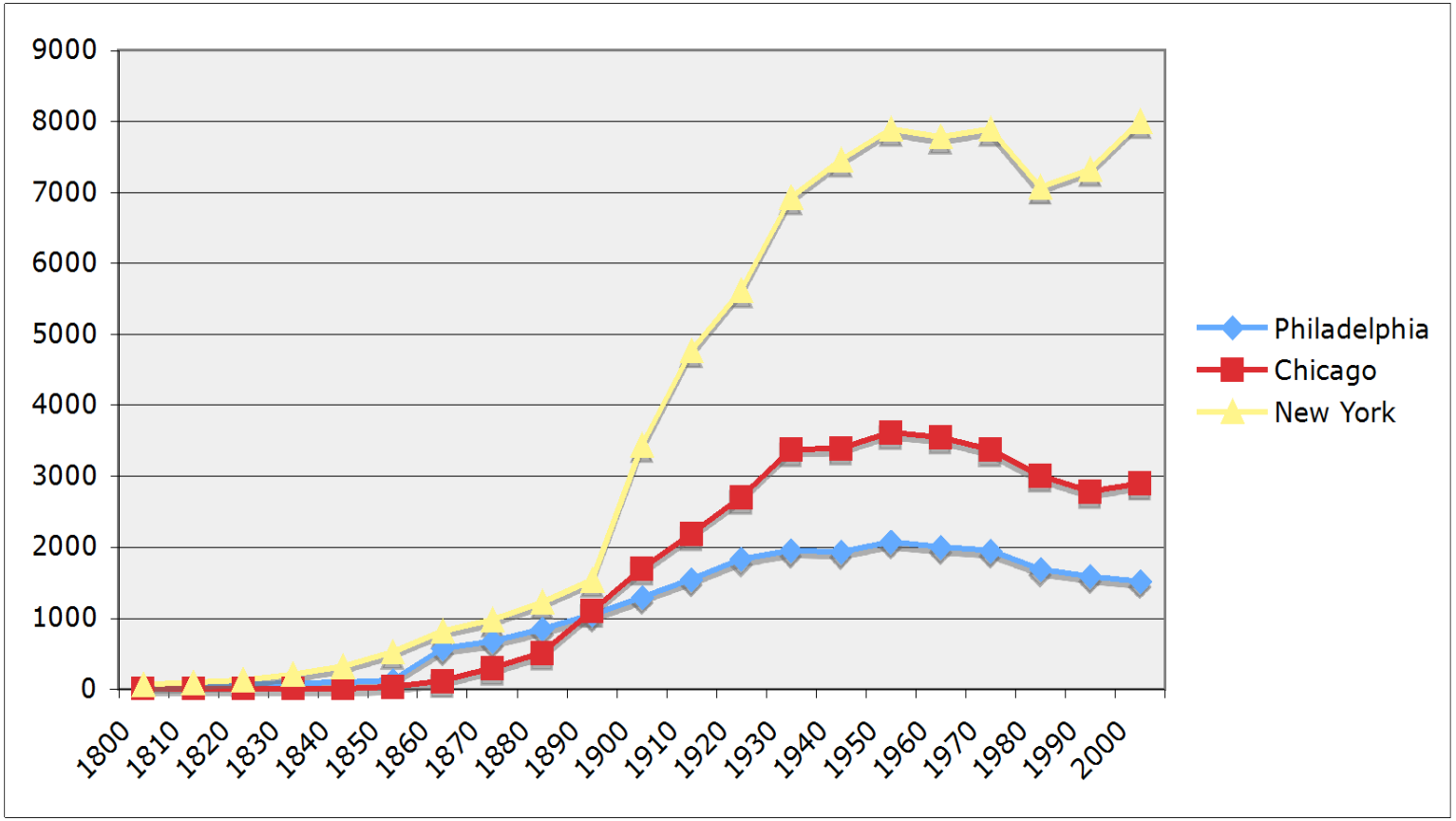
A systems view stands back just far enough to...

- Deliberately blur discrete events into patterns of behavior
- Deliberately move from a focus on individual decisions to a focus on policy structure

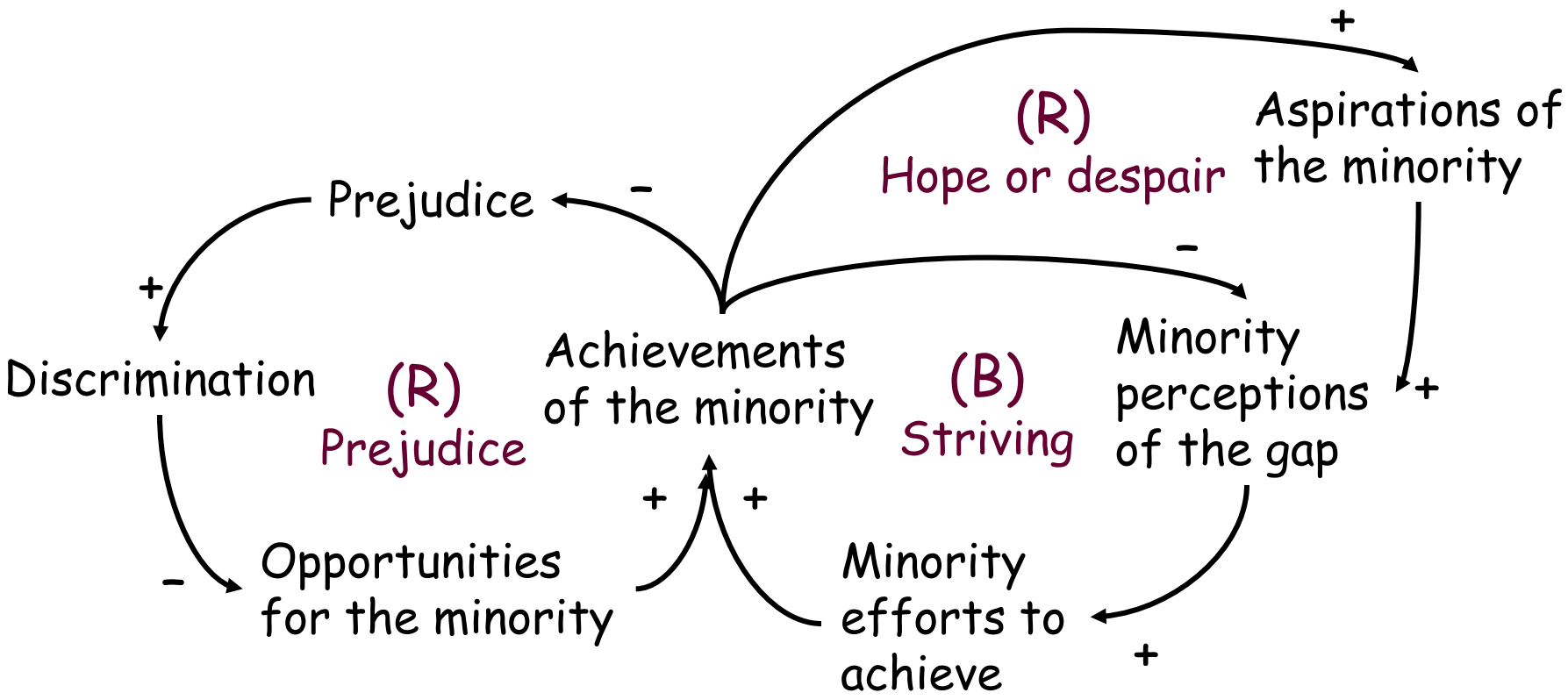
Four Key Patterns of Thought

- Dynamic thinking (graphs over time)
- Causal thinking (feedback loops)
- Stock-and-flow thinking (accumulations)
- Thinking endogenously (system as cause)

New York, Chicago & Philadelphia, 1800-2000

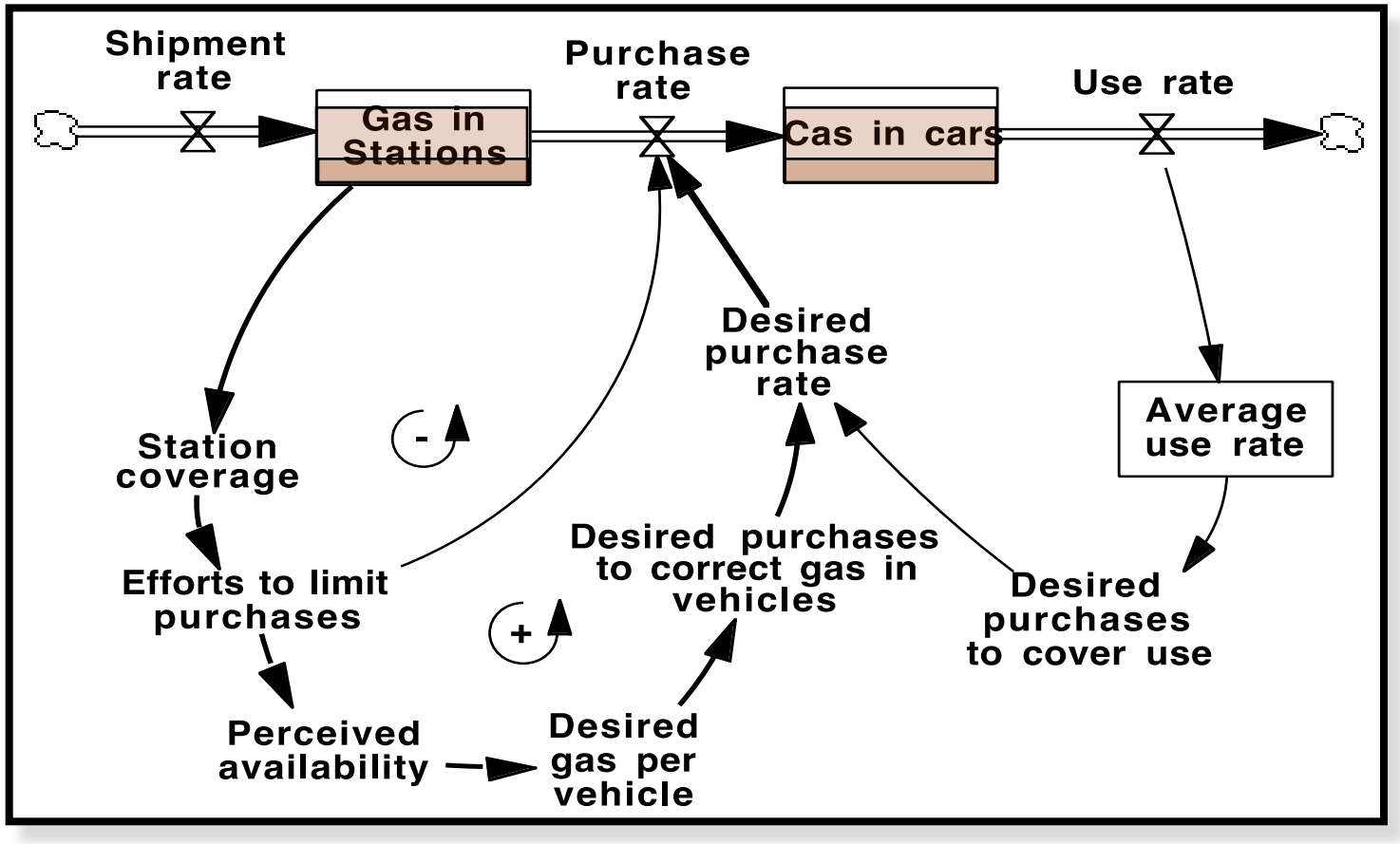


Prejudice and Minority Achievement (Myrdal, Merton)



