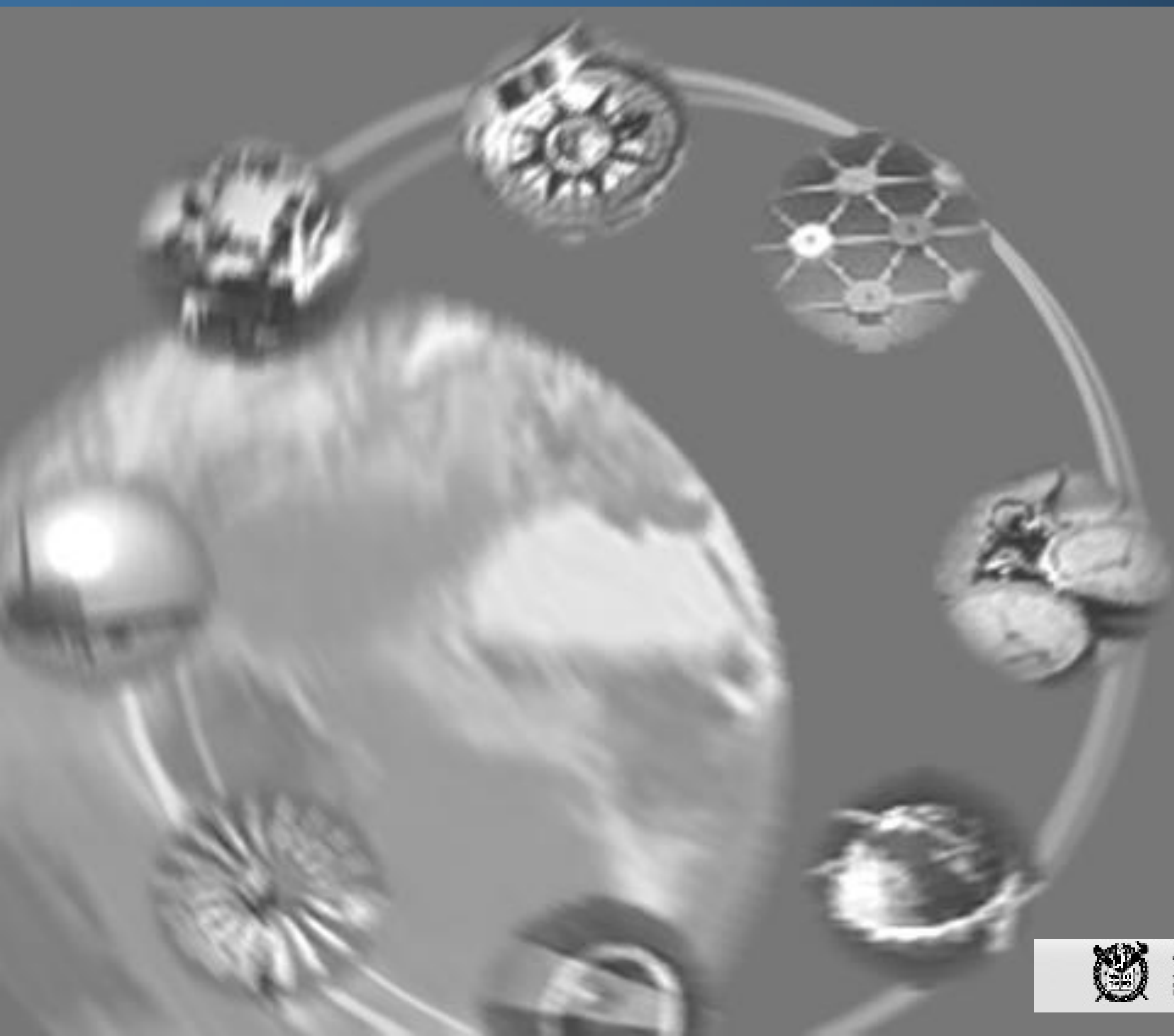
Formulating a simple model structure

401.661 Advanced Construction Technology



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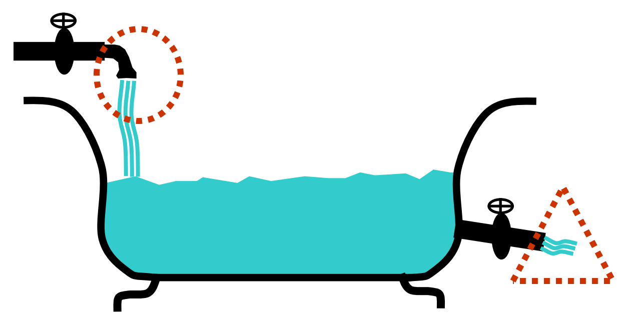
Equilibrium

- Stock in equilibrium when unchanging
  **System in equilibrium when all its stocks are unchanging.*

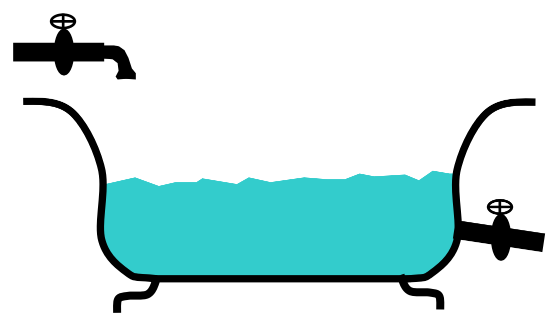
- Dynamic Equilibrium
  e.g., # of US senate

inflow = outflow



- Static Equilibrium
  **Same contents. e.g., # of Bach cantatas*

inflow = outflow = 0



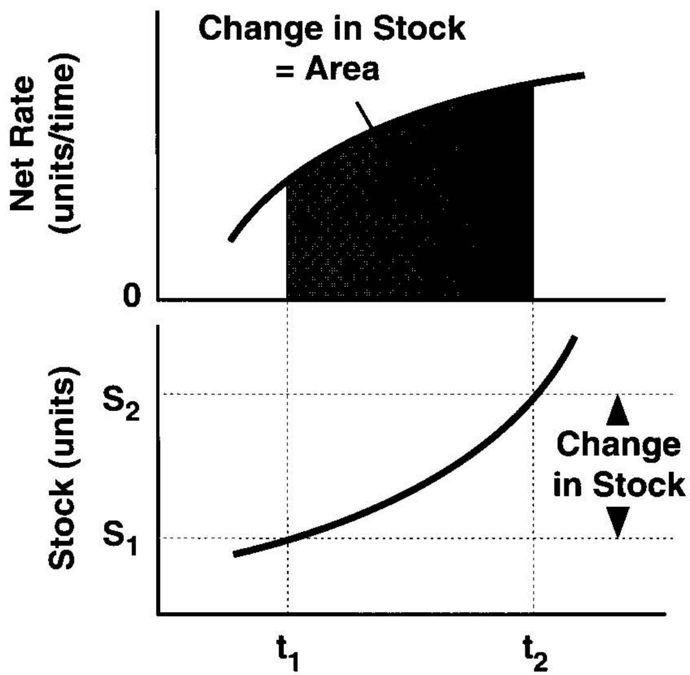
Integration & Differentiation

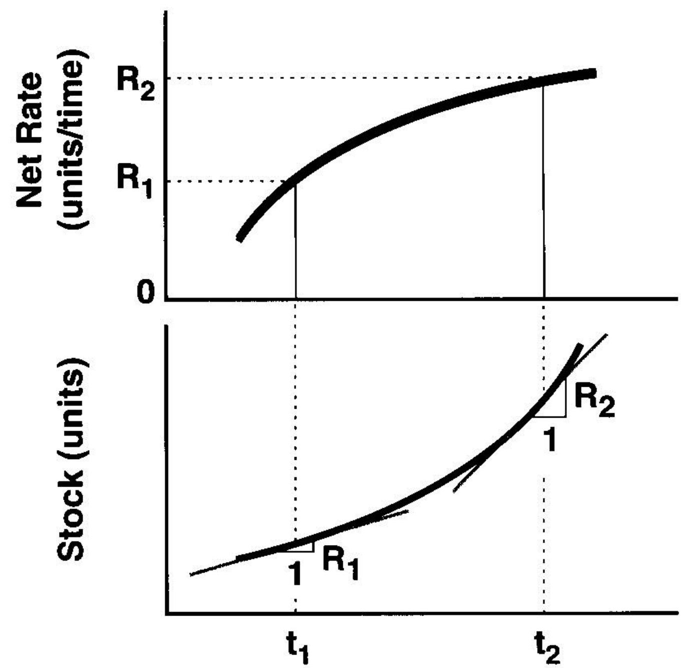
Stocks accumulate or *integrate* their net flow. The quantity added to a stock over any interval is the area bounded by the graph of the net rate between the start and end of the interval. The final value of the stock is the initial value plus the area under the net rate curve between the initial and final times.

