CT561: Systems Modelling & Simulation

4. Additional Flows and Higher Order Stock Systems

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https://github.com/JimDuggan/SDMR

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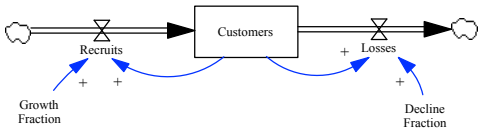
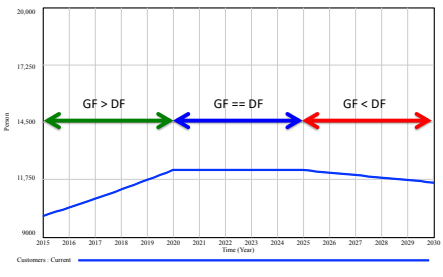
Summary to date

- Stocks and Flows
- Feedback
- Integration: Graphical and Numerical Euler's equation (spreadsheet and Vensim)
- One stock examples
  - Customer growth
  - Bank Balance
  - World Population





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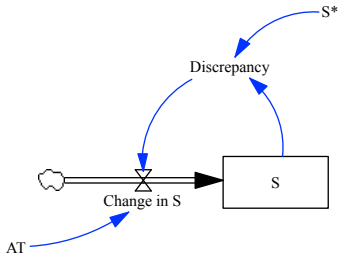
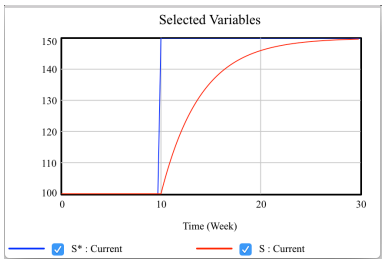
(3) Formulating flows: *adjustment to a goal*

- Managers often seek to adjust the state of the system until it equals a goal or desired state.
- The simplest form of this negative feedback is
  - R_I = Discrepancy/AT = (S^* - S)/AT





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Observations on Goal Adjustment

- "**Desired** minus **actual** over **adjustment time**" is the classic linear negative feedback system. (Sterman 2000).
- Examples:
  - **Change in Price** = (Competitor Price – Price)/Price Adjustment Time
  - **Heat Loss from Building** = (Outside Temperature – Inside Temperature)/Temperature Adjustment Time
  - **Net Hiring Rate** = (Desired Labour – Labour)/Hiring Delay

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Challenge 4.1

- For each of the following, build a one-stock model and show the impact three different adjustment times have on the stock variable.
  - **Net Hiring Rate** = (Desired Labour – Labour)/Hiring Delay
  - **Change in Price** = (Competitor Price – Price)/Price Adjustment Time
  - **Heat Loss from Building** = (Outside Temperature – Inside Temperature)/Temperature Adjustment Time

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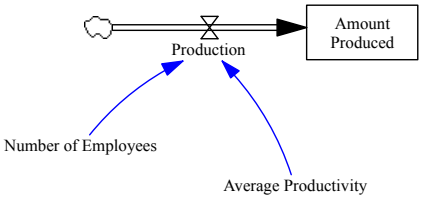
(4) Flow = Resource * Productivity

- The flows affecting a stock frequently depend on resources other than the stock itself
- The rate is determined by a resource and the productivity of that resource
- Can be applied to an inflow or outflow
- Rate = Resource * Productivity
- Production = Labour Force * Average Productivity



Amount Produced = INTEG(Production , 0)
Units: Units

Average Productivity = 10
*Units: Units/(People*Day)*

Number of Employees = 100
Units: People

Production = Average Productivity * Number of Employees
Units: Units/Day

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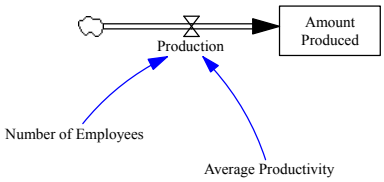
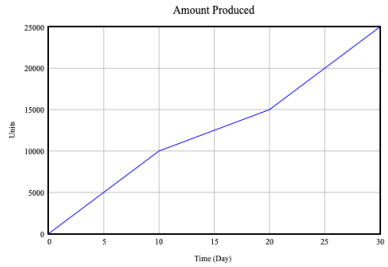
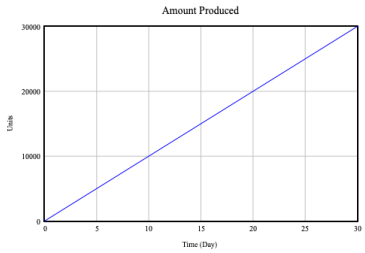
Possible Scenarios

