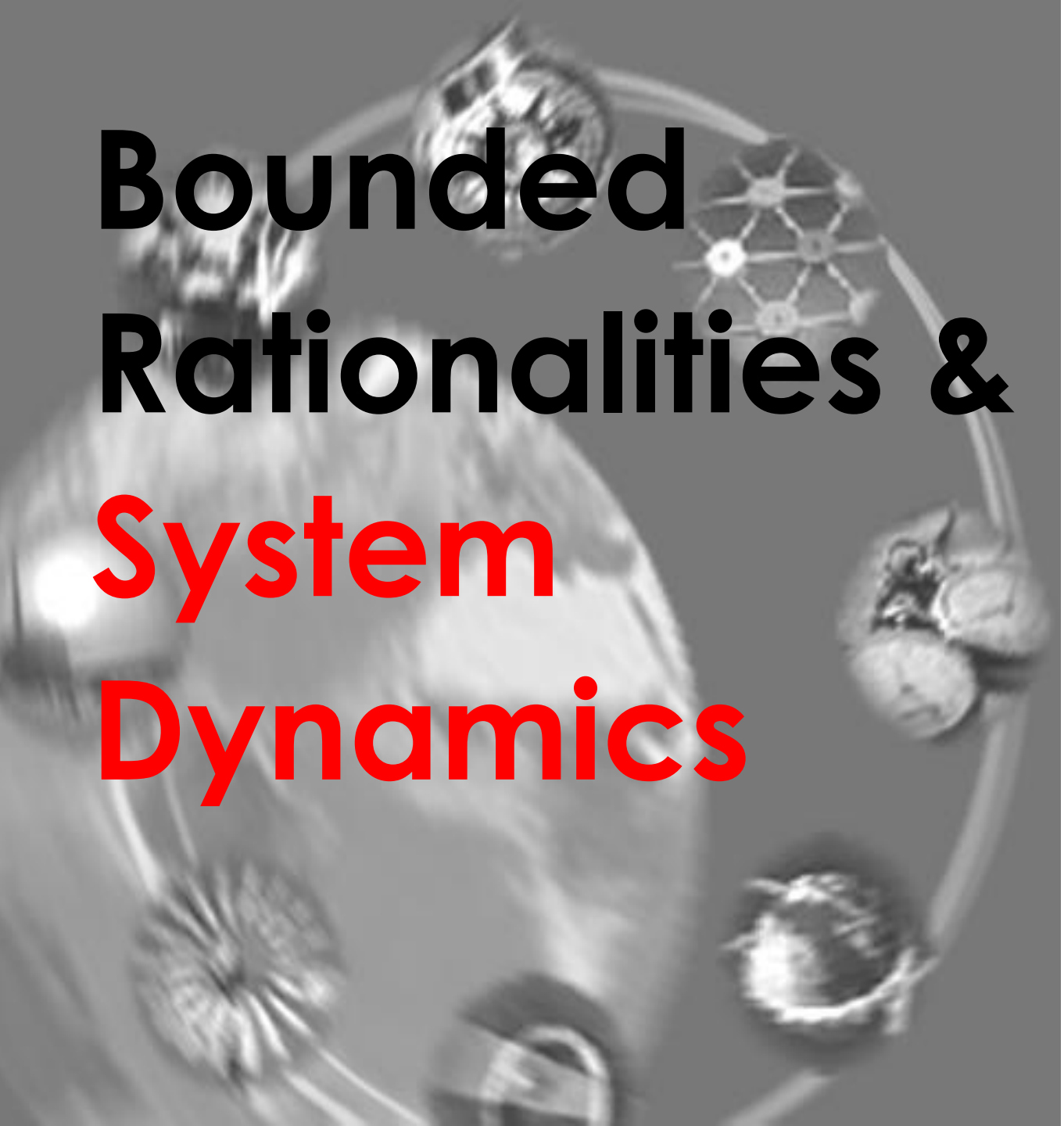

Bounded Rationalities & System Dynamics

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Why do women live longer than men?

1 To find a woman you need Time and Money therefore:

$$\text{Woman} = \text{Time} \times \text{Money}$$

2 "Time is money" so

$$\text{Time} = \text{Money}$$

3 Therefore

$$\text{Woman} = \text{Money} \times \text{Money}$$

$$\text{Woman} = (\text{Money})^2$$

4 "Money is the root of all problems"

$$\text{Money} = \sqrt{\text{Problems}}$$

5 Therefore

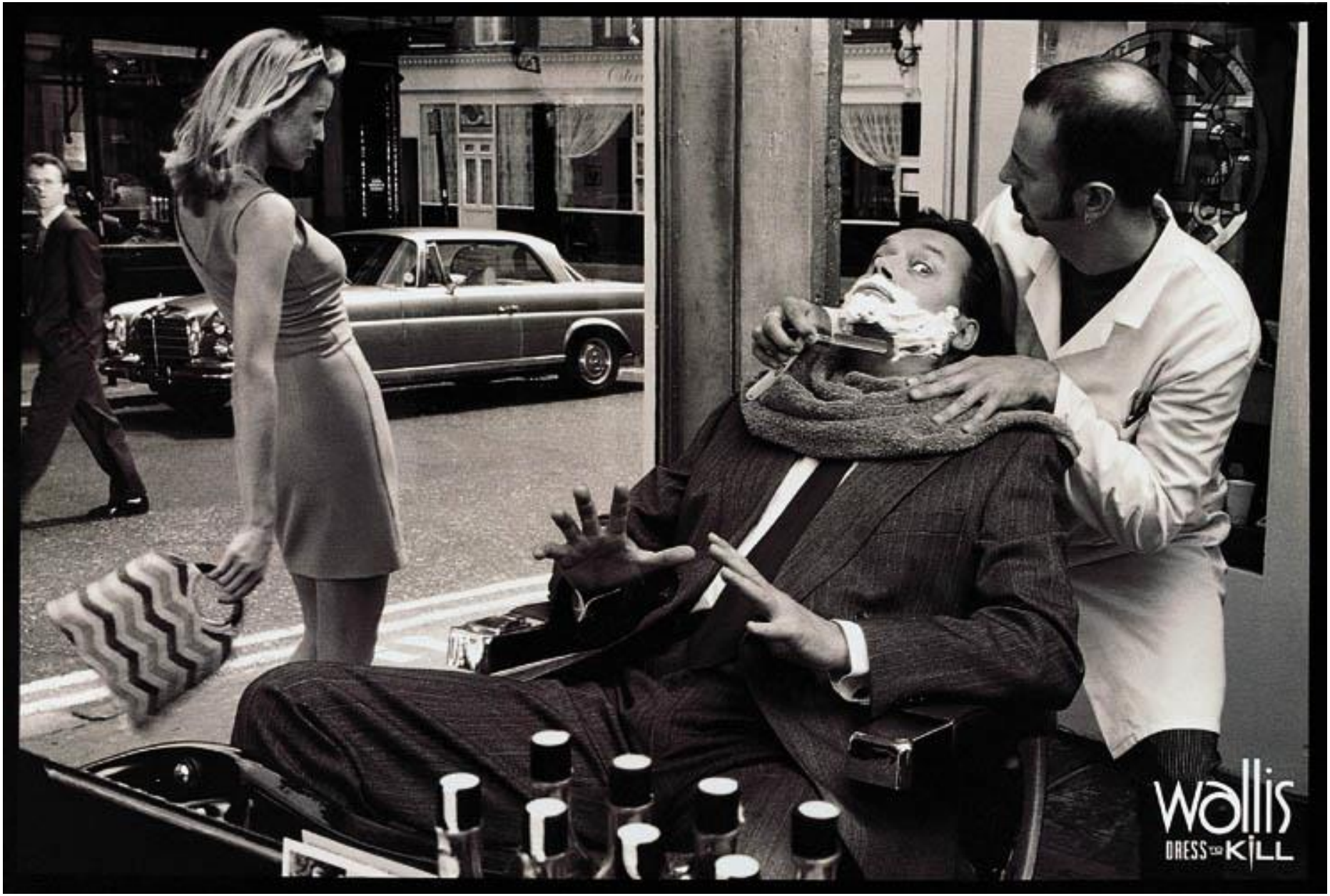
$$\text{Woman} = (\sqrt{\text{Problems}})^2$$

$$\text{Woman} = \text{Problems}$$

A+


DANGER
wallis
DRESS TO KILL


Pulp Fiction
wallis
DRESS TO KILL


wallis
DRESS TO KILL

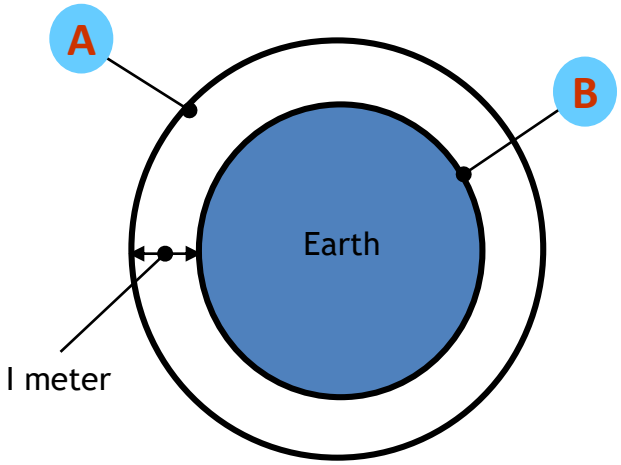
Anchoring

Suppose

We measure the circumference of the earth 1 meter above the earth surface, which is ‘A’.

And, the original circumference is ‘B’.

Then, A - B would be?

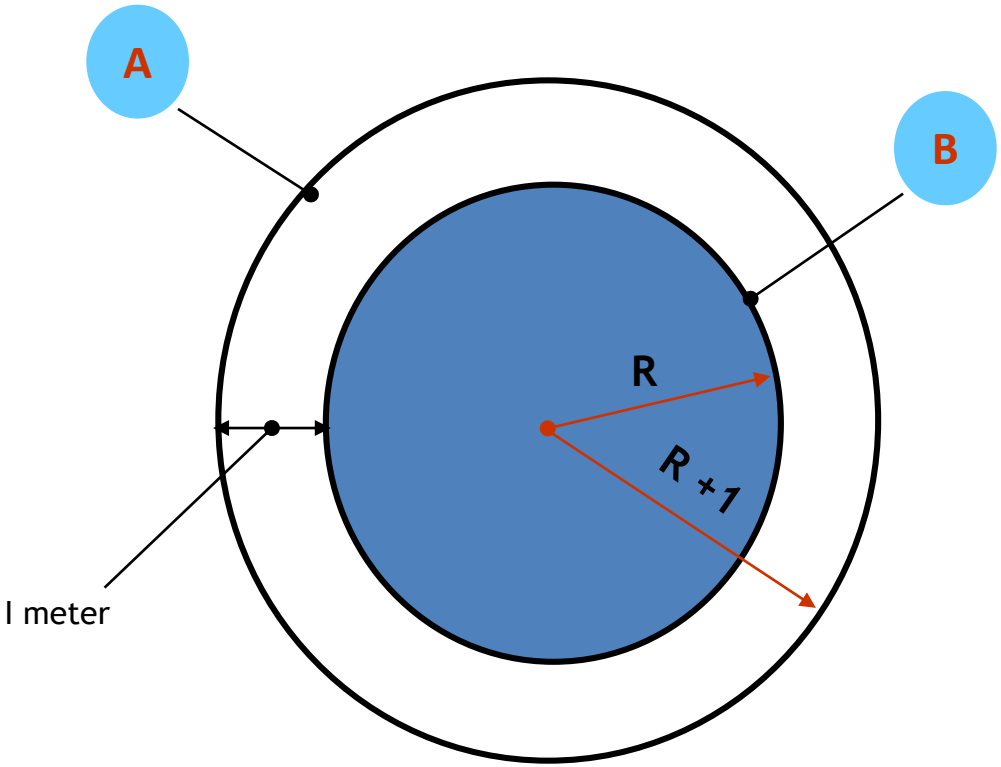


1) < 10 M

2) About 10 KM

3) About 1000 KM

4) > 1000 KM



$B = 2*\pi*R \qquad \pi = 3.14...$

$A = 2*\pi*(R+1)$

$A - B = 2*\pi*(R+1) - 2*\pi*R$

$= 2\ \pi$

$= 2*3.14...$

$= 6.28...$

8

Underestimating Feedback Effect

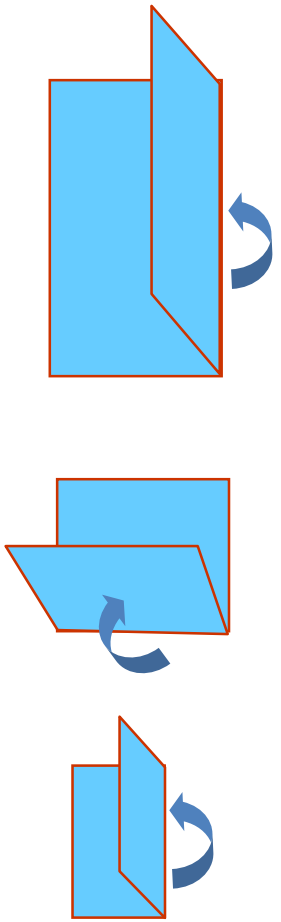
Suppose

You have a paper big enough to fold several times.

Once, Twice, Three times,

And so on…

If you fold the paper 50 times, what would be the thickness of the paper?



1) < 10 CM

2) About 1 M

3) about 1 KM

4) > 1000 KM

9

Suppose

The thickness of the original paper is '*x*', which was 0.01 CM.