In the example below, the value of the stock at time $t_1 = S_1$. Adding the area under the net rate curve between times t_1 and t_2 increases the stock to S_2.

The slope of a line tangent to any point of the trajectory of the stock equals the net rate of change for the stock at that point. The slope of the stock trajectory is the *derivative* of the stock.

In the example below, the slope of the stock trajectory at time t_1 is R_1, so the net rate at $t_1 = R_1$. At time t_2, the slope of the stock is larger, so the net rate at $t_2 = R_2$ is greater than R_1. The stock rises at an increasing rate, so the net rate is positive and increasing.



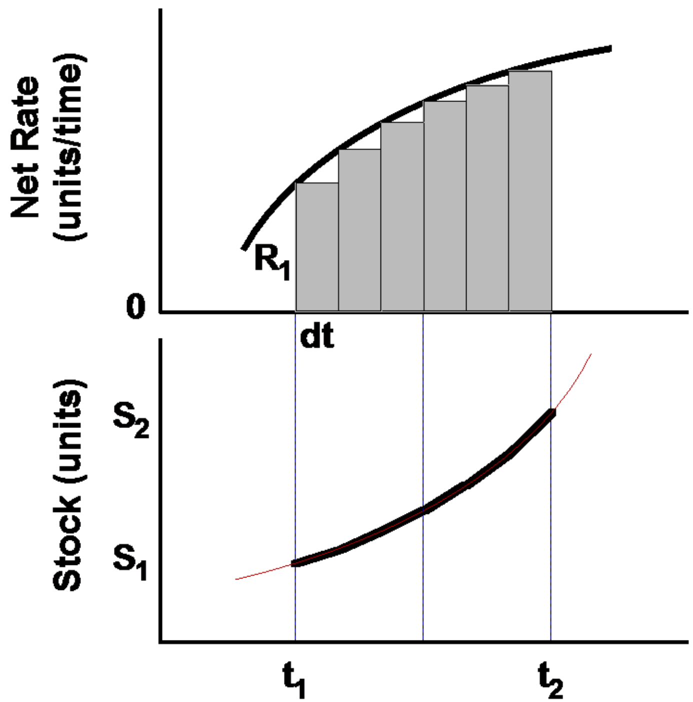


Calculus without Mathematics

Quantity added during interval of length dt

= R (units/time) * dt (time) *R = the net flow during the interval

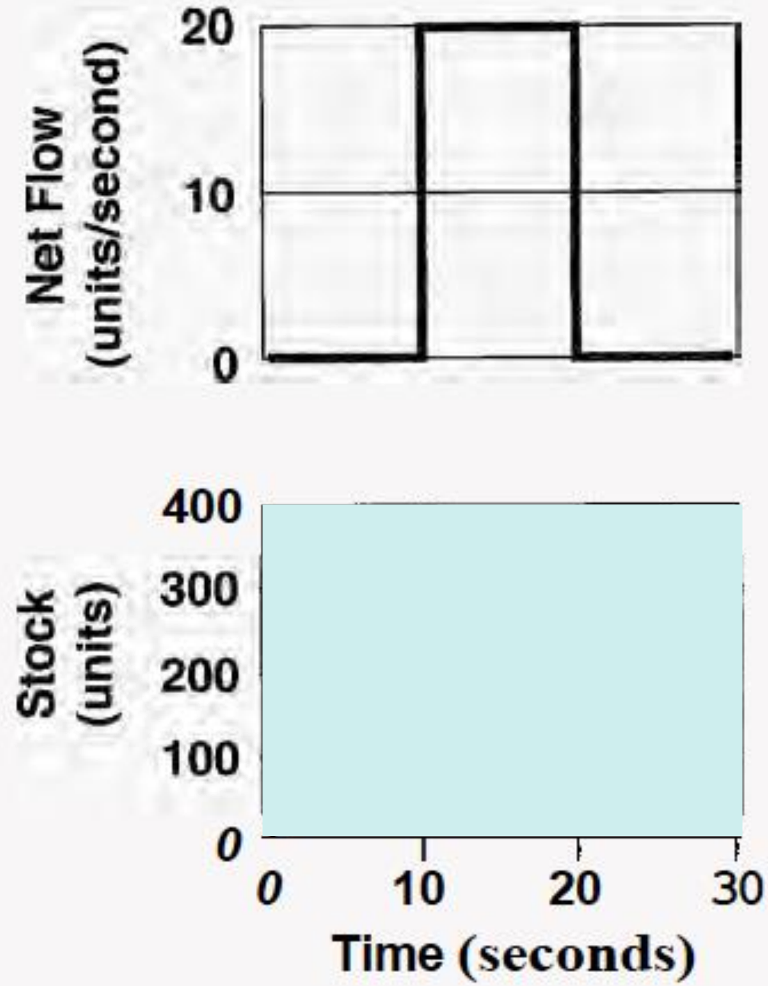
Concrete Mixer Example



- Area of each rectangle= $R_i$dt
- Adding all six rectangles = Approximation of total water added
- How to increase accuracy?

Challenge it!

Initial stock level
= 100 units



Challenge it!

Initial stock level
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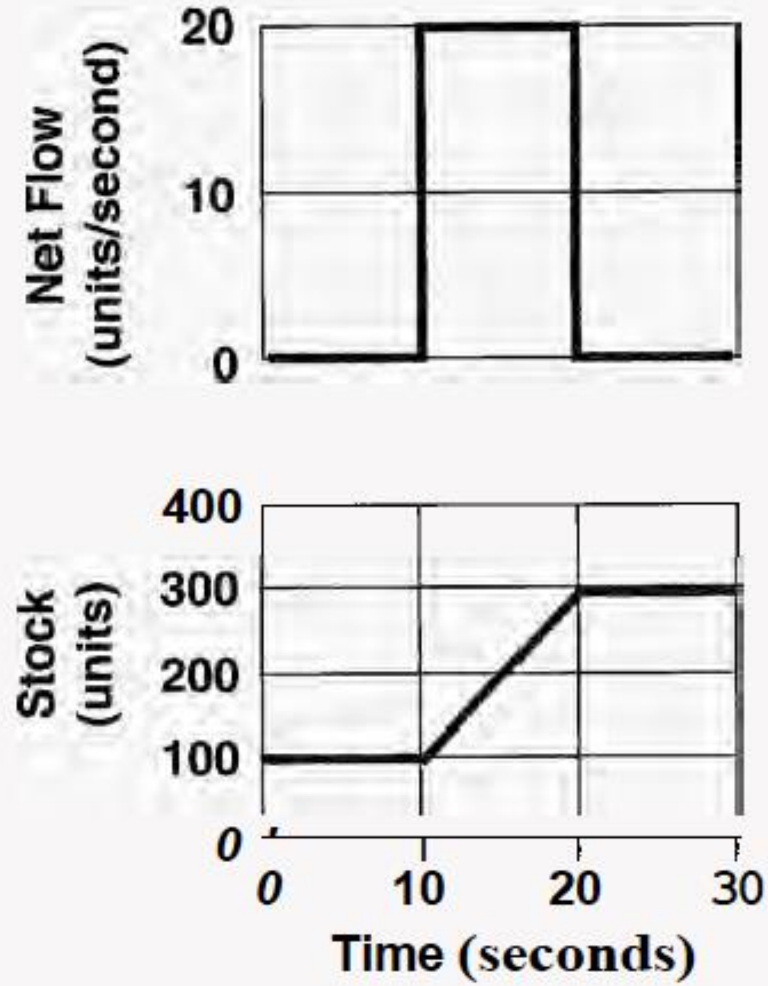
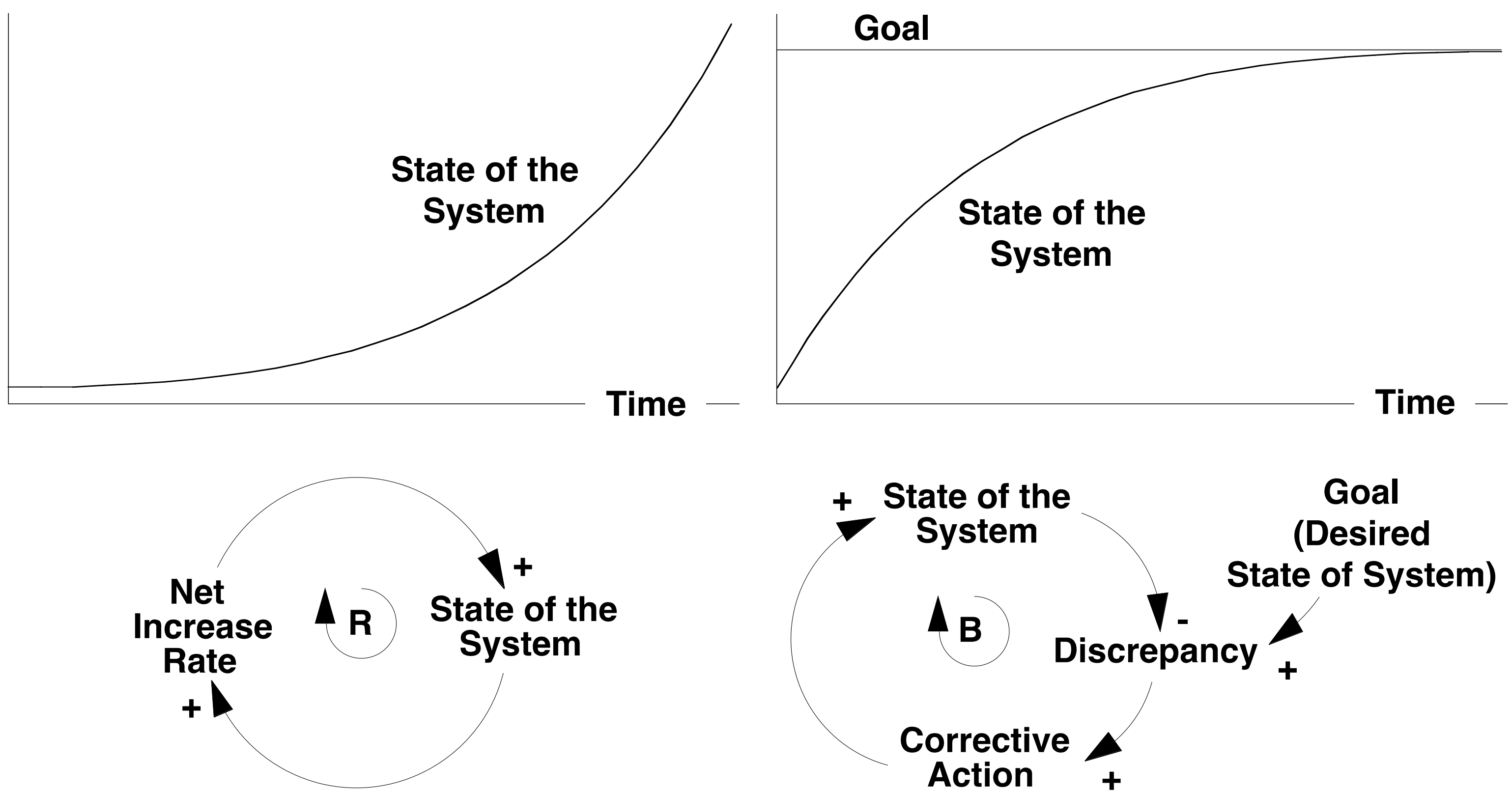