Stocks, Flows, and Feedback Loops

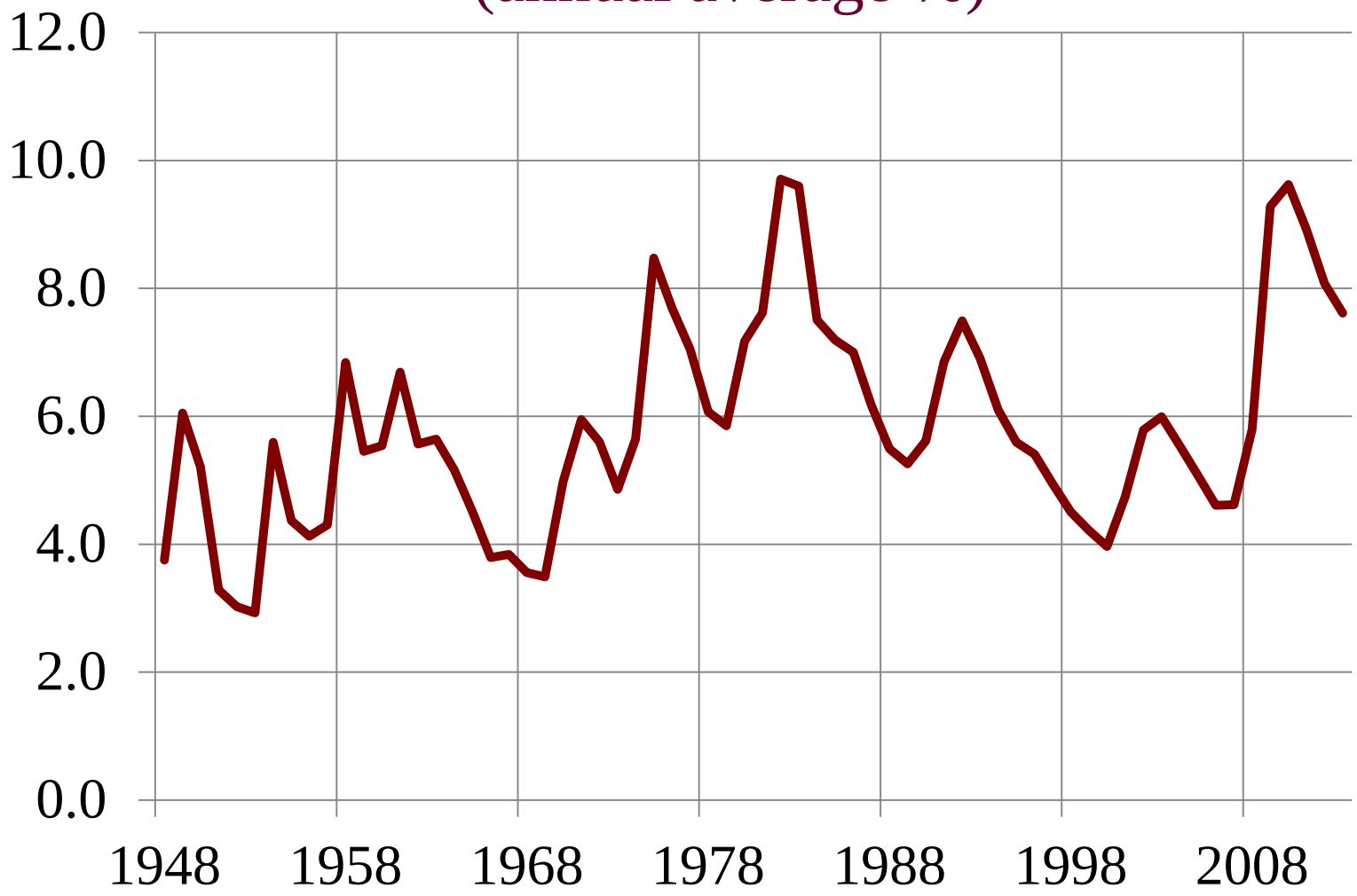
Here: a gasoline shortage crisis



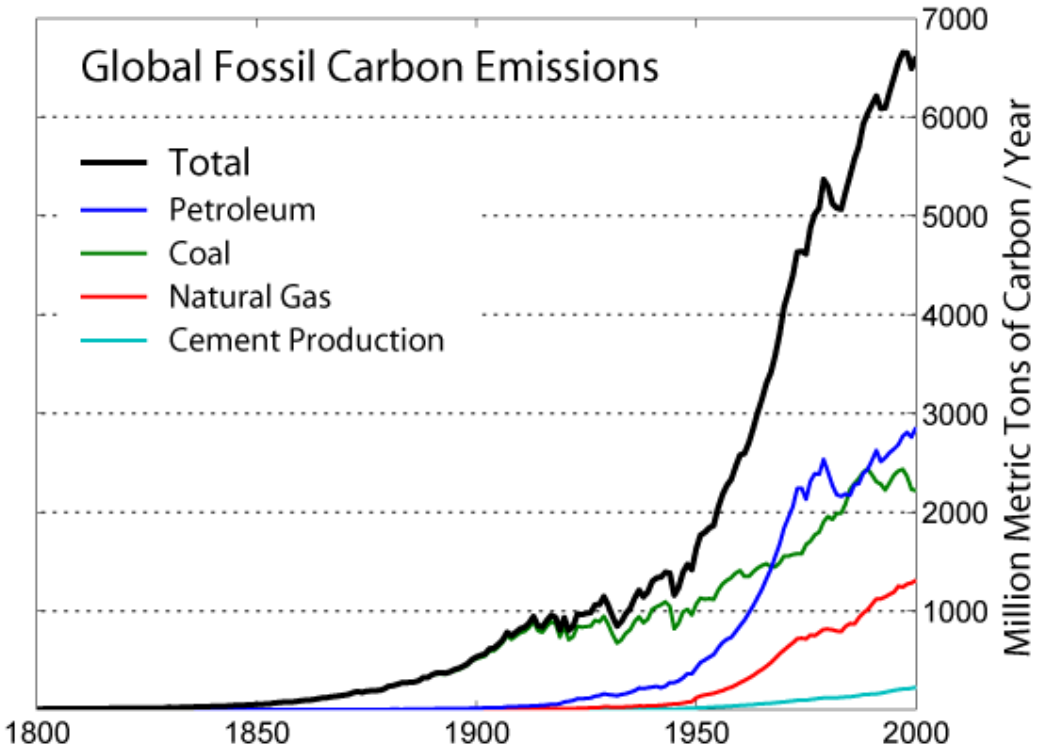
Dynamics

- Define problems in terms of graphs over time.
  - Graph important variables
  - Graph historical data
  - Graph anticipated dynamics
  - Graph preferred dynamics
- Use these to focus systems thinking and modeling

U.S. Unemployment 1948-2012
(annual average %)



Carbon Emissions 1800-2000

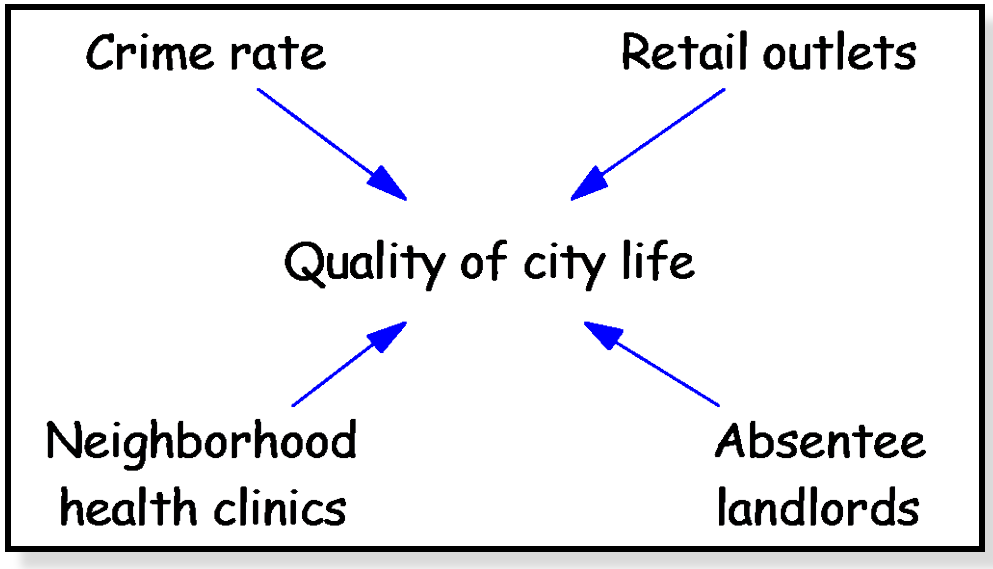


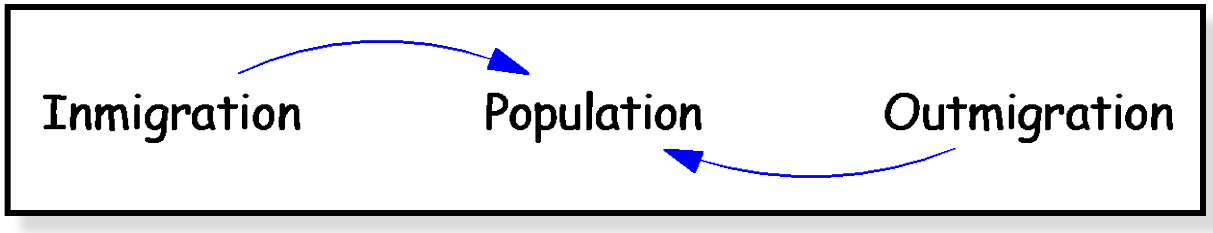
Systems Structure

- Accumulations (populations, resources…)
- Causal structure: “feedback” loops
- Delays
- Perceptions (a kind of accumulation)
- Pressures
- Affects, emotions, (ir)rationalities
- Policies governing decisions

Causal Diagrams

- Causal mapping is a powerful tool for representing structure in complex systems.
- Arrows indicate *causal* influence.



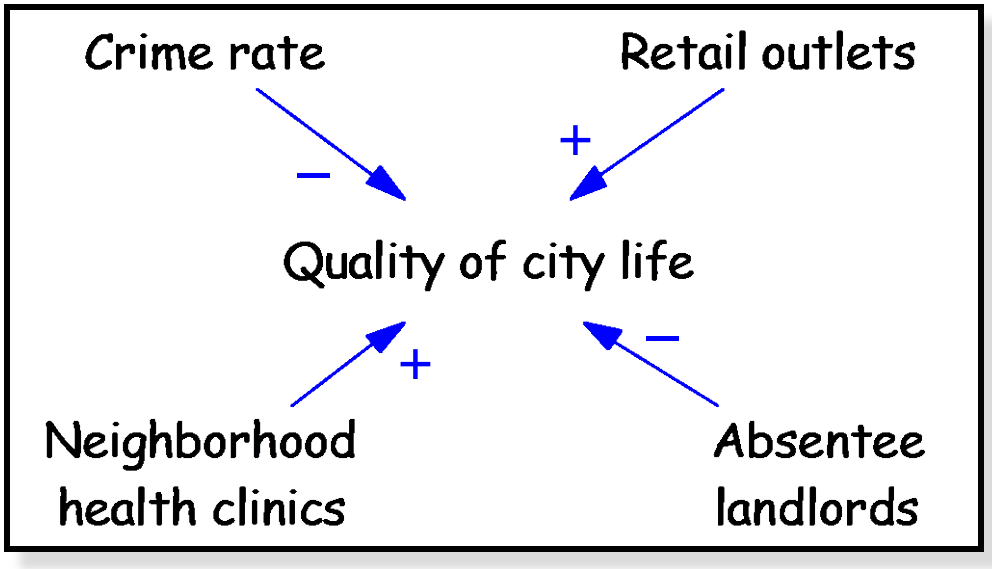


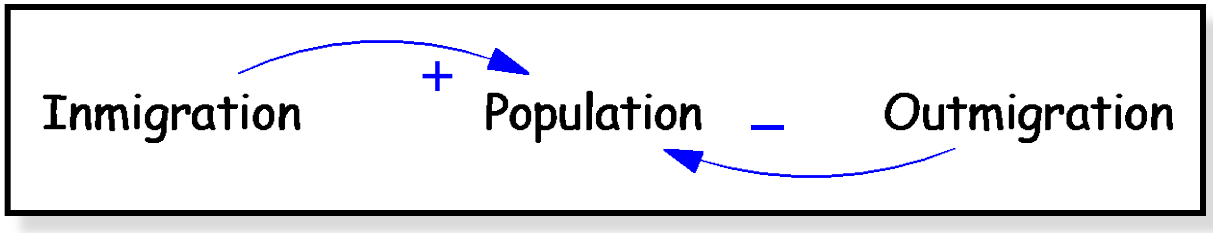
Polarities of Causal Links

- Positive and negative signs show the direction of causality:

  + ... "direct" relation

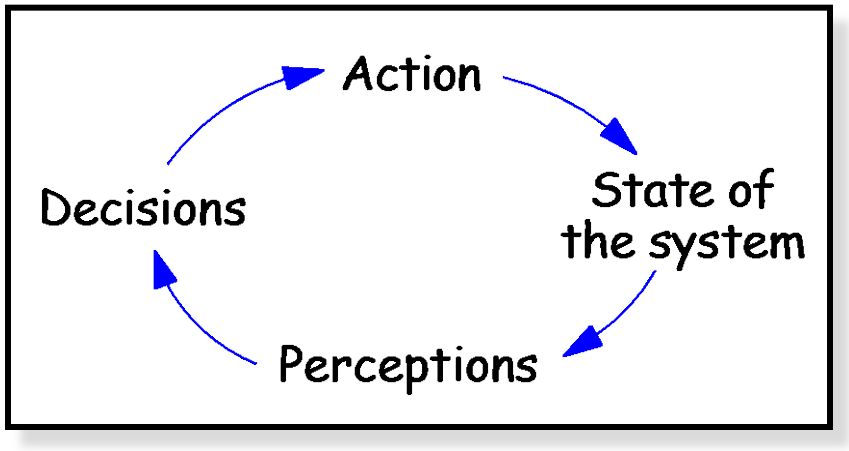
  – …"inverse" relation





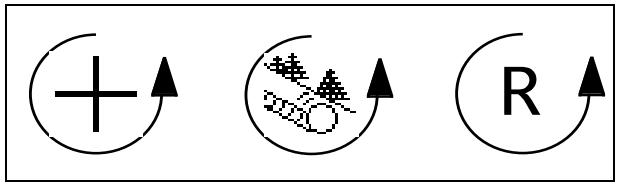
Feedback Loops

A feedback loop exists when decisions change the state of the system, changing the conditions and information that influence future decisions.