When you fold the paper twice, the thickness will be $x*2^1$

When you fold the paper 10 times, the thickness will be $x*2^{10}$

When you fold the paper 50 times, the thickness will be

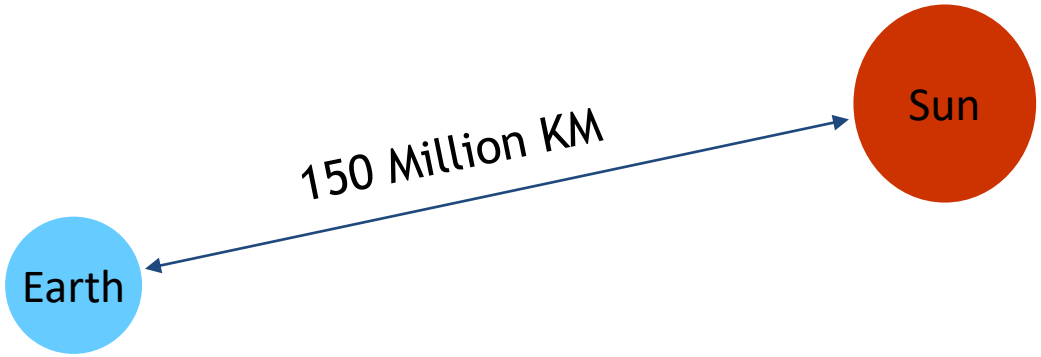
$x*2^{10}*2^{10}*2^{10}*2^{10}*2^{10} = 10^{-2}*10^3*10^3*10^3*10^3*10^3 = 10^{13}$ CM $= 10^8$ KM

= 100 Million KM

,where $x = 10^{-2}$ CM

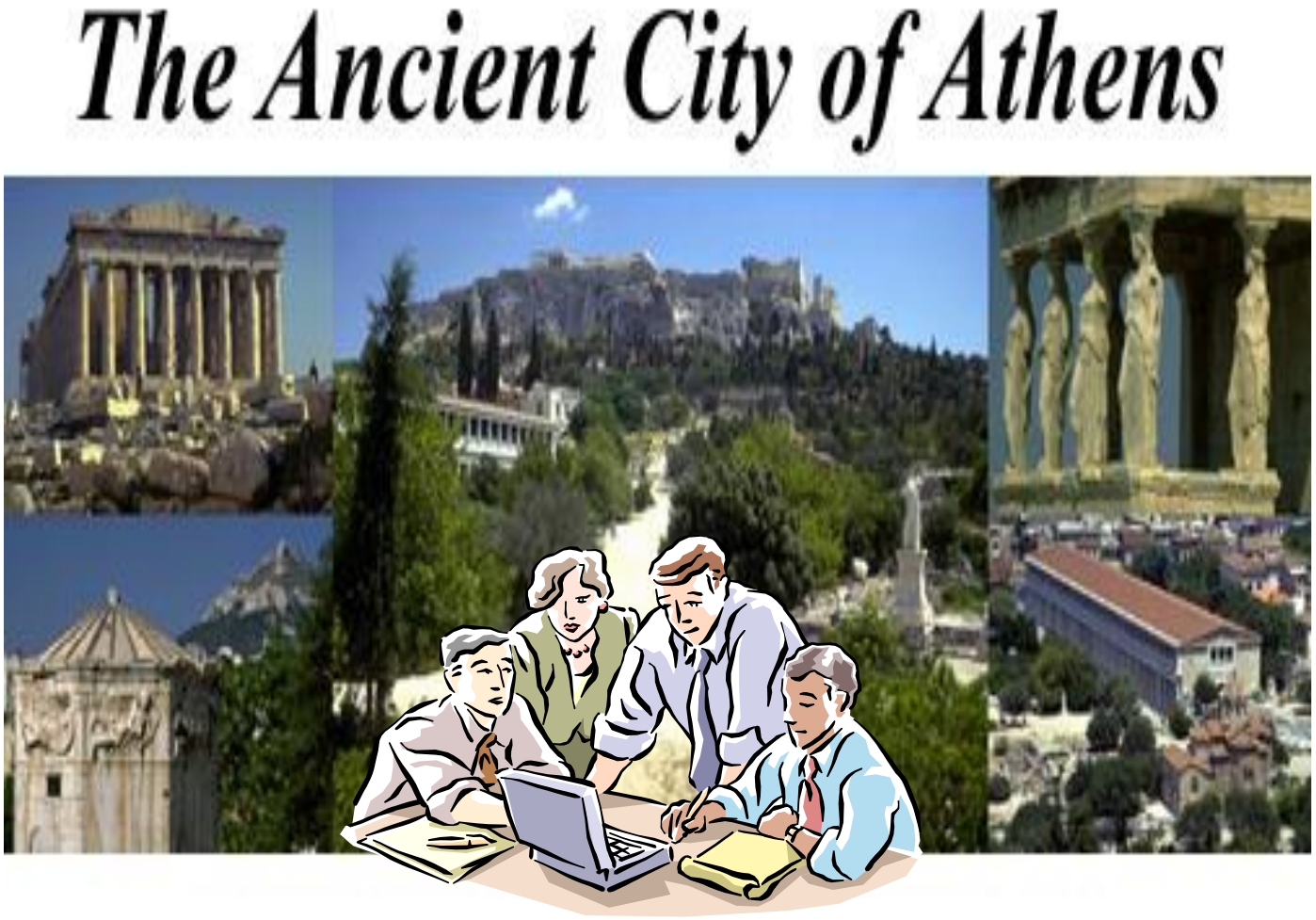
$2^{10} = 1024 =$ about 10^3

1 KM = 10^5 CM



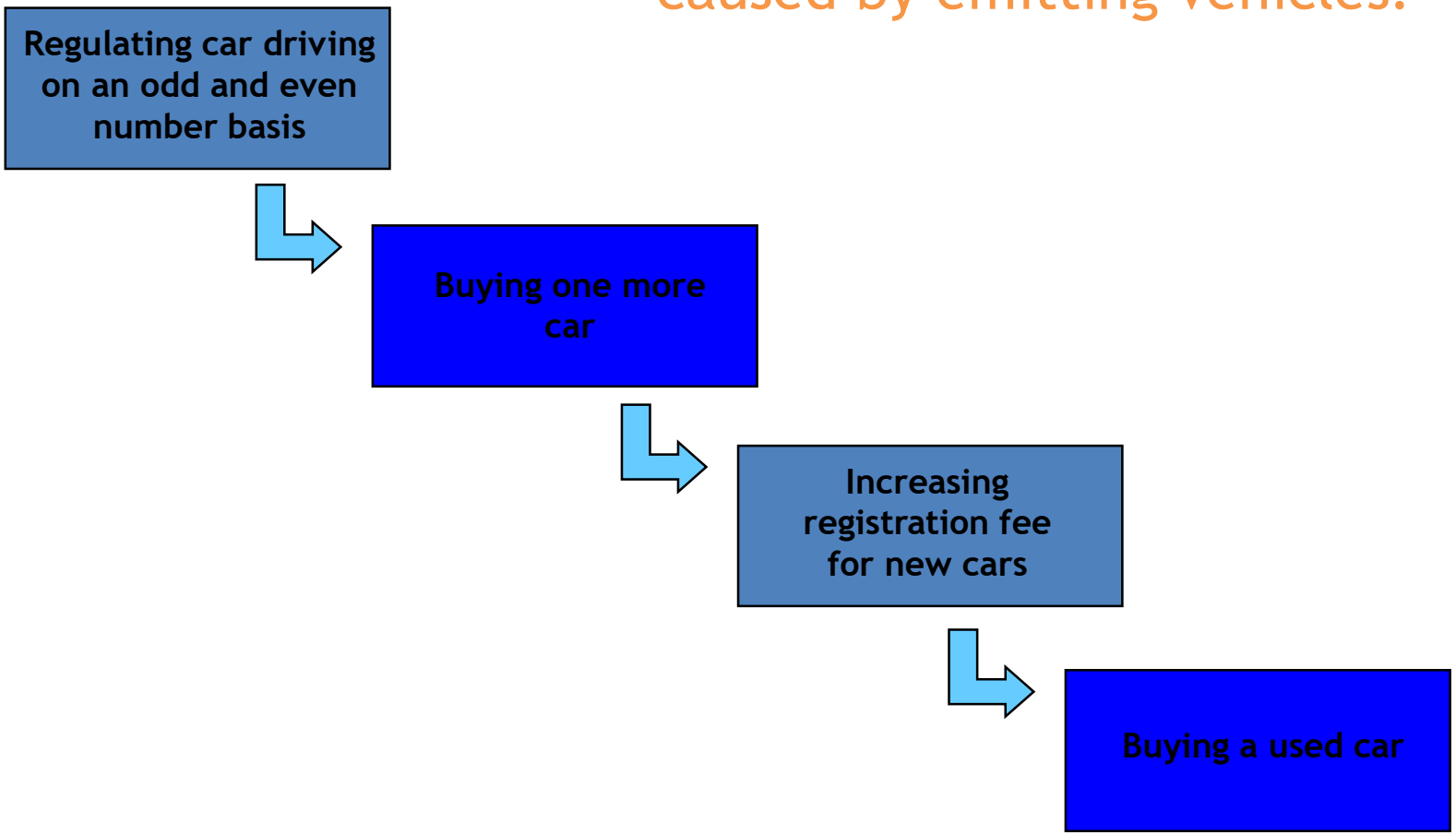
10

Lack of Empathy A Government Policy Failure Example



They found a clue BUT…

How to reduce air pollution caused by emitting vehicles?



Cognition Trap

- Cognition (인지): a human being's 'conscious' mental process including attention, solving problems and decision-making.

- Cognition Trap (인지함정): a frame of thinking that leads to a mistake by static cling (정태적인 집착으로 실책을 이끄는 사고의 틀).

- *Our decision-making is prone to a mistake, as many cognition traps exist in the uncontrolled real world.*

Blunder, Zachary Shore 2007

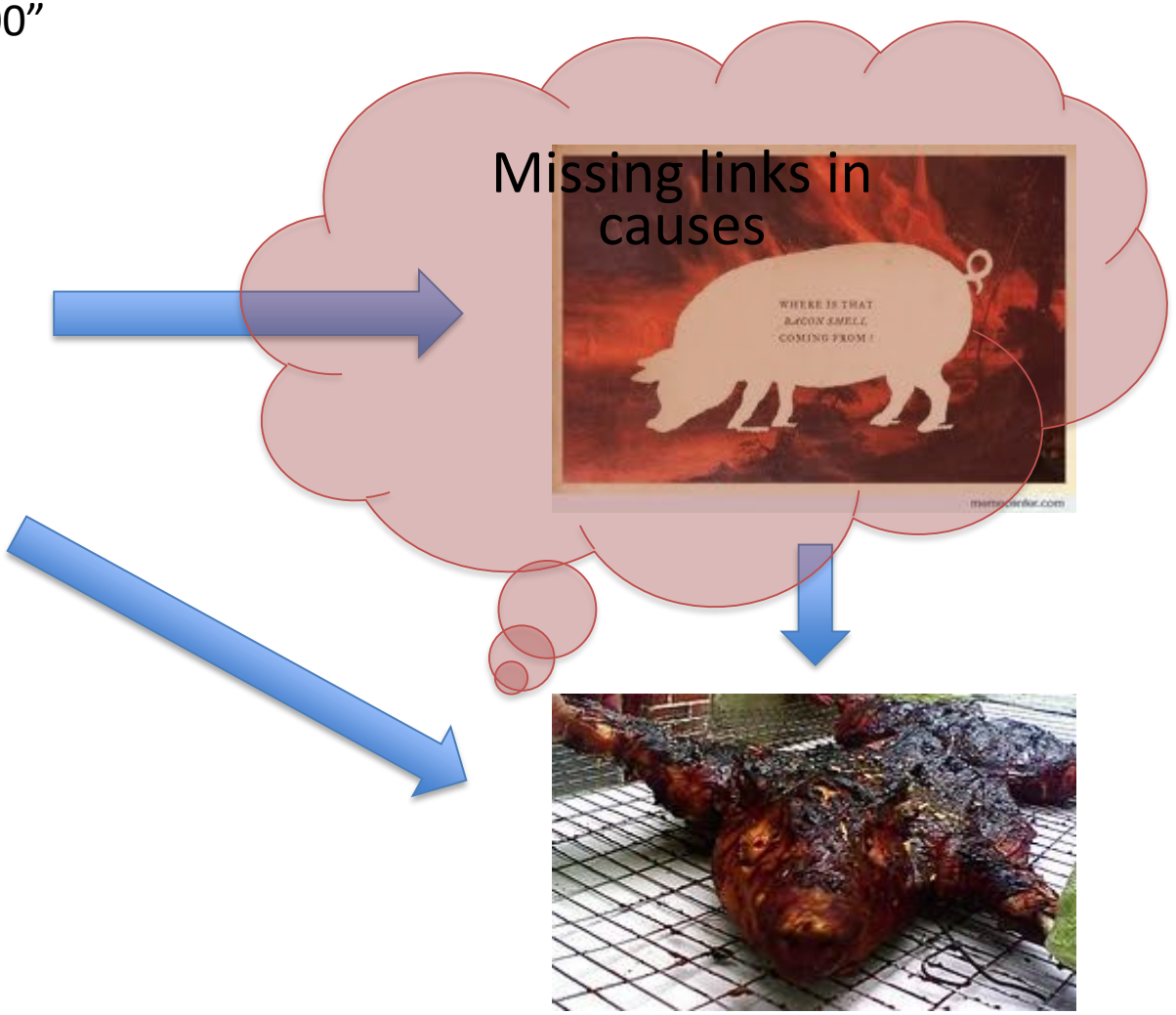
Cause Confusion

Confusing the causes of complex events

- More difficult to identify what the problem is than you expect.
- Once identified, less difficult to solve than you worry
- The problem should be a ‘nightmare’.

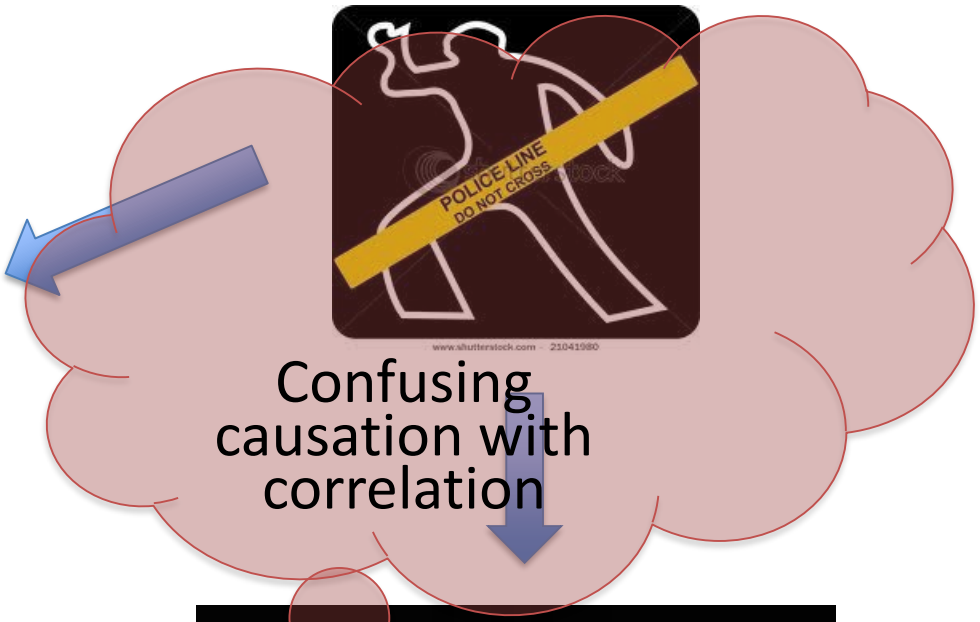
Over-simplifying by missing links

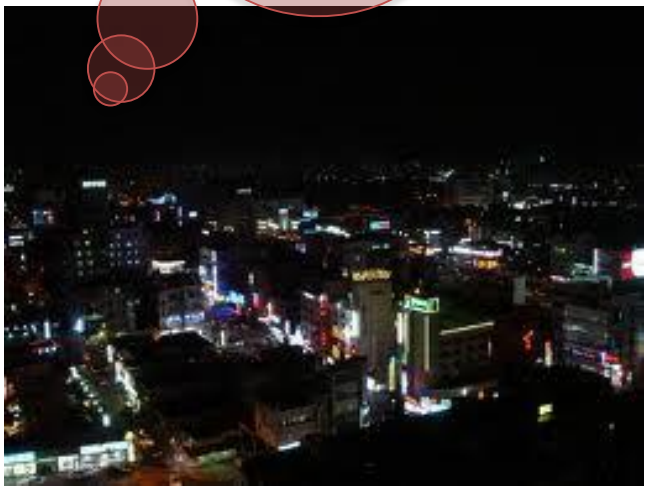
"Charles Lamb's Essay, 1800"



Blunder, Zachary Shore 2007

Causation vs Correlation





Blunder, Zachary Shore 2007

Backward Causation

You observe the shopping cart of a fat woman, which is full of diet food.

Blunder, Zachary Shore 2007

Not always that simple…

Chemical Imbalance

What if chemical imbalance is the result of depression?