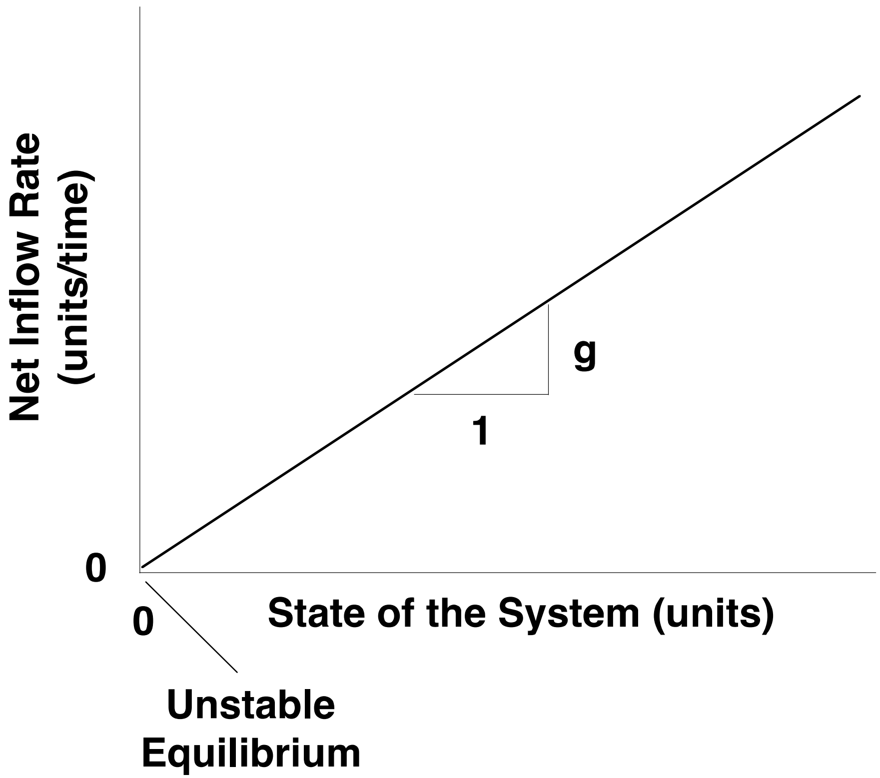
Fundamental Modes

- Positive feedback causes exponential growth, while negative feedback causes goal-seeking behavior.



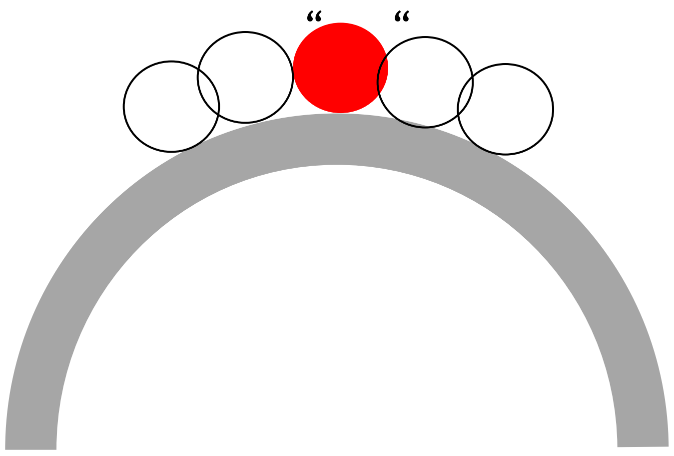
▪Sterman, J., “Business Dynamics”, Mcgraw-Hill, 2000

dS/dt = Net Inflow Rate = gS



Phase plot for the first-order, linear positive feedback system

Unstable Equilibrium



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Power of Positive Feedback

- Paper Folding
- The Rule of 70

Positive feedback leads to exponential growth, when the fractional net increase rate is constant.

