

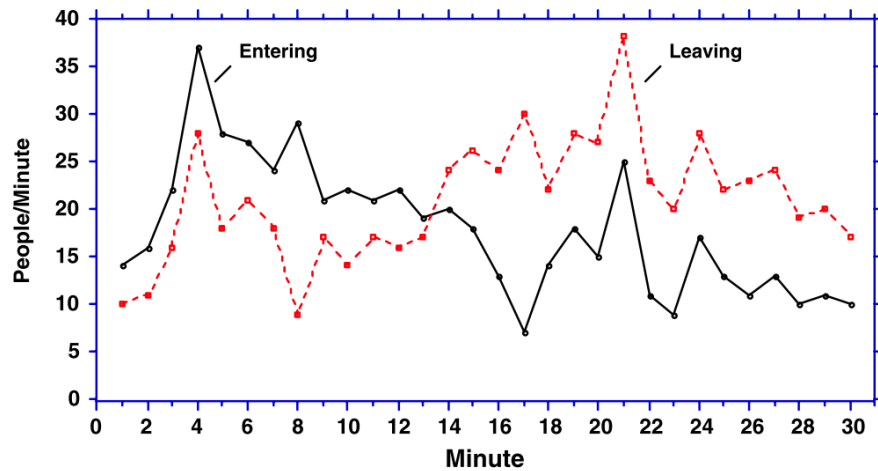


Seminar 3: Non-linear Dynamics

- Brain teaser
- Debrief from last week's Beer Game
- Open vs. Closed Systems
- Multi-loop feedback systems
- Postcard Stories Exercise



Warm up exercise: Stermann's Store

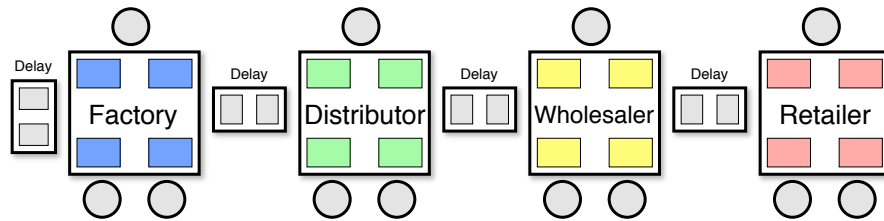


Source: Cronin M, et al, 2009 Why don't well-educated adults understand accumulation?