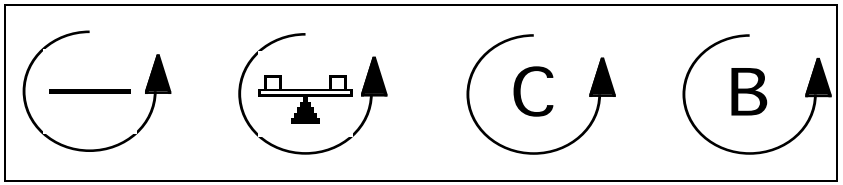


Two kinds of feedback loops

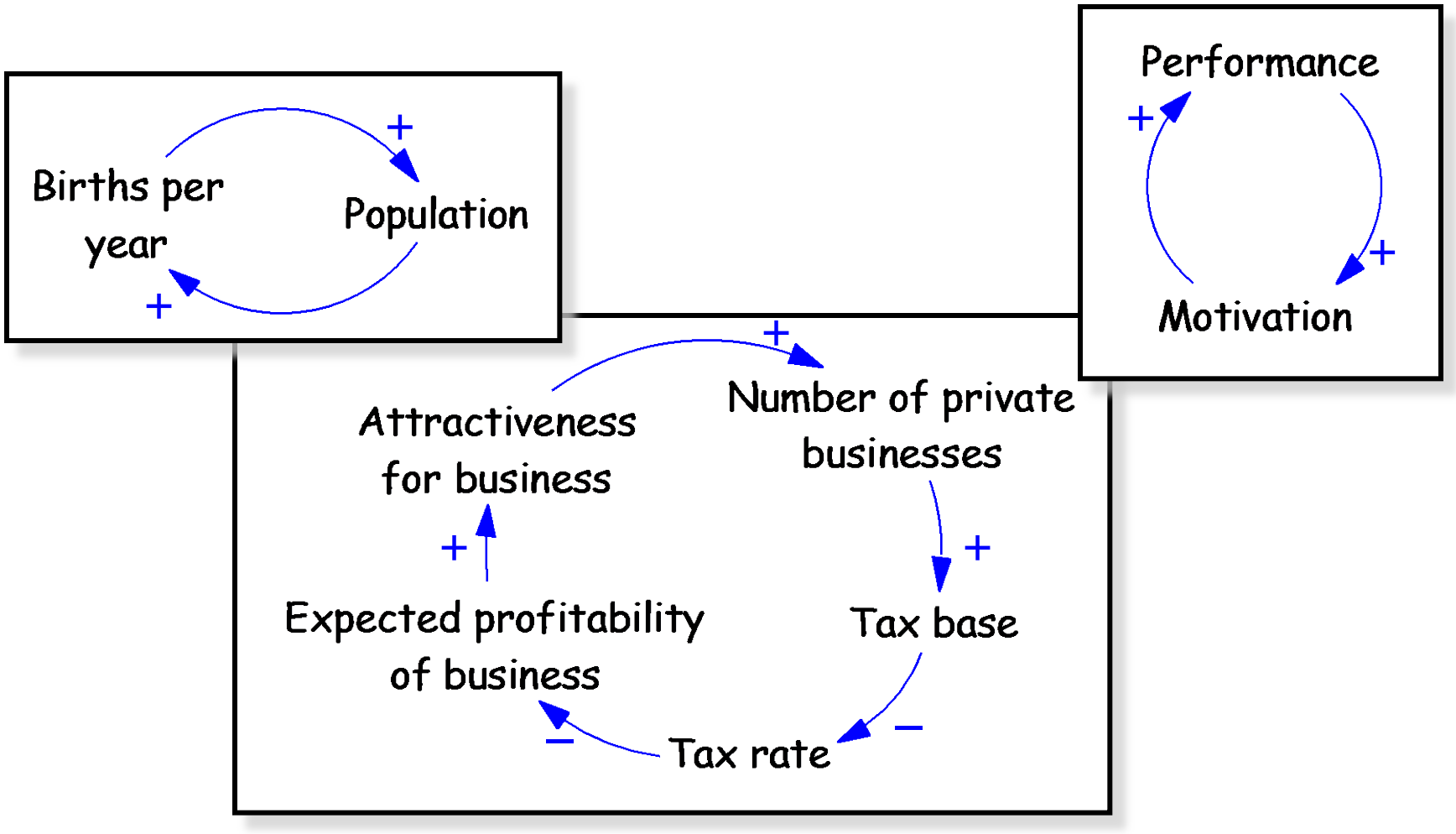
- **Reinforcing loops**
  - Growth producing
  - Destabilizing
  - Accelerating
  - Positive: an even number of –'s
- **Symbolized by**



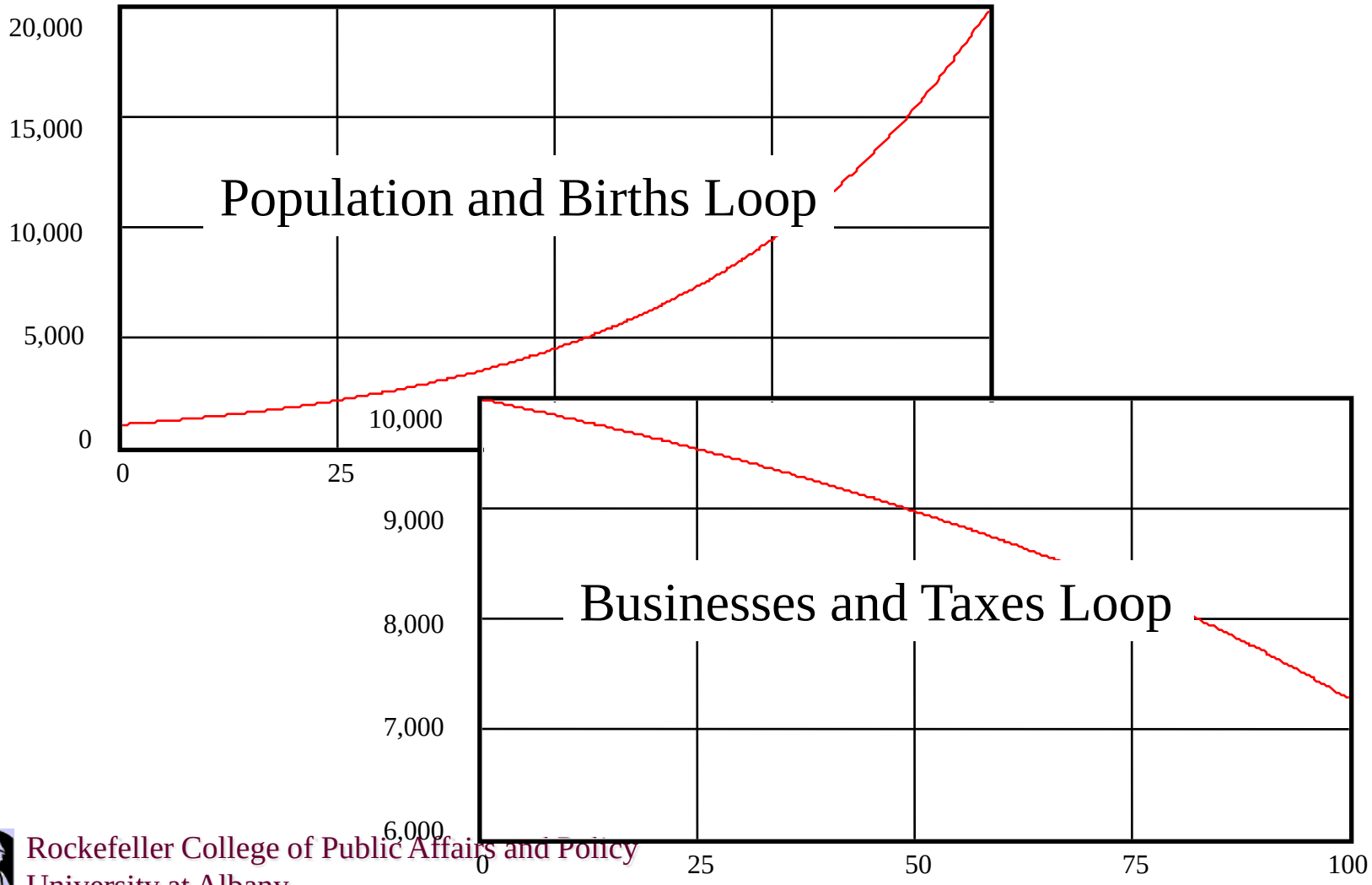
- **Balancing loops**
  - Counteracting
  - Goal seeking
  - Stabilizing
  - Negative: an odd number of –'s
- **Symbolized by**



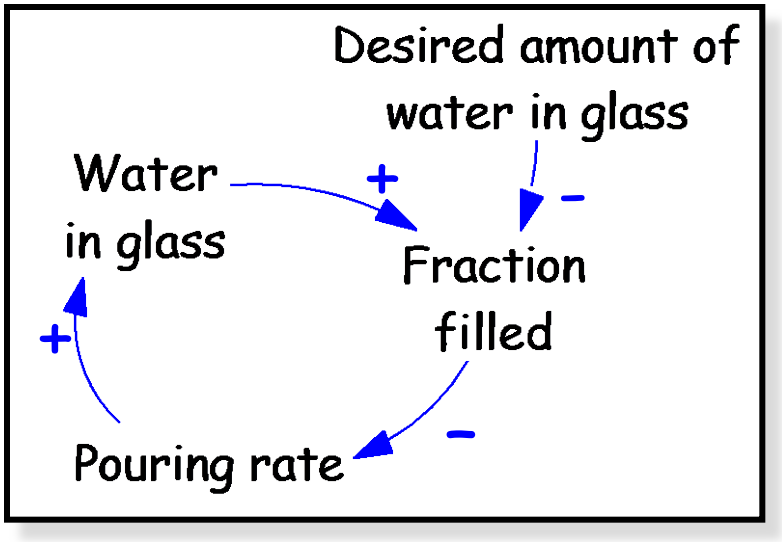
Examples of Reinforcing Loops

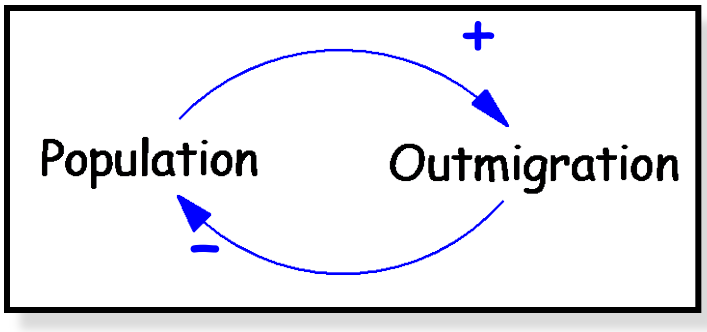


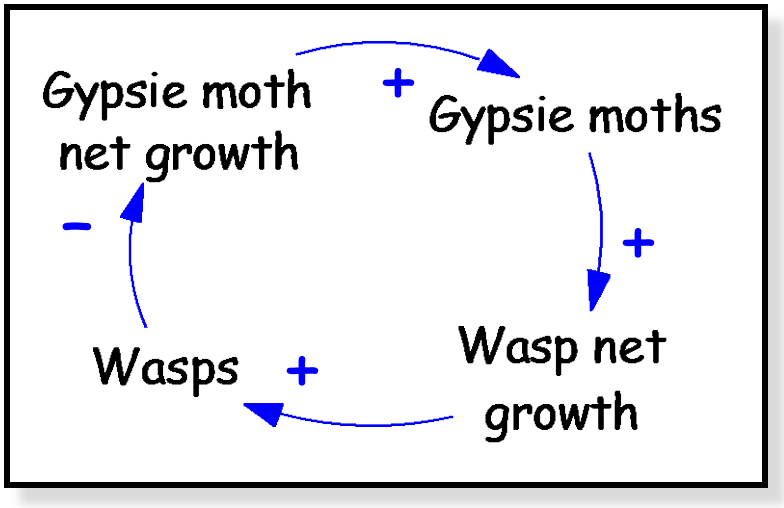
Typical Reinforcing Loop Behaviors



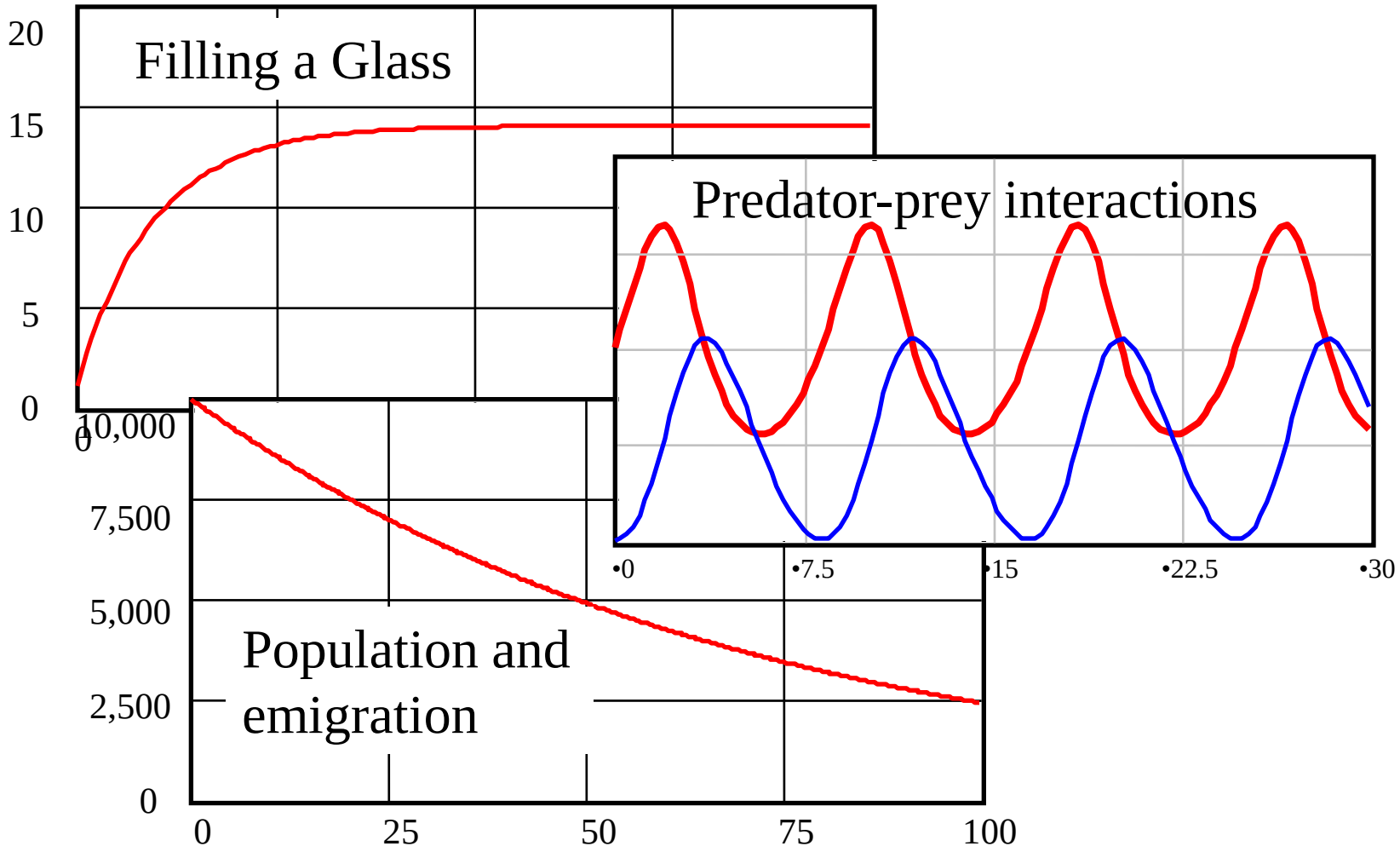
Examples of Balancing or Counteracting Loops