$2S(0) = s(0)\exp(gt_d)$

$t_d = \ln(2)/g$, where $\ln(2) = 0.6931\ldots$

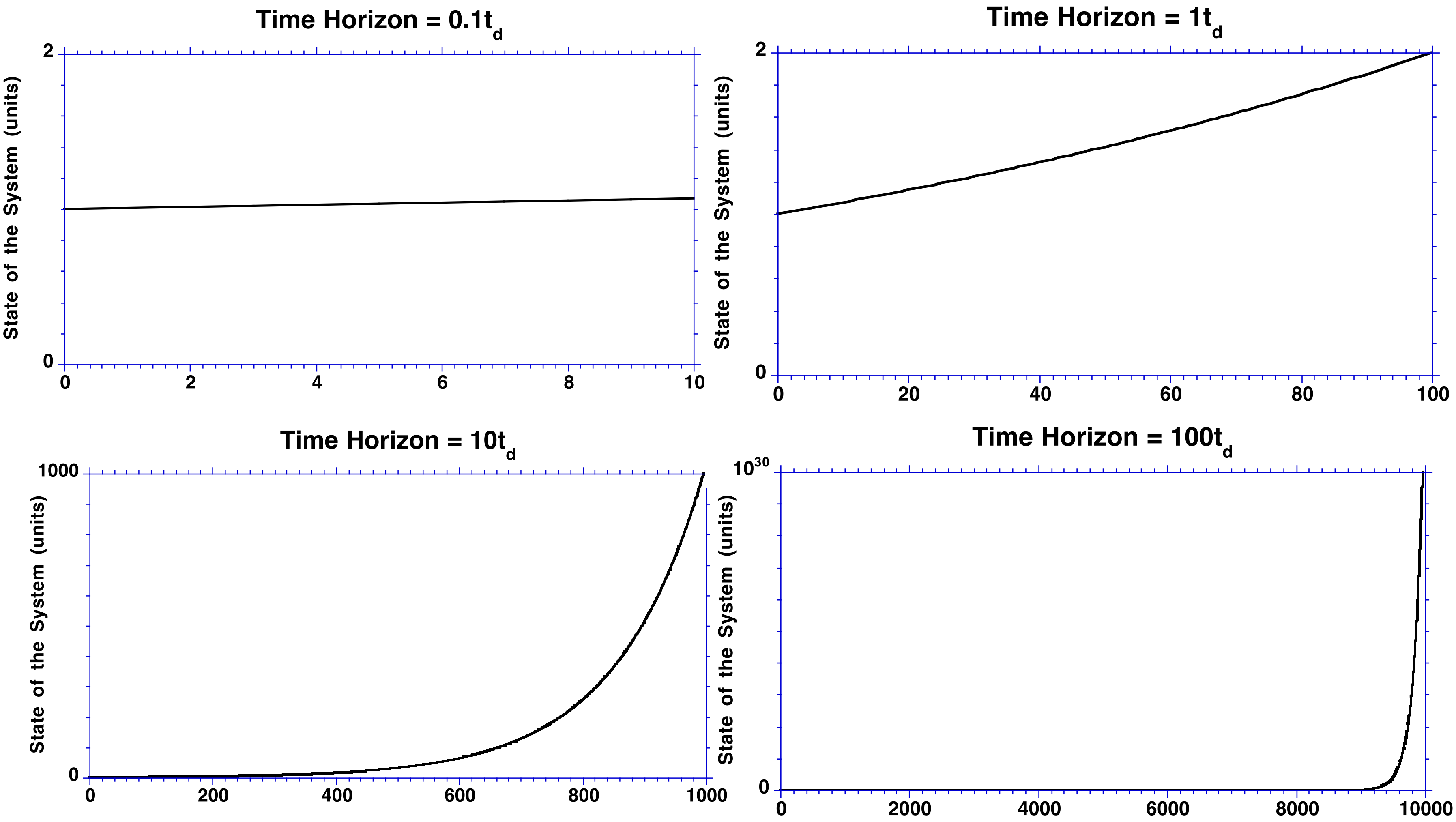
$\underline{t_d = 70/(100g)}$

E.g., an investment earning 7%/year doubles in 10 yrs

Misperception of Exponential Growth

- We tend to assume a quantity increases by the same *absolute* amount per time period, while exponential growth *doubles* the quantity in a fixed period of time.

- The counterintuitive characters of exponential growth can be seen by examining it over different time horizons.



Exponential growth over different time horizons

The state of the system is given by the same growth rate of 0.7%/time period in all cases (doubling time = 100 time periods).

▪Sterman, J., "Business Dynamics", Mcgraw-Hill, 2000

- No real quantity can grow forever (positive feedback processes approach their limits rapidly and often unexpectedly).

An old French riddle

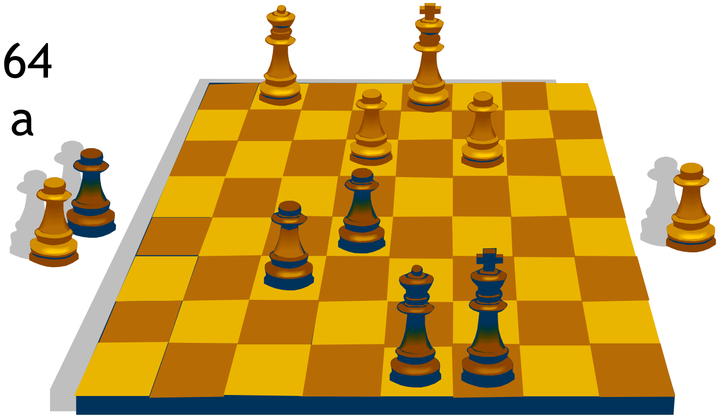
- A water lily doubles in size each day.
- It would completely cover the pond in 30 days.
- On what day will it cover half the pond so you have to cut it back?

- As limits are approached, nonlinearities always weaken the positive loops and strengthen the negative feedbacks.

An old Persian legend

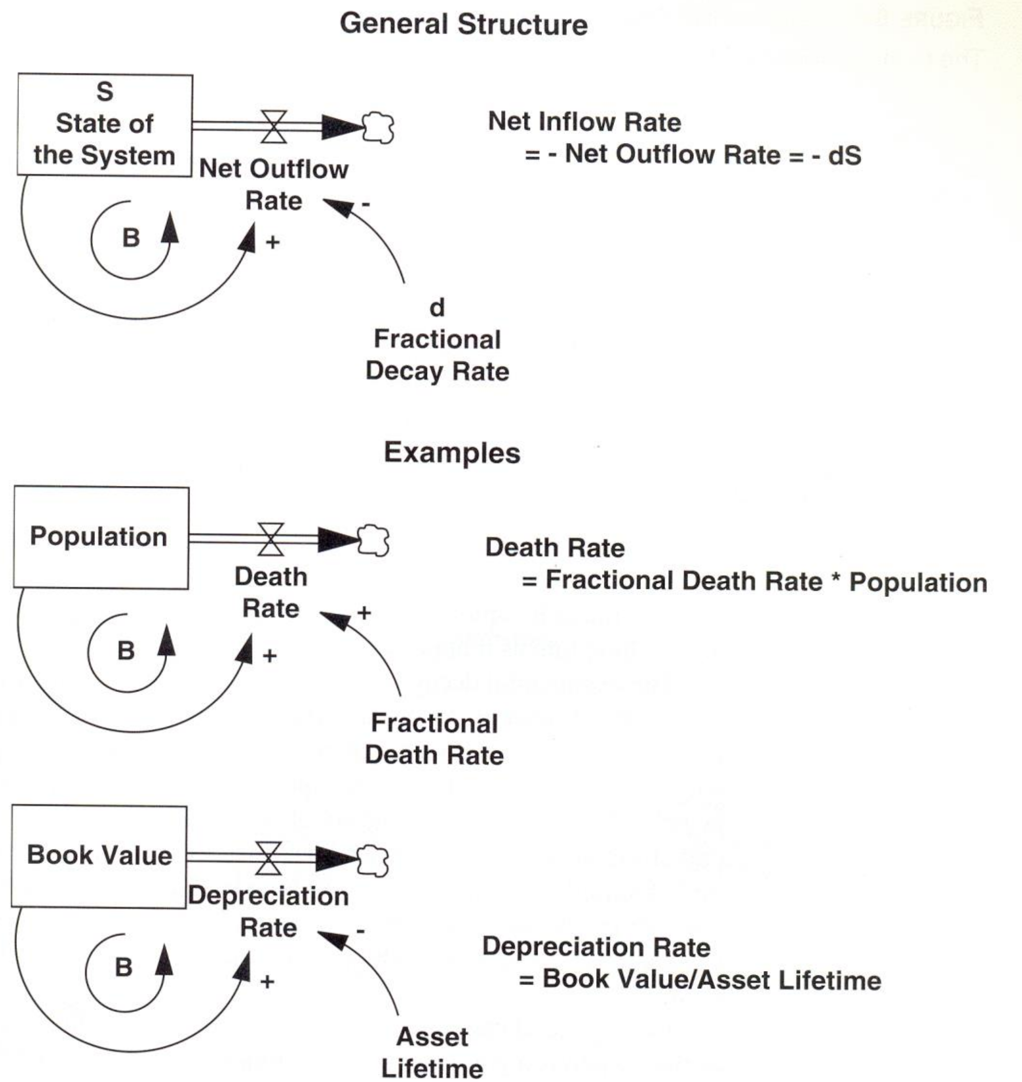
- A courtier presented a chessboard to his king.
- Requesting the king give him in return a grain of rice for the square of the
  board, 2 grains for the 2nd square...
- Is it feasible?

* The total quantity of rice on all 64 squares would cover all of Iran to a depth of more than 5 feet.



Negative feedback and Exponential Decay

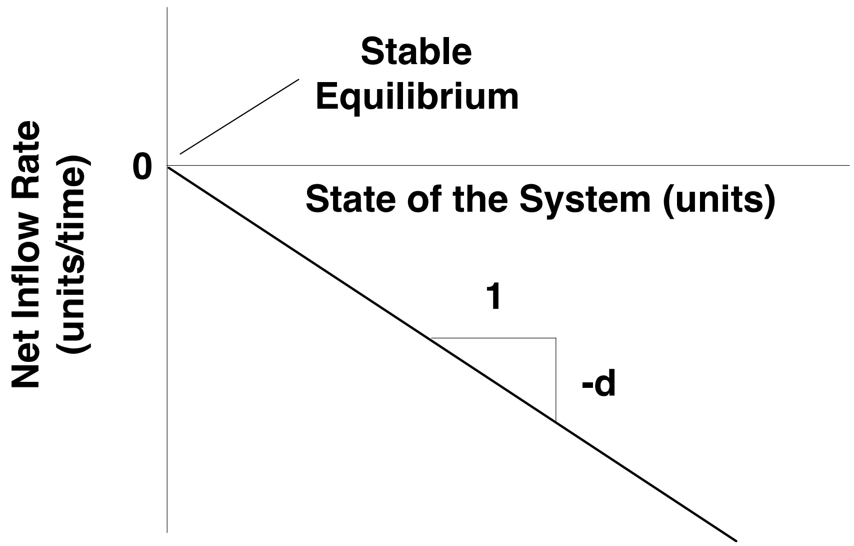
- First-order negative feedback systems generate goal-seeking behavior. When the system is linear, the behavior is pure exponential decay.