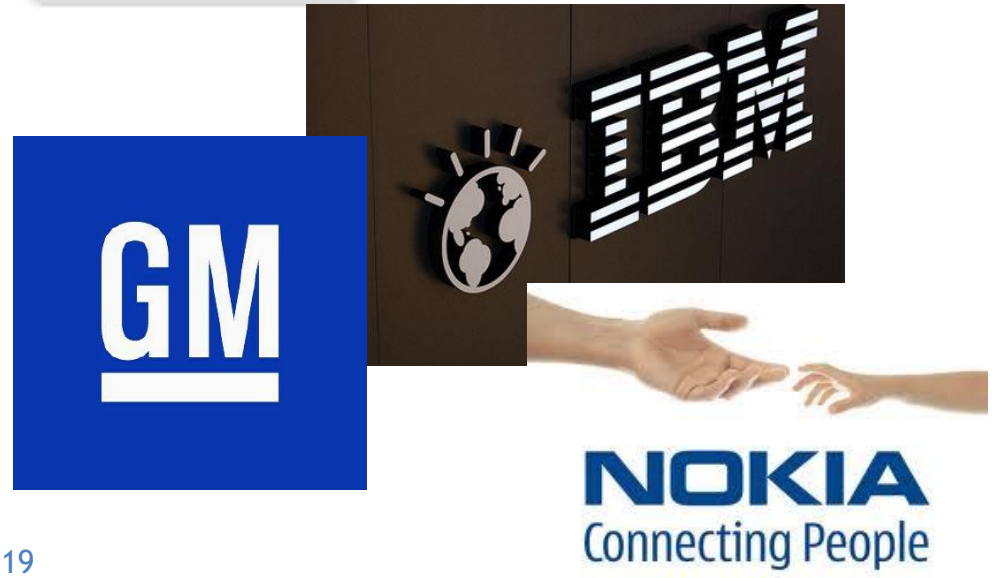
Depression

Drugs

Blunder, Zachary Shore 2007

Static Cling

Refusal to accept a changing world



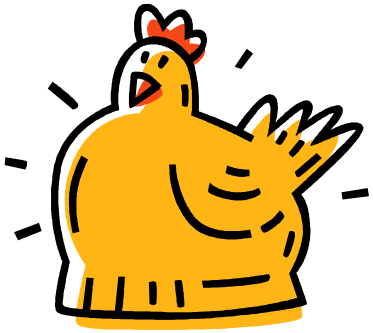
- Longing for things (prosperity, peace, success) to remain.
- BUT
- There is often something more important than fact.

Blunder, Zachary Shore 2007

Categorization Risk

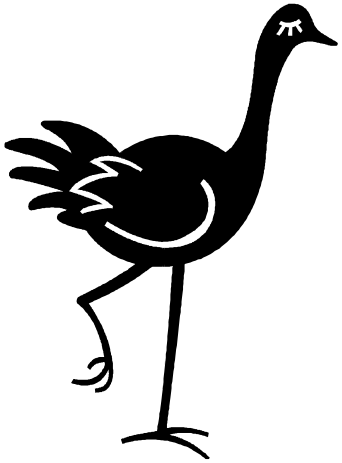
Tend to think idealized best examples in prototypes

A robin



A chicken

Is it a bird?

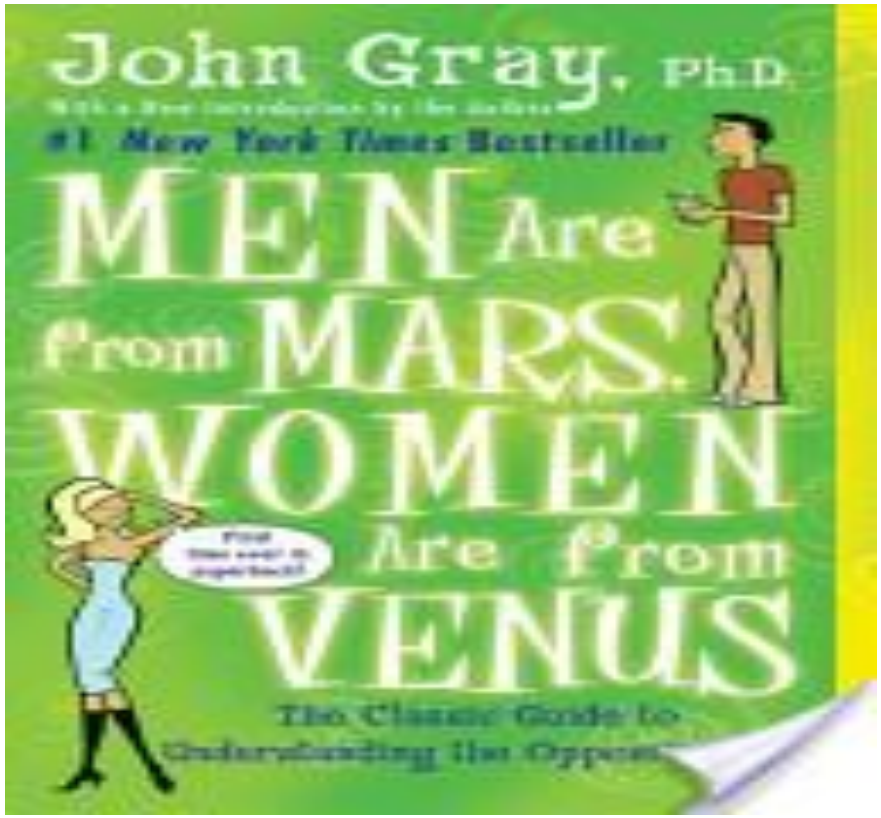


An ostrich

- Categorization is critical in daily life
- Relate all objects, events, and ideas as classes
- Tend to think idealized best examples in prototypes
  Ex. When hearing “bird”, people imagine a robin or another bird like it
- Thus, allow a thing only inside the category or outside, NO in between
  Ex. characterize people according to blood types
- Susceptible to flatview and cure-allism

Mirror Imaging

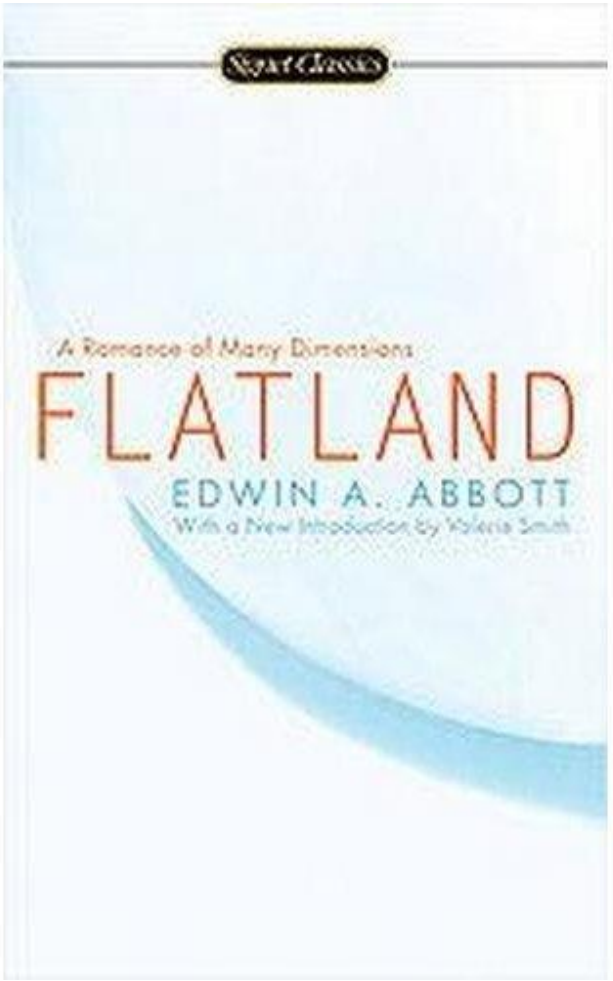
Tendency that the other people think like themselves.



Men are from Mars, Women are from Venus

Blunder, Zachary Shore 2007

Flatview



- Mostly caused by categorization, lack of Empathy and Imagination

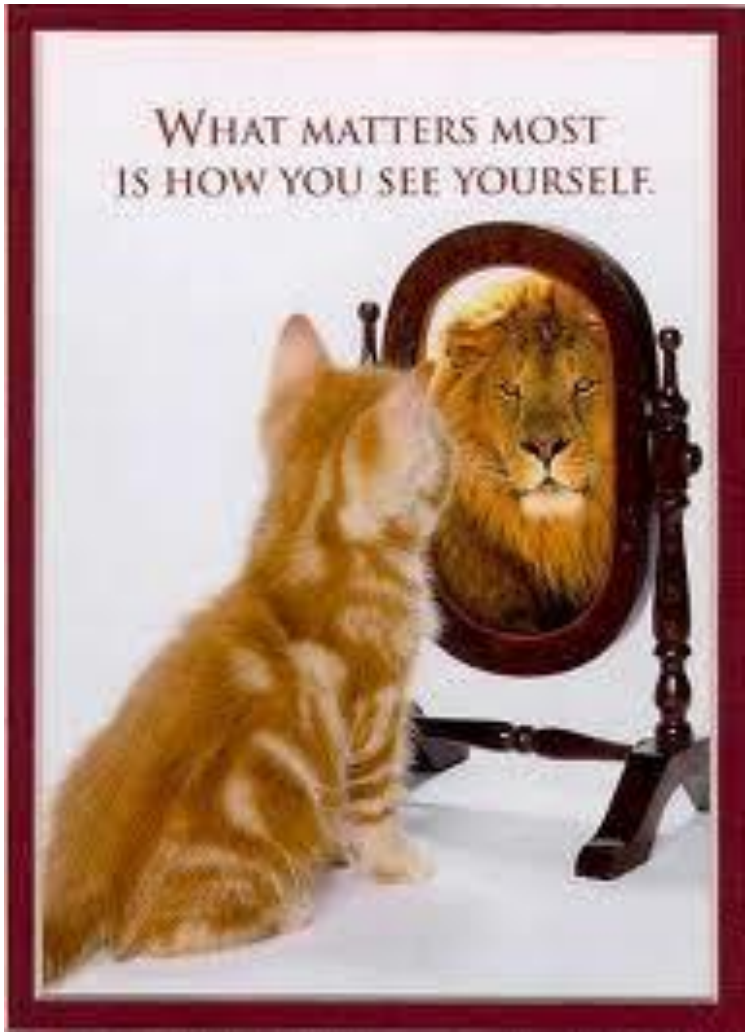
  *empathy (feel with) cf. sympathy (feel for)

- Lead to 'black or white view'

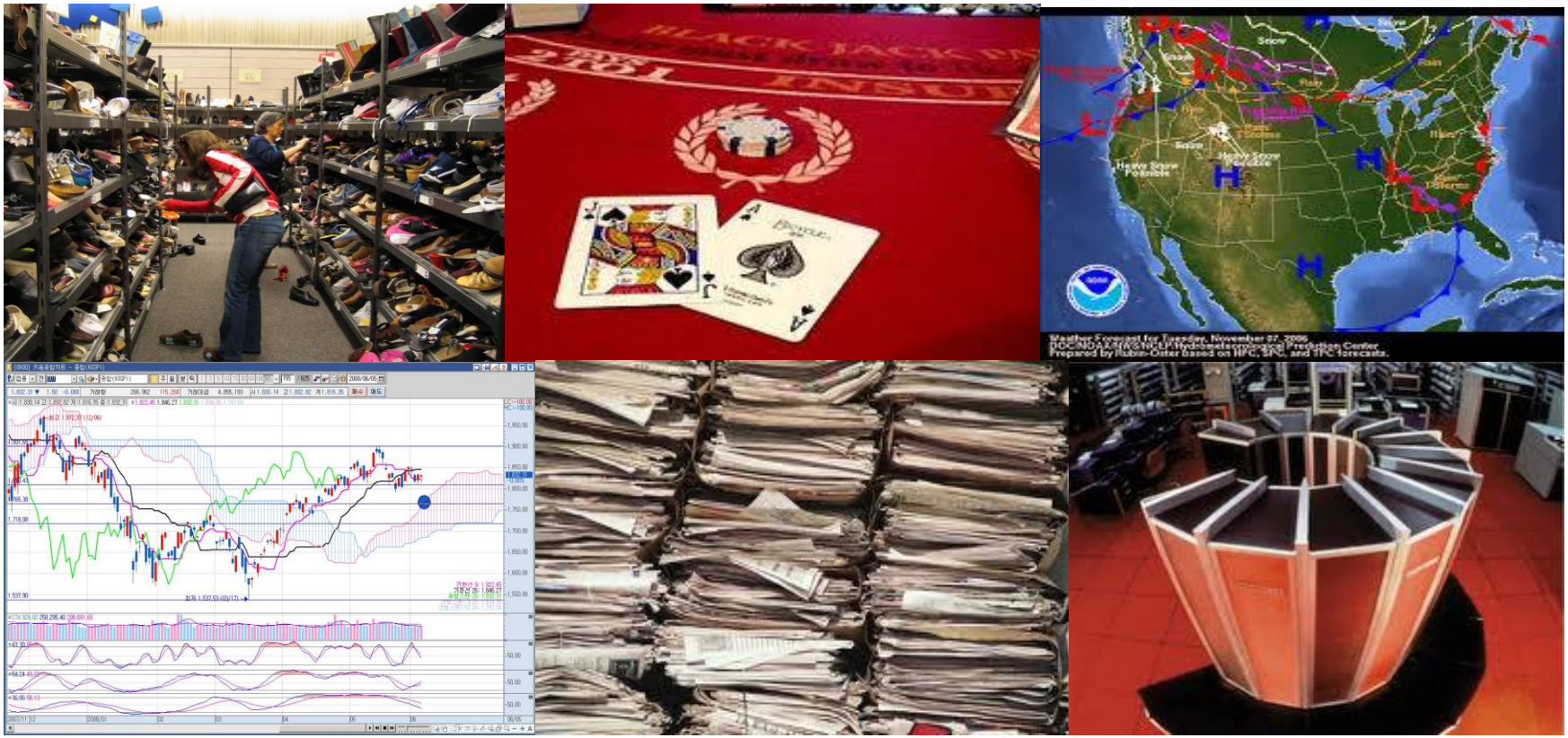
- Important to understand that all people (enemies or allies) are ruled by emotion and their decision making is 'optimized (good or bad)' to the given situation

Blunder, Zachary Shore 2007

Selective Perception



Infomania



- Amount of information guarantees a good decision?
- Lead to overconfidence about their decision
- Rather, relevance is more important….