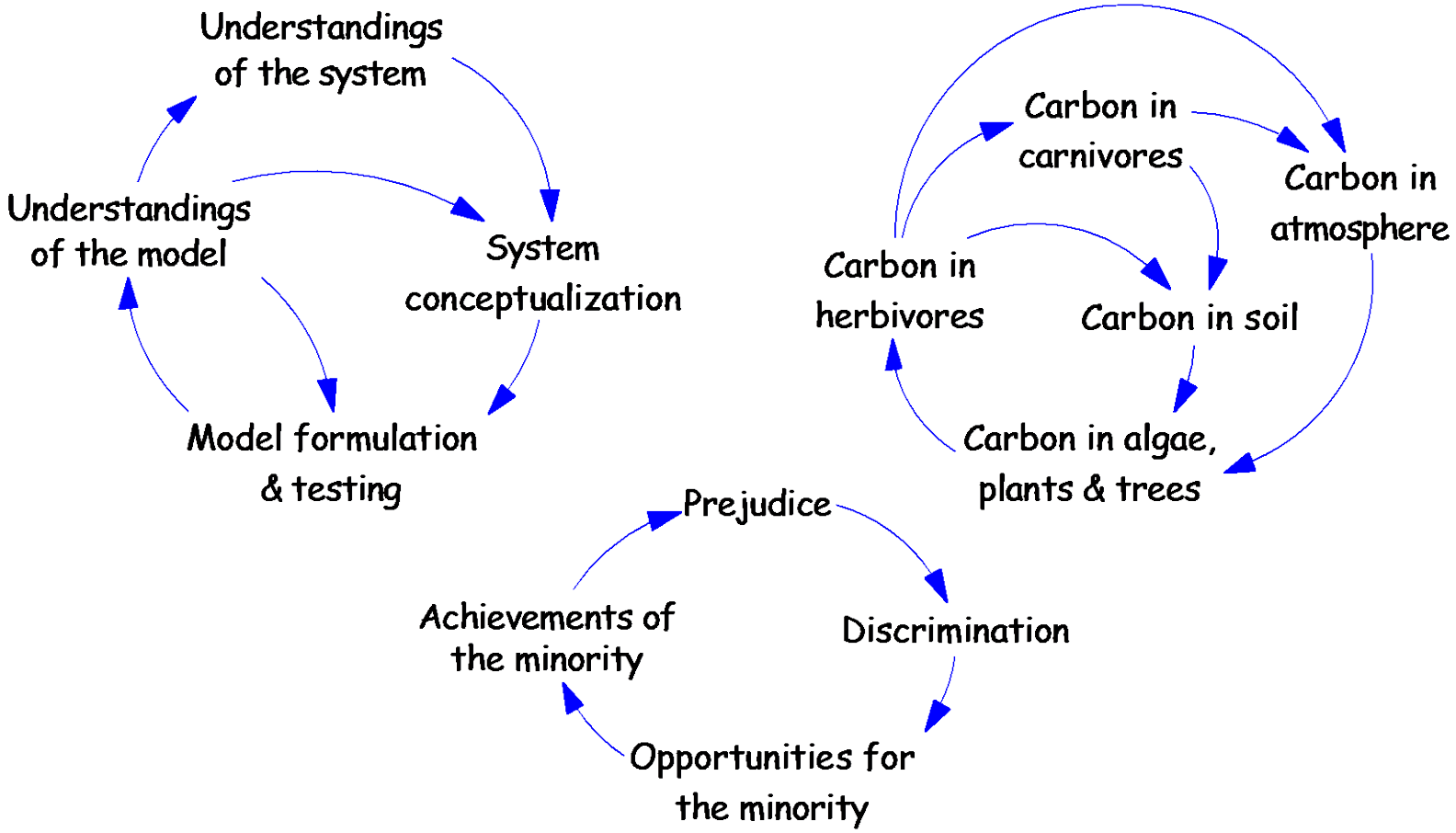




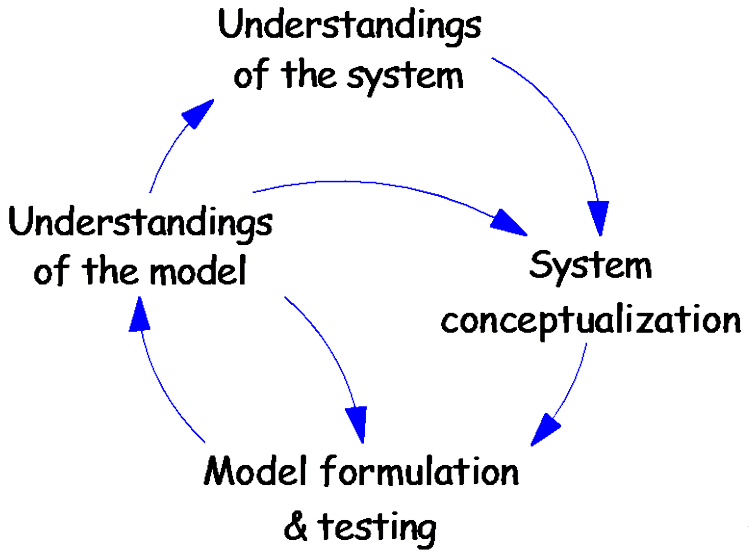
Typical Counteracting Loop Behaviors



But There are Subtleties:
Not all Word-and-Arrow Diagrams are Alike!



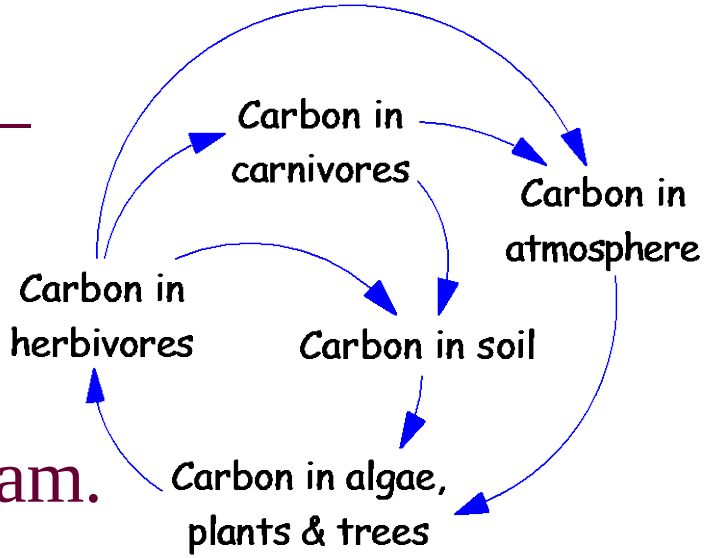
These arrows mean 'and then'



- We start with some understandings of the problem and its systemic context, ***and then*** we conceptualize (map) the system.
- ***Then*** we build the beginnings of a model, which we ***then*** test to understand it.
- ***Then*** we reformulate, or reconceptualize, or revise our understandings, or do some of all three, ***and then*** continue…

Arrows here are *flows* of material

The words here represent accumulations of carbon – *stocks* -- *and* the arrows represent *flows*.

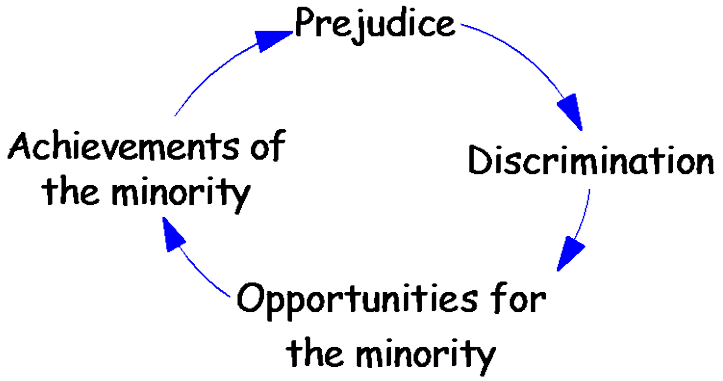


This is not a *causal* diagram.

This is a view of the "carbon cycle."

Only this one is a *causal* loop

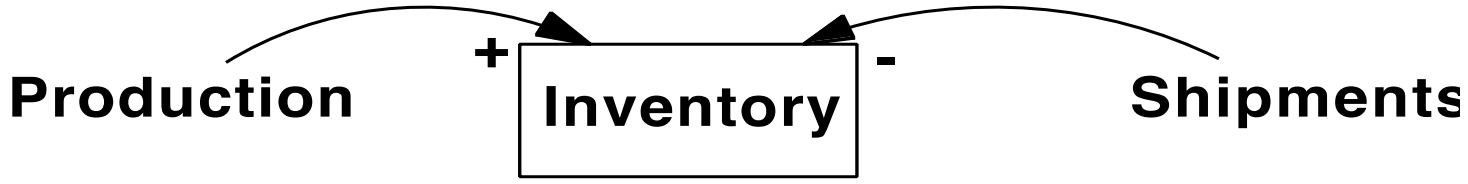
This causal loop tells a very compelling and important self-reinforcing story.



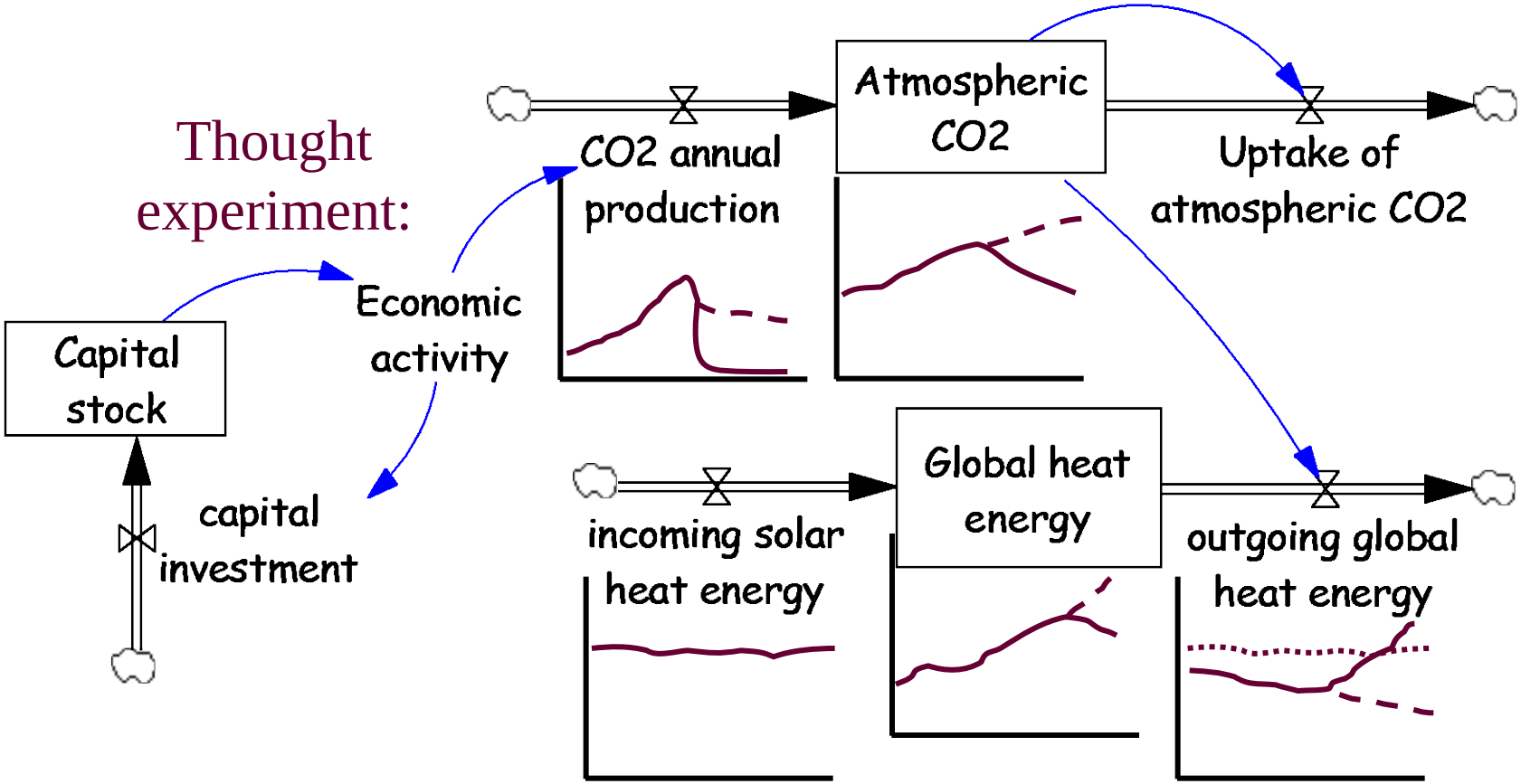
Stocks and Flows

Stocks are accumulations.