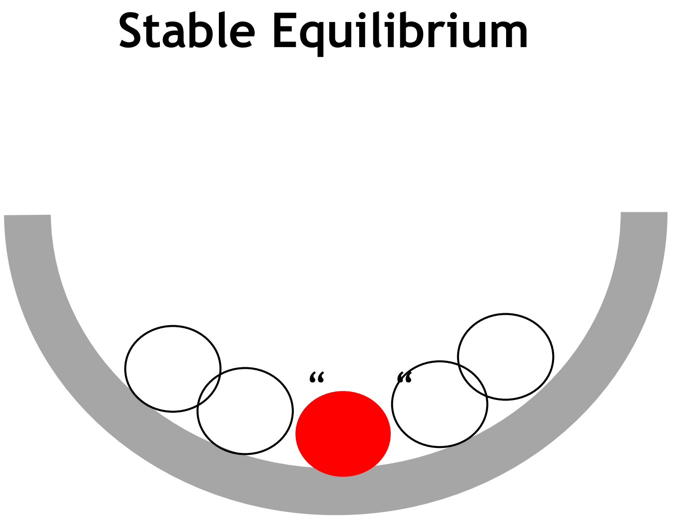


Net Inflow Rate = - Net Outflow Rate = - dS

- Sterman, J., “Business Dynamics”, Mcgraw-Hill, 2000

Net Inflow Rate = - Net Outflow Rate = - dS



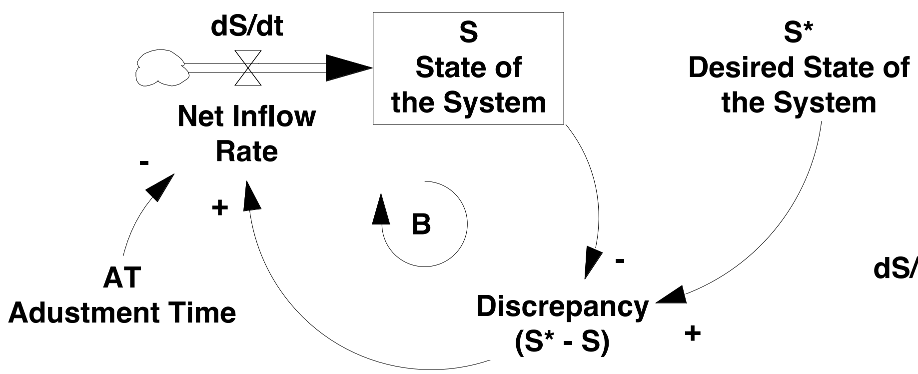


Phase plot for exponential decay via linear negative feedback

▪Sterman, J., "Business Dynamics", Mcgraw-Hill, 2000

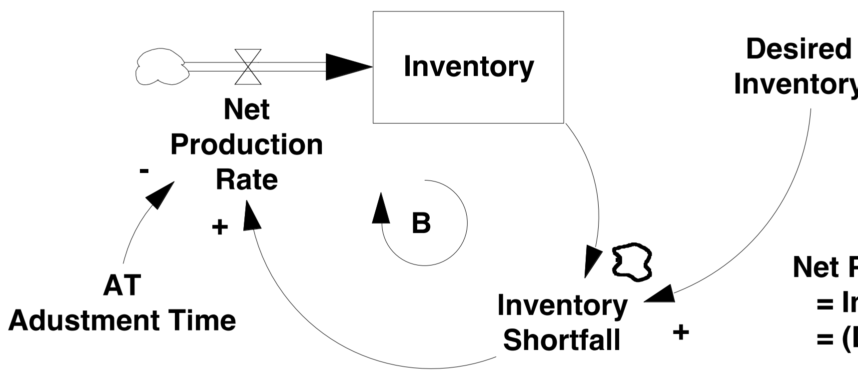
First-order linear negative feedback system with explicit goals

General Structure

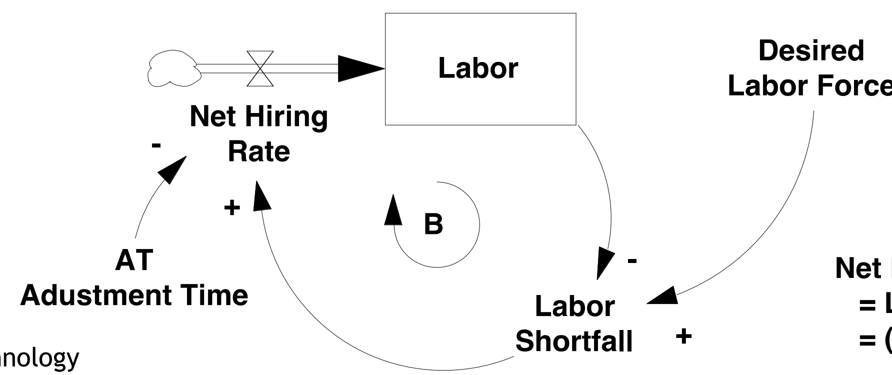


dS/dt = Net Inflow Rate
= Discrepancy/AT
= (S* - S)/AT

Examples



Net Production Rate
= Inventory Shortfall/AT
= (Desired Inventory - Inventory)/AT



Net Hiring Rate
= Labor Shortfall/AT
= (Desired Labor - Labor)/AT

▪Sterman, J., "Business Dynamics", Mcgraw-Hill, 2000

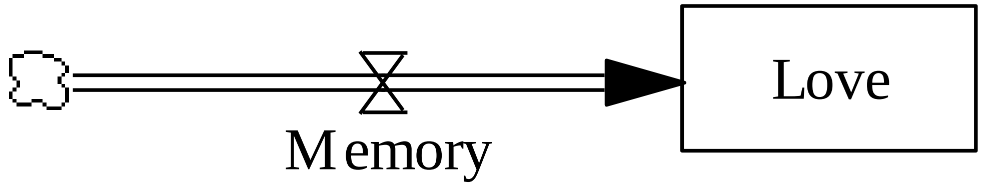
Modeling Practice: Human Behavior

Romeo & Juliet

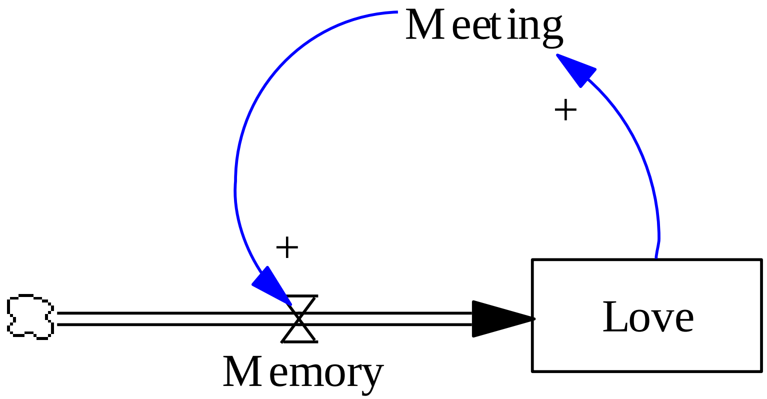
- Identify dynamics associated with love between a beast and a beauty.
- It could be matured, leading to marriage.
- Often it is broken as well.

Recommended variables: love, meetings, quarrels, understanding, expectation, memory

What makes LOVE?...

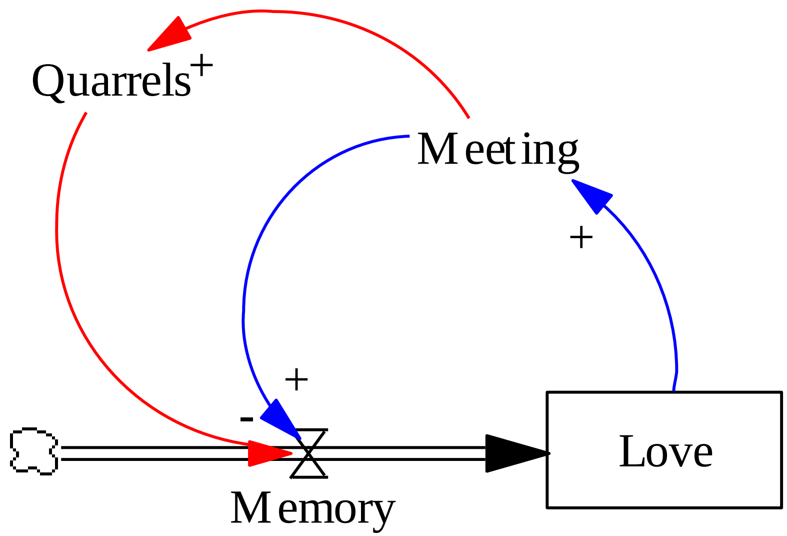


Memories are from?...