Blunder, Zachary Shore 2007

Infomisering (정보독점)

- "The Necklace", Maupassant
- Job posting example
- Occurs when people are afraid that their position is threatened when knowledge is spread
- But, often sharing information helps avert disaster

Blunder, Zachary Shore 2007

Infovoidering (정보회피)

- Believe avoiding information can help achieve goals
- Shun the information that could keep from blunders
- Similar with Infomisering in that it retreats from the wisdom of others

Blunder, Zachary Shore 2007

System View

- System
- See as a whole
- See the unseen

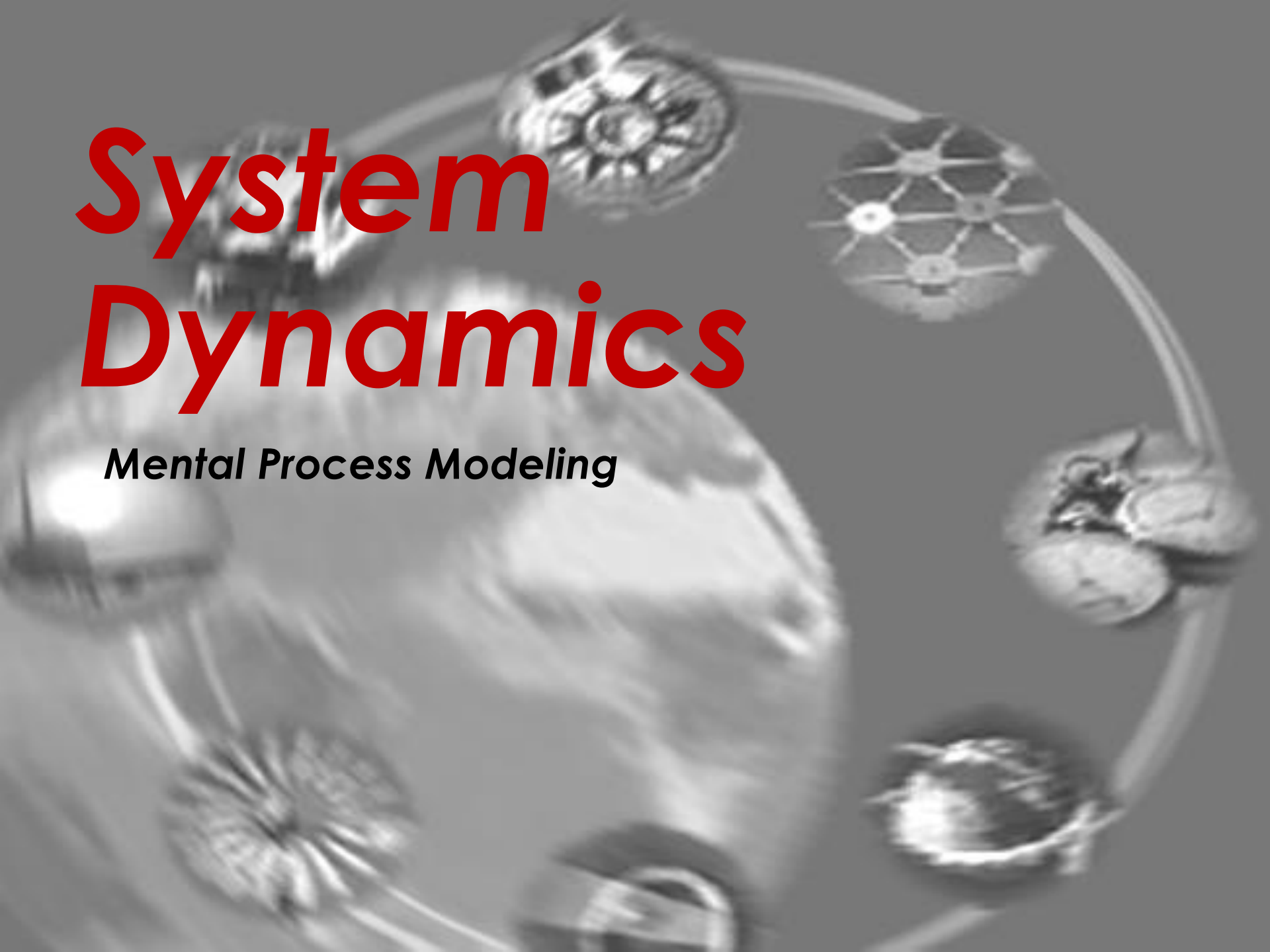
System

See as a whole NOT as parts

See the unseen

There is God as unseen wind moves reed (Pascal).

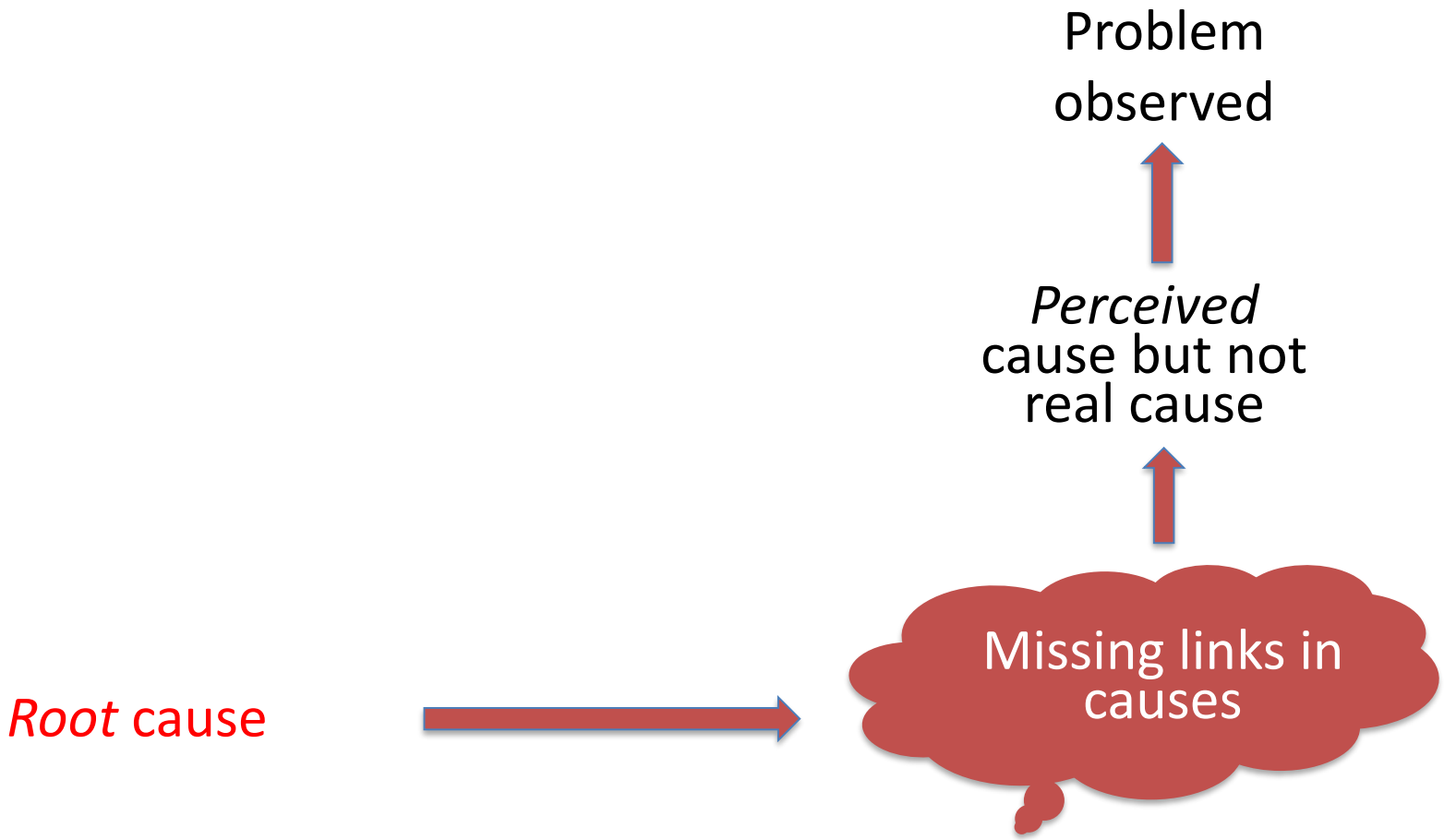
System thinking can be trained?...


System
Dynamics
Mental Process Modeling

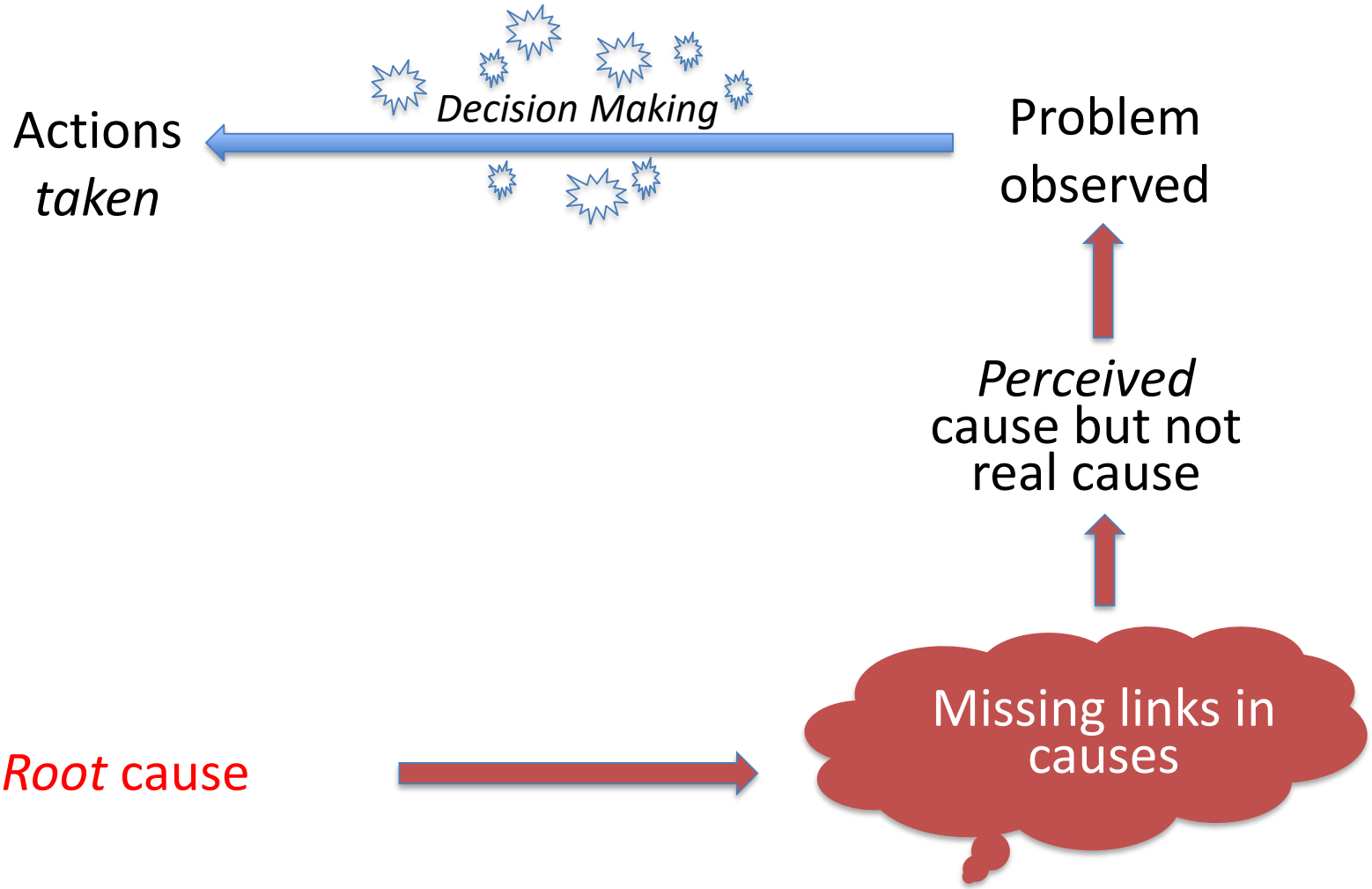
System Dynamics

- Extend our mental models through the creation of explicit models, which are clear, easily communicating and can be compared with each other. *Wikipedia*
- Increase the probability that the consequences of how we will decide and act in accordance with how we plan to. *Wikipedia*
- Developed to apply control theory to the analysis of industrial systems in the late 1950's by Jay Forrester, MIT Professor
- Used to analyze industrial, economic, social and environmental systems of all kinds

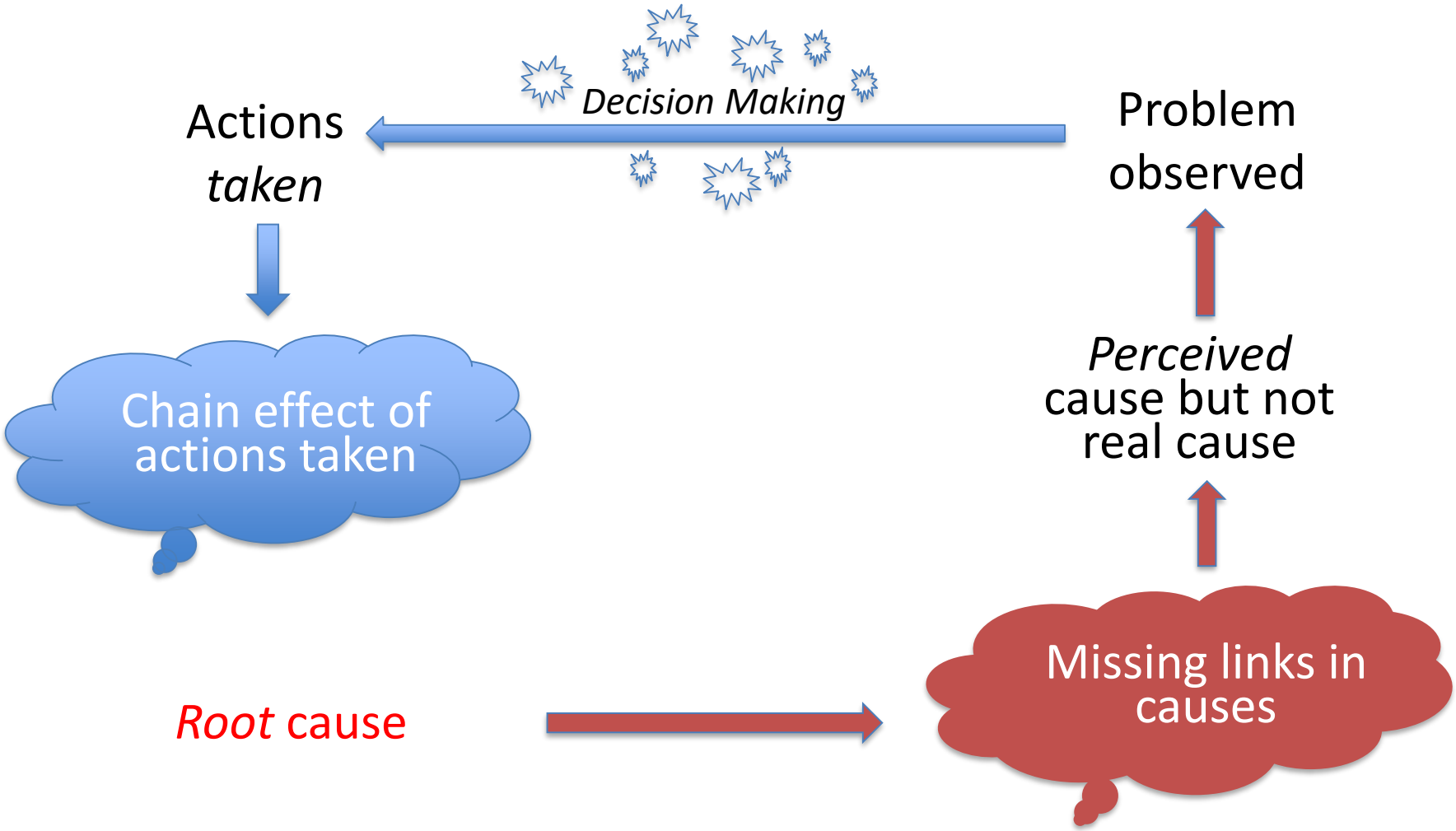
Finding the Root Cause by identifying missing links in causes