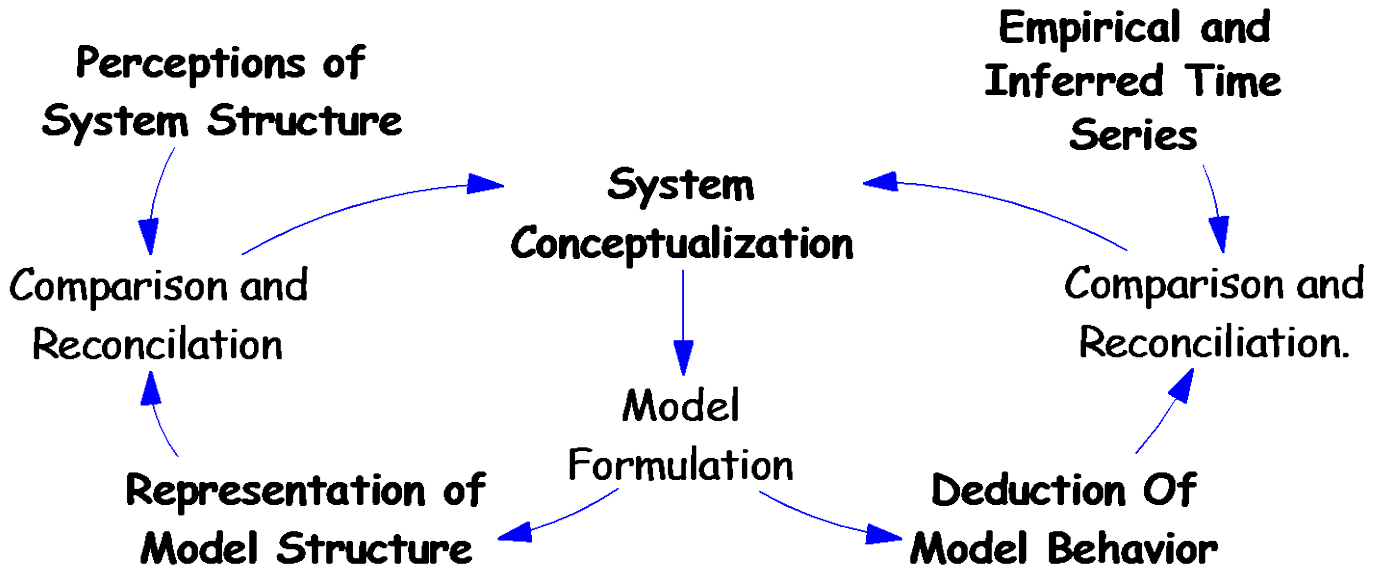
- Stocks are increased by **inflows** and decreased by **outflows**.
- When a link means "add" or "subtract" we have a stock-and-flow structure.
- Example: Inventory



Human Activity, CO2, and Global Temperature

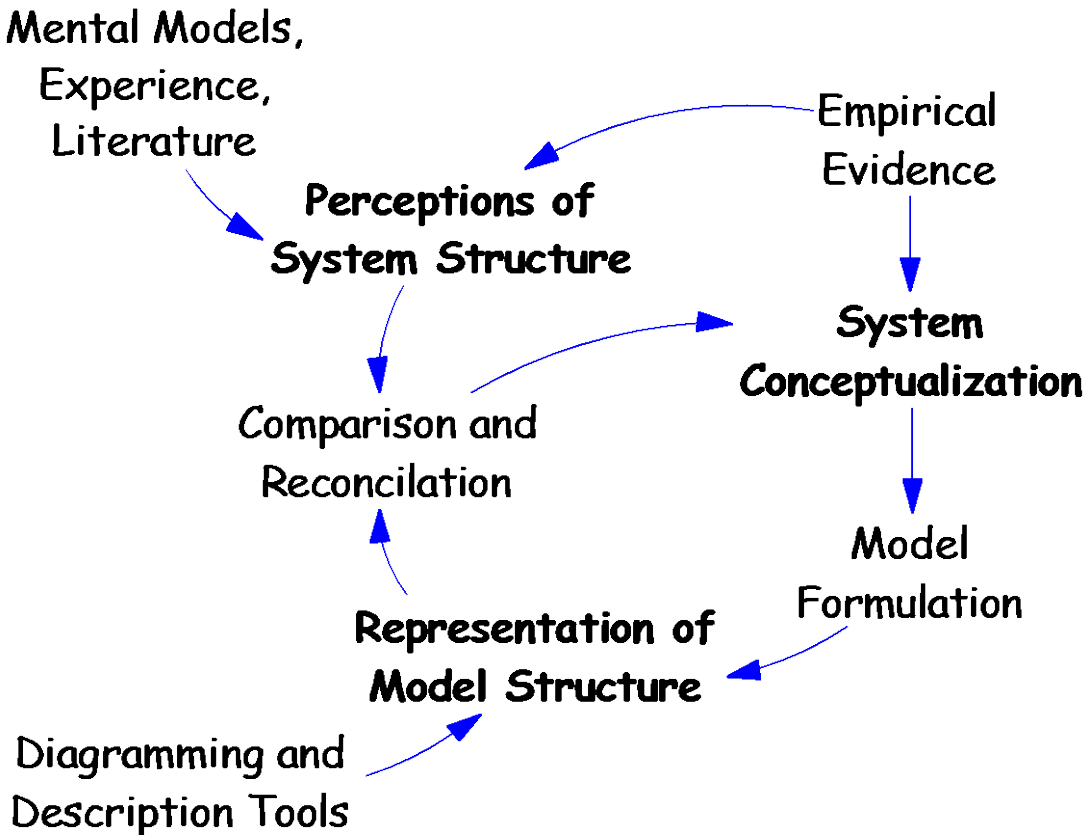


The system dynamics modeling process

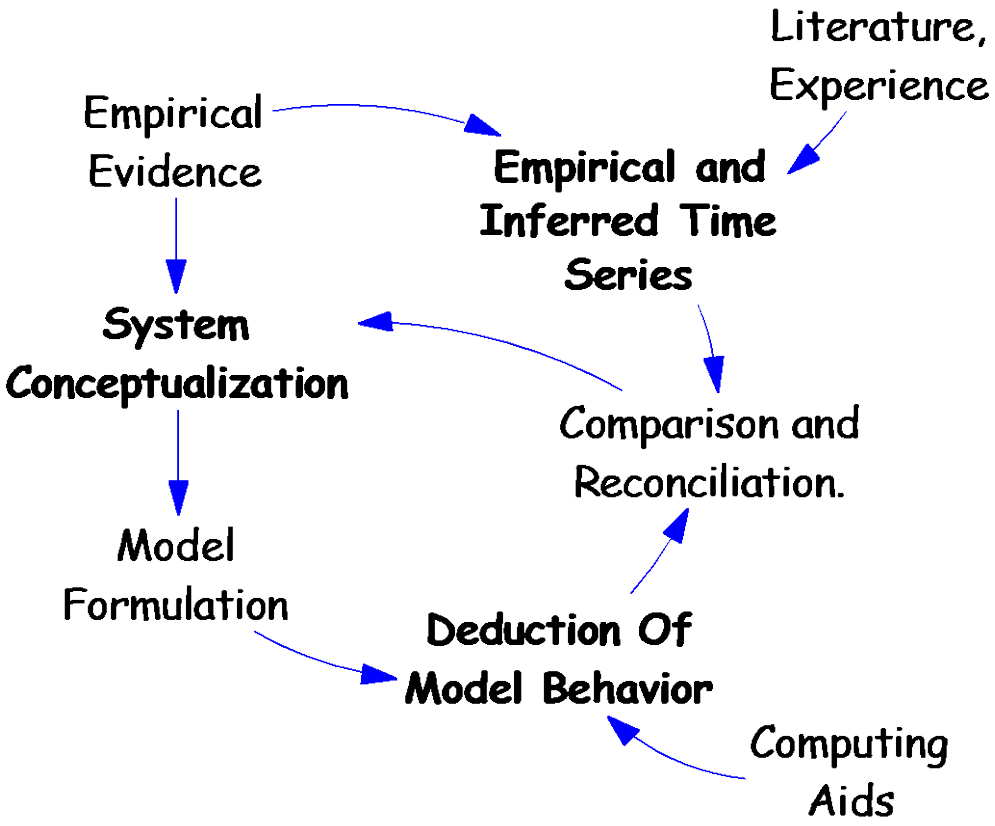


Adapted from Saeed 1992

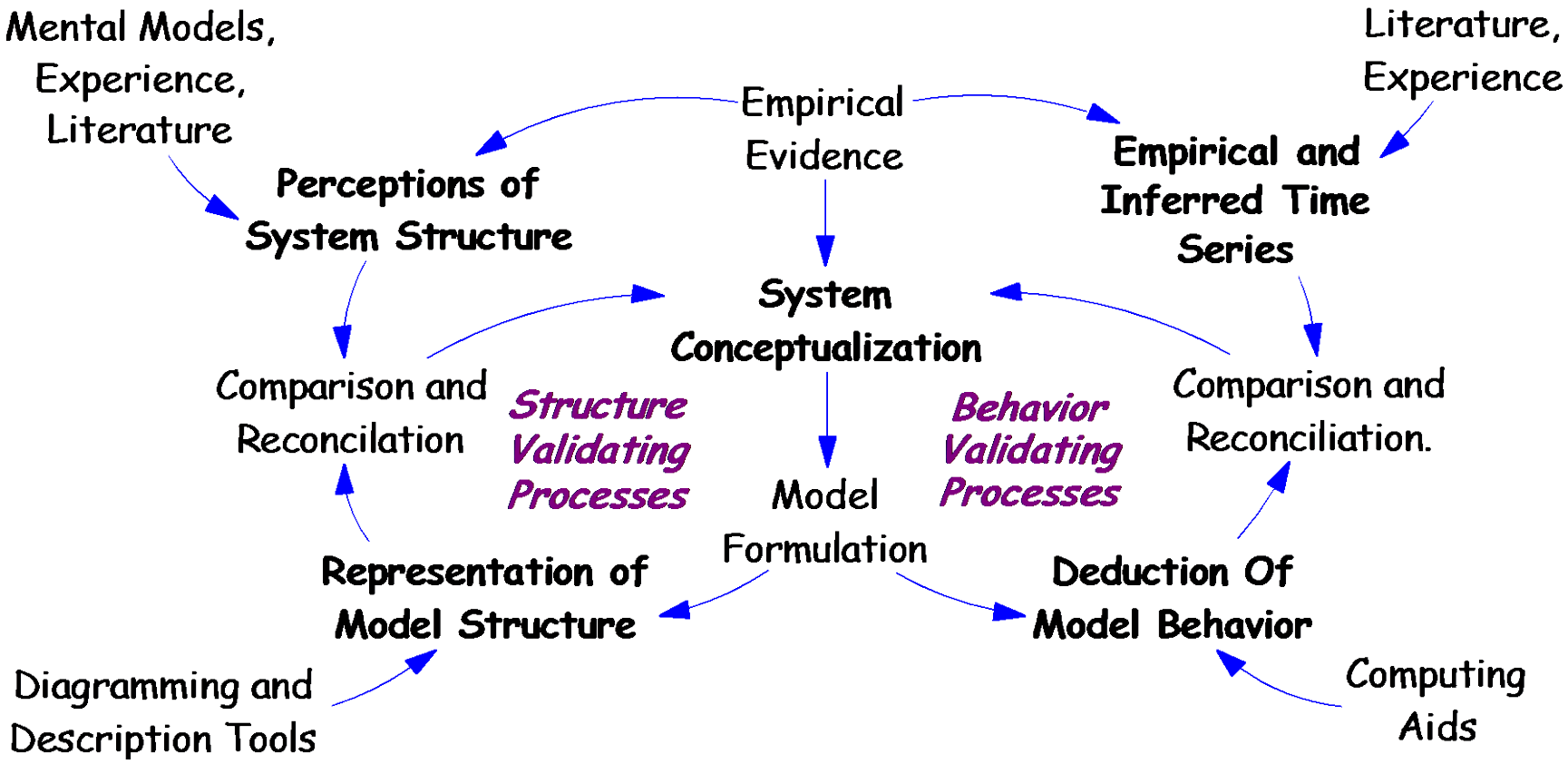
Processes focusing on system structure



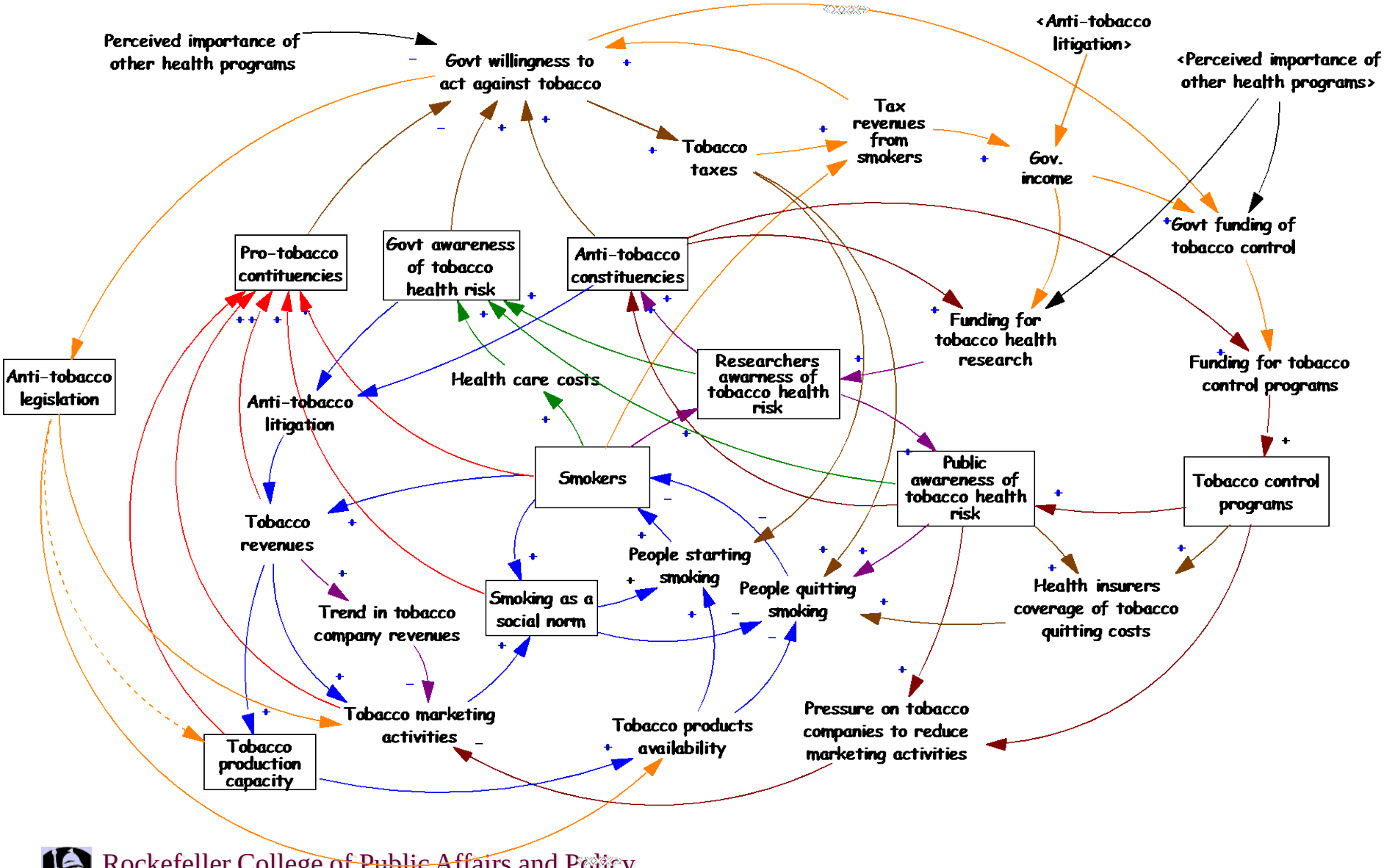
Processes focusing on system behavior



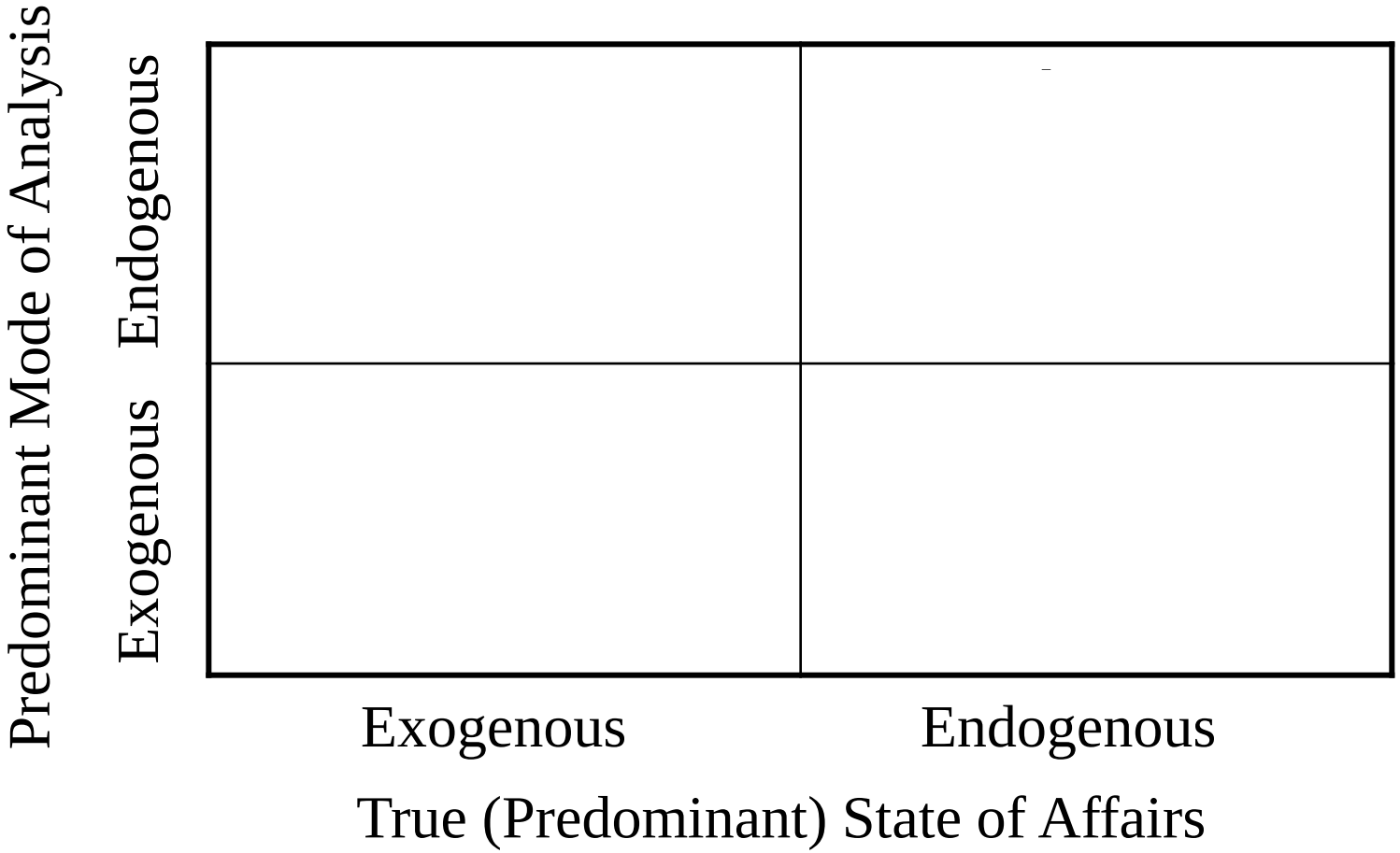
Two kinds of validating processes



Pictures Can Get Really Complicated!



The Endogenous Point of View
The "X/N" Matrix



A Lightening-Fast Example

- Security on **off-shore oil platforms** during a technology transition
- Mixed consulting / theory building intervention
- Two group model building workshops, May and September with various high-level management people from Norsk Hydro and related professional groups

Hopes and fears

Hopes

Fears

Establish a Platform for Communicating SD for Hydro.

Consensus about 3 yr agenda

come up with a useful case/ model

Hope Hydro becomes very involved

We do not catch Hydro's interest

Clear Picture of Workshops down the road

Will get a few really dynamically interesting cases

come up with some artificial case

Get a firm understanding system dynamic mapping

HYDRO is new to group modelling

Find a common case for all (AUC,SINTEF, HYDRO)

Norsk Hydro may not be the right case

Establish a SD Model giving new insight

Scenario discussions

How to simulate Risk/Stress

Too little time to be successful

Centrifugal Forces blow AMBASEC, IRMA, HYDRO apart

Getting lost in detail

Establishing a SD Model that gives no new insights

Understanding of integrated operation

focus on security

Identify valuable insights for all

More safe & secure e-operations

to much focus on safety

This SD-Modell does not improve security (& safety) in e-Operation

Process will help Hydro understand what may happen

Some managers think we should never open the platforms

We don't understand the situations

Someone on-shore will inadvertently intervene off-shore

Stakeholders

● Prioritization by group members

✚ Added day two

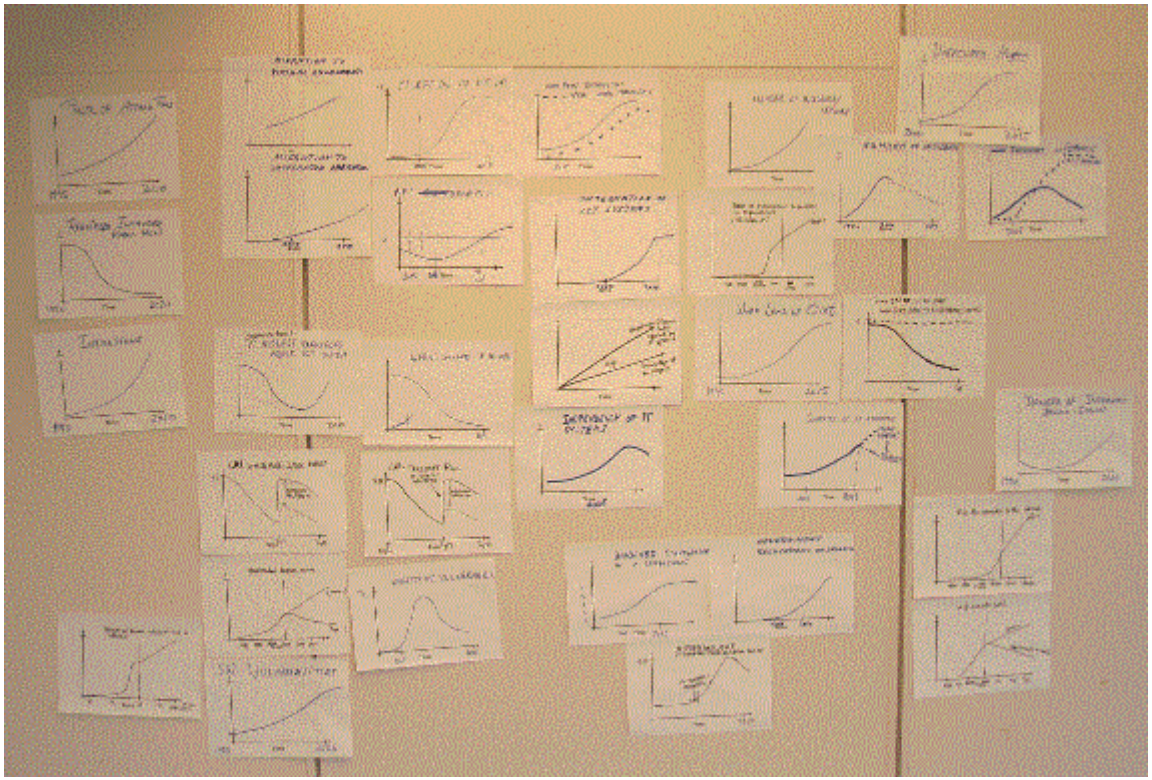
INFLUENCE

INTEREST

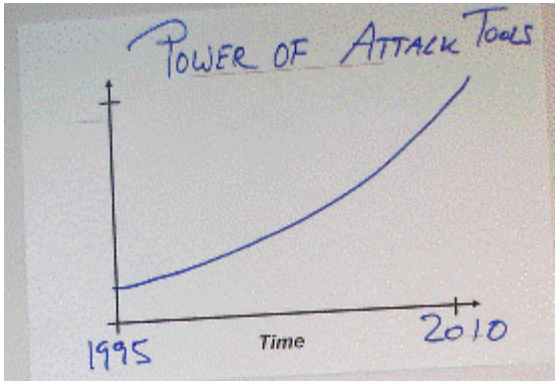
		Chief Executive Officer			People responsible for e-Op Change processes	Management Crises Team ● ● ●	OIL COMPANY (System Owner)
MEDIA	PTIL ●	NPD ● PSA ● DSB	NSM	OLF	✚ Contractors doing drilling & modification fixed platforms	Incident Response Team Manager	PLATFORM CHIEF
Managers of unsecured external networks ●	National Politicians	HSE responsible ●	✚ Local Politicians	CIO	CISO (Chief InfoSeq. Officer)	Work planner / administrator	Control Room Manager ● ●
	Government	Developers of COTS	IT EXPERT (Support)	SYSTEM ADMIN	The one detecting the incident ●	Incident Response Team Member	CRO ● Control Room ● Operator ●
	DEVELOPERS OF ATTACK TOOLS	STOCK OWNERS	SOFTWARE PROVIDERS	Worker (uses IT systems)	ECOLOGICAL ACTIVISTS	Operator	Organized Crime ●
Supplier (maintenance of PCs/ESD) ●	Service Supplier (handling within their organization) ●	CSIRT in a virtual organisation ●	Local Communities/ Generel, Public	MALICIOUS OUTSIDER	Interval Intruder Attacker	Terrorists	COMPETING OIL COMPANY

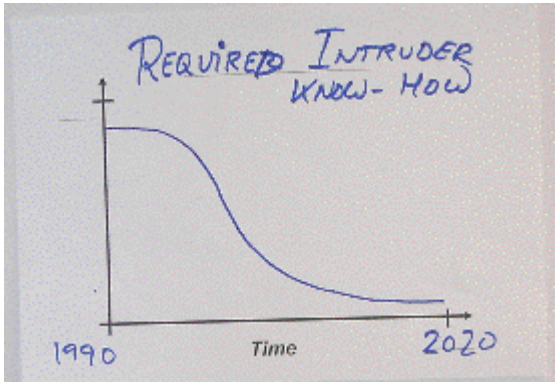
Nature

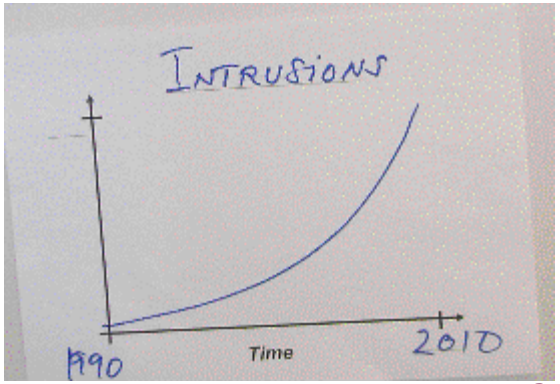
Behaviour over time



Overview







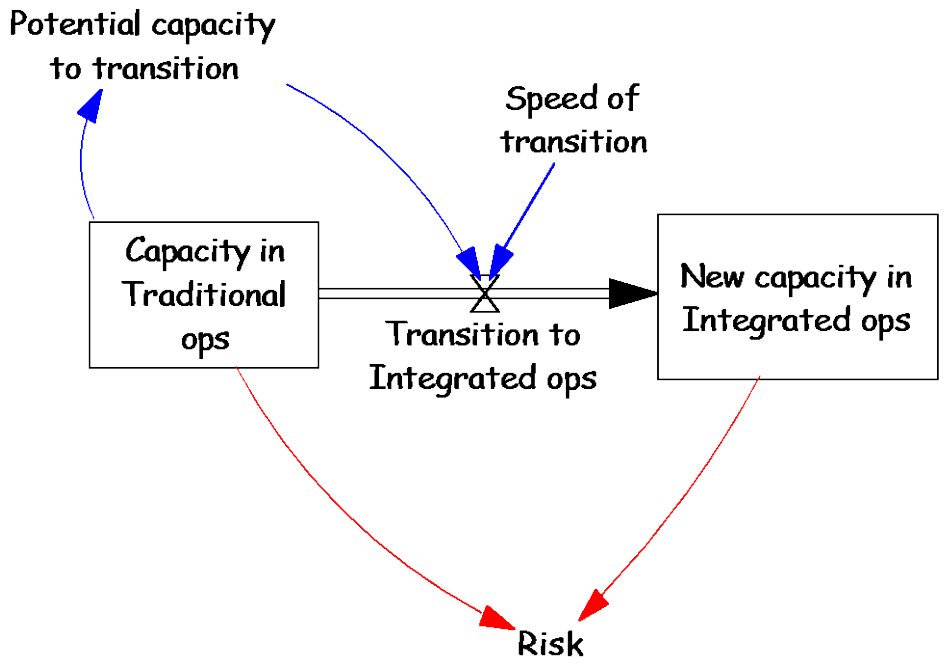
Policies

Prioritization by group members

Added day two

- Improve the safety and security culture
- Prevent out of sight out of mind mentality
- Annual awareness campaigns measures security culture
- Increase the amount of incident reports from IRT & CEO
- Be open about security incidents
- Increase knowledge information sharing across industry
- Establish common risk perception
- Common security requirement on products and services
- Higher level of security
- improve incident reporting
- Establish CSRS
- Cooperation between IRTs in different organisations
- Create collaborate arena & culture for information sharing on-shore / off-shore
- Balance work & RD of CSIRT
- Understand the erosion of compliance
- Increase CSIRTS authority
- Create formal CSIRTS
- Establish common system incident report management -common report in –publish incidents in industry
- Build IDS to systematically gather information
- Continuous training
- Invest in survivability Solutions
- Identify 'Best practice' other countries other industries
- Establish Best /Good Practice Against Insider Threat
- Training to close knowledge gap
- a warning system for the communication network
- share and learn from incident B/W Orgs. & W/n Orgs
- Perform HazOp of the e-operation solution of 2010
- Invest in Vulnerability Detection
- Perform Pilots do intrusion tests and spread success stories
- Risk assessment in change processes (continuously)
- Monitor/Measure Risk Change (Auditing)
- Establish a security Quality process improvement

A Tiny Model Capturing the Problem Dynamics



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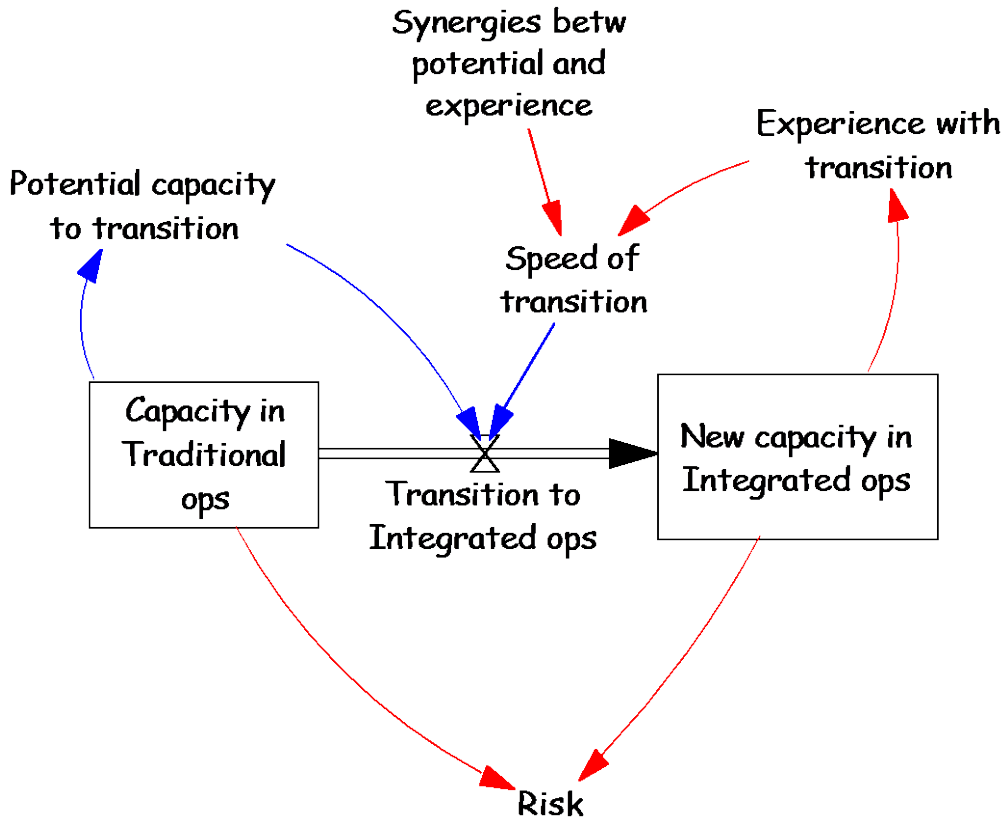
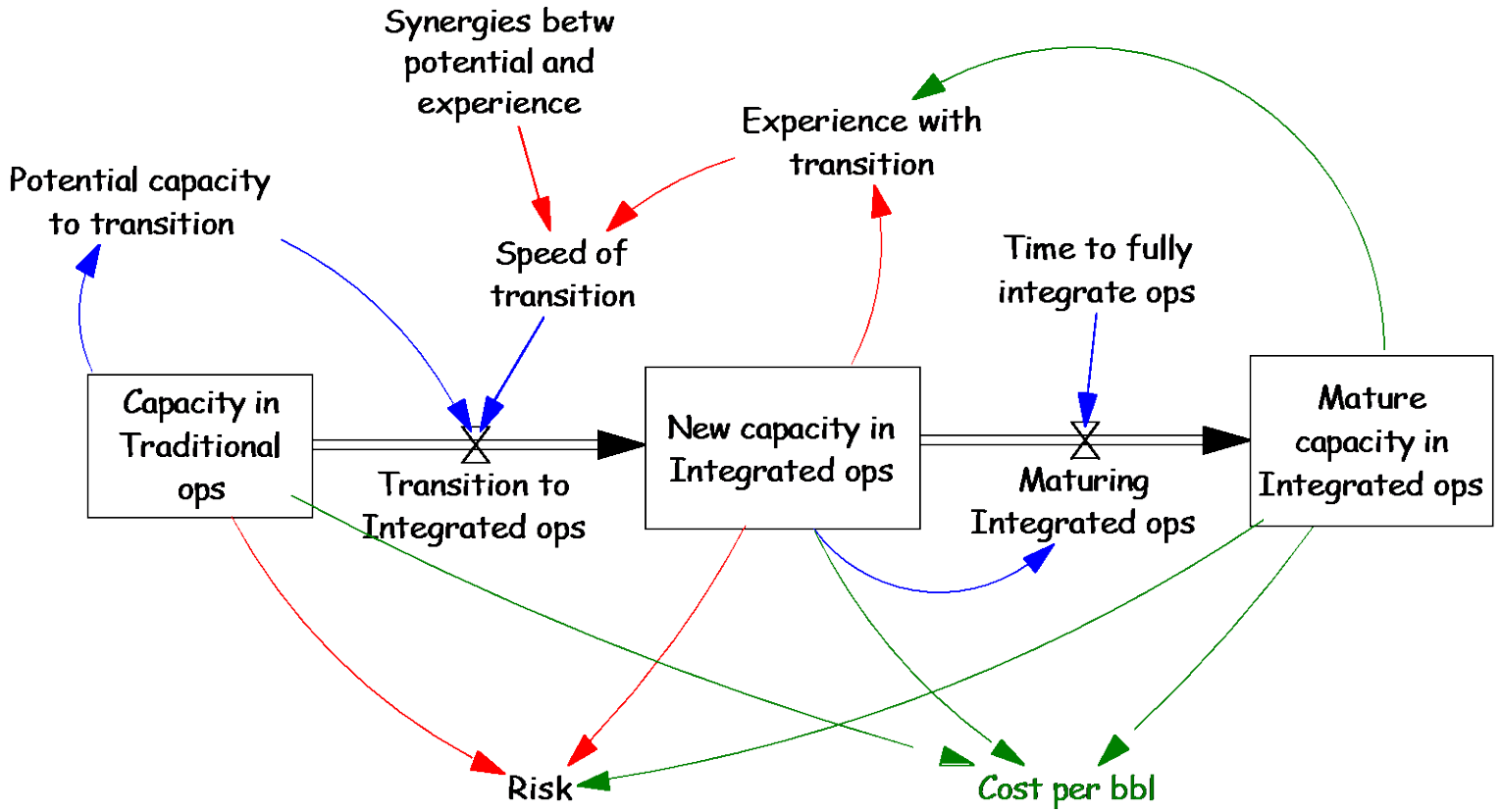