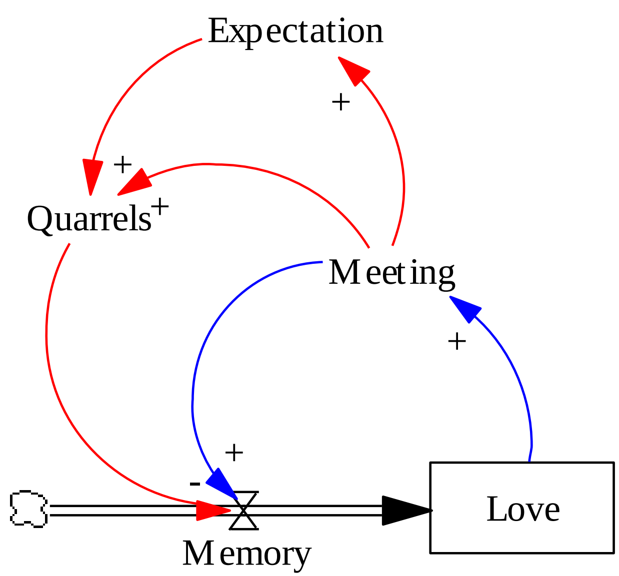


Generally this continues for a while..

BUT, as having more meetings…

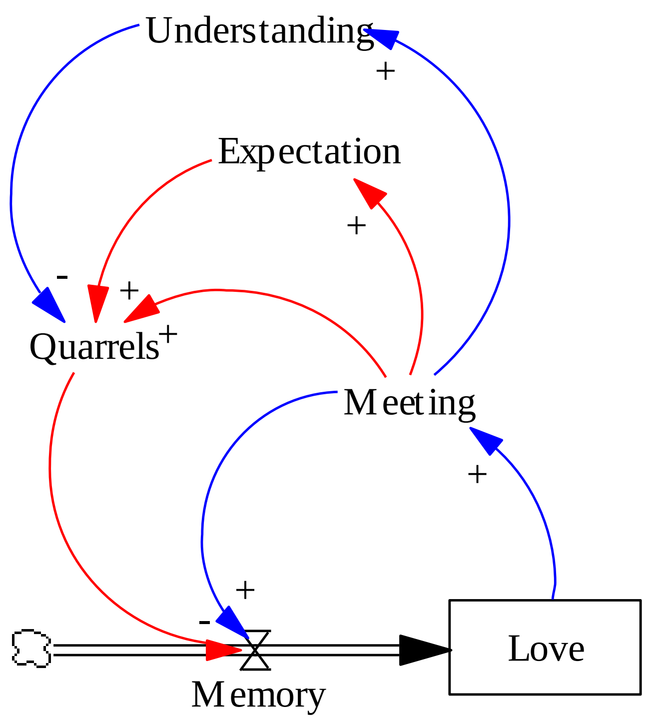


What makes this?...

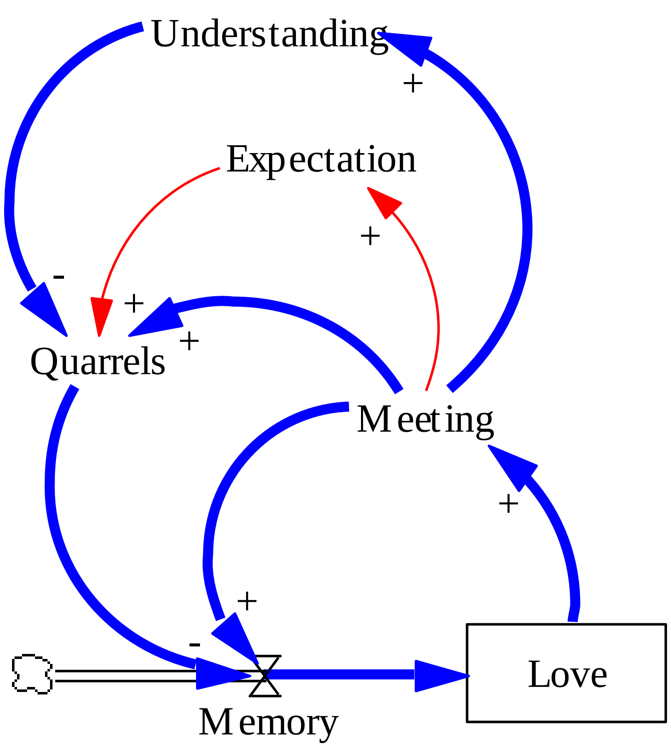


End of story here to some couples

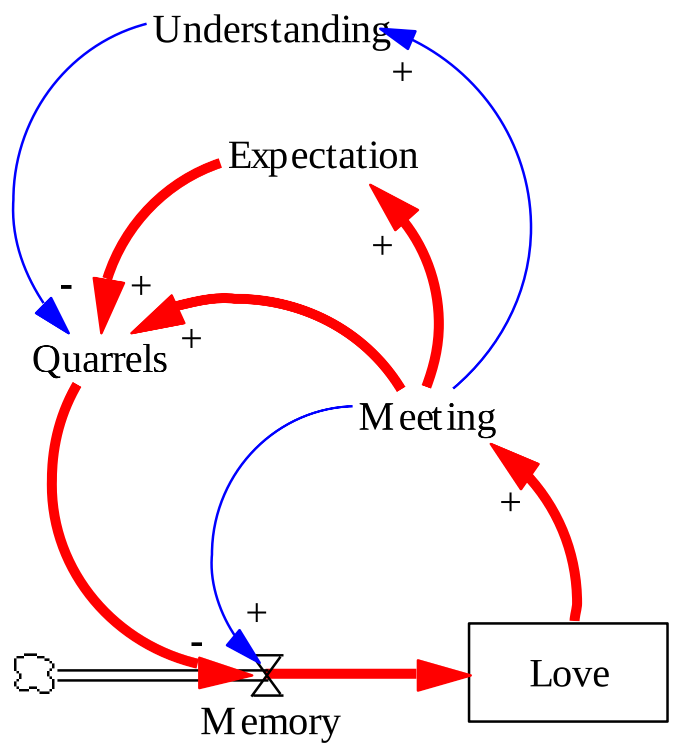
This is also true…



Two types



Understanding
+
Expectation
+
-
+
+
Quarrels
Meeting
+
+
-
Love
Memory



Understanding
+
Expectation
+
-
+
+
Quarrels
Meeting
+
+
-
Love
Memory

Assignment 5:
any suggestions to a couple in danger?

Model improvement:
Your suggestions?

Modeling Practice: The Food Chain

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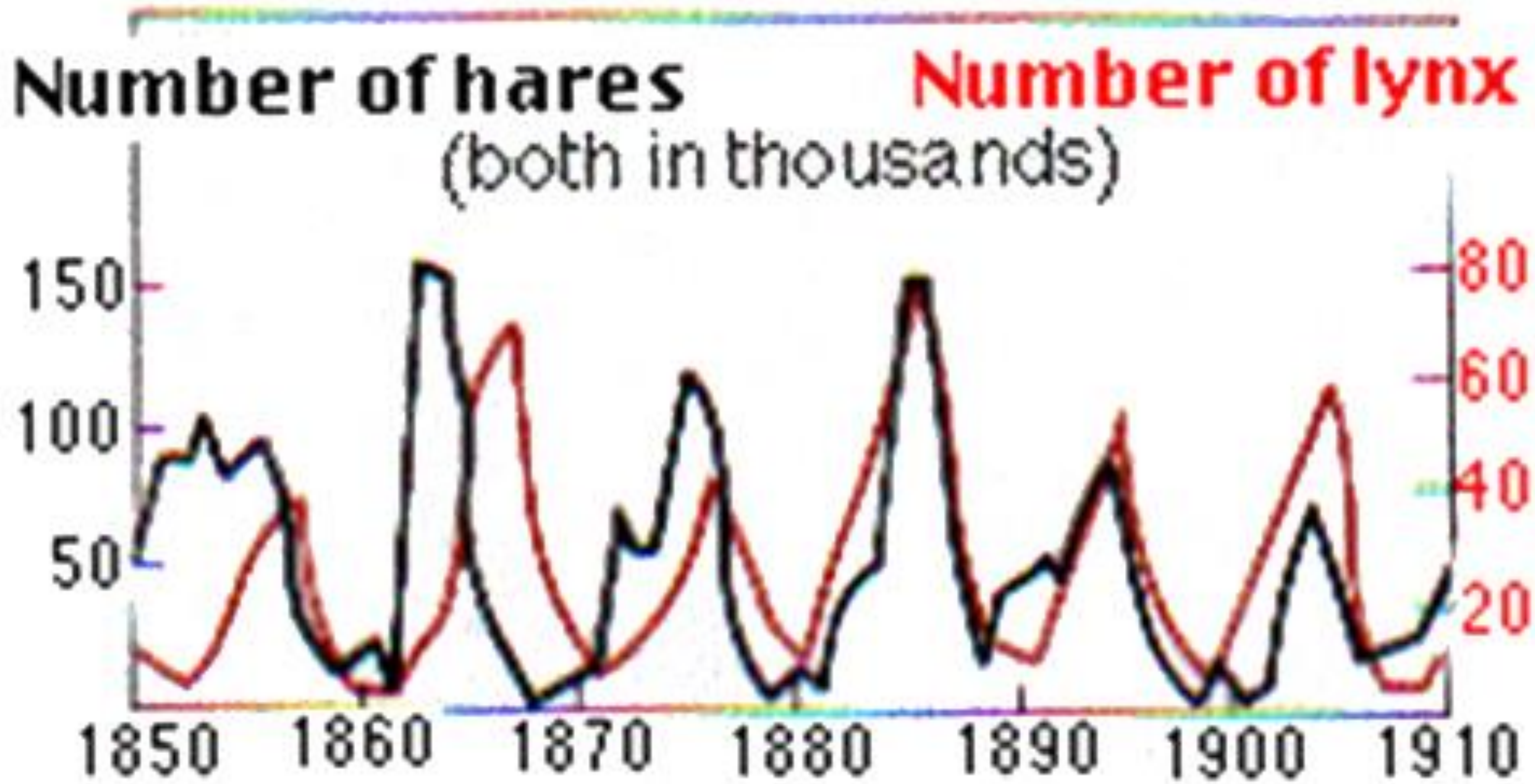
Problem statement

