

Introduction to the Loop Impact Method of Feedback Dominance Analysis

Session 1

Using Loop Impact to Explore System Behaviour

Worksheets

John Hayward

School of Computing & Mathematics

University of South Wales

john.hayward@southwales.ac.uk

sociomechanics.com

36th International Conference of the System Dynamics Society 2020

Abstract

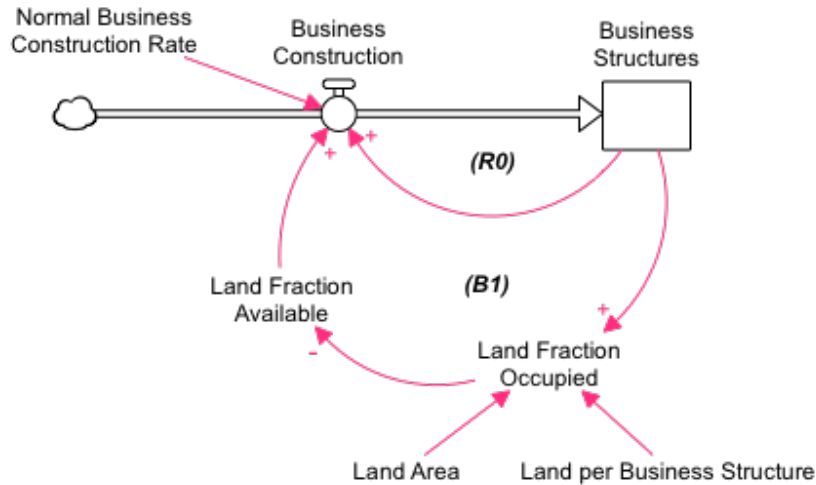
A central premise of system dynamics is that dynamical behaviour can be explained by model structure, especially its feedback loops. For example, the familiar S-shaped growth of the limits-to-growth archetype is explained using shifting loop dominance. Although such an explanation appears clear, what is less clear is how a loop is quantified, how dominance is defined, and what aspect of dynamical behaviour is being explained. These issues become more pronounced as the number of variables and feedback loops increases.

This workshop will introduce participants to the Loop Impact Method of feedback dominance analysis. In this first session participants will explore a number of models using the method's definitions of behaviour, structure and dominance, and compare them with their own understanding of the model's behaviour and structure. Participants will be encouraged to work in groups and share ideas. Models will be accessed using the isee exchange web platform.

In the second session participants will learn how to implement the Loop Impact method by adapting standard models in Stella Architect.

Limits to Growth

A fixed amount of land is designated for a new trading estate in order to encourage business development in a town. Initially, the trading estate grows rapidly as more businesses attract more business developments - the urban attractiveness hypothesis. However, as growth continues, land availability falls, and business development slows. The result is S-shaped growth