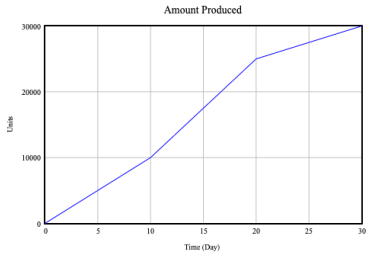
Average Productivity = 10
*Units: Units/(People*Day)*

Number of Employees = 100
Units: People









Number of Employees=100-step(50,10)+step(50,20)

Average Productivity=10+step(5,10)-step(10,20)

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Challenge 4.2

- Build a resource/productivity flow equation for *Vaccines Dispensed*
- Variables include *Health Care Worker* and *Health Care Worker Productivity*
- Extend the model to include Vaccines as a resource that gets depleted every time a vaccine is dispensed. Ensure that vaccines cannot be dispensed unless there is a vaccine in stock.

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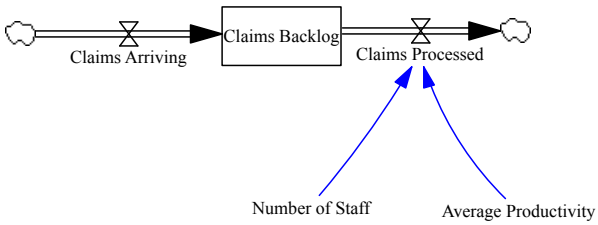
Flow = Resource * Productivity

- Rate = Resource * Productivity
- Can be applied to an outflow
- Example:
  - Insurance Claims Backlog
  - Claims Arriving
  - Claims Completed
    - Number of Staff
    - Productivity (claims/person/day)



Average Productivity = 2

Claims Arriving = 50

Claims Backlog = INTEG(Claims Arriving - Claims Processed , 25)

Claims Processed = Average Productivity * Number of Staff

Number of Staff = 25

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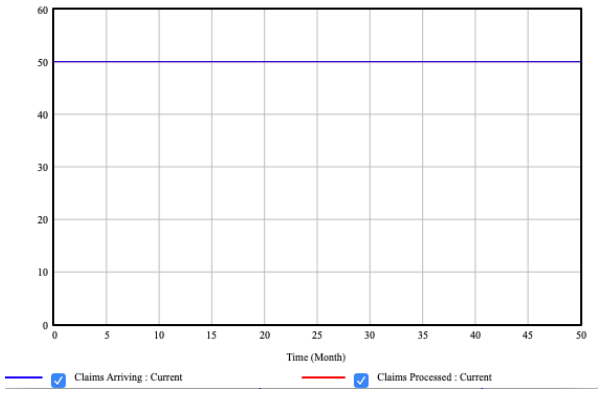
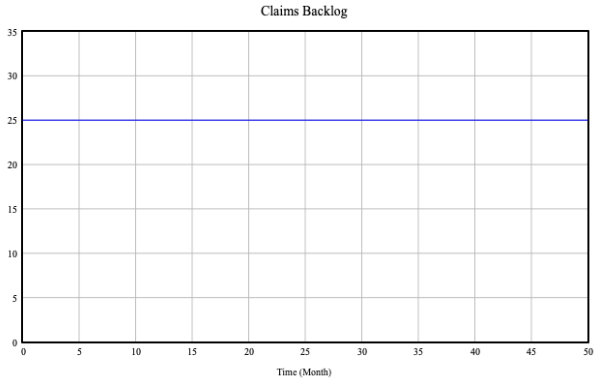
Model Behaviour – Dynamic Equilibrium