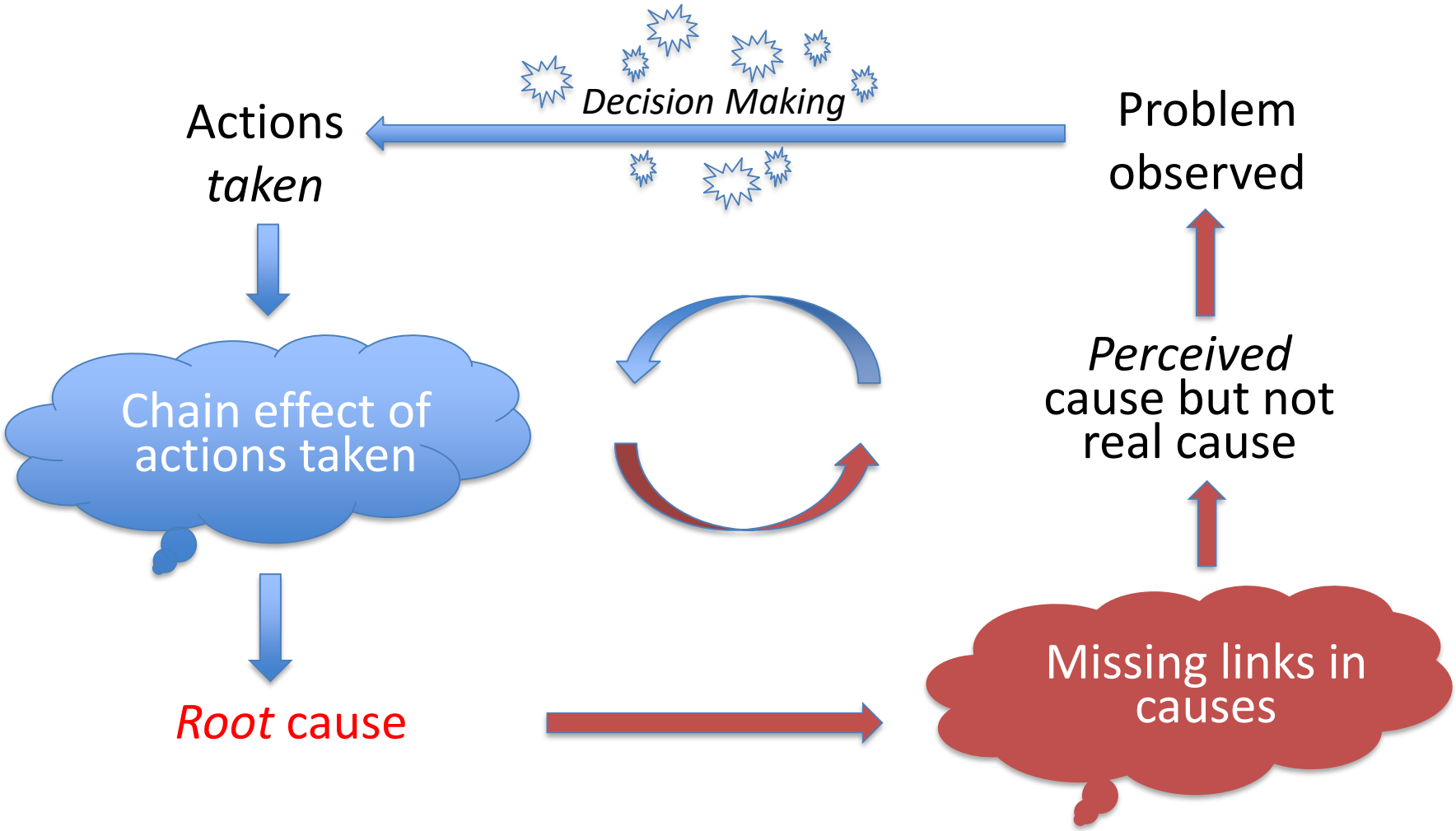
Decision making against cognition traps



Analyzing consequence of actions taken by simulating their chain effect



Also, understating their feedback effect back into the root cause



공통점은?...

나비효과

Mapping

System Dynamics

Stocks & Flows

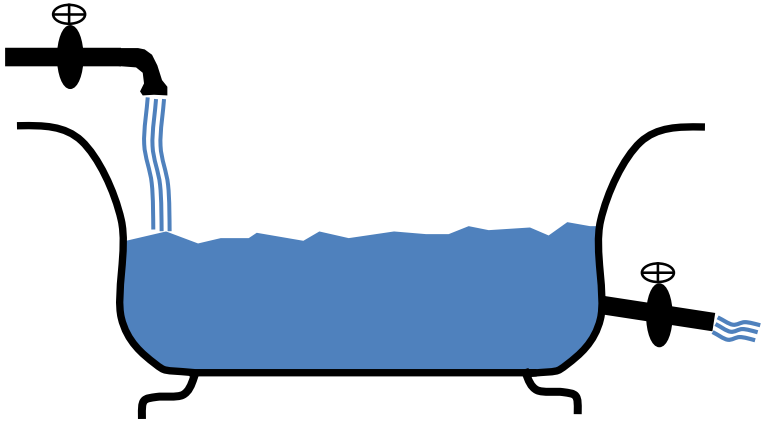
As the final element of system structure, there are two kinds of variables ...

- Stocks (also called ‘levels’): define the state of a system and represent stored quantities

- Flows (also called ‘rates’): define the rate of change in system states and control quantities flowing into and out of stocks

Representations

Hydraulic Metaphor:



Stock & Flow Diagram:

"Clouds" represent stocks outside the system boundary

Integral Equation:

$$\text{Stock}(t) = \int_{t_0}^{t} [\text{Inflow}(s) - \text{Outflow}(s)]ds + \text{Stock}(t_0)$$

Terminologies in Different Disciplines

Discipline	Stocks	Flows
Mathematics, Physics, Engineering	Integrals, states, state variables, stocks	Derivatives, rates of change, flows
Chemistry	Reactants, reaction products	Reaction rate
Manufacturing	Buffers, inventories	Throughput
Economics	Levels	Rates
Accounting	Stocks, balance sheet items	Flow, cash flow or income statement items
Biology, Physiology	Compartments	Diffusion rate, flows
Medicine, Epidemiology	Prevalence, reservoirs	Incidence, infection, morbidity, mortality rates

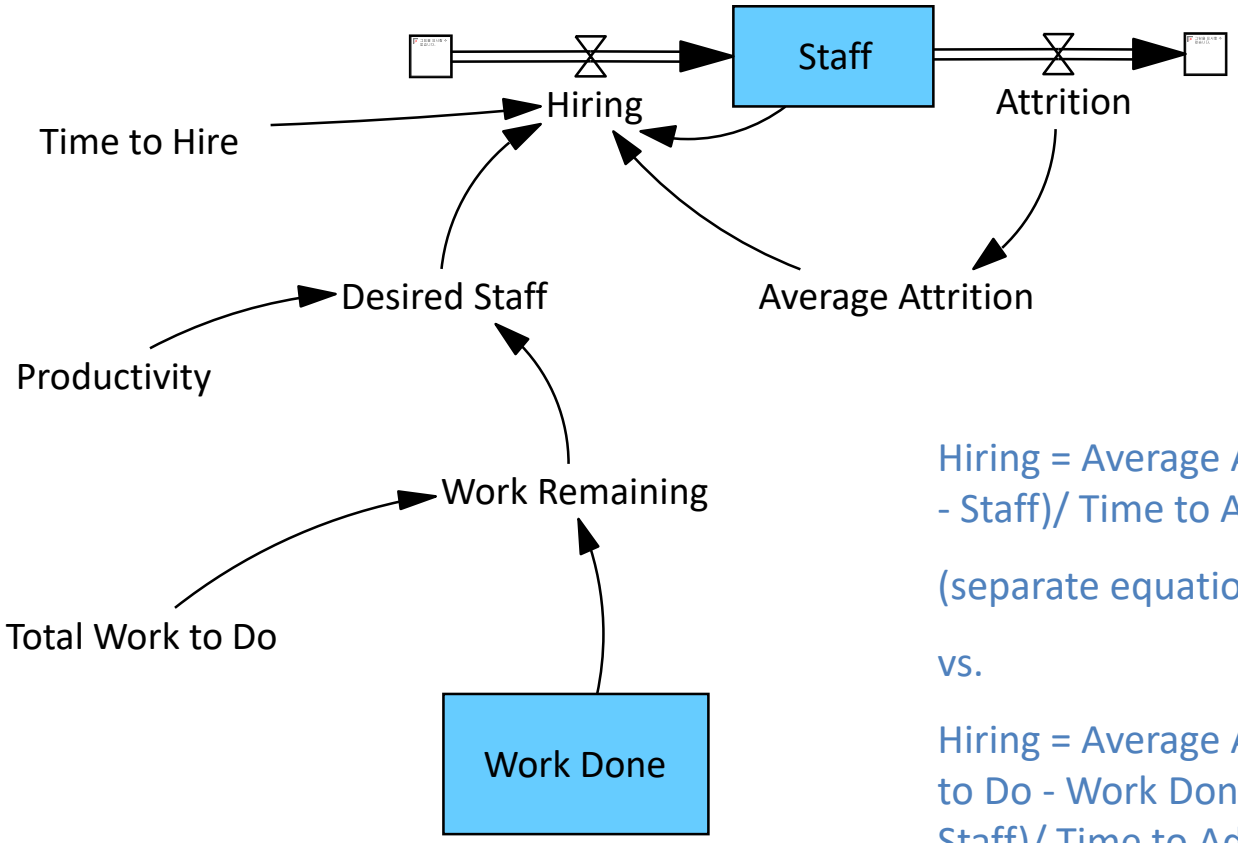
Business Dynamics, J, Sterman, 2000

Auxiliaries & Constants

- Auxiliaries: intermediate variables to be used for easy of communication and clarity

  - Break up rates into meaningful components
  - Provide alternative measures for stocks or flows
  - Reduce diagram “clutter”

- Constants: factors which may be stocks or flows, but which do not change over the time span of the simulation



Hiring = Average Attrition + (Desired Staff - Staff)/ Time to Adjust Staff

(separate equations for components)

vs.

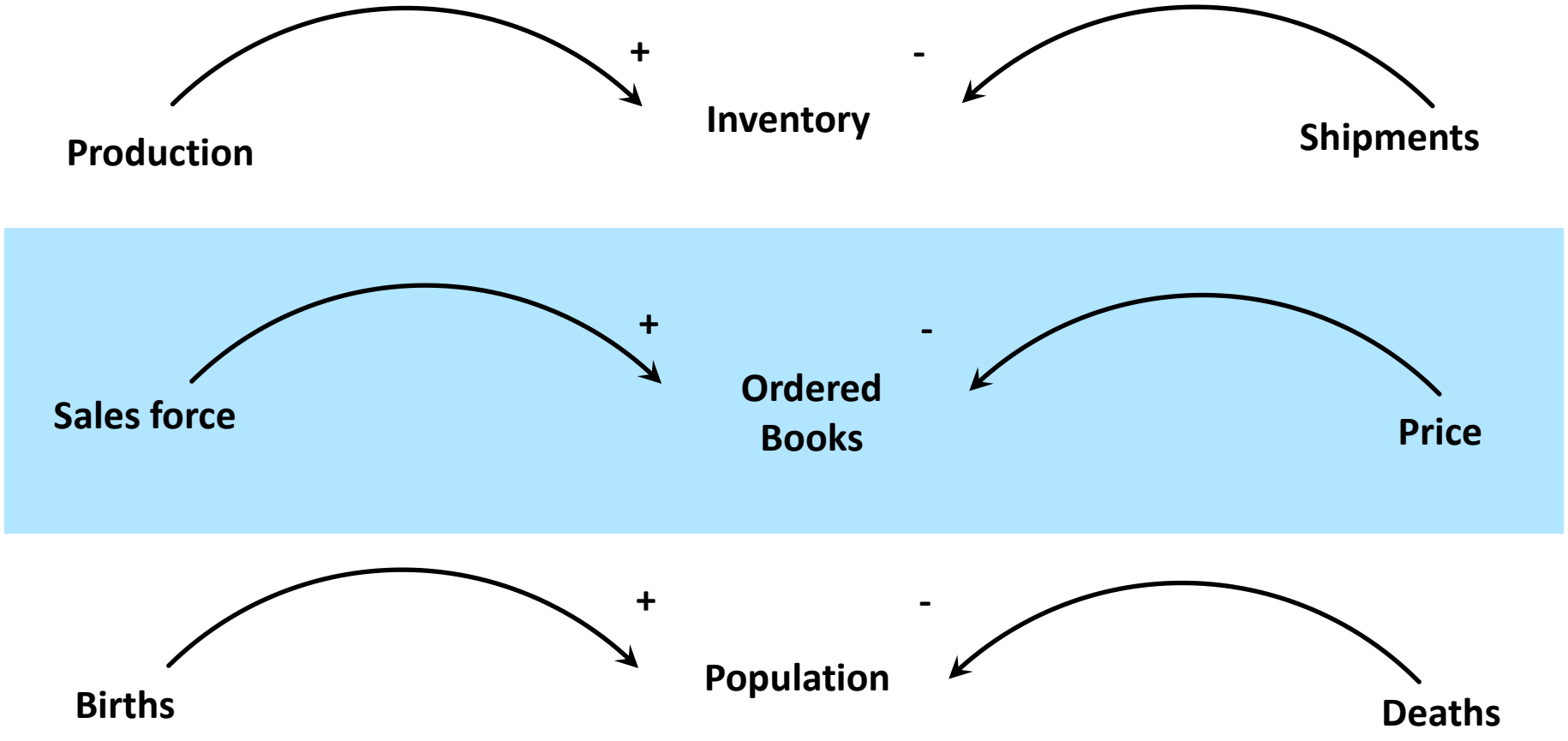
Hiring = Average Attrition + (((Total Work to Do - Work Done) / Productivity) - Staff)/ Time to Adjust Staff

Causal Links (Not Casual …)

- An arrow with a positive sign (+): all else remaining equal, an increase (decrease) in the first variable increases (decreases) the second variable *above (below) what it would otherwise have been.*

- An arrow with a negative sign (-): all else remaining equal, an increase (decrease) in the first variable decreases (increases) the second variable *below (above) what it otherwise would have been.*

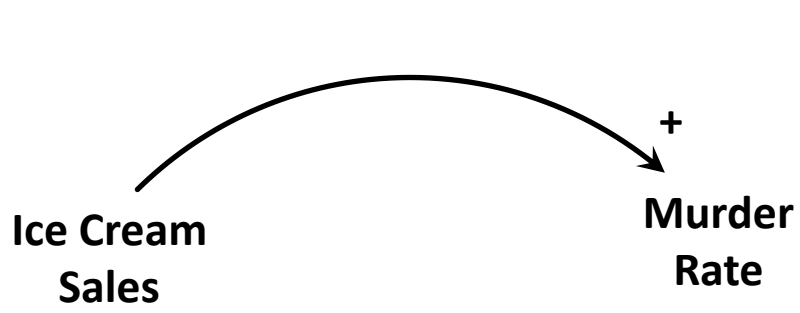
Labeling Link Polarity



Causation vs. Correlation

Causal diagrams must include only those relationships that capture the underlying causal structure of the system.