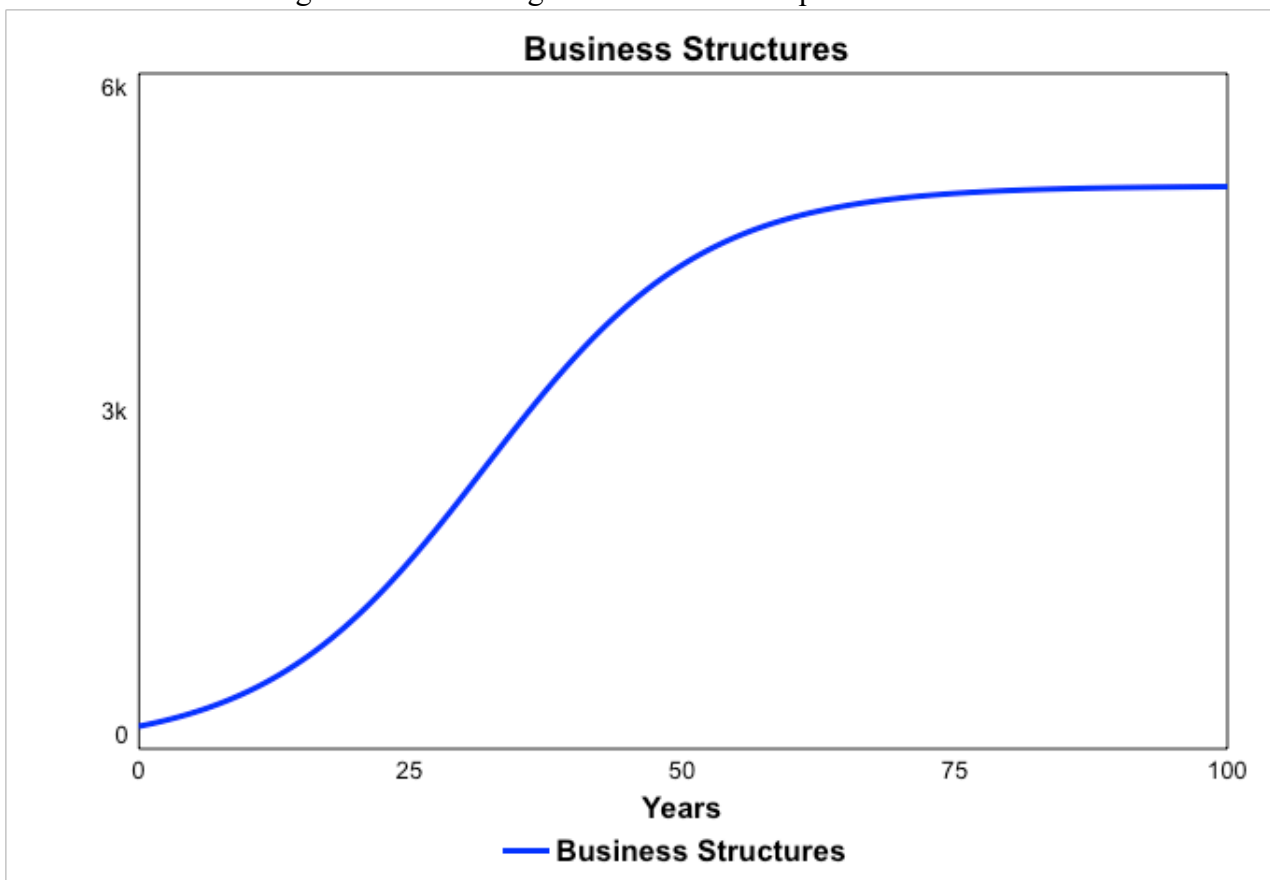


R0 – Reinforcing Loop

B1 – Balancing Loop

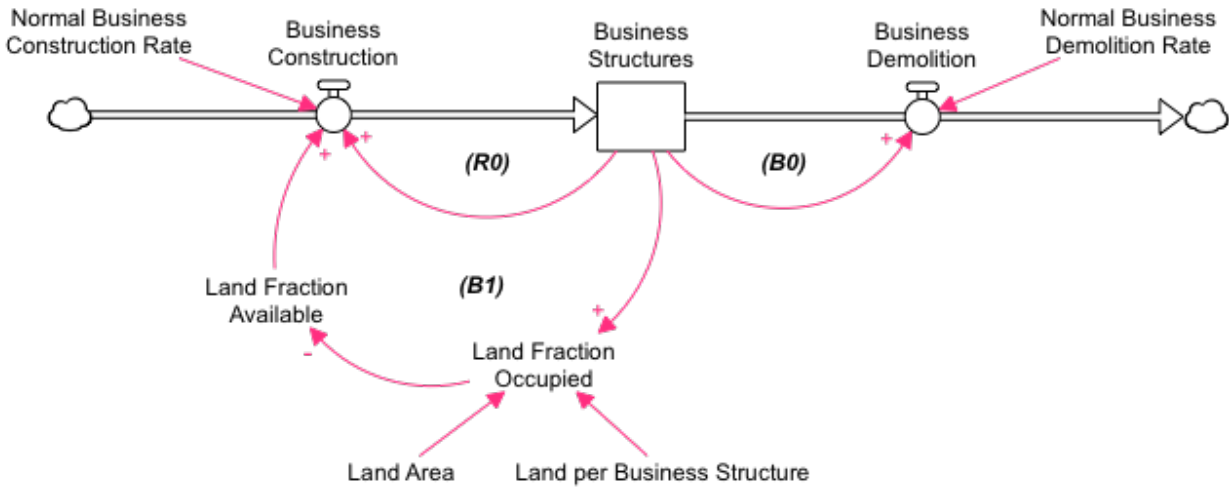
Stock achieves carrying capacity of 50,000 structures

- Mark on the diagram below the regions where each loop dominates behaviour



Limits to Growth Continued

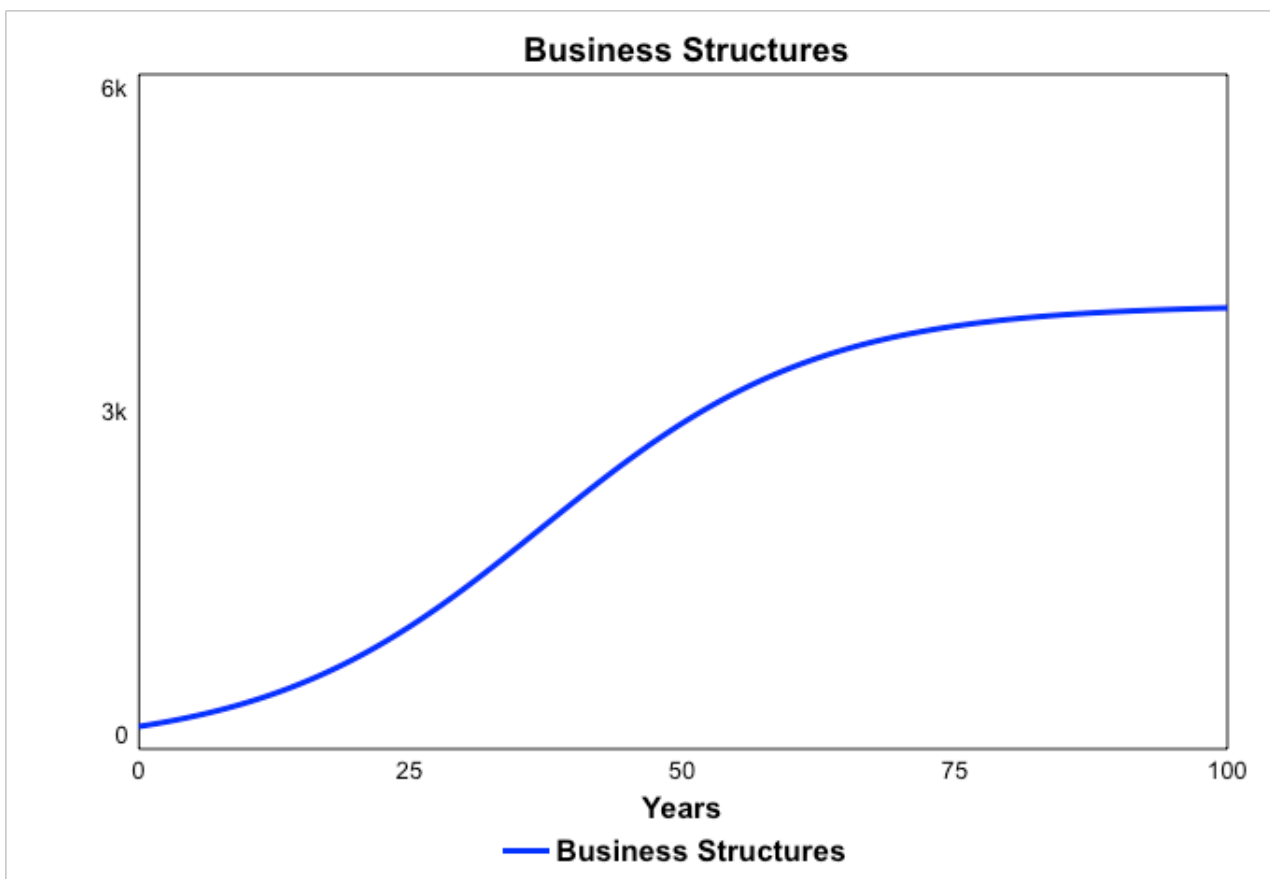
Business may now be demolished, a third loop, B0, balancing.



The normal business demolition rate is set to non-zero.

Business Structures falls short of the 50,000 carrying capacity.

- Mark on the diagram below the regions where each loop dominates behaviour



Check your answers with the online model at:

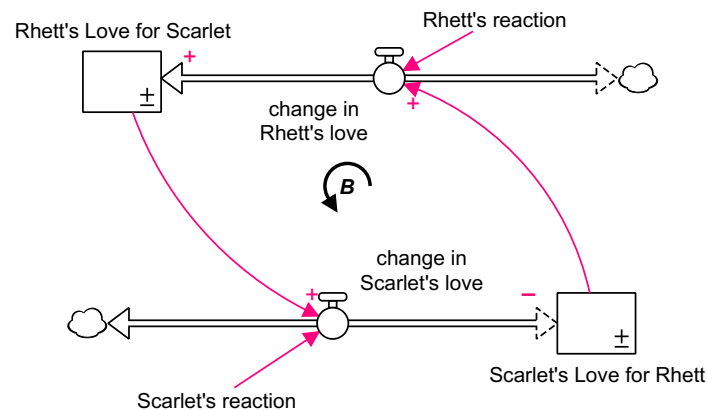
<https://exchange.iseesystems.com/public/john-hayward/limits-to-growth-archetype>

Gone with the Wind

The novel *Gone with the Wind* by Margaret Mitchell concerns the story of a man, Rhett and a woman Scarlet, with a difficult relationship. Scarlet wants what she cannot have. When Rhett is indifferent to her, she is attracted to him and her love for him grows. But when Rhett is attracted to her, she scorns him, her love declines.

However, Rhett is attracted to Scarlet when she is attracted to him - his loves grows. But when she is indifferent to Rhett, or treats him badly, he gets frustrated, and his love for her declines.

Rhett's love is positively affected by Scarlet's love, but Scarlet is negatively affected by Rhett's love - the classic balancing loop.

