Introduction to System Dynamics Modelling

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Outline of the day

- Introduction to the WHO CC (10 min) – Leandro
- Foundations of systems thinking (15 min) – Leandro
- Foundations of system dynamics (20 min) – Mehdi
- Q&A (10 min)
- Causal loop diagrams (CLDs) (15 min) – Mehdi
- Q&A (5 min)
- Hands-on example of public health CLD (15 min) – Leandro
- Q&A (15 min)
- Closing (5 min) – Leandro

Introduction to the WHO CC

COMPLEX SYSTEMS AND NETWORK SCIENCE FOR PREVENTION AND CONTROL OF NONCOMMUNICABLE DISEASES

A WHO COLLABORATING CENTRE FOR RESEARCH AND TRAINING

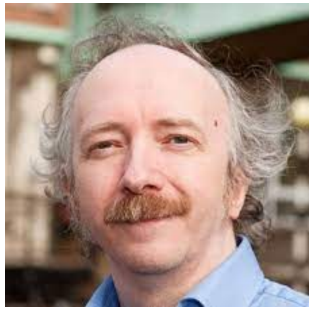
Support the WHO in:

- **building capacity** in the application of complex systems and network science by offering training
- research involving the **application** of complex systems and network science approaches in NCD prevention and control
- development and provision of an online tool for undertaking **stakeholder network analyses** to support implementation research

Members:

- Ruth Hunter, public/planetary health
- Neil Anderson, computer science
- Mike Clarke, evidence synthesis
- Leandro Garcia, complexity science
- Frank Kee, public health medicine
- Ciaran O’Neill, health economist
- Niamh O’Kane, complexity science
- Sophie Jones, complexity science
- Roisin Corr, administrator









The WHO Regional Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

Member States

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Armenia
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Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Tajikistan
Turkey
Turkmenistan
Ukraine
United Kingdom
Uzbekistan

53 countries
Work mainly eastern European including Albania, Armenia, Azerbaijan, Bulgaria, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Lithuania, Poland, Romania, Russia, Tajikistan, Ukraine, Uzbekistan

COMPLEX SYSTEMS AND NETWORK SCIENCE FOR PREVENTION AND CONTROL OF NONCOMMUNICABLE DISEASES

A WHO COLLABORATING CENTRE FOR RESEARCH AND TRAINING

- Training: https://www.qub.ac.uk/sites/who/training/
- To date, over 1000 people have taken part in our training

QUEEN'S UNIVERSITY BELFAST

Research and Training on Complex Systems and Network Science for NCD Prevention and Control

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Capacity Building And Training

SNA Workshop 1 - 21 May 2024

Introduction to Stakeholder Network Analysis

SNA Workshop 2 - 29 May 2024

Introduction to Stakeholder Network Analysis (advanced)

SNA Workshop 1 - 22 Oct 2024

Introduction to Stakeholder Network Mapping and Analysis

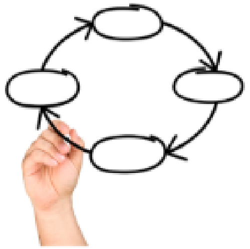
SNA Workshop 2 - 29 Oct 2024

Introduction to Stakeholder Network Mapping and Analysis (advanced)

World Health Organization European Region

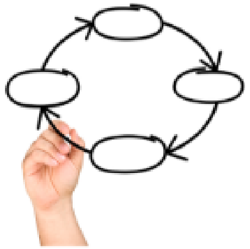
Summer School: 16-19 July 2024

Systems Thinking And Innovation For The Prevention Of Noncommunicable Diseases



Workshop 1 - 24 January 2024

Online Training: Introduction to Systems Thinking and Causal Loop Diagrams



Workshop 2 – 26 January (Group 1) and 2 February 2024 (Group 2)

Online Training: Introduction to Systems Thinking and Causal Loop Diagrams

World Health Organization European Region

Summer School: 18 - 20 July 2023

A Systems Approach To The Promotion Of Healthy Lifestyles

Further information

https://www.qub.ac.uk/sites/who/

Keep in touch

WHO Collaborating Centre for Research and Training on Complex Systems and Network Science for NCDs

A WHO Collaborating Centre to build capacity in systems science skills, and to formulate innovate ways to address NCDs.

https://www.linkedin.com/company/who-collaborating-centre-for-research-and-training-on-complex-systems-and-network-science-for-ncds/

COMPLEX SYSTEMS AND NETWORK SCIENCE FOR PREVENTION AND CONTROL OF NONCOMMUNICABLE DISEASES

A WHO COLLABORATING CENTRE FOR RESEARCH AND TRAINING