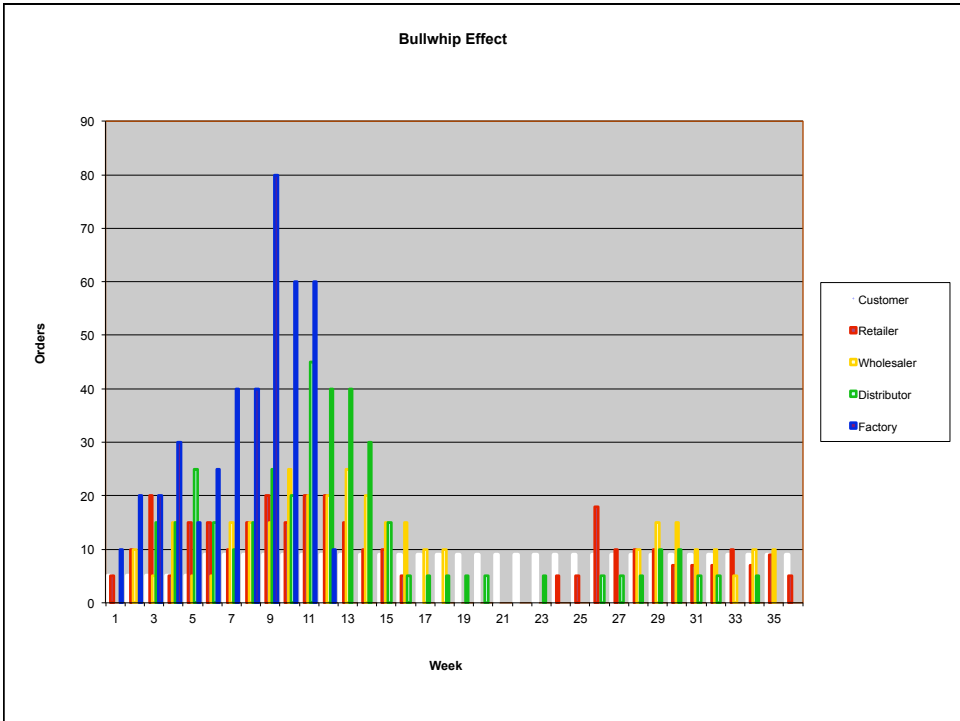
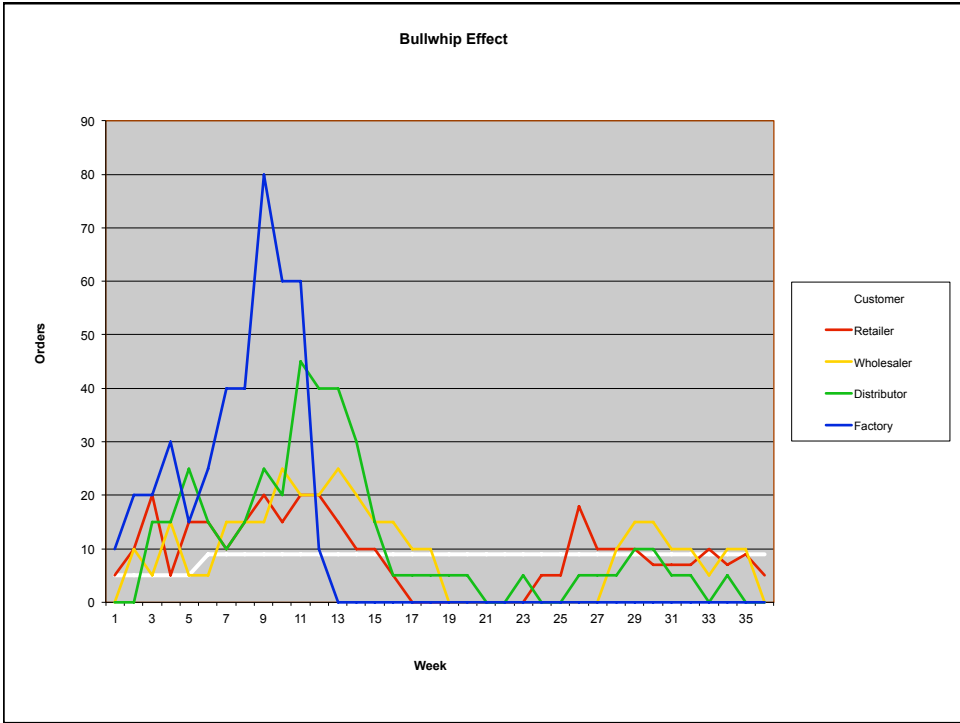
The Beer Game