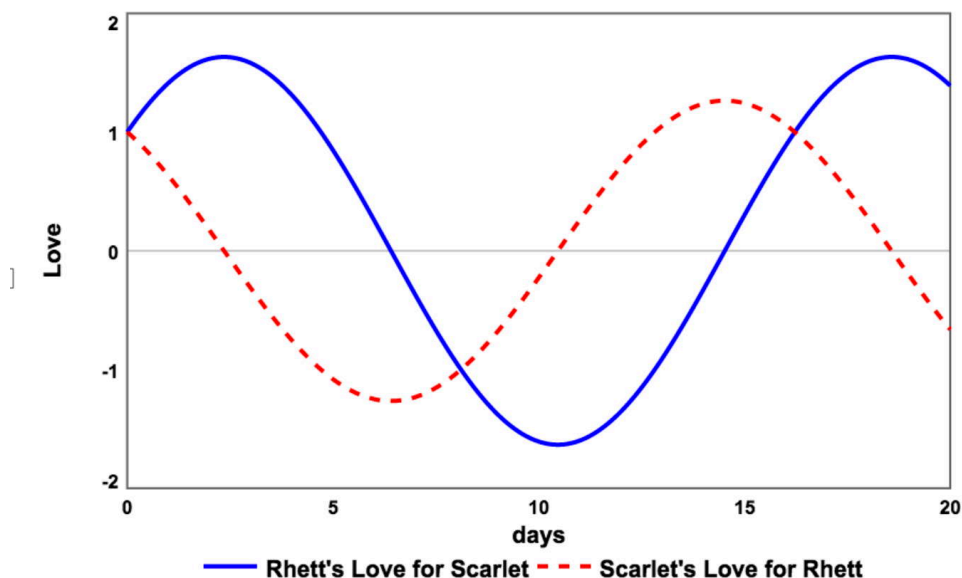


B – Second-Order Balancing Loop

Scarlet's reaction = 0.3, Rhett's reaction = 0.5. Thus loop gain = $(-0.3) \times 0.5 = -0.15$.

Oscillation – loop B dominates behaviour throughout, frequency determined by loop gain.

- Mark on the diagram below the changes of polarities of impact of B on the two stocks



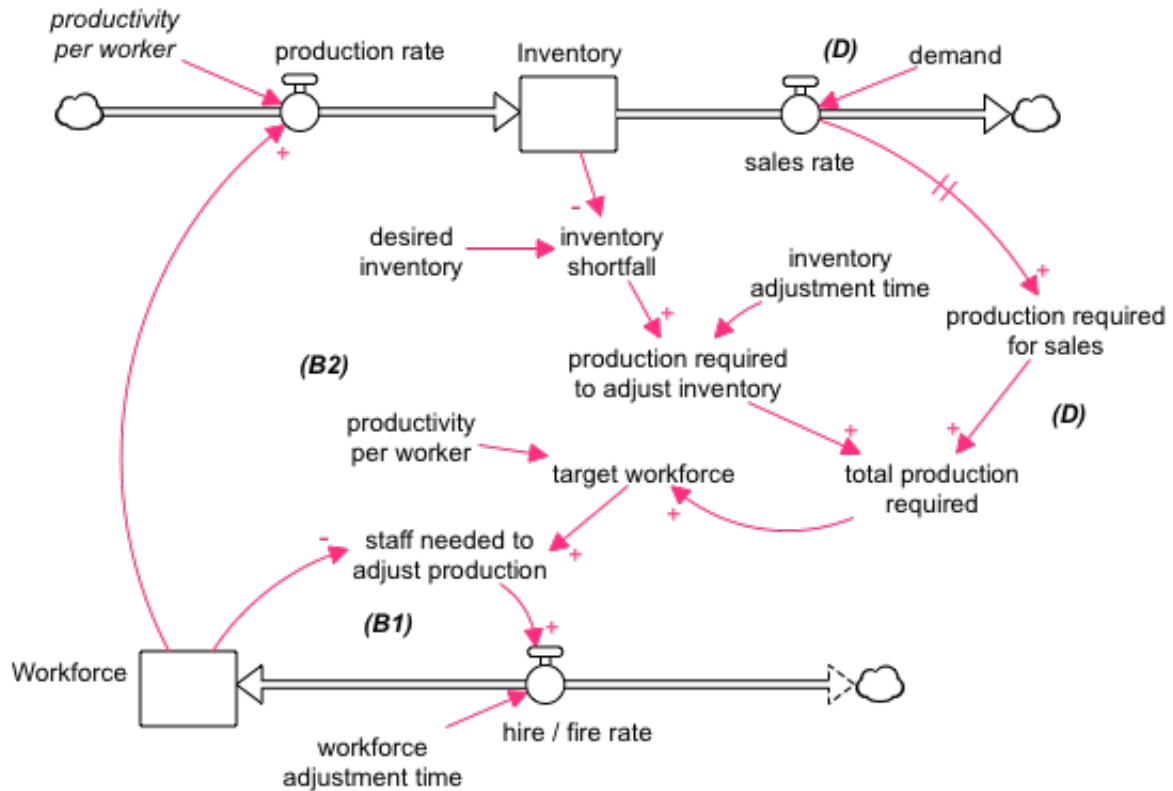
Check your answers with the online model at:

<https://exchange.iseesystems.com/public/john-hayward/gone-with-the-wind/index.html#page1>

- Using the online model read the values of the impacts at different times and check their product is the loop gain of -0.15.

Inventory Workforce Model

A manufacturing company maintains an inventory of goods ready for sale to customers. The inventory is maintained at a fixed level. If demand increases, then the company will need to increase production so that sales can be met, and the inventory size maintained. Thus, workers are hired, or fired, accordingly.