Why does their population oscillate?



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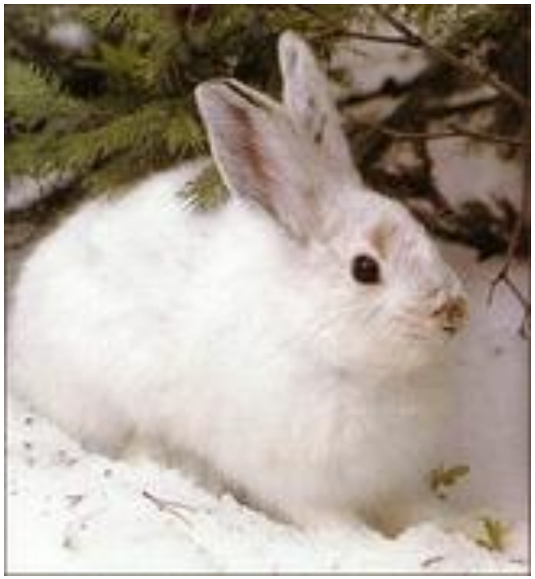
Rabbit: Prey



It all begins with the birth rate of the rabbits which increase their population. These rabbits will grow and reproduce, thus also increasing the birth rate. However, some of them would encounter the disease. Since the disease will spread rapidly in a bigger population, this would also increase the death rate of the rabbits. The loop of the birth rate and population shows positive feedback, while the loop made by population, disease incidence and death rates denote negative feedback.

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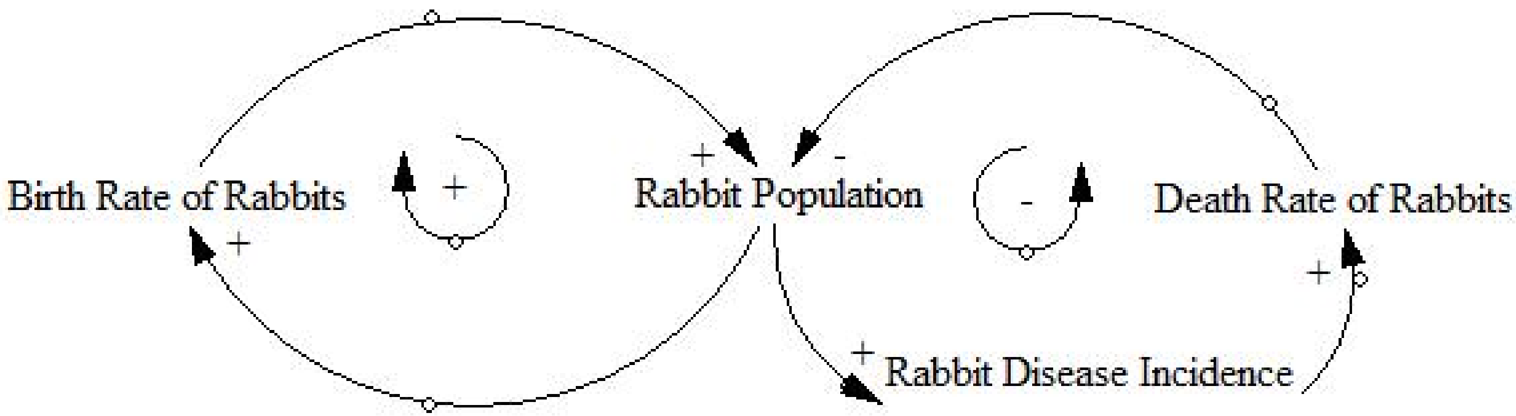

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Lynx: Predator

the loop starts with the birth rate of the lynx, which increases the population. While the population increases, the food supply would decrease as they would compete among themselves for the food. The lower the food supply, the higher the starvation rate would be. This would ultimately lead to decreasing the population. However, if food supply increases, more lynx would survive to reproduce and increase their population.

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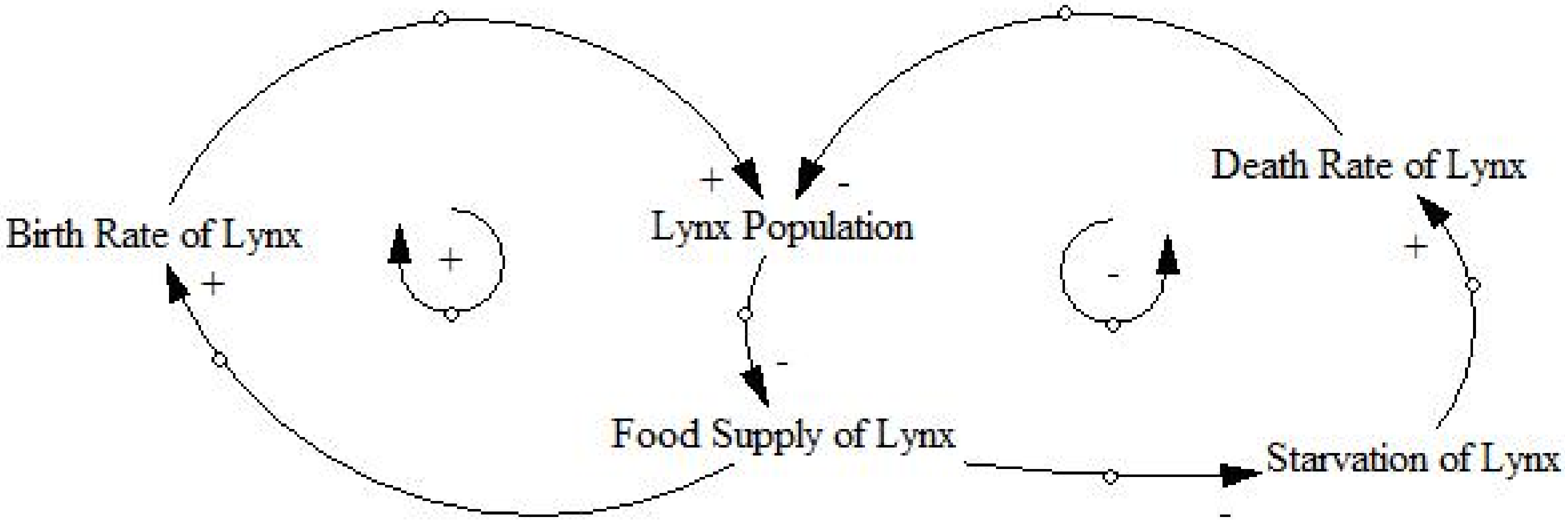

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Putting together

Lastly, to put these two loops of separate entities together, links are made between the food supply of the links and the rabbit population and death rate. Since lynx hunt rabbits as their food and means of sustenance, this would all depend on how many rabbits are present in the same place. The more rabbits there are, the more food supply the links will have. That is why this is given a positive polarity. However, as the lynx consume the rabbits as their prey, the death rate of the rabbits increases. Their population would also decrease, which would subsequently lead to starvation and death of the lynx. This is another negative feedback loop.