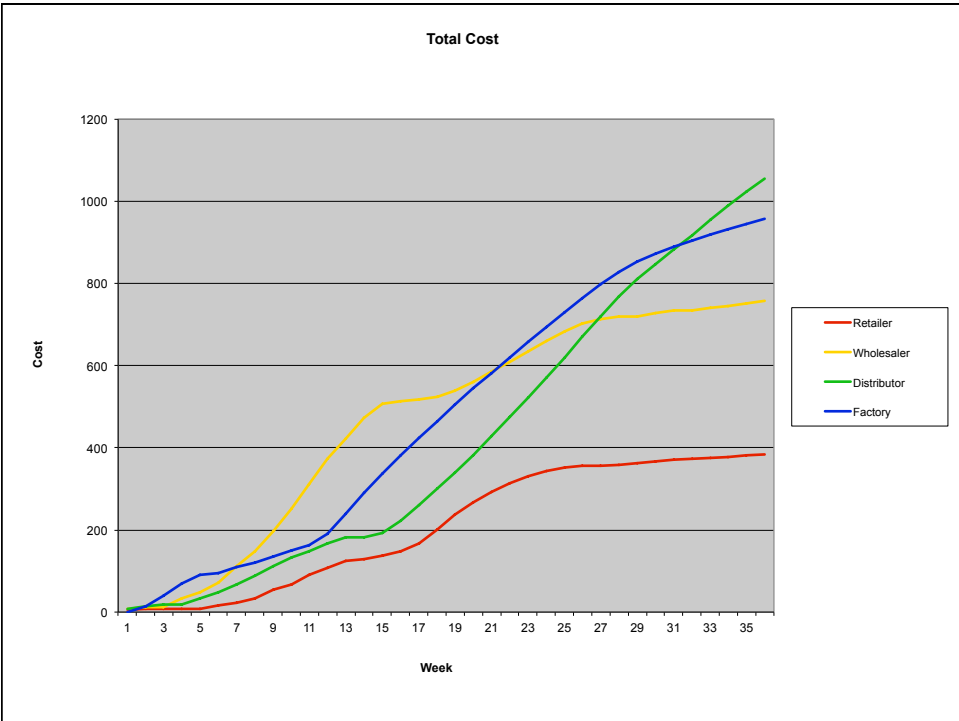
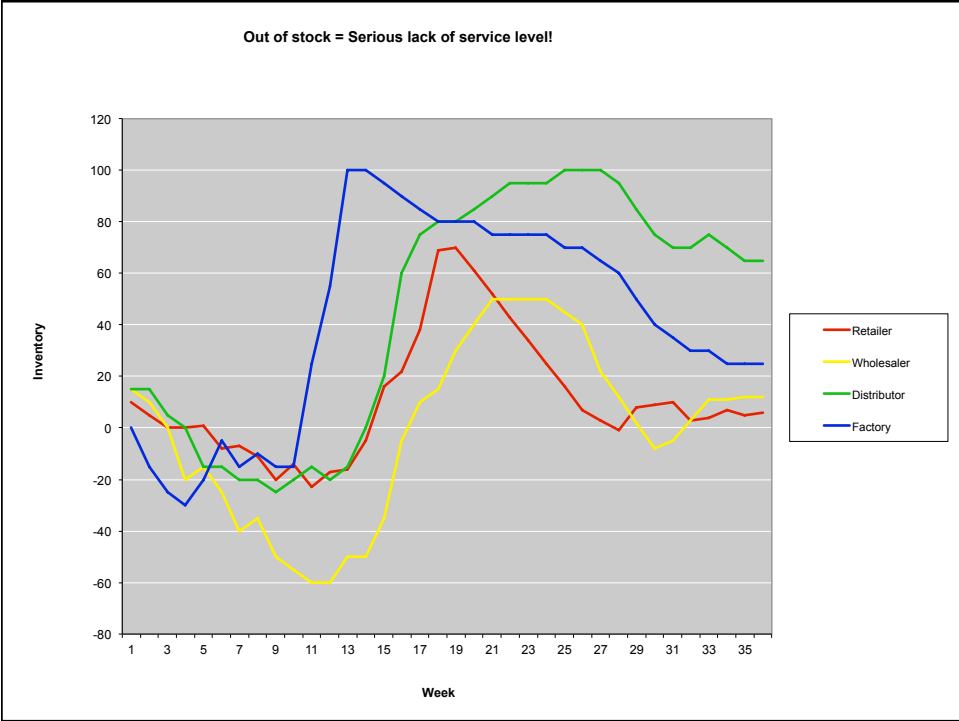


Debriefing Structure

1. **Tell the Story**
 - ↳ What happened?
 - ↳ How did you feel about it?
2. **Graph the Variables**
3. **Model the System Structure**
4. **Identify Lessons Learned**

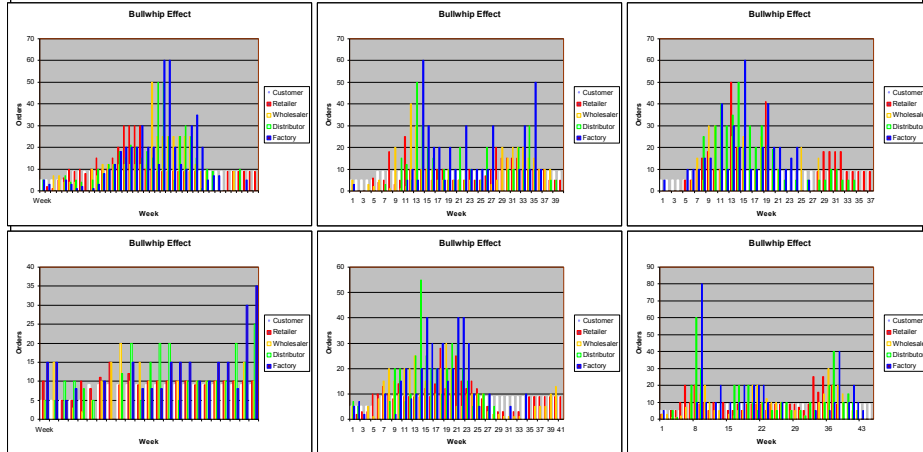








Other groups



Source: Beergame Debriefing, by Kai Riemer, <http://www.beergame.org>



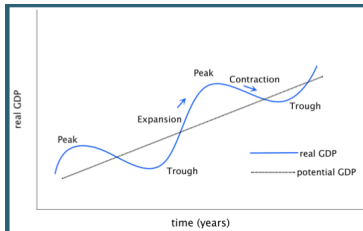
Key Lessons

- **Delays in feedback cause volatility**
- **Structure of the system determines its behaviour**
- **Cannot change system behaviour without changing the structure that gives rise to it**
- **Need info on whole system in order to manage it**

Q: What other systems have this behaviour?



Other Systems

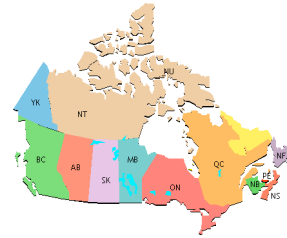
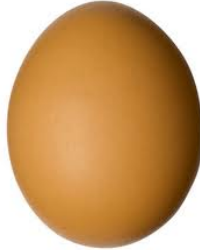


Open vs. Closed Systems

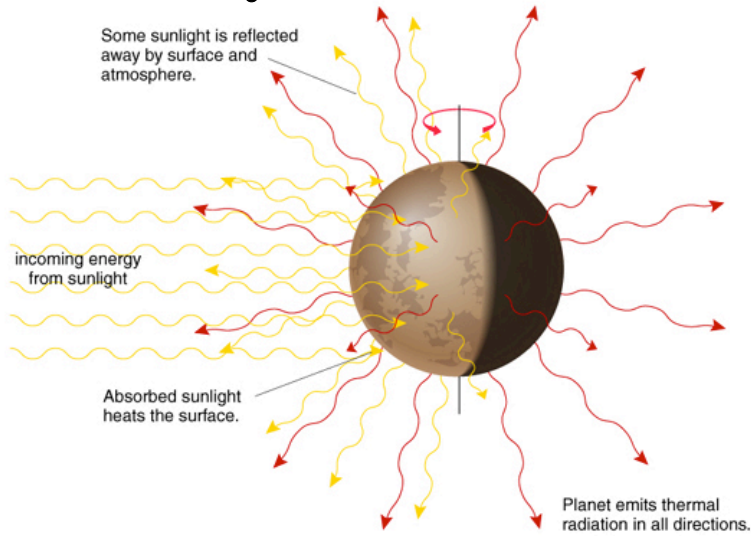
- **Openness: The degree to which a system can be distinguished from its environment**
- **A closed system has no environment**
 - ↳ If we describe a system as closed, we ignore its environment
 - ↳ E.g. an egg can be described as a closed system (except...?)
- **A fully open system merges with its environment**



Open vs. Closed?



"Black-body" Radiation from the Earth



© Addison-Wesley Longman





A very simple climate model

Incoming solar radiation = Outgoing blackbody radiation

$$(1-a)S\pi r^2 = 4\pi r^2 \epsilon \sigma T^4$$

albedo of the earth

solar radiation

radius of the earth

emissivity of the earth

temperature of the earth's surface

Stefan-Boltzmann constant

Solving for temperature, you get:

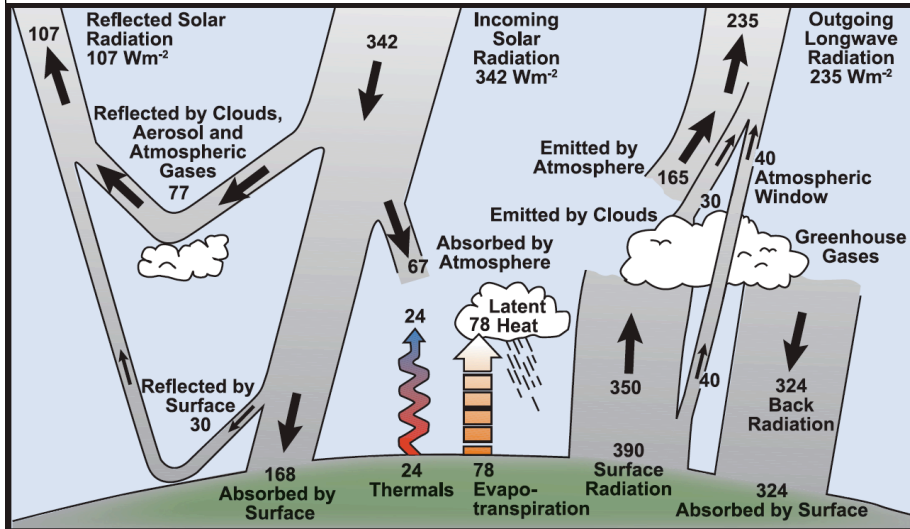
$$T = \sqrt[4]{\frac{(1-a)S}{4\epsilon\sigma}} \approx 12^\circ\text{C}$$

Source: http://en.wikipedia.org/wiki/Climate_model



Basic Energy Balance Model

(Source: IPCC AR4, 2007, WG1, pg96)





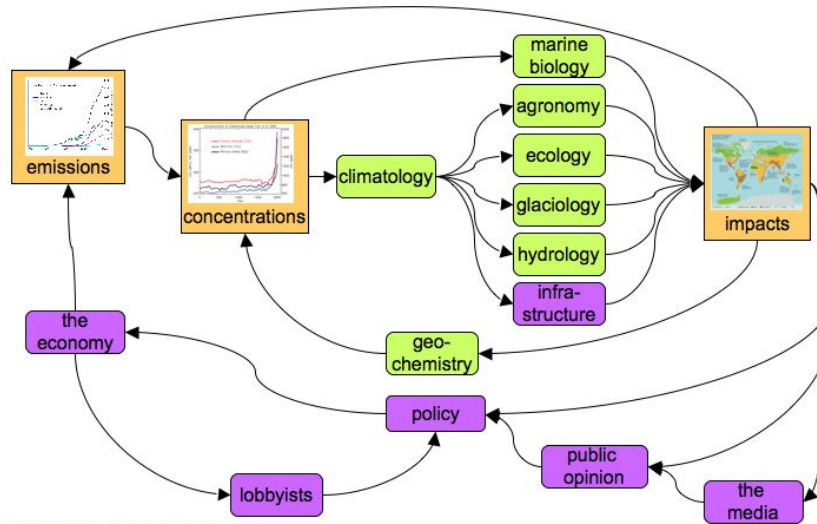
Open or closed systems?

Media coverage of climate change

International policy Negotiations?



System of Systems for Climate Change



Adapted from a diagram by Michael Tobis