Observed behavior: "…Ice cream sales and murder rise in summer and fall in winter…"



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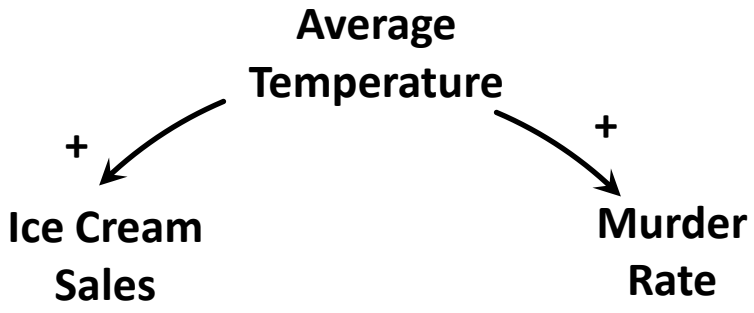
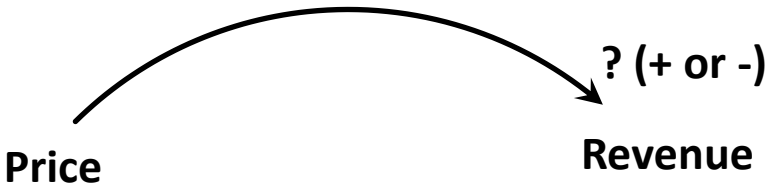


Correct

Having Unambiguous Polarities

All causal links must have unambiguous polarities.

* Apparently ambiguous polarities usually imply the presence of multiple causal pathways that can be represented separately.



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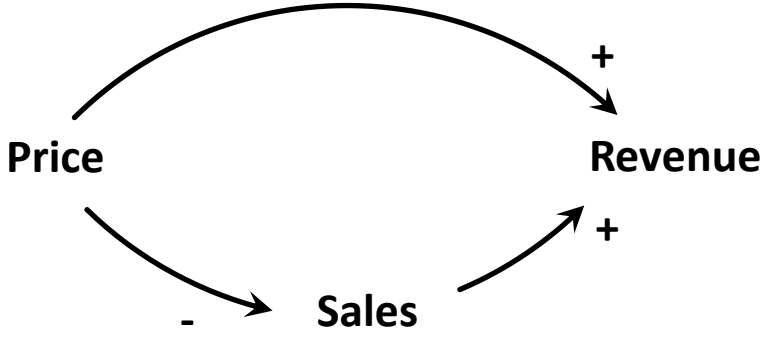
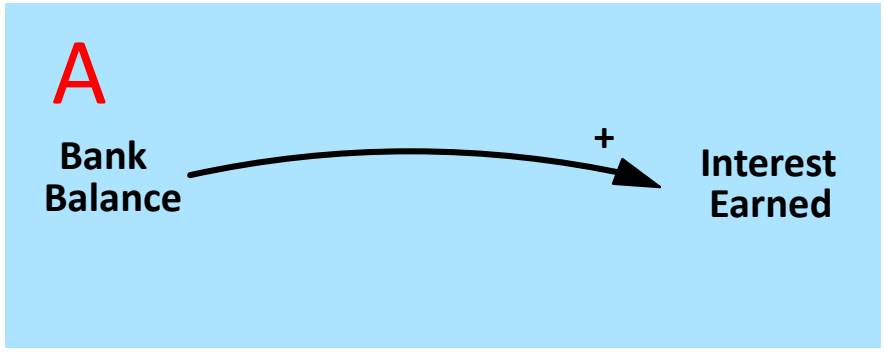
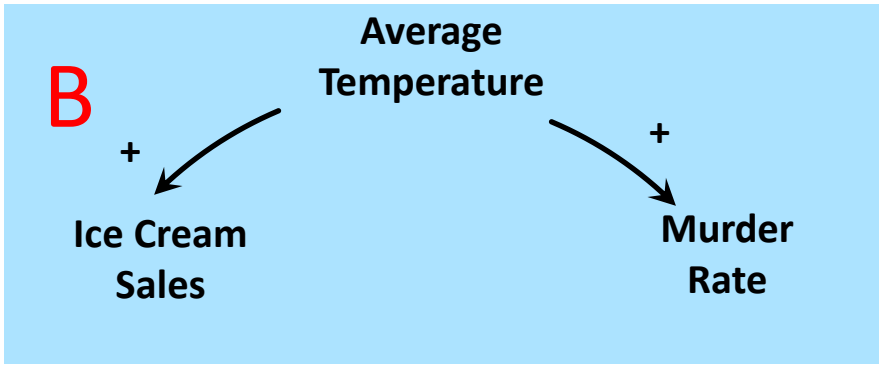
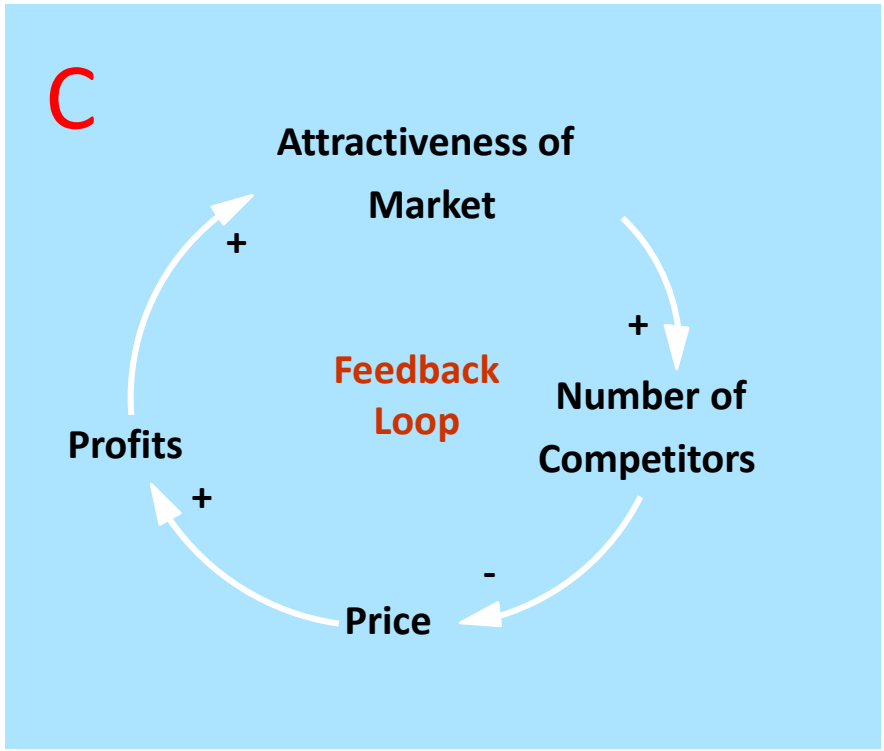


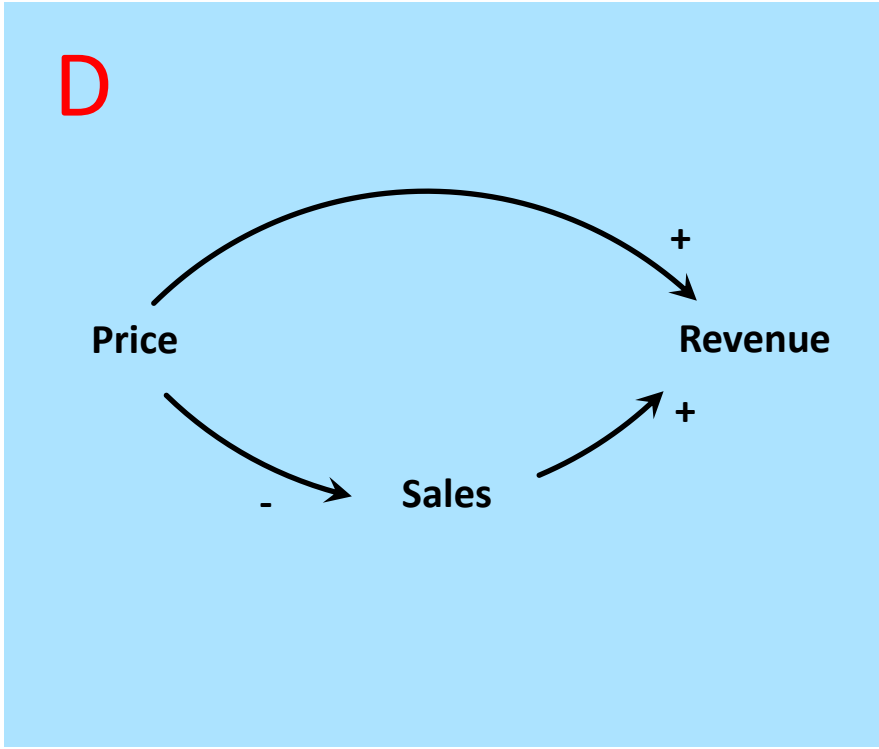
Correct

Identifying the Feedback Loop

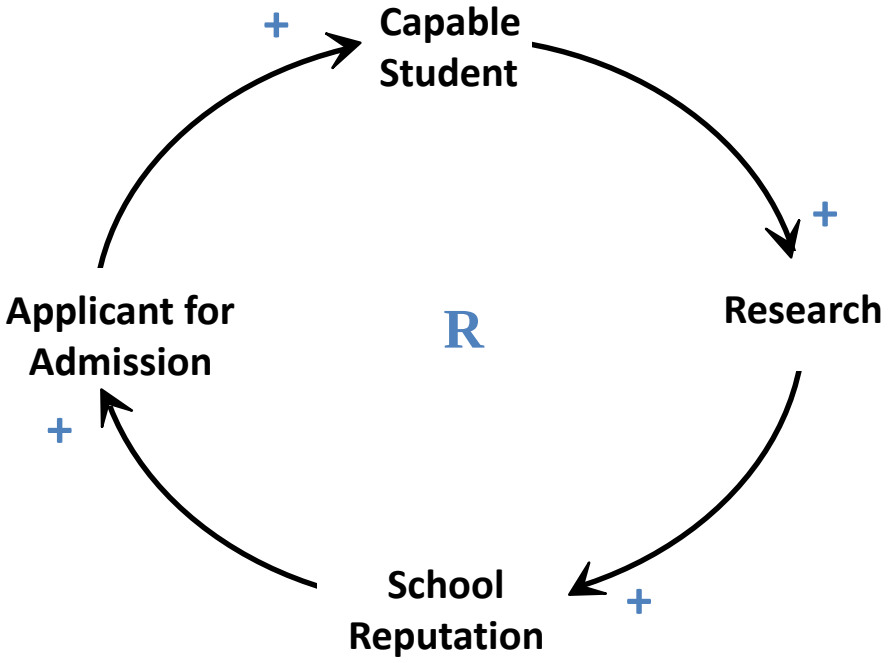






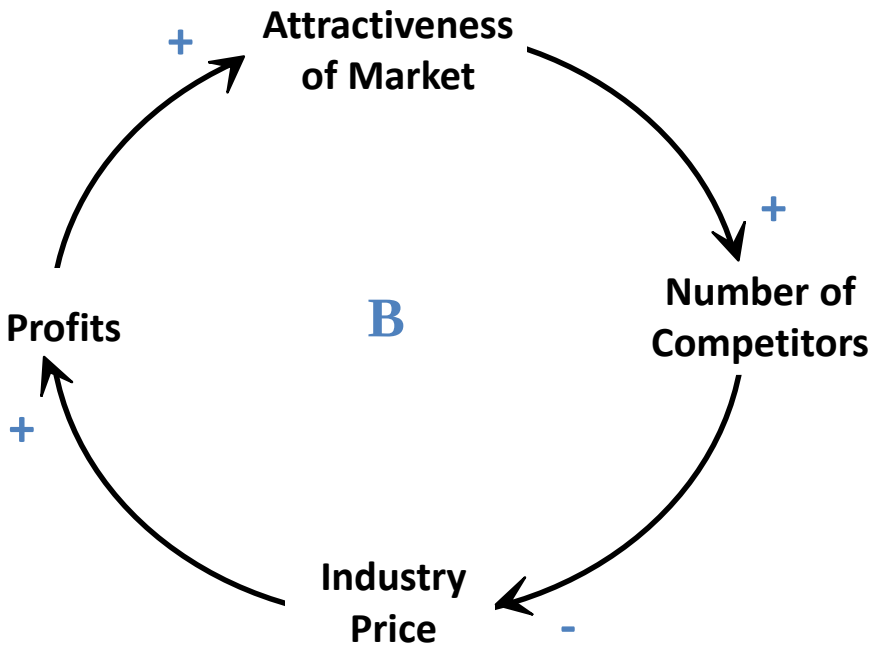


Loop Polarities: Reinforcing or Balancing?



Balancing Loops: loops with an odd number of negative causal links

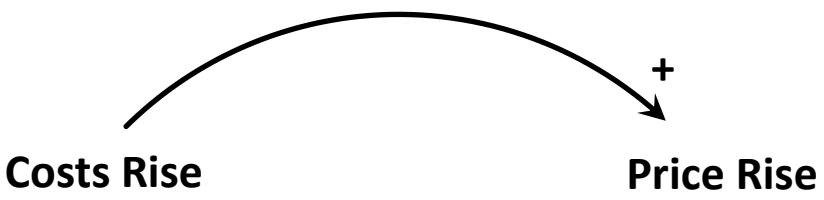
Reinforcing Loops: loops with all positive or an even number of negative causal links



Naming Variables

Names should be nouns or noun phrases.

- The actions (verbs) are captured by the causal links
- A causal diagram captures the structure of the system, not its behaviors



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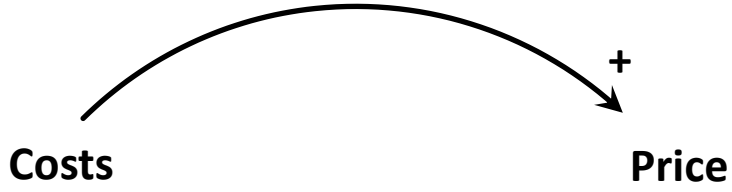
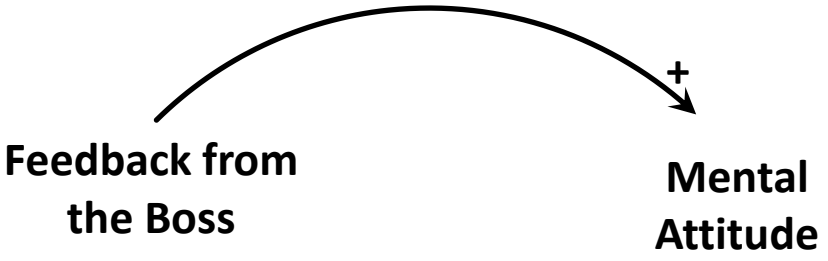


Correct

Naming Variables

Names should have a clear sense of direction.