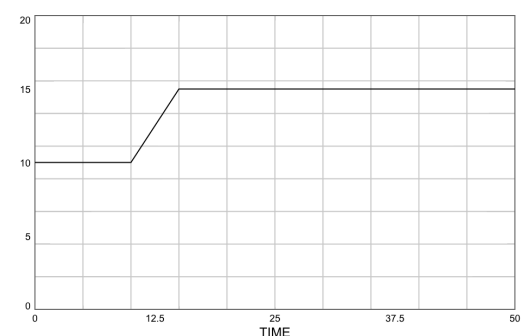
B1 – Balancing Loop, First Order

B2 – Balancing Loop, Second Order

D – Demand, Exogenous, rising from 10 to 15 units/month

demand graph

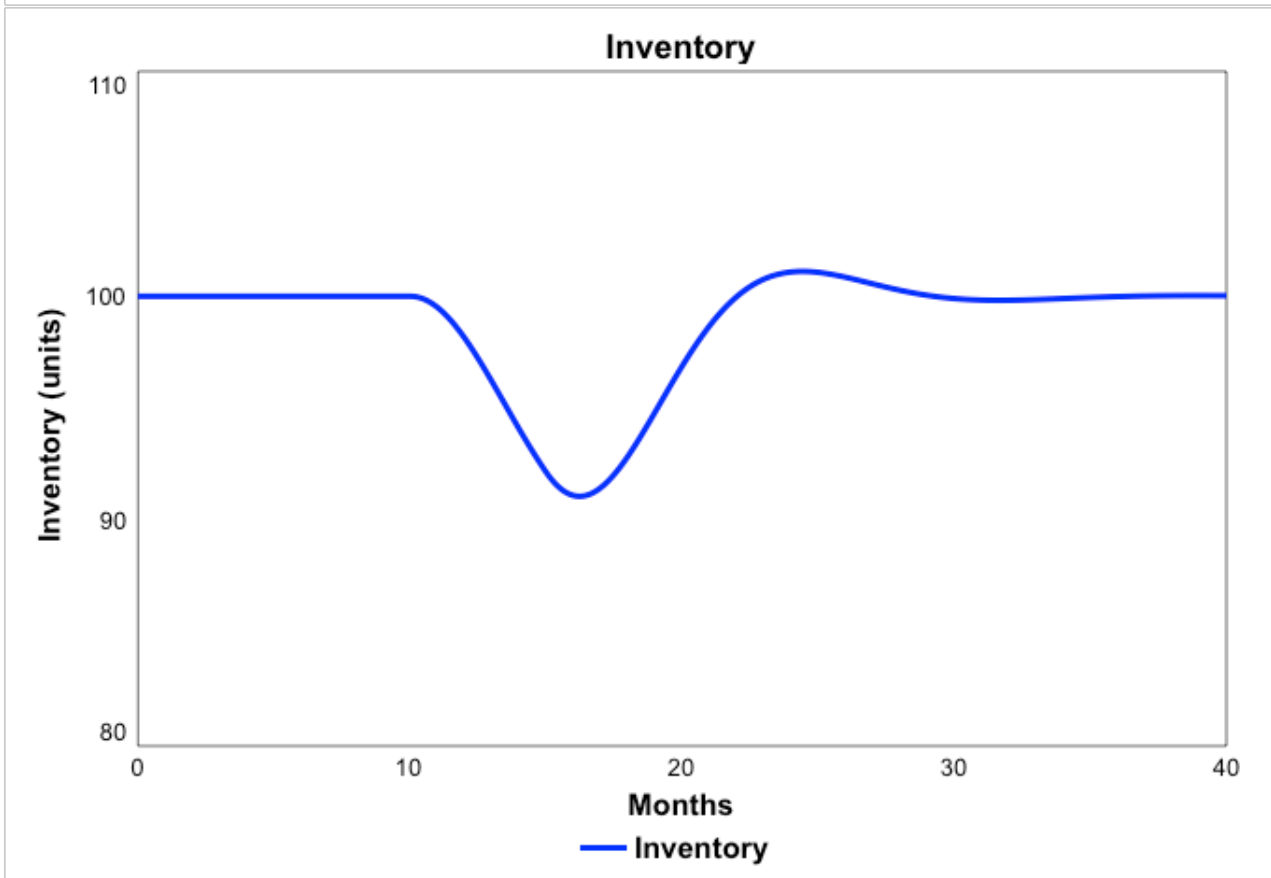
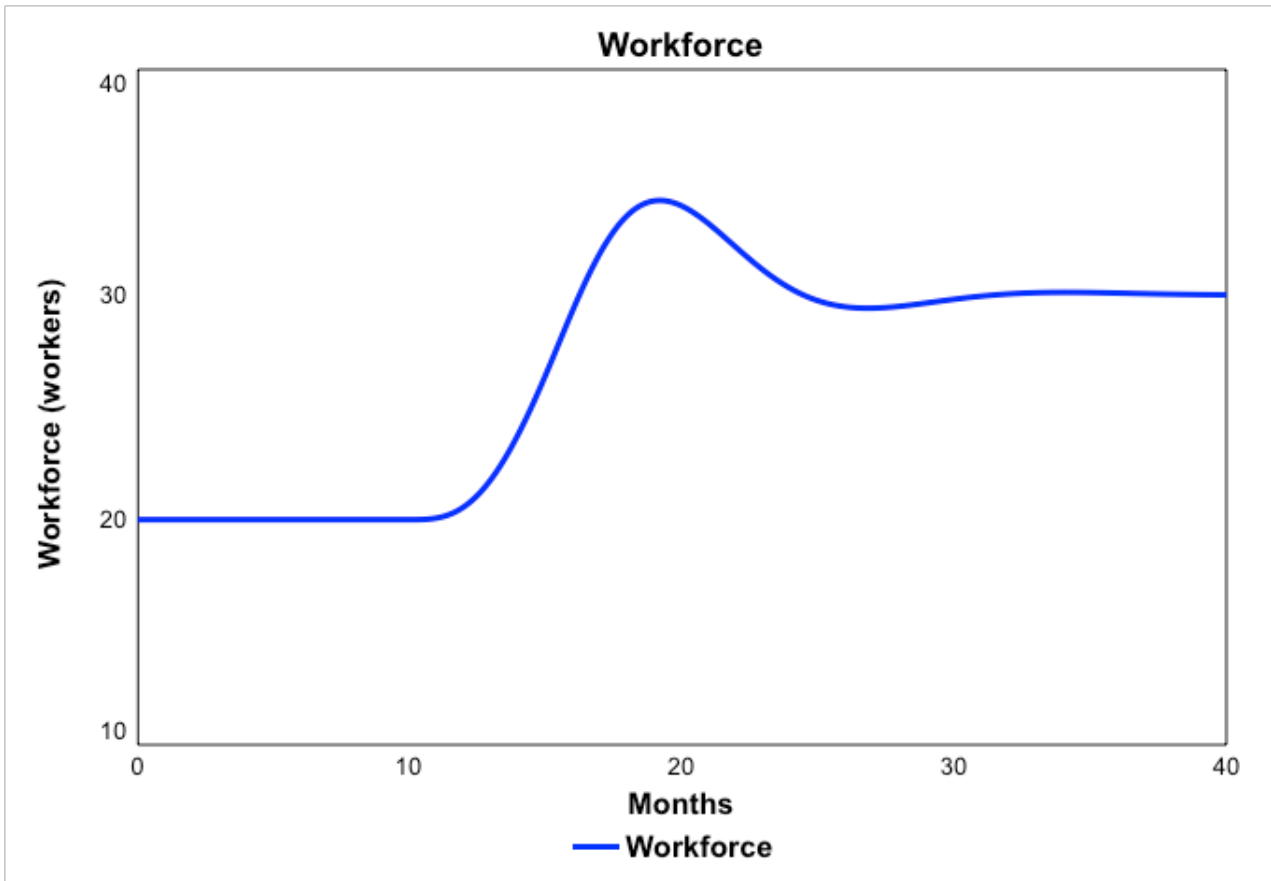
[Table](#)



Desired Inventory = 100 units

Productivity per worker = 0.5 units/month/worker

- Mark on the diagrams (next page) the regions where each loop dominates behaviour.
- How does the second order loop, B2, affect each stock?
- How does demand affect dominance?