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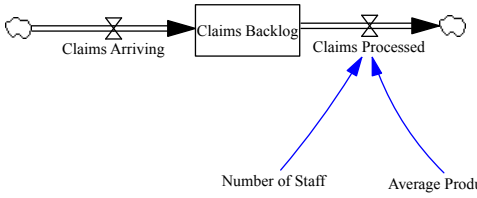
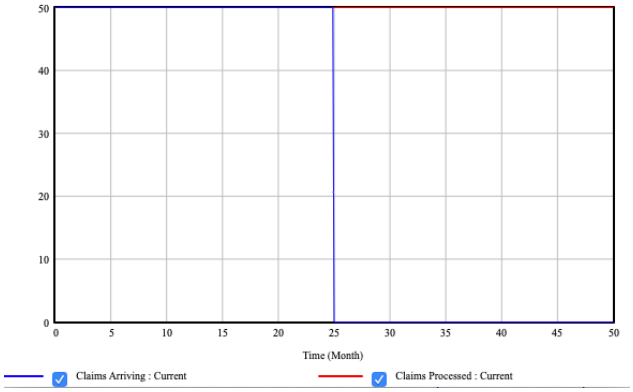
New Scenario: What will happen?





Average Productivity = 2

Claims Arriving = 50 – step(50,25)

Claims Backlog = INTEG(Claims Arriving - Claims Processed ,

Claims Processed = Average Productivity * Number of Staff

Number of Staff = 25

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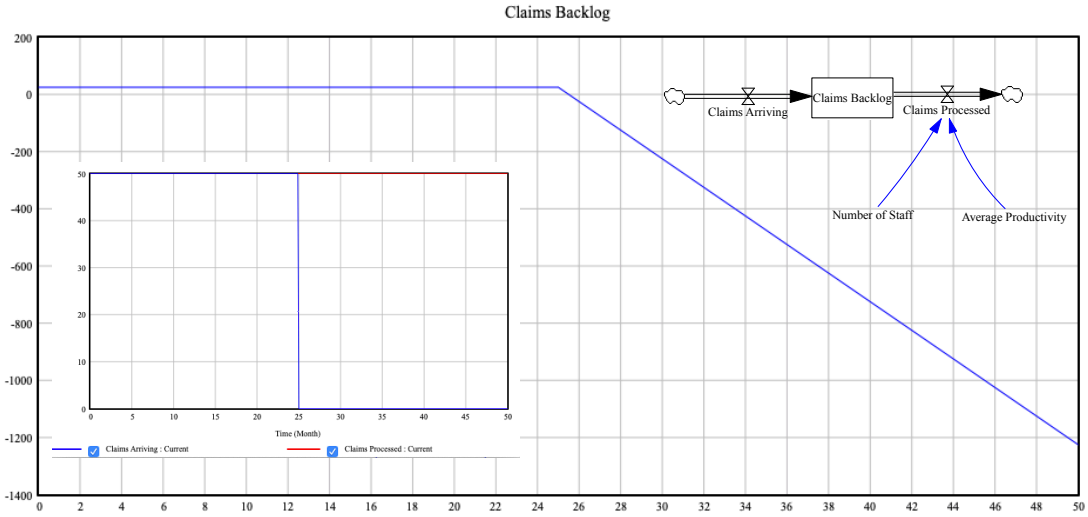
Stock behaviour?



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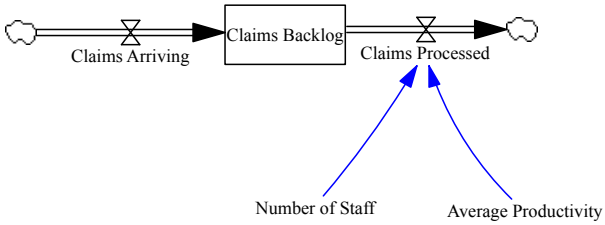
Need to ensure stock stays positive

- Rules:
  - If there is no claims backlog, then the claims processed should be zero
  - If the claims backlog is less than the claims processing capacity, then only the backlog should be processed
  - If the claims backlog is greater than the claims processing capacity, then only the claims processing capacity should be processed.