Choose names for which the meaning of an increase or decrease is clear



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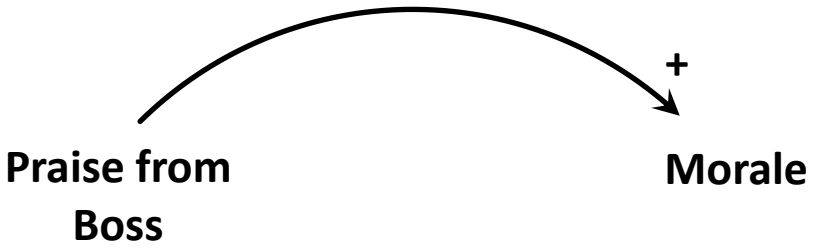
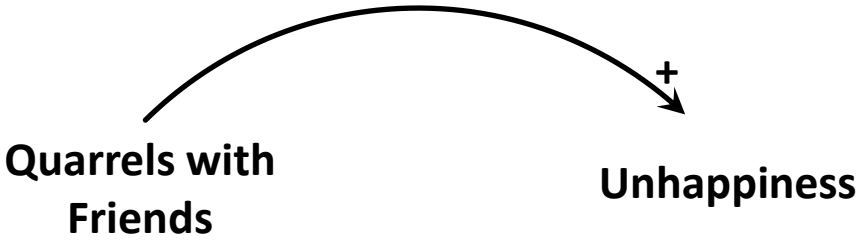


Correct

Naming Variables

Choose variables whose normal sense of direction is positive.

Avoid the use of variable names containing prefixes indicating negation (non, un, etc.)



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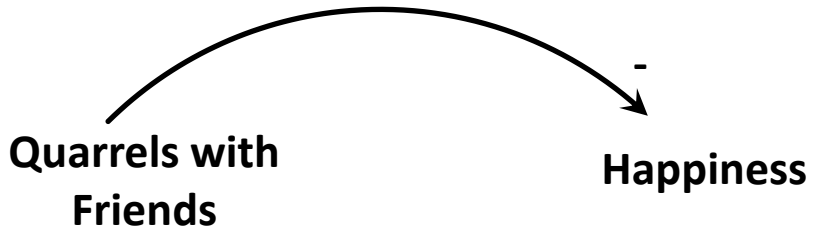


Correct

Making Goals Explicit

Make the goals of negative loops explicit.

- All negative feedback loops have goals (the desired state of the system)
- They function by comparing the actual state to the goal, then initiating a corrective action in response to the discrepancy.
- Making goals explicit encourages people to ask how the goals are formed.

Making Goals Explicit

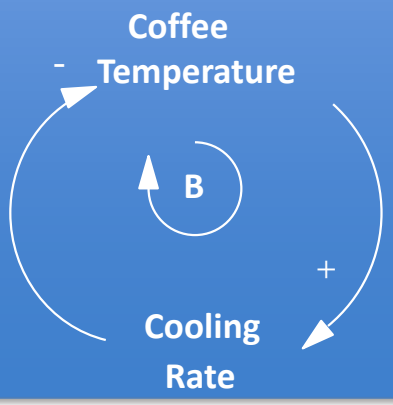
The goal of the loop is determined by management decision (human behaviors).

Incorrect

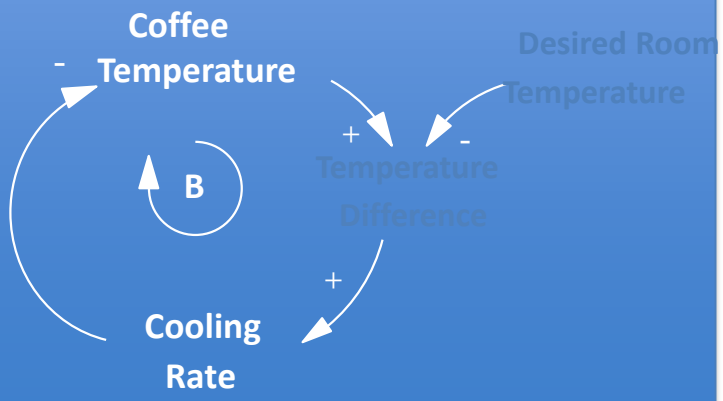
Correct

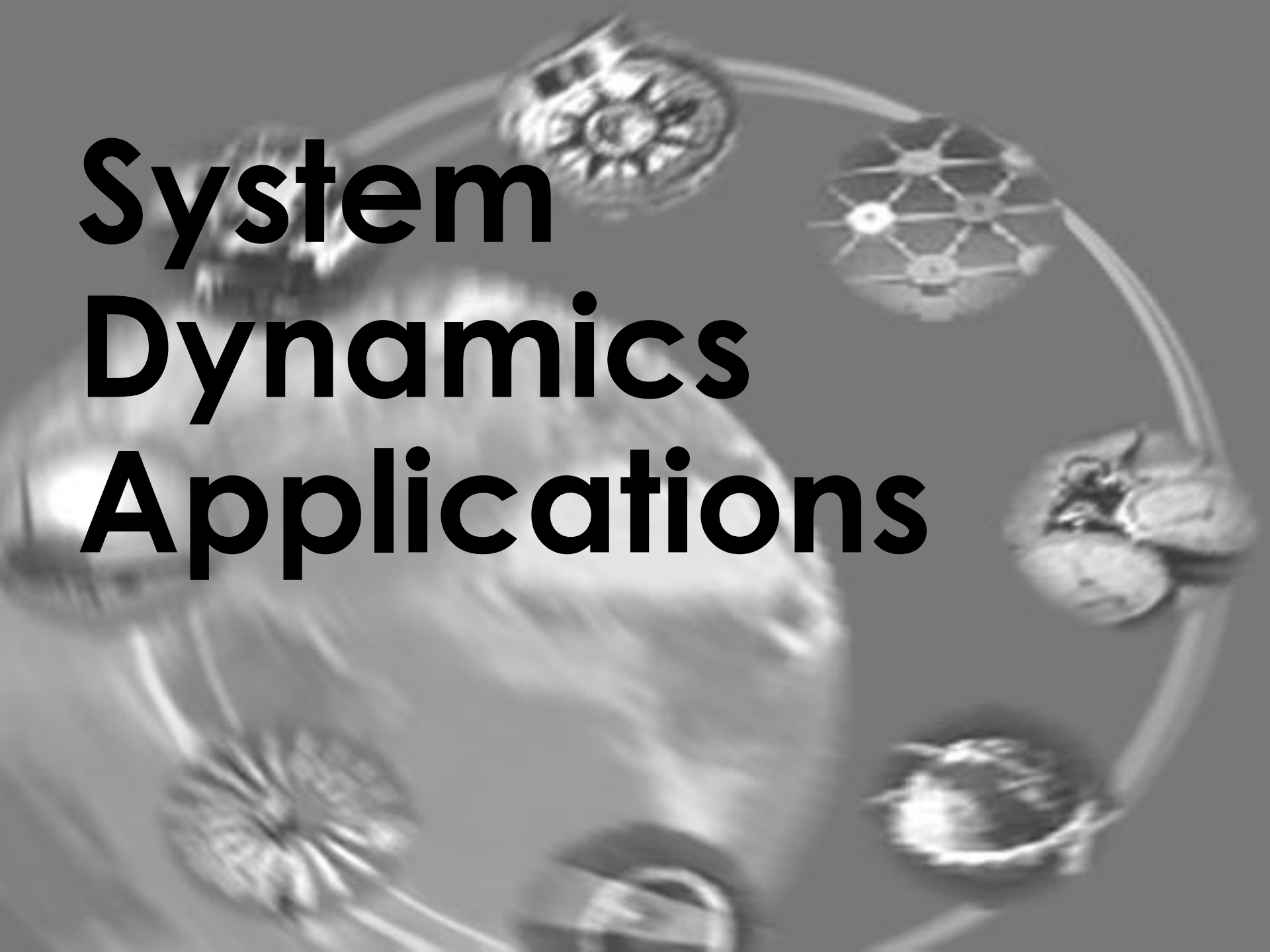
The goal of the loop is determined by the laws of thermodynamics (natural processes).

Incorrect

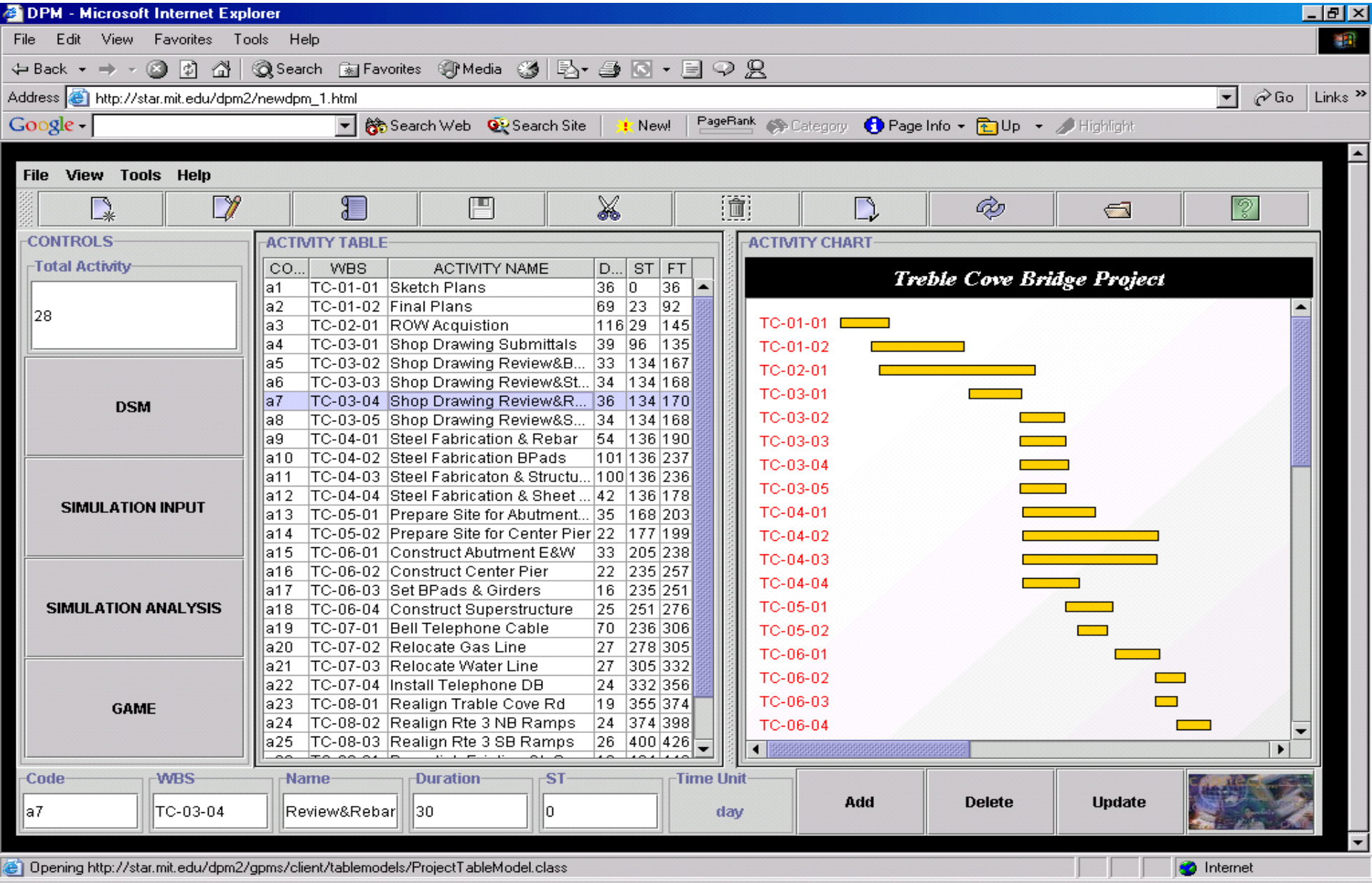


Correct

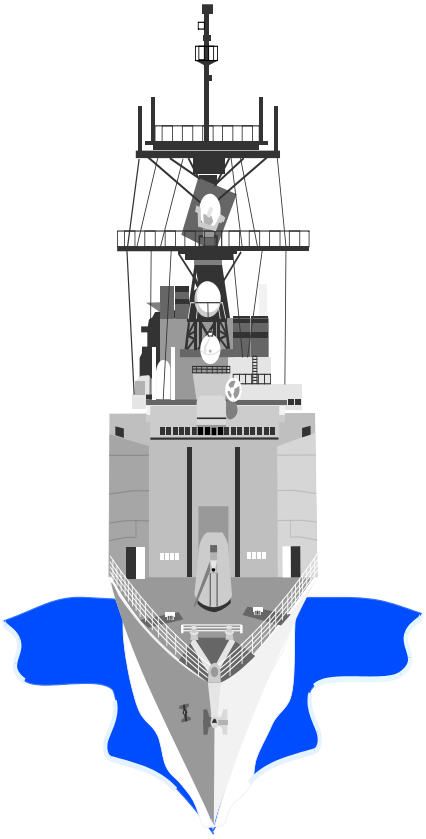



System
Dynamics
Applications

DPM


DPM - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://star.mit.edu/dpm2/newdpm_1.html
Go Links
Google Search Web Search Site New! PageRank Category Page Info Up Highlight
File View Tools Help
CONTROLS
Total Activity
28
DSM
SIMULATION INPUT
SIMULATION ANALYSIS
GAME
ACTIVITY TABLE
CO... WBS ACTIVITY NAME D... ST FT
a1 TC-01-01 Sketch Plans 36 0 36
a2 TC-01-02 Final Plans 69 23 92
a3 TC-02-01 ROW Acquistion 116 29 145
a4 TC-03-01 Shop Drawing Submittals 39 96 135
a5 TC-03-02 Shop Drawing Review&B... 33 134 167
a6 TC-03-03 Shop Drawing Review&St... 34 134 168
a7 TC-03-04 Shop Drawing Review&R... 36 134 170
a8 TC-03-05 Shop Drawing Review&S... 34 134 168
a9 TC-04-01 Steel Fabrication & Rebar 54 136 190
a10 TC-04-02 Steel Fabrication BPads 101 136 237
a11 TC-04-03 Steel Fabricaton & Structu... 100 136 236
a12 TC-04-04 Steel Fabrication & Sheet ... 42 136 178
a13 TC-05-01 Prepare Site for Abutment... 35 168 203
a14 TC-05-02 Prepare Site for Center Pier 22 177 199
a15 TC-06-01 Construct Abutment E&W 33 205 238
a16 TC-06-02 Construct Center Pier 22 235 257
a17 TC-06-03 Set BPads & Girders 16 235 251
a18 TC-06-04 Construct Superstructure 25 251 276
a19 TC-07-01 Bell Telephone Cable 70 236 306
a20 TC-07-02 Relocate Gas Line 27 278 305
a21 TC-07-03 Relocate Water Line 27 305 332
a22 TC-07-04 Install Telephone DB 24 332 356
a23 TC-08-01 Realign Trable Cove Rd 19 355 374
a24 TC-08-02 Realign Rte 3 NB Ramps 24 374 398
a25 TC-08-03 Realign Rte 3 SB Ramps 26 400 426
ACTIVITY CHART
Treble Cove Bridge Project
TC-01-01
TC-01-02
TC-02-01
TC-03-01
TC-03-02
TC-03-03
TC-03-04
TC-03-05
TC-04-01
TC-04-02
TC-04-03
TC-04-04
TC-05-01
TC-05-02
TC-06-01
TC-06-02
TC-06-03
TC-06-04
Code a7
WBS TC-03-04
Name Review&Rebar
Duration 30
ST 0
Time Unit day
Add
Delete
Update
Opening http://star.mit.edu/dpm2/gpms/client/tablemodels/ProjectTableModel.class
Internet