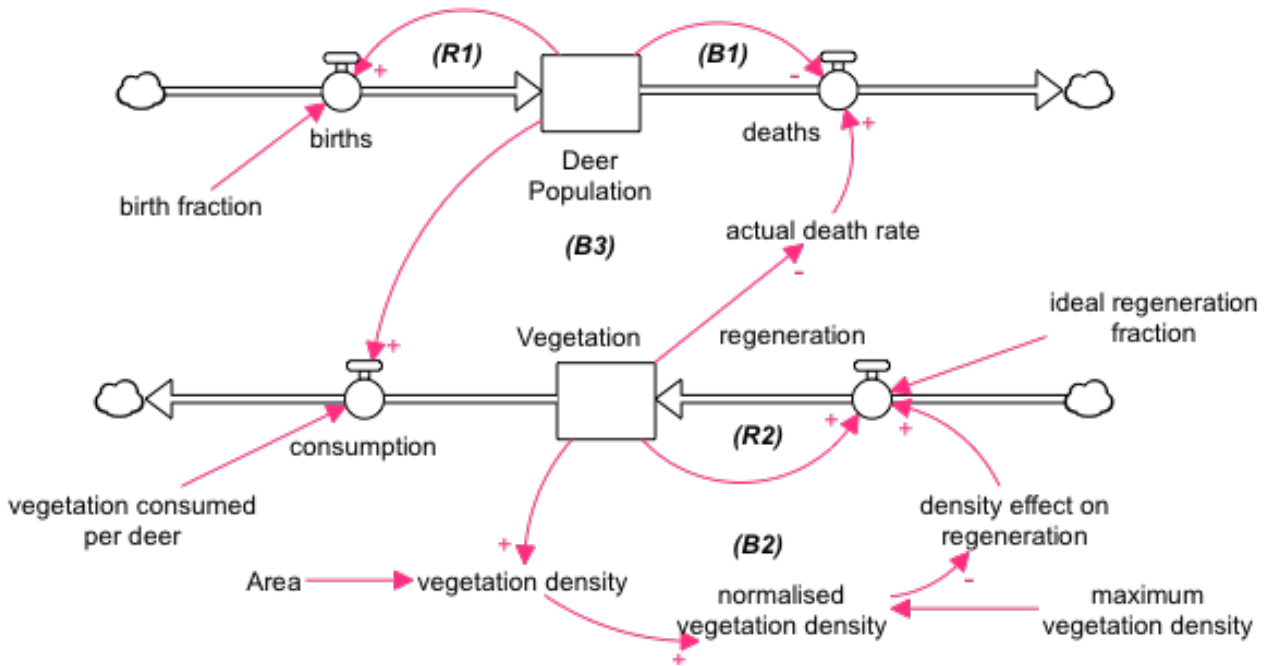


Check your answers with the online model at:

<https://exchange.iseesystems.com/public/john-hayward/inventory-workforce-model>

Overshoot and Collapse

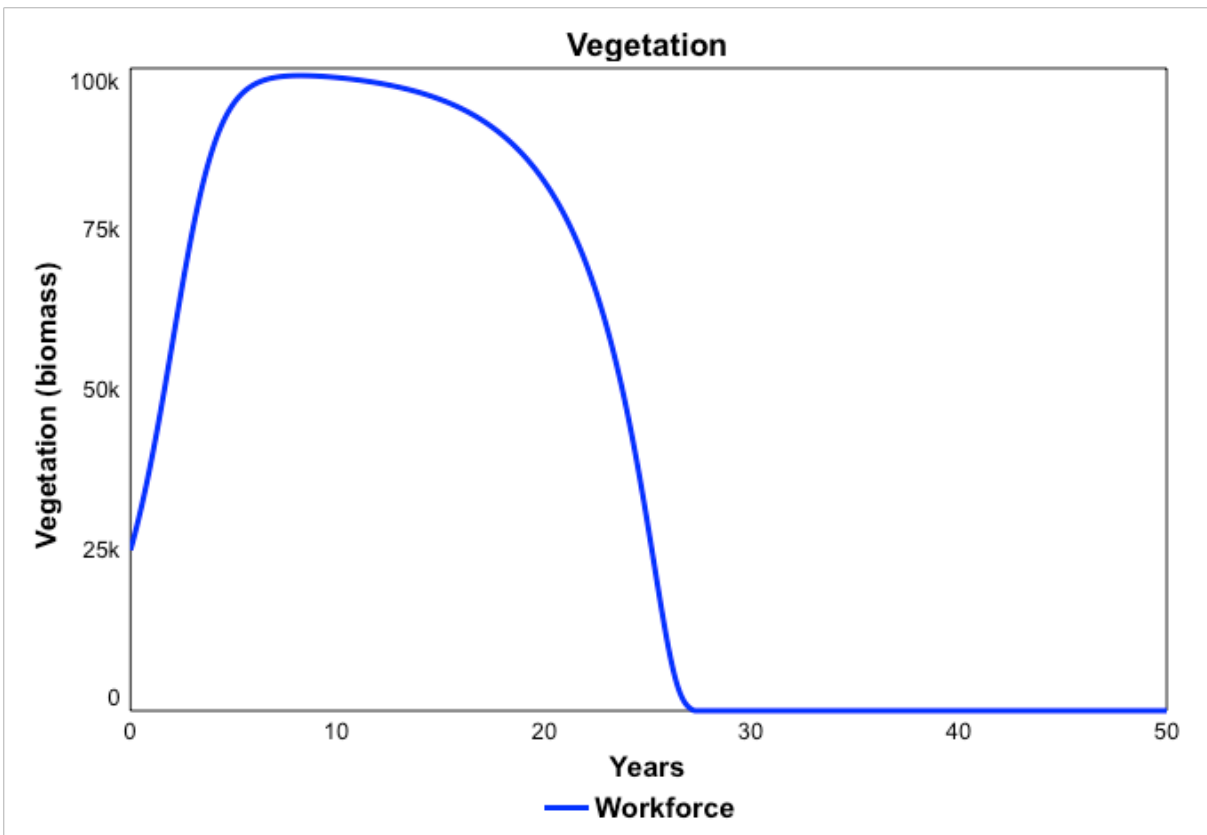
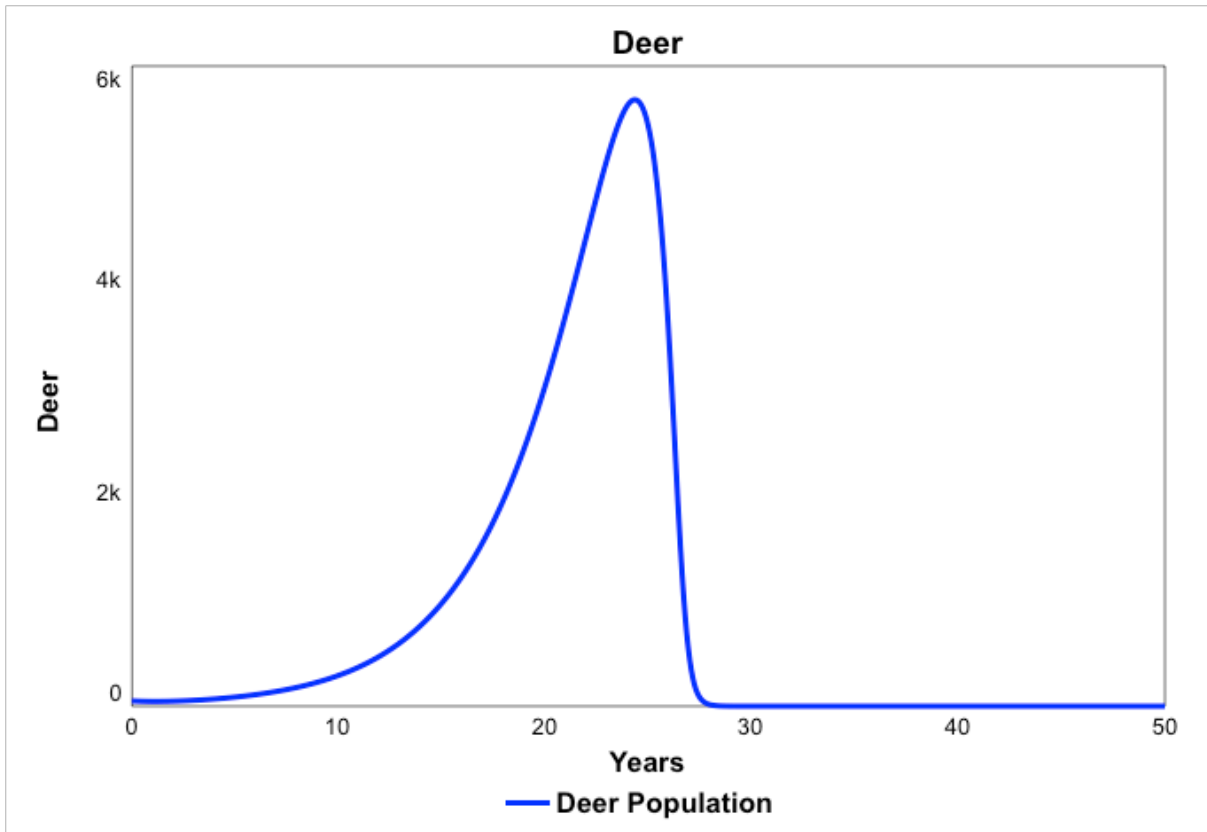
A population of deer live on a plateau, consuming its vegetation. When the vegetation is plentiful, the birth rate of the deer is much higher than its death rate. However, the plateau limits the growth of the vegetation; thus there comes a point where there is insufficient food supply for the expanding deer population. The food supply is depleted and the deer population falls. Under some circumstances recovery is not possible and both populations collapse to zero.