Claims Backlog	Number of Staff	Average Productivity	Capacity	Claims Processed
0	25	2	50	0
49	25	2	50	49
2000	25	2	50	50

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IF-ELSE RULE – MIN Function

Claims Backlog	Number of Staff	Average Productivity	Capacity	Claims Processed
0	25	2	50	0
49	25	2	50	49
2000	25	2	50	50

Claims Processed = MIN(Claims Backlog, Number Staff * Average Productivity)

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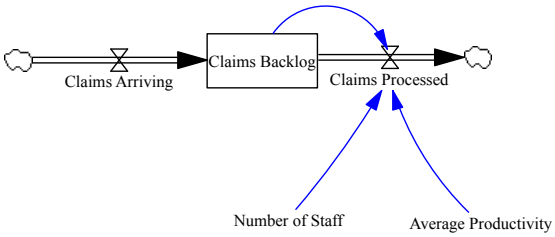
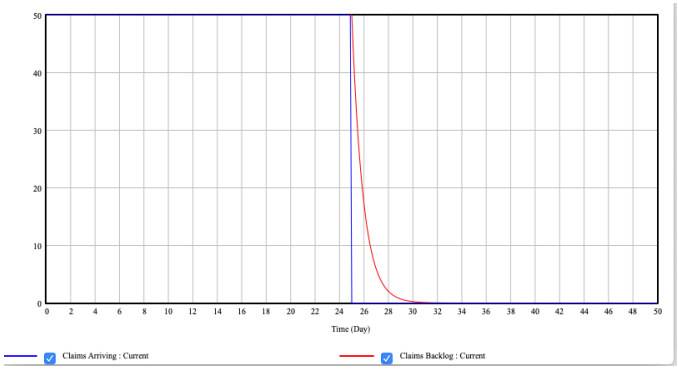
Updated Model

Claims Processed = MIN(Claims Backlog, Number Staff * Average Productivity)



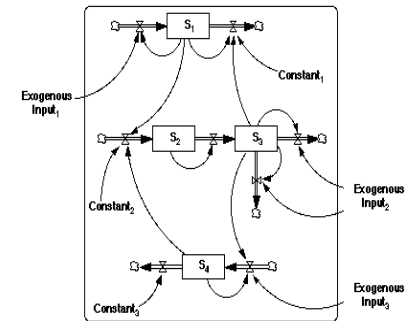


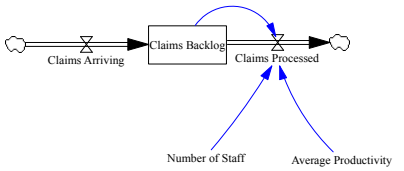
Challenge 4.3

- Extend the Vaccine Model to include
  - Those Yet to be vaccinated
  - Those Vaccinated
  - Those with non-effective vaccines (assume efficacy of 73%)
- Make the vaccination flow subject to two constraints
  - Vaccine availability
  - Health Care workers
  - HCW Productivity
- Identify all possible outcomes (similar to earlier table)

Higher Order Systems (Multiple Stocks)

- We can extend our models to build models with more than one stock (interacting stocks).
- Basic formulations include
  - Fractional increase
  - Fractional decrease
  - Adjustment to a goal
  - Resources/Productivity





Challenge 4.4
2-Stock Model of University

- Create a 2-stock University Model
- Students are recruited and graduate using fractional increase & decrease (0.25/year)
- Start with 10000 students
- Staff (initial value 500) are recruited using a goal adjustment structure
- Assume the desired student/staff ratio is 20:1
- Sketch the stock and flow structure, with equations
- Identify the feedback in the model
- Speculate on how the stocks will react to the following separate scenarios:
  - The desired student staff ratio drops to 15
  - There is a new influx of 1000 students per year from 2025
- How might the stock of staff influence the stock of students?