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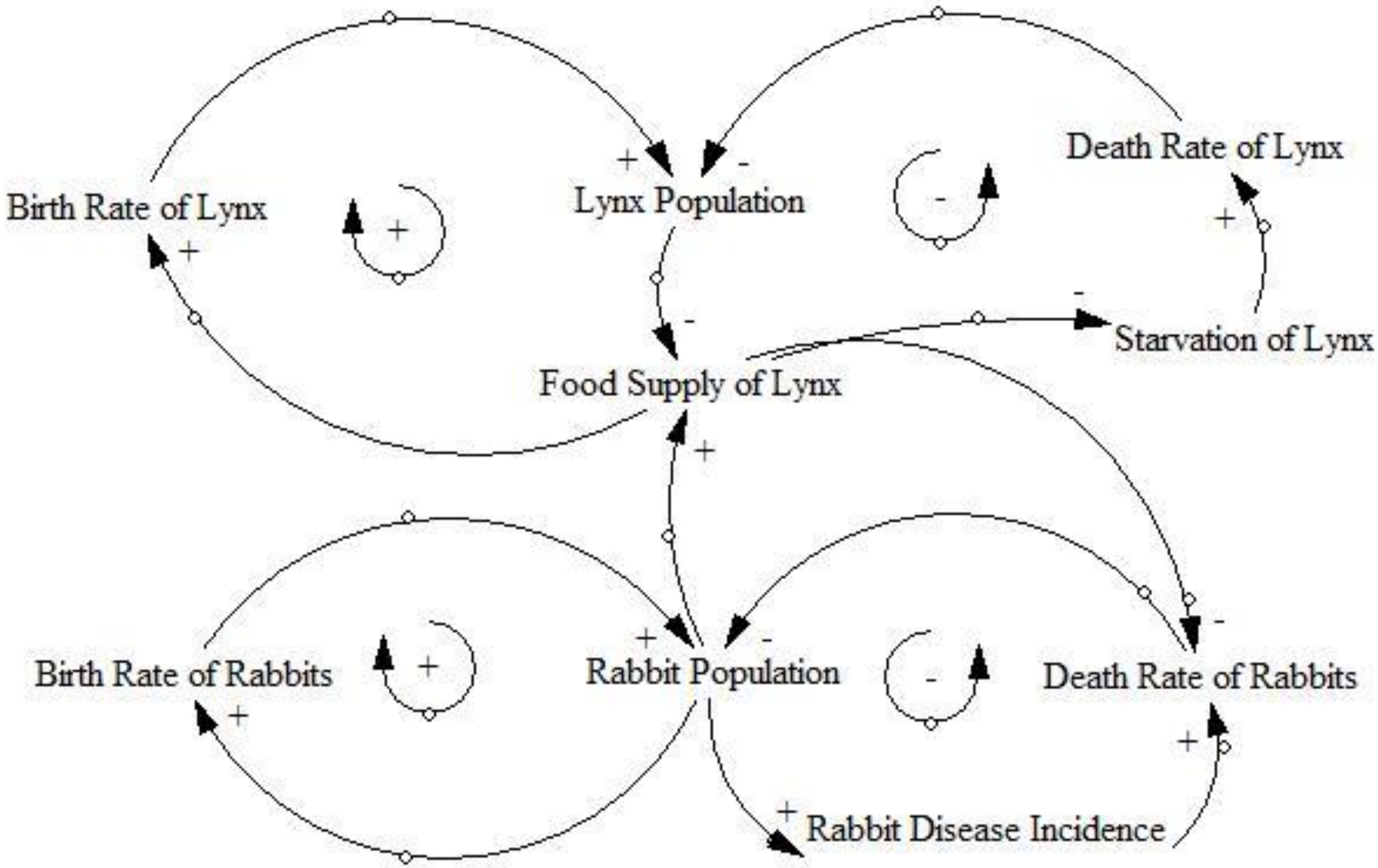

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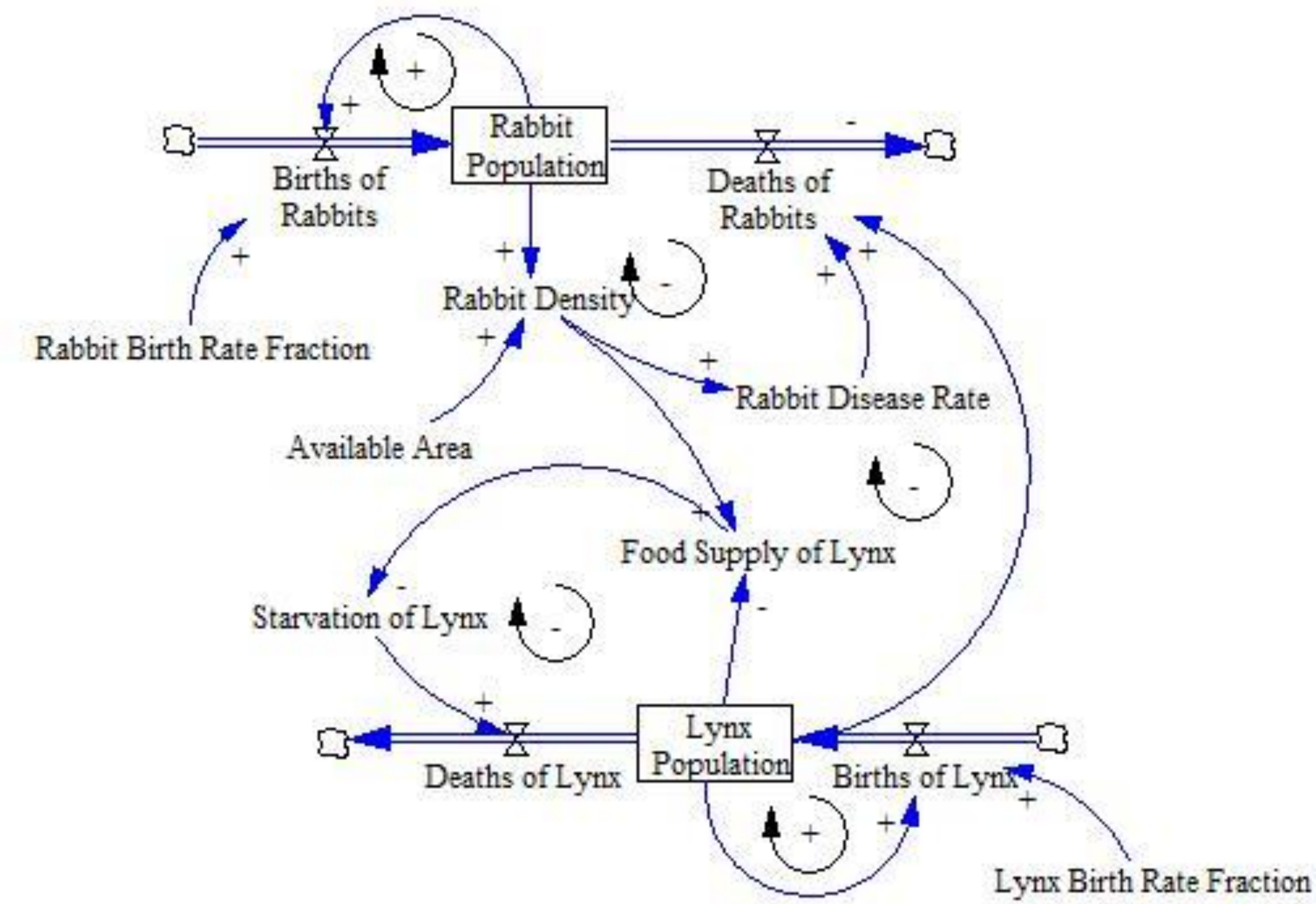
S&F model



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Assignment 6:
Build a quantitative model and demonstrate how & why the population of Lynx and Rabbit oscillate.

References

- Avraham Shtub, Jonathan F. Bard, Shlomo Globerson, “Project management : engineering, technology, and implementation”, Englewood Cliffs, NJ, Prentice Hall, 1994
- Frederick E. Gould, Nancy Joyce, Chapter 8, “Construction project management”, Upper Saddle River, NJ, Prentice Hall, 1999
- James M. Lyneis *, Kenneth G. Cooper, Sharon A. Els, “Strategic management of complex projects: a case study using system dynamics”, System Dynamics Review, Vol. 17, No. 3, 2001
- Christopher M. Gordon, “Choosing appropriate construction contracting method”, J. of Construction Engineering & Management, Vol. 120, No. 1, 1994
- Feniosky Pena-Mora, Jim Lyneis, “Project control and management”, MIT 1.432J Lecture Material, 1998
- Barrie, D.S., and Paulson, B.C., “Professional Construction Management”, McGraw Hill, 1992
- Halpin, D.W., “Financial and Cost concepts for construction management”, John Wiley & Sons, 1995
- Yehiel Rosenfeld, “Project Management”, MIT 1.401J Course Material, 2000
- Sarah Slaughter, “Innovation in construction”, MIT 1.420 Course Material, 1999
- Gray and Hughes, “Building Design Management”,.
- Murdoch and Hughes, “Construction Contracts: Law and Management”, E&FN SPON, 1996
- Gray, Hughes and Bennett, “The Successful Management of Design”, Reading, 1994
- Sterman, J., “Business Dynamics”, Mcgraw-Hill, 2000