R1 – Reinforcing Loop, First Order
 R2 – Reinforcing Loop, First Order
 B3 – Balancing Loop, Second Order

B1 – Balancing Loop, First Order
 B2 – Balancing Loop, First Order

- Mark on the diagrams (next page) the regions where each loop dominates behaviour.
- How does the second order loop, B2, affect each stock?

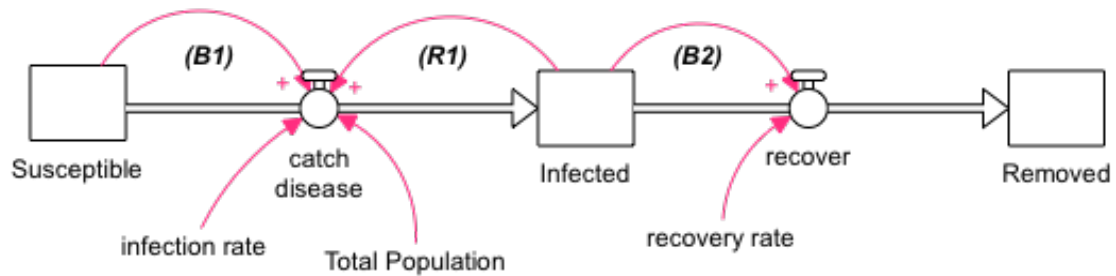


Check your answers with the online model at:

<https://exchange.iseesystems.com/public/john-hayward/overshoot-and-collapse>

SIR Model

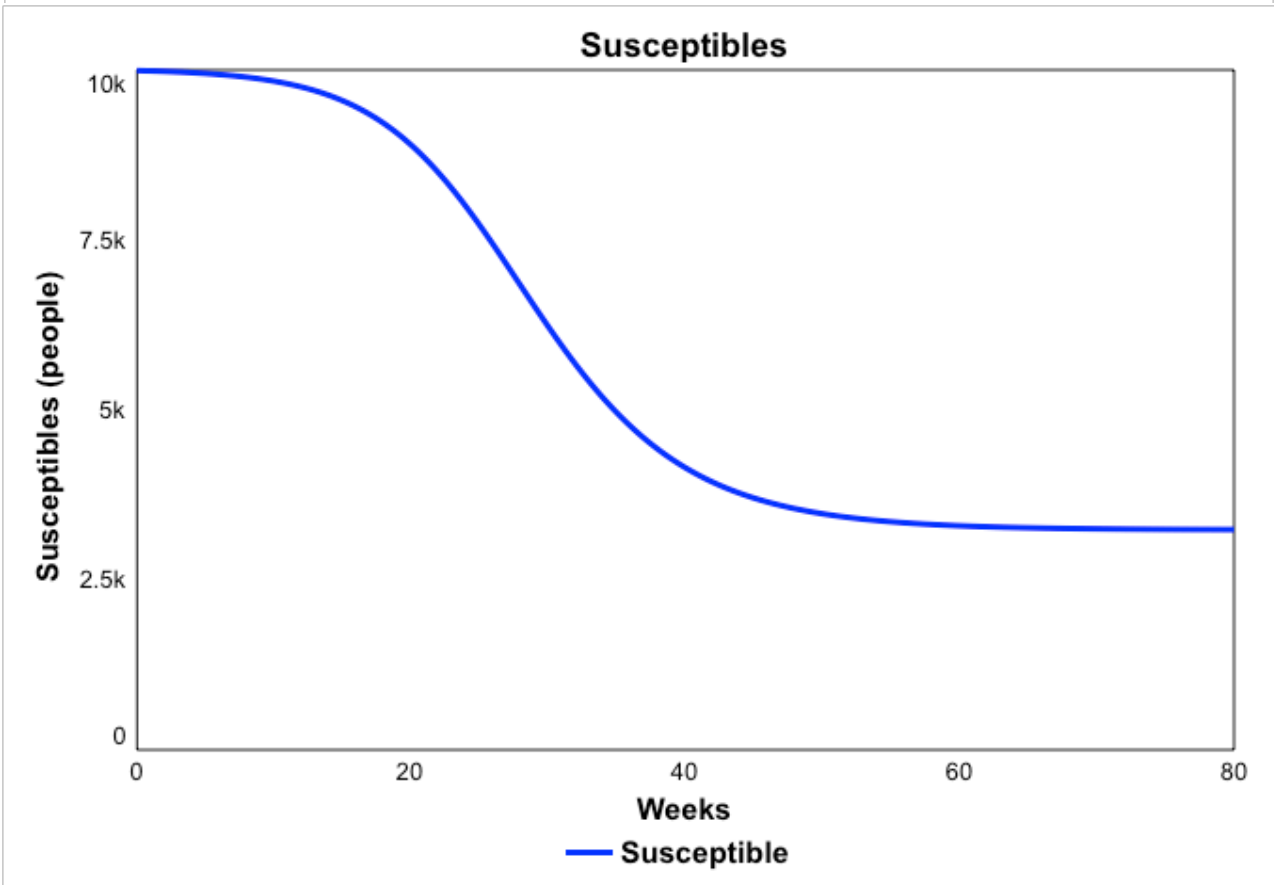
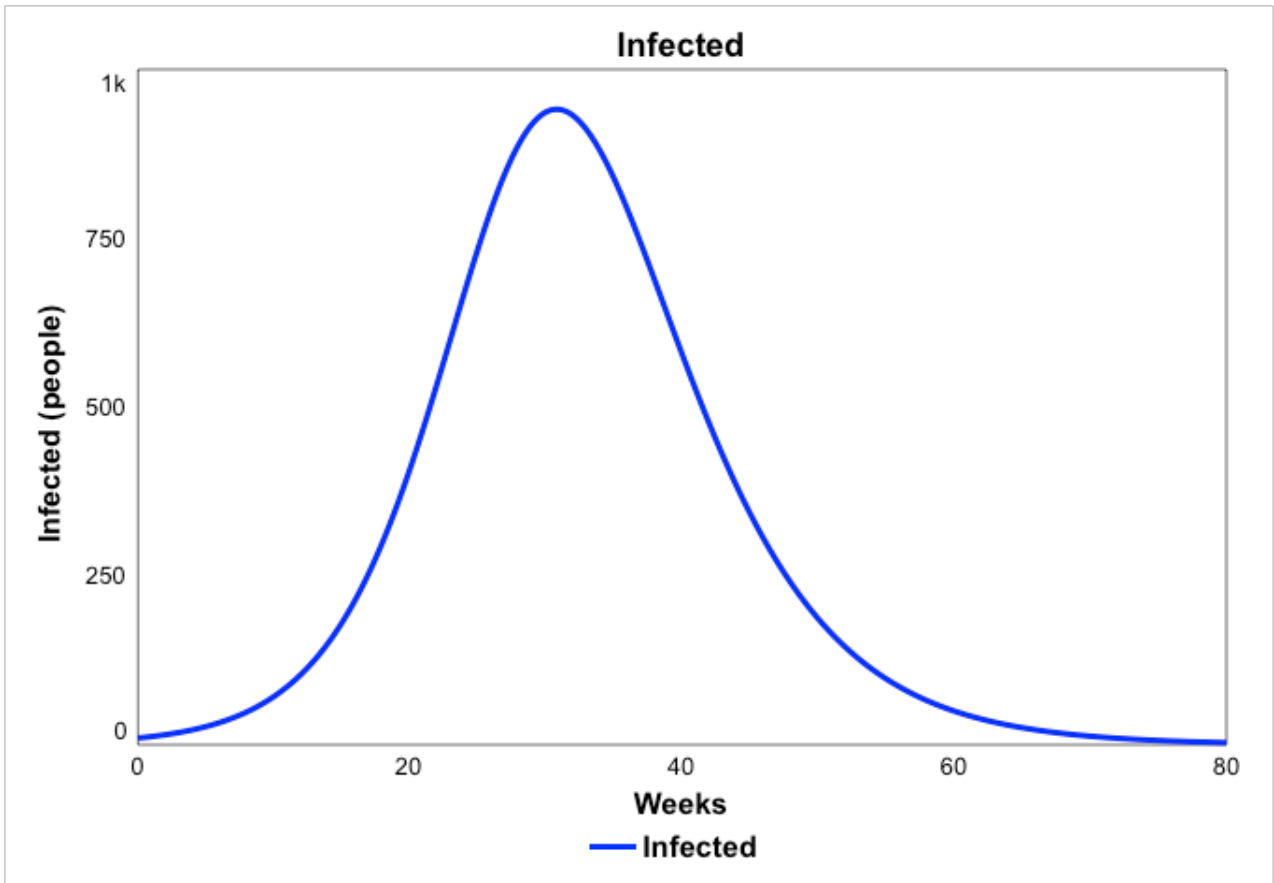
A disease spreads in a population of fixed size. Initially most people are susceptible (*S*) to the disease. An infected (*I*) person passes the disease on to a susceptible person, perhaps through contact, or through an airborne mechanism. People who are infected become infectious immediately, and remain so until the disease ends after a fixed period of time. Once cured, people are no longer susceptible to re-infection, the removed (*R*) category.



R1 – Reinforcing Loop, First Order
 B2 – Balancing Loop, First Order

B1 – Balancing Loop, First Order

- Three feedback loops are displayed in the diagram. However, how many loops are really active in this model?
- Mark on the diagrams (next page) the regions where each loop dominates behaviour.
- How can the turning point in *Infected* be explained using feedback loops?

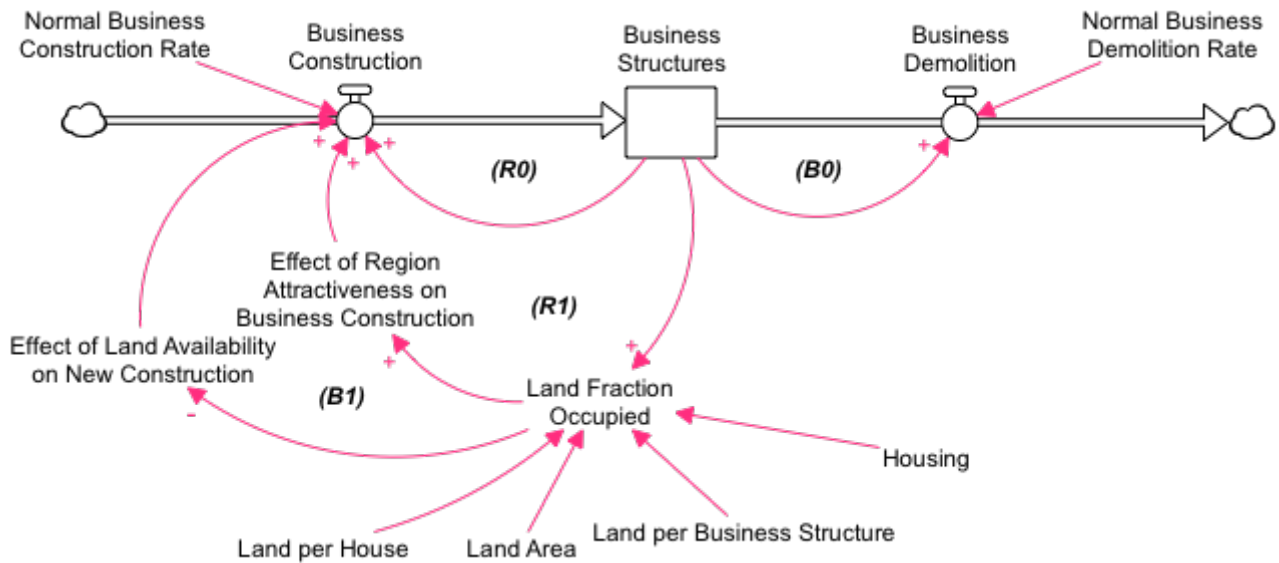


Check your answers with the online model at:

<https://exchange.iseesystems.com/public/john-hayward/spread-of-disease>

Urban Business Dynamics

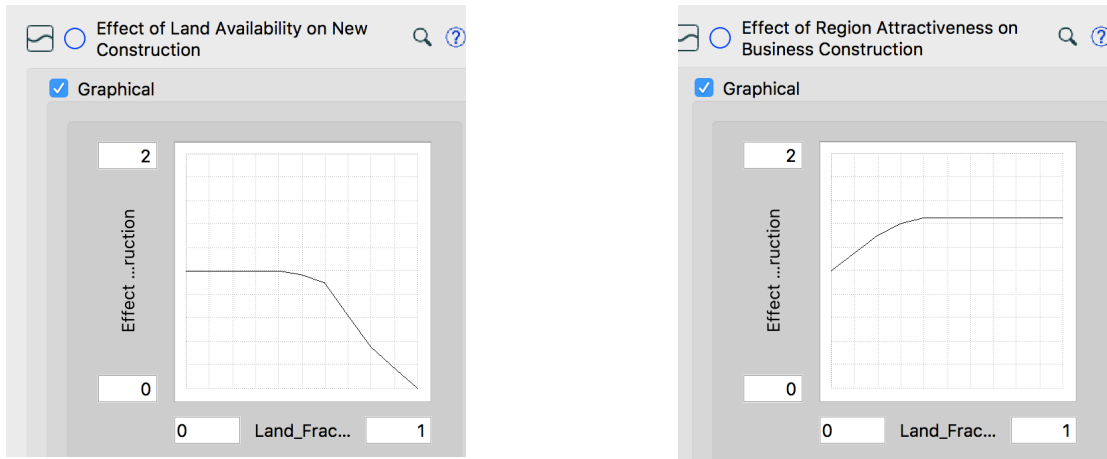
The limits to growth model, applied to businesses in an urban environment, has an extra loop added to modify urban attractiveness when land occupancy is sparse. It is the business sector of a model by Ghaffarzadegan, Lyneis & Richardson (2011), itself a simplified version of Forrester's (1969) original urban dynamics model.



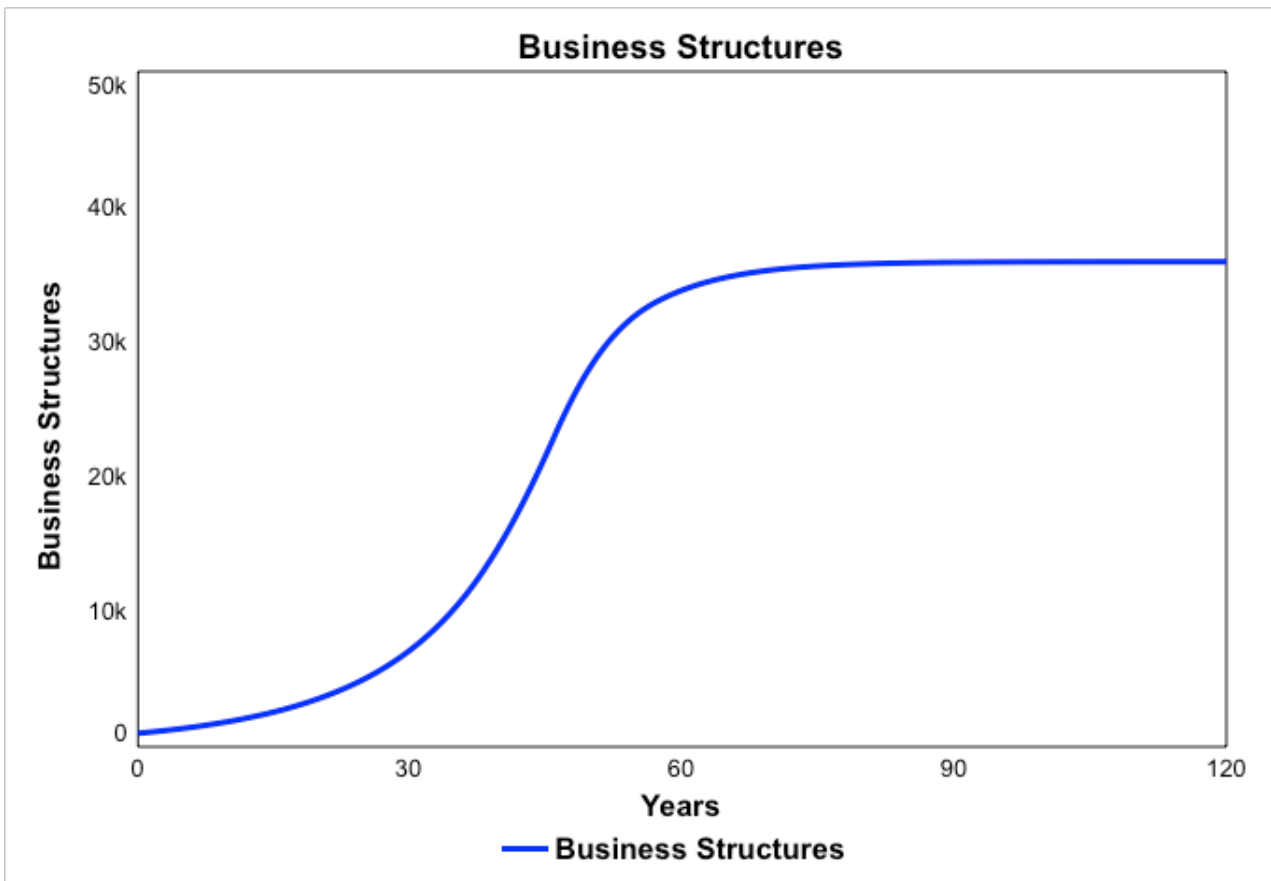
R0 – Reinforcing Loop
 R1 – Reinforcing Loop
 B0 – Balancing loop
 B1 – Balancing Loop

Housing is fixed, Labour is ignored. Loops R0 and B0 were not labelled in *Ghaffarzadegan, Lyneis & Richardson*, and not mentioned in their discussion of loop dominance.

Note the two graphical converters, in R1 and B1:



- Mark on the diagram (next page) the regions where each loop dominates behaviour



Ghaffarzadegan N, Lyneis J & Richardson GP. (2011). How small system dynamics models can help the public policy process. *System Dynamics Review*, 27(1), 22-44.

Forrester JW. (1995). *Urban Dynamics*. MIT Press: Cambridge, MA. (Now available from Pegasus Communication, Waltham, MA).

Check your answers with the online model at:

<https://exchange.iseesystems.com/public/john-hayward/urban-business-expansion>