The US Navy and Ingalls case



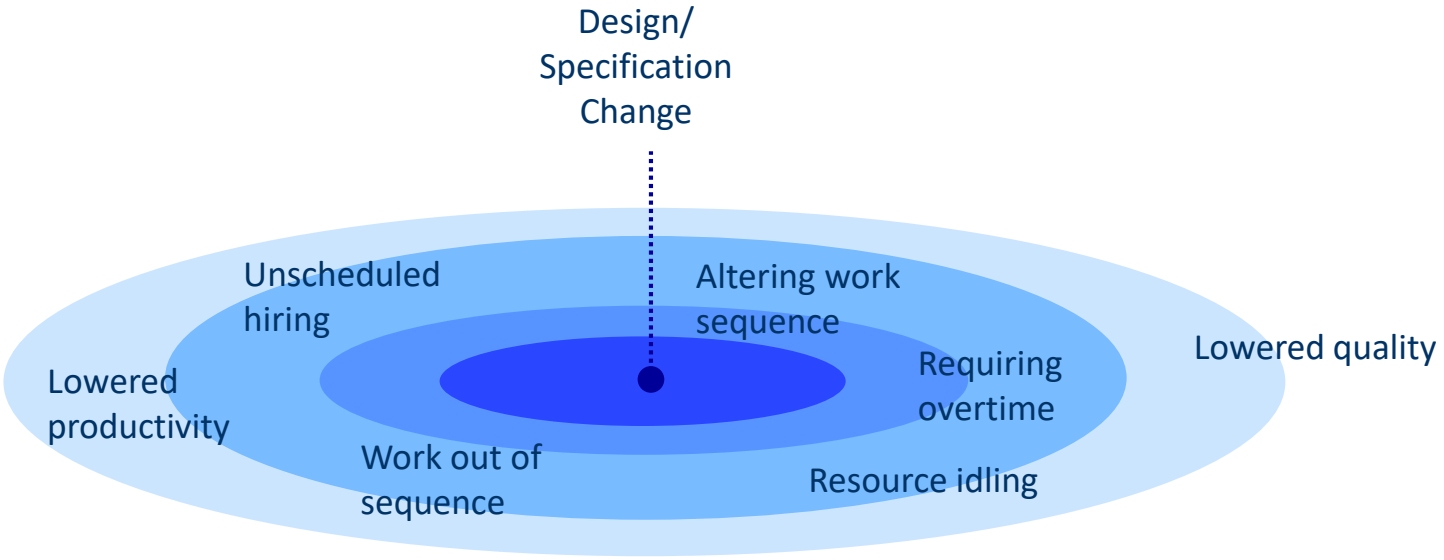
A system dynamics model developed by Pugh-Roberts Associates in the US was used to settle the claim against the US Navy in the late 1970's.

With help of this modeling approach, the ship builder, Ingalls managed to receive $447 million as compensation for their financial losses caused by the owner's design and specification changes.

Reference: Business Dynamics (Sterman, 2000); Strategic management of complex projects (Lyneis et al., 2001)

Quantifying the ripple effects

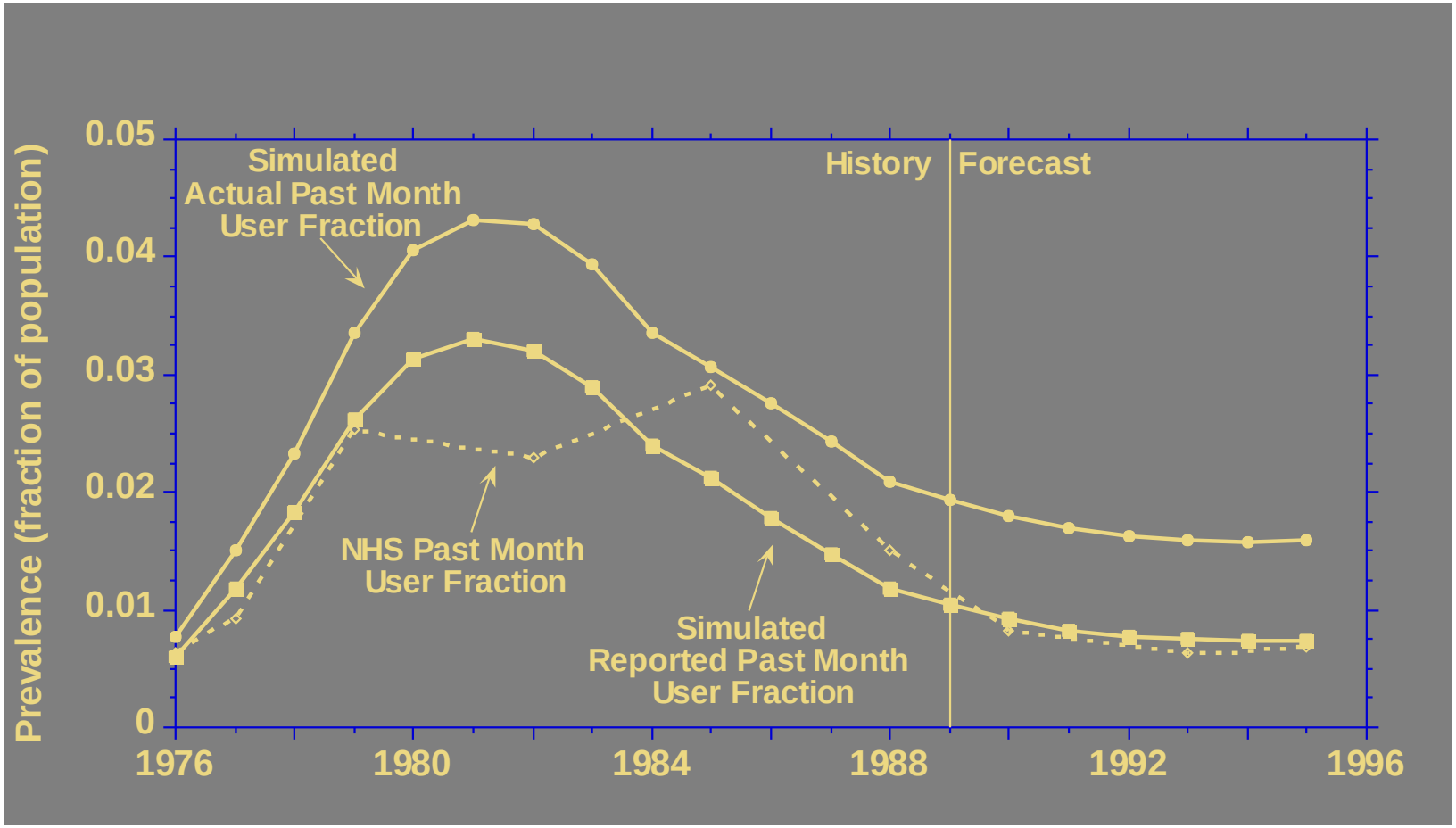
Traditional project management tools such as CPM, PDM, and PERT do not provide a mean to quantify the ripple effects that multiply the direct impact many times, leading to significant overall delay and disruption.



Reference: Business Dynamics (Sterman, 2000); Strategic management of complex projects (Lyneis et al., 2001)

The War on Drugs

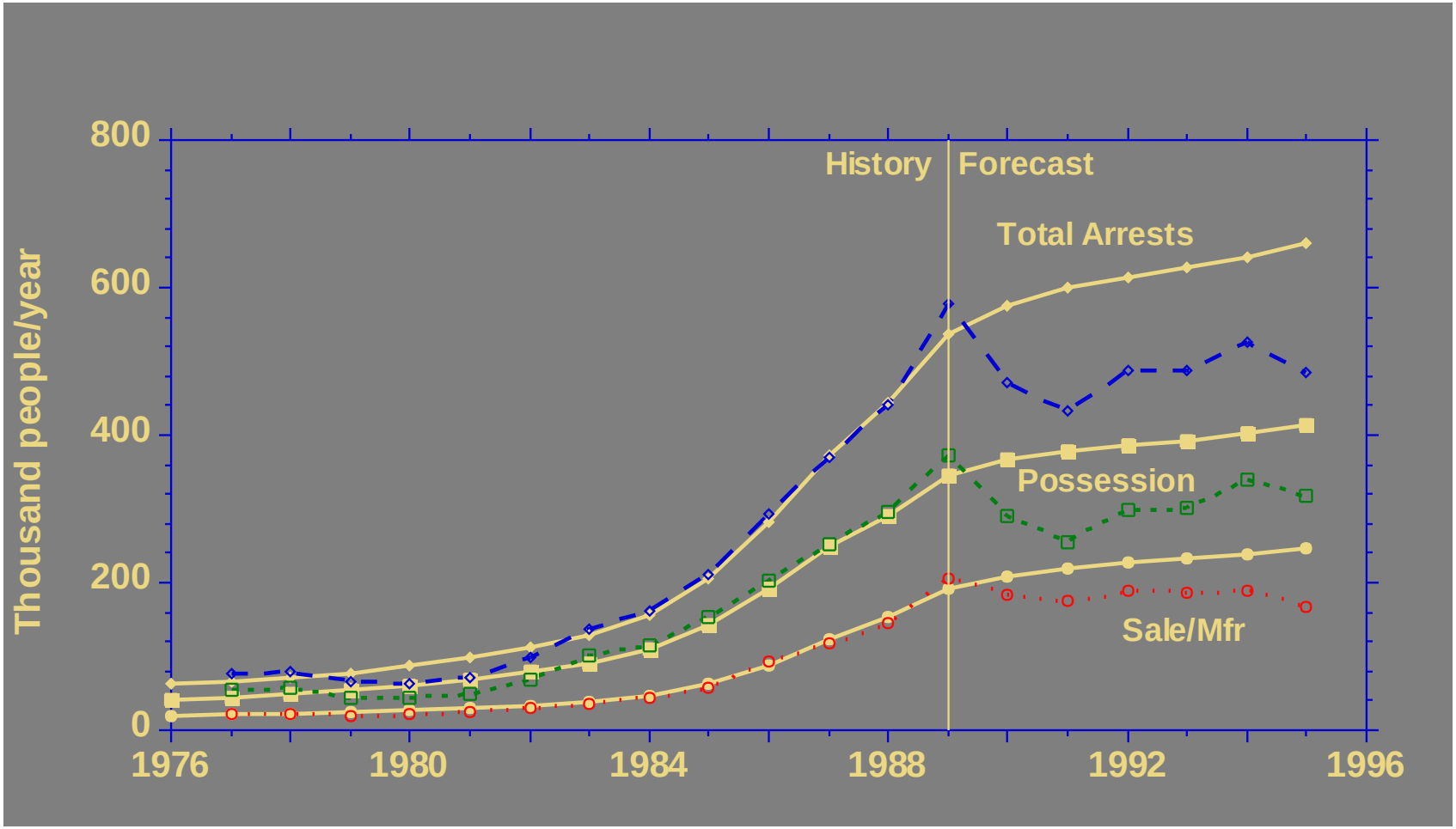
Past month user friction decreased…



Simulated vs. actual cocaine epidemic. Dashed lines, data; solid lines, model.

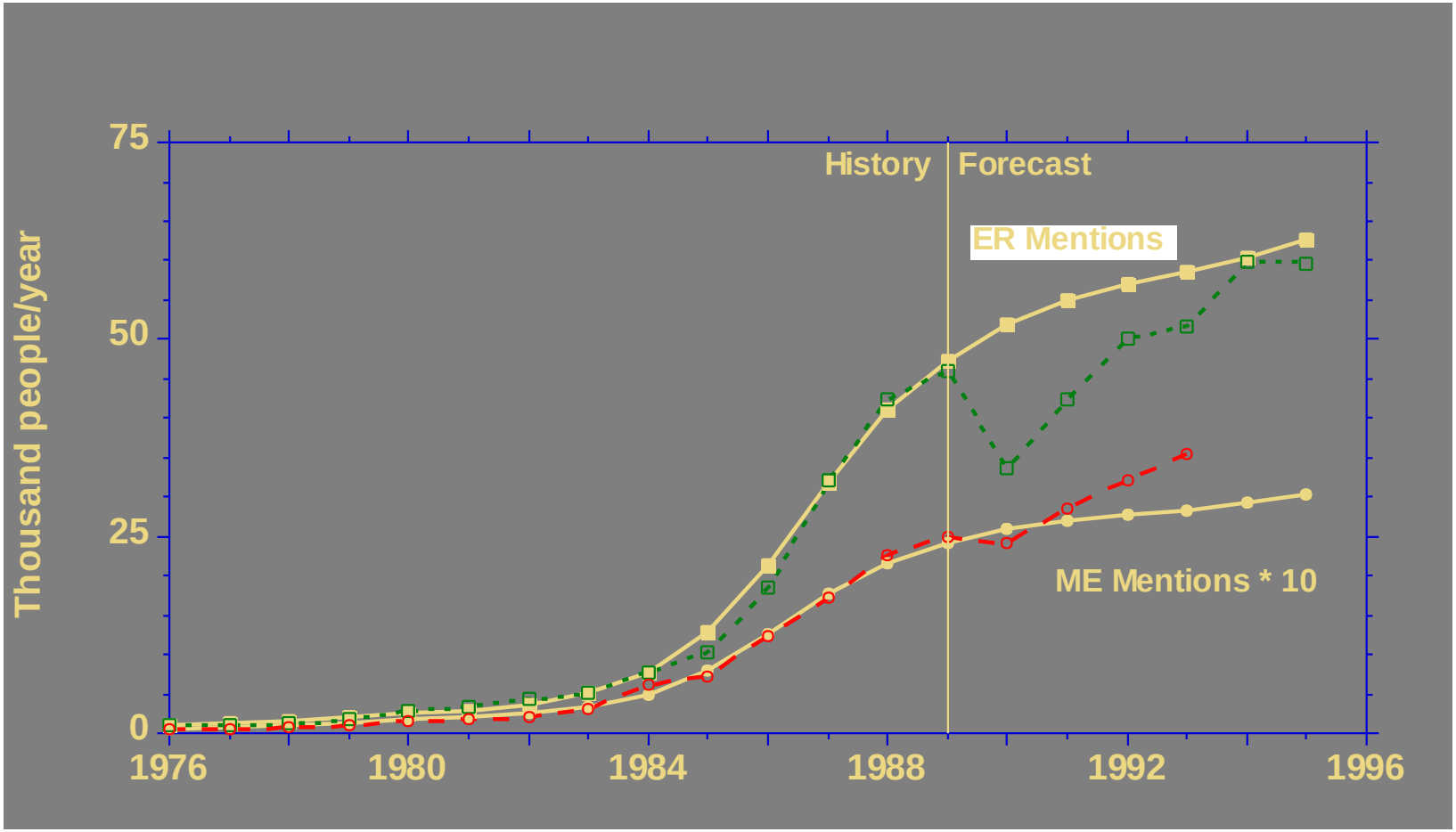
***Source*: Homer (1993, 1997)**

But, drug possession, arrests, sales increased



***Source*: Homer (1993, 1997)**

Even worse…


75
50
25
0
Thousand people/year
1976
1980
1984
1988
1992
1996
History
Forecast
ER Mentions
ME Mentions * 10

Where to Get More

- System Dynamics Group at MIT

  http://sysdyn.mit.edu/sd-group/

- System Dynamics Society

  http://www.albany.edu/cpr/sds/

- System Dynamic Review

  SNU Library

- Ventana Systems: download Vensim PLE version

  http://www.vensim.com/

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- **Sarah Slaughter, "Innovation in construction", MIT 1.420 Course Material, 1999**
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Where did the gasoline go?