A Tiny Model Capturing the Problem Dynamics

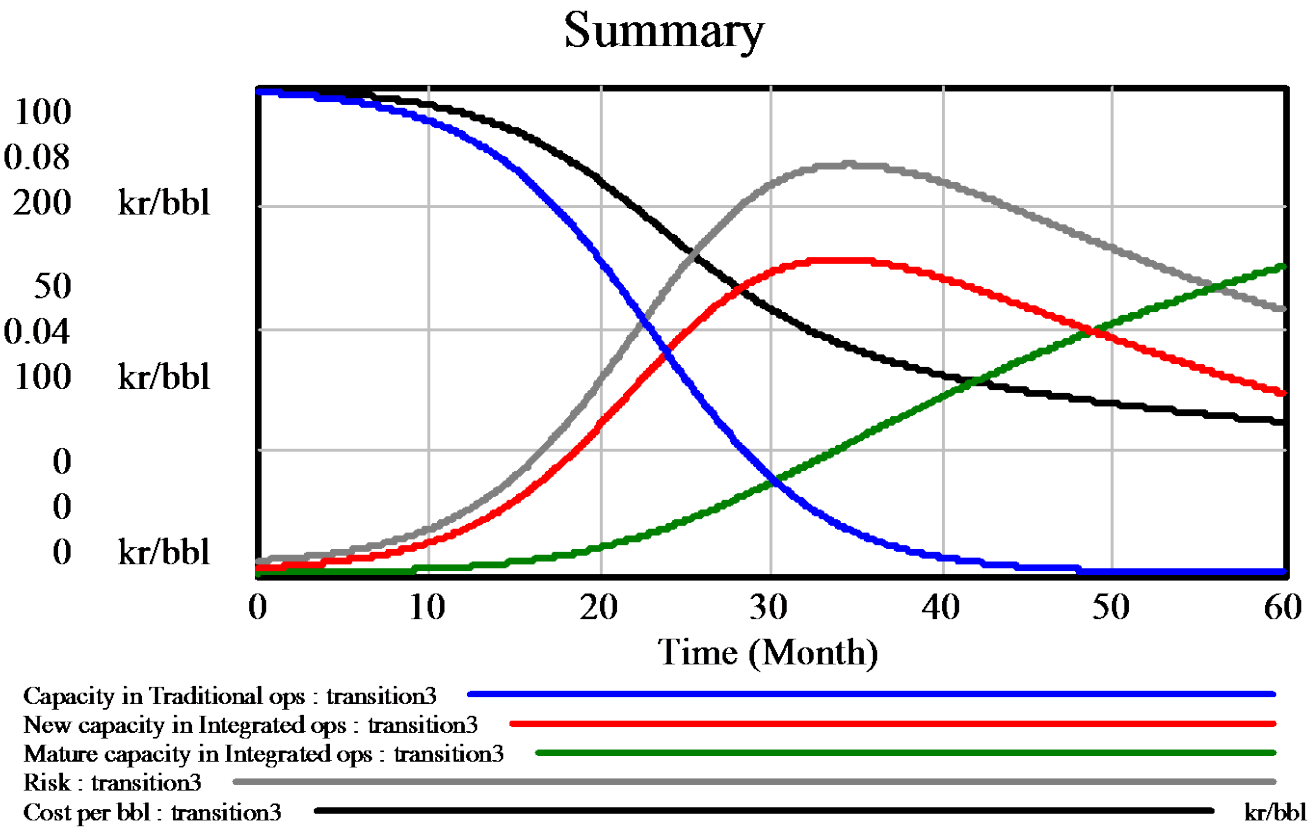


Behavior of this Tiny Beginning Model

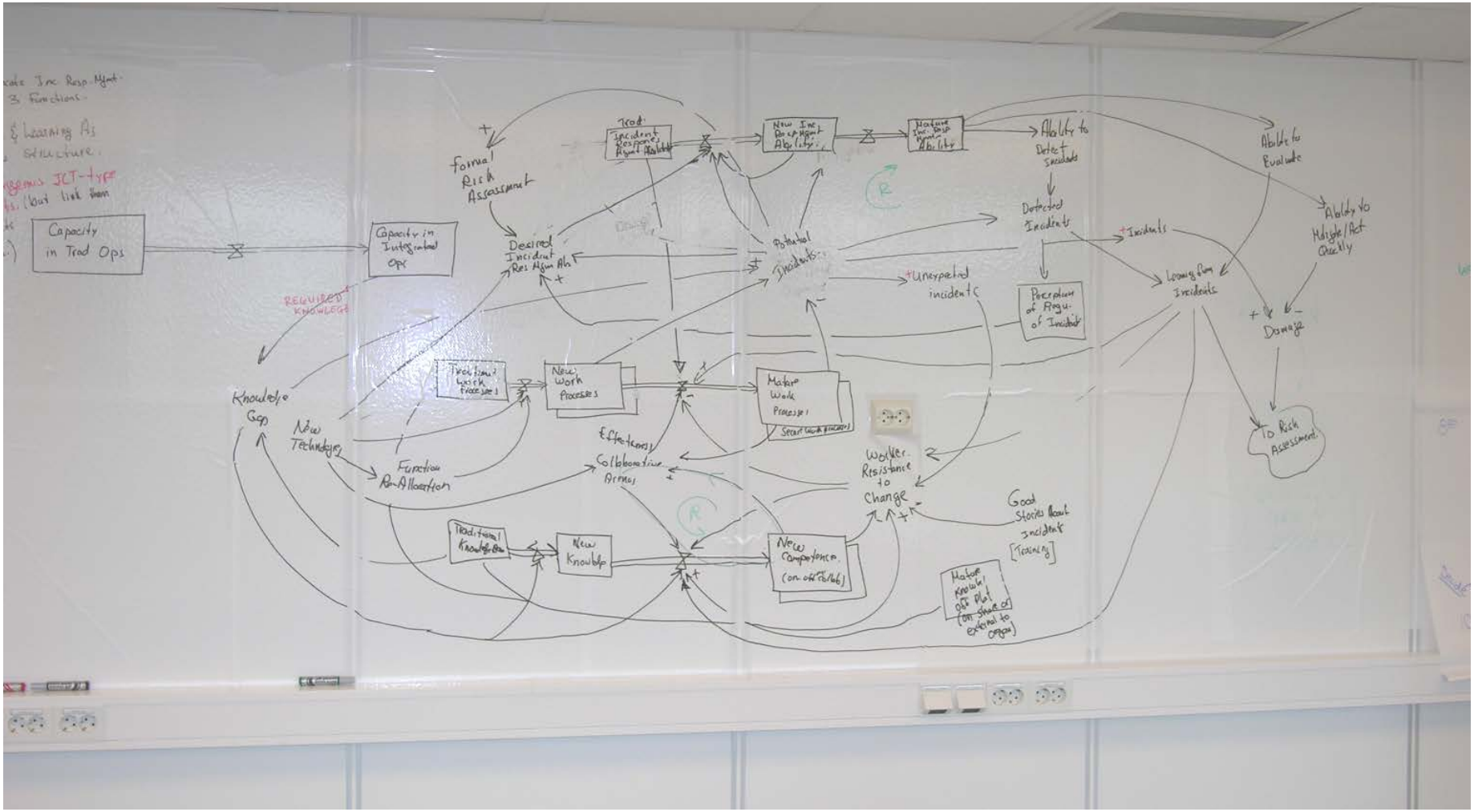
- Traditional capacity (blue) phasing out
- New capacity (red) rising, peaking and declining
- Mature capacity (green) slowly rising
- Cost per barrel (black) declining to a new low
- Risk (grey) rising, peaking, and declining
- …all just what the problem description called for

But vastly oversimplified.

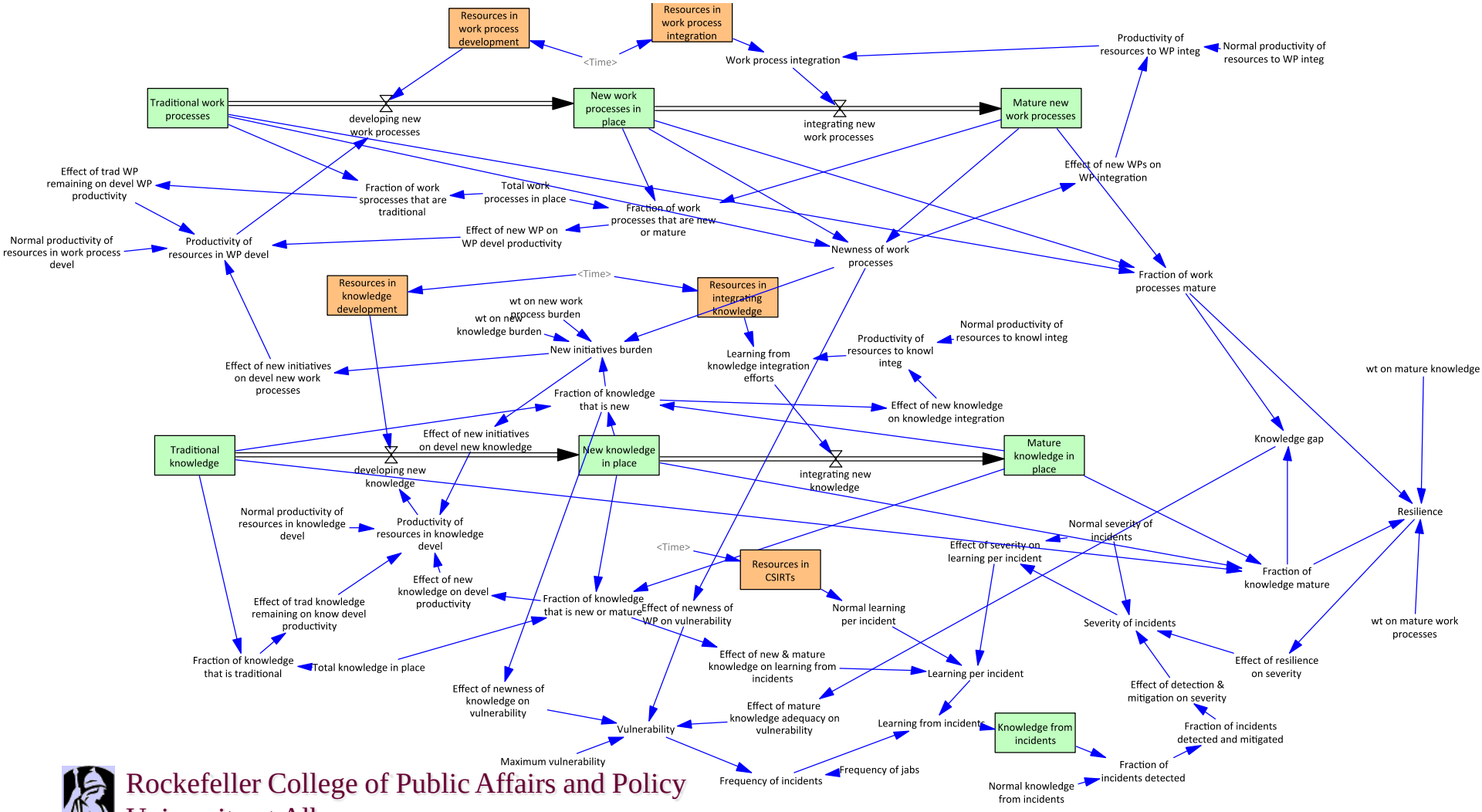
Serious group modeling was needed.



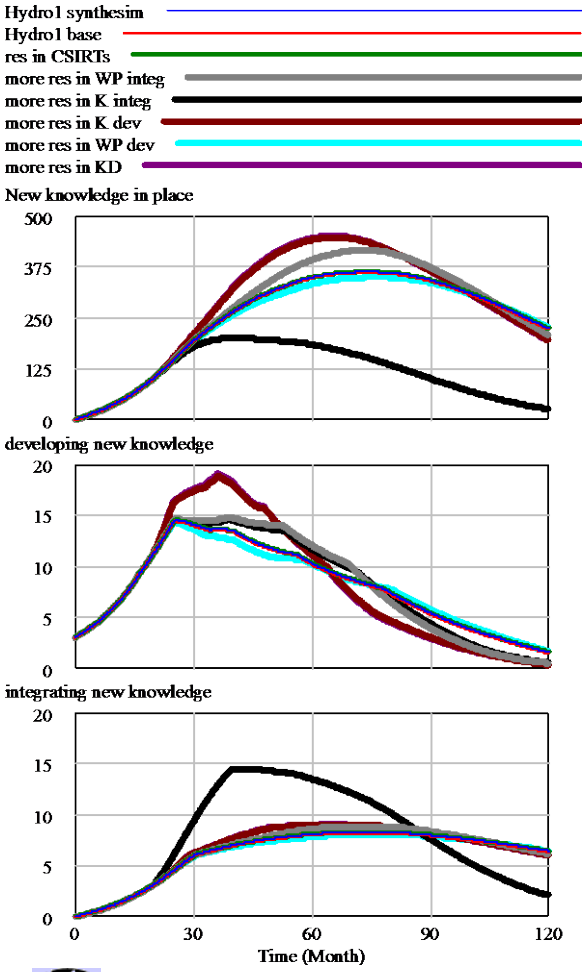
Group Modeling Work in Process

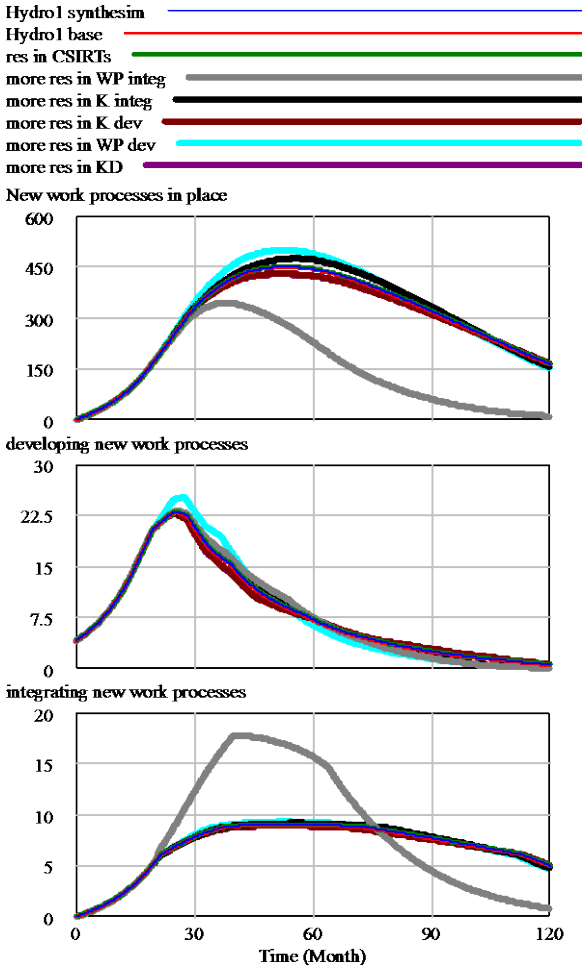


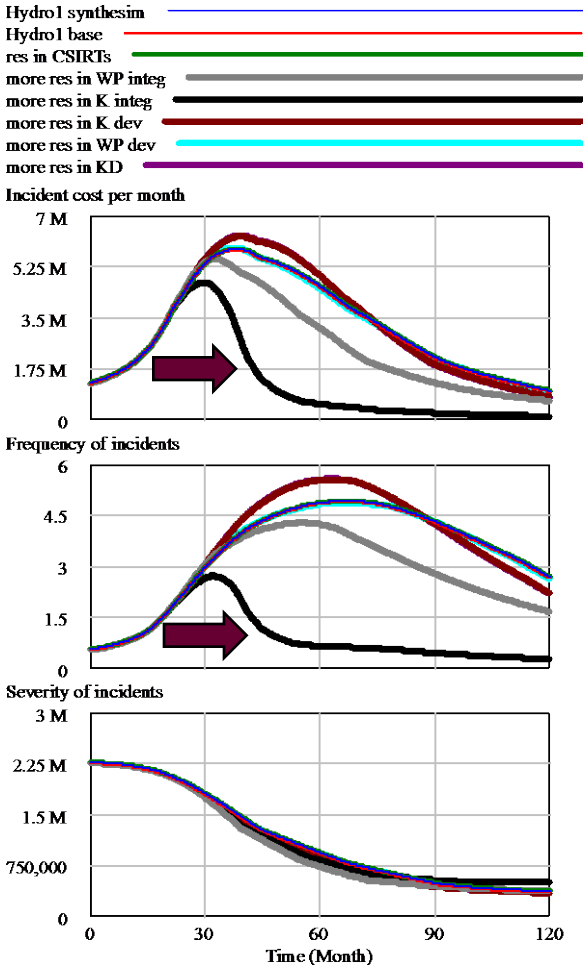
After Much Client and Team Work – *"Hydro1"*



Policy Simulations with Hydro1







When It Works, Why?

- Engagement
- Mental models
- Complexity
- Alignment
- Refutability
- Empowerment