Structural Transparency of a Factory Simulation Model

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Webinar at Department of International Finance, Financial University, Moscow, Russia.
February 10, 2014. Available online:
http://www.iff.fa.ru/index.php?q=en/en/content/seminar-2-02122013

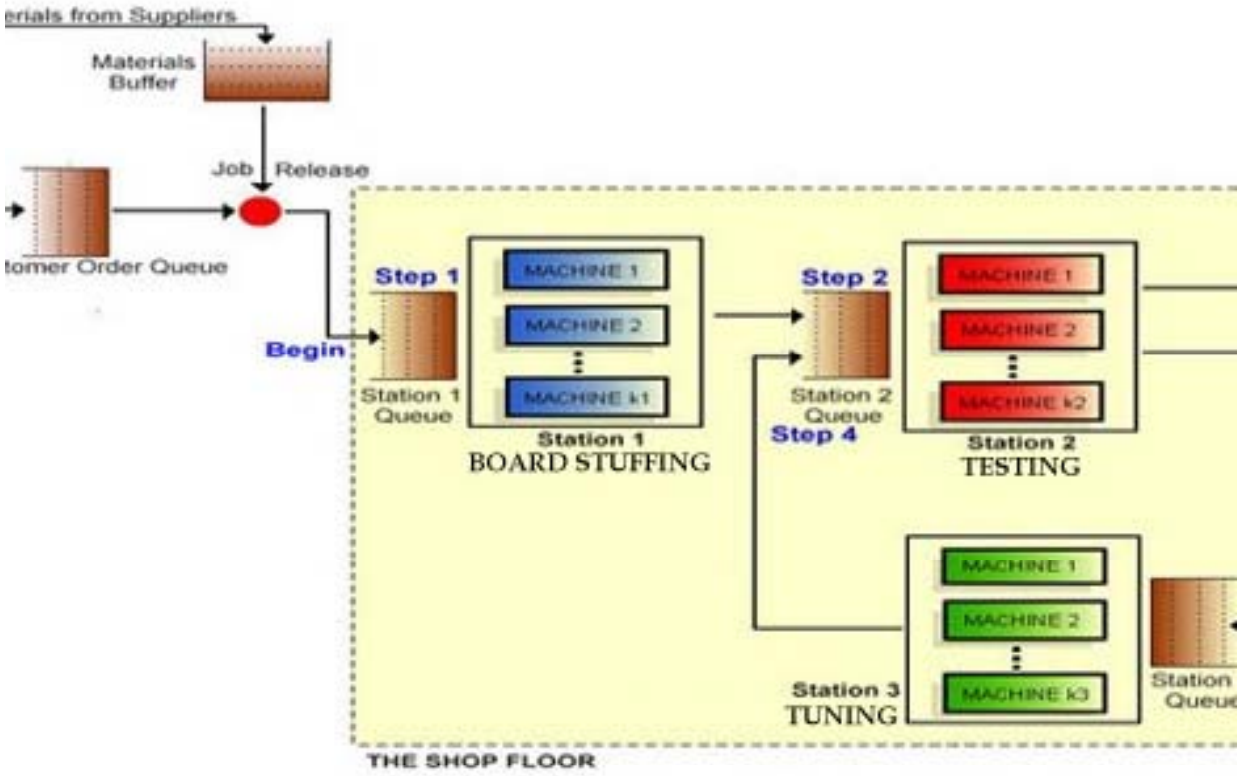
WPI

Cornell University

Littlefield Simulation

- Part of an Executive MBA course at Cornell University on Operations Management
- Played by students over 5 days
- Students are professionals, average age about 35
- Commercial online simulation of a small factory
- Learning objectives: managing inventory, in-process queues
- This team project is worth 12% of the grade
- Deliverables: participation in the simulation, written report

Littlefield Simulation



Job orders

3 stations

4 steps

Machines

Raw materials

Lead time

3 types of contracts

What does this project do?

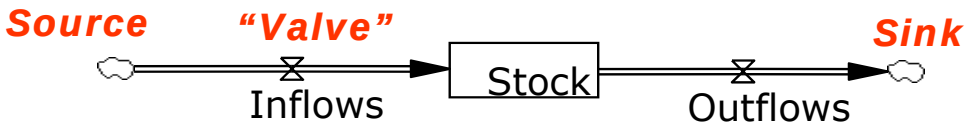
- Original simulation (Littlefield Technologies) is a black box
- Purpose of this project is to create a debriefing protocol for a business simulation
- Use simulation of a simulation approach
- System Dynamics methodology is used to create a simulation of a simulation
- We add structural transparency to a black box
- The model, the causal loop diagrams, stock and flow diagrams as well as documentation of structural equations can also be used for prior exploration

Why debriefing?

- Historically 3 uses of debriefing: military, psychological experiments, education
- The size and the use of debriefing can vary
  - Talking in groups
  - A journal
  - A written report
- Our debriefing is an instructional enhancement
  - Debriefing improves learning
  - Learning vs. performance in the simulation
- Helps the adoption of simulation-based instruction

System dynamics

- Stocks
  - Stocks define the state of the system
  - Stocks = Levels = States = Accumulations = Integration
  - Stocks can only change by the action of flows
  - Stocks decouple flows
    - Make it possible for an inflow and outflow to be different (i.e, create a disequilibria) E.g., spend more than earn
    - Make it possible for inflow to be controlled by different sources of information
  - Stocks create delays
  - Things that accumulate
  - What is left if you stop time
  - Stocks have inertia, memory, persistence
    - If you turn off the flow to a stock, the stock remains
  - "Clouds" represent stocks outside the system boundary



System dynamics

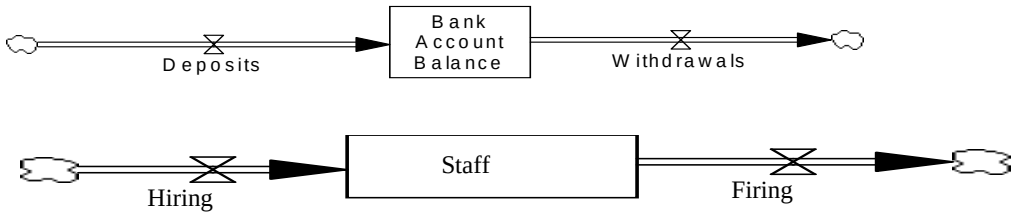
- Flows
  - A flow defines the rate of change in the system state
  - Flow = rate
  - Flows show some activity
  - Disappear (or "stop") if you stop time
  - Units of flows are units of the stock over time
- Math of stocks and flows

$$S_t = \int_{t_0}^{t} (\mathit{Inflow} - \mathit{Outflow})\, ds + S_{t_0}$$

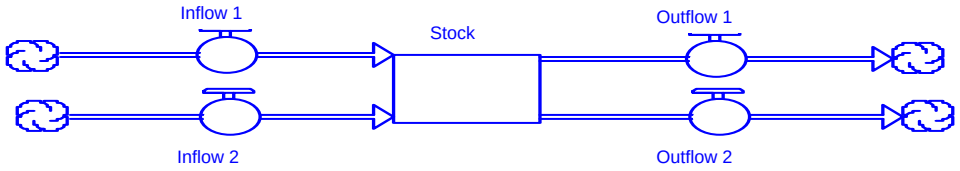
- Usage example
  - Company resources are stocks

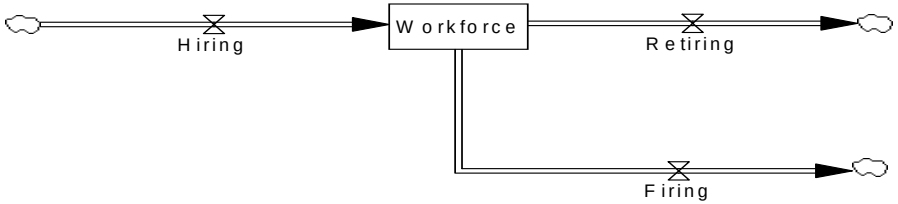
Related terminology in other fields

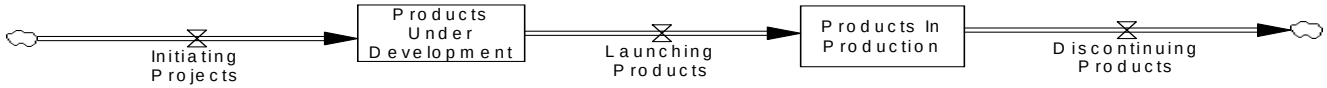
Field	Stocks	Flows
Economics/SD	**Stocks**	**Flows**
Original SD	**Levels**	**Rates**
Accounting	**Balance**	**Income**
Math	**Integral**	**Derivative**



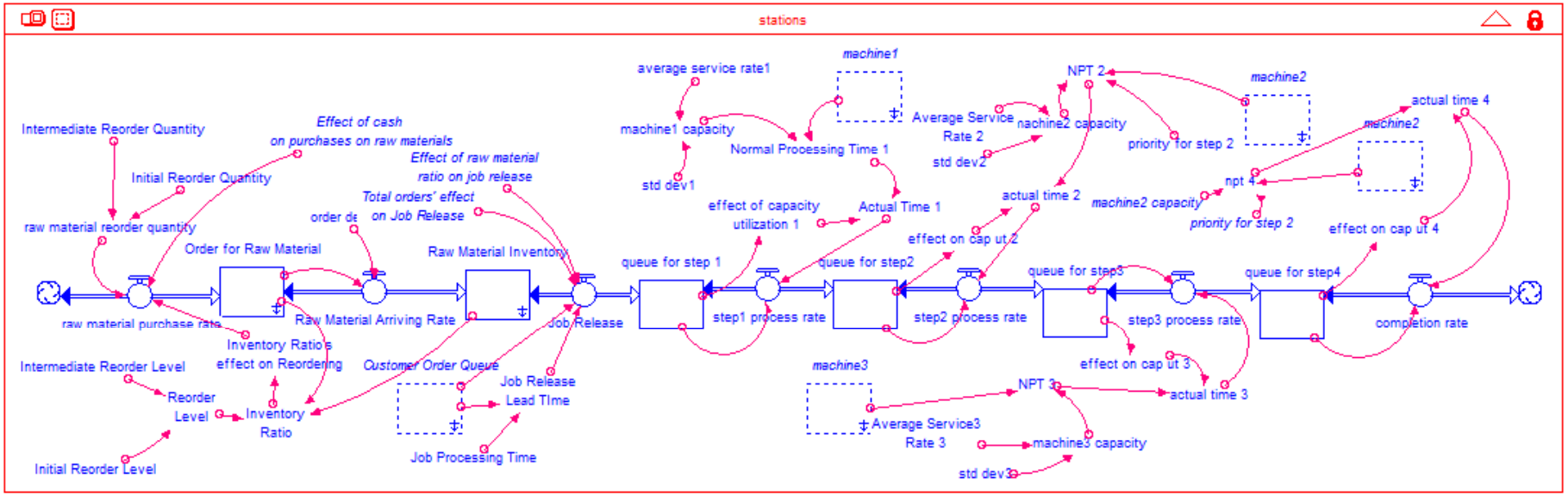
Examples from system dynamics



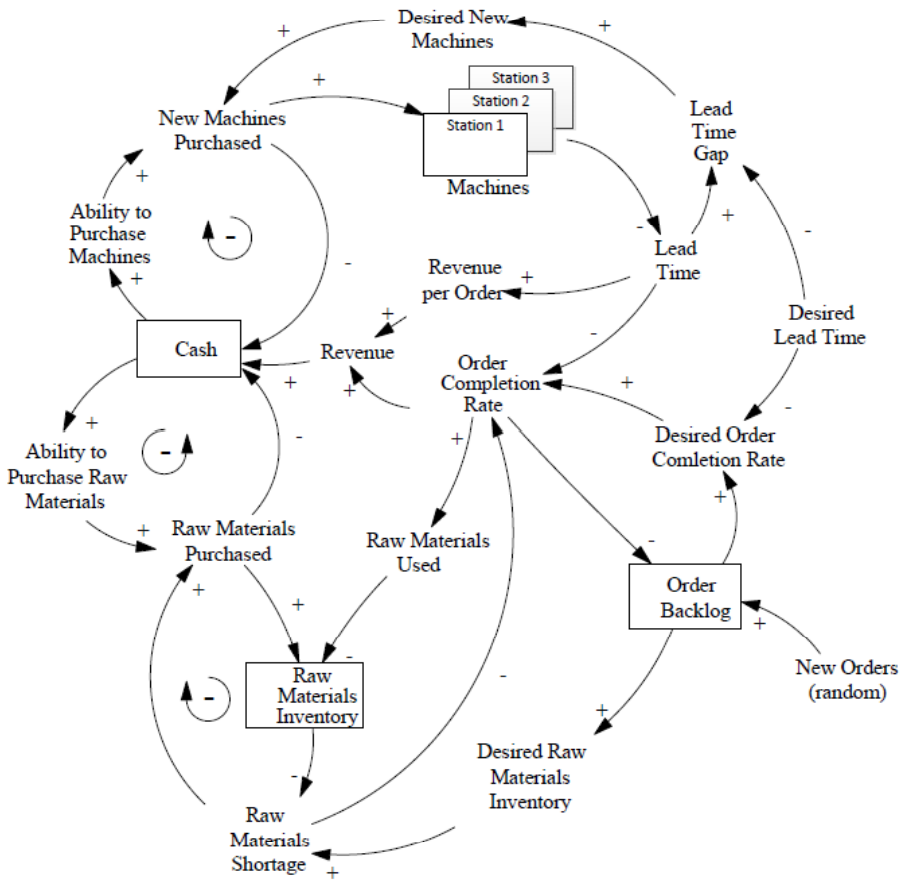




Manufacturing flow



Causal loop diagram of Littlefield simulation



- People have difficulty with accumulation, feedback and delays
- With this debriefing students can visualize the stocks, flows, delays
- Students can discuss the structure of the simulation (structural transparency)
- Students can generalize the lessons from the simulation to general problems of operations including resource based view of the firm

Research Designs to Measure the Value of Debriefing

Group A	Group B	Group C	Group D	Group E
Non-game teaching method	Game – debriefing	Game + minimal debriefing	Game + full debriefing	Game + full debriefing + 2nd game + debriefing
Pretest	*Pretest*	*Pretest*	*Pretest*	*Pretest*
Teaching	Game	Game	Game	Game 1
		Postgame test	*Postgame test*	*Postgame test*
		Small debriefing	**Full debriefing**	**Full debriefing**
				Posttest 1
				Game 2
				Full debriefing
Posttest	*Posttest*	*Posttest*	*Posttest*	*Posttest 2*
Long-term test	Long-term test	Long-term test	Long-term test	Long-term test

Adapted from Crookall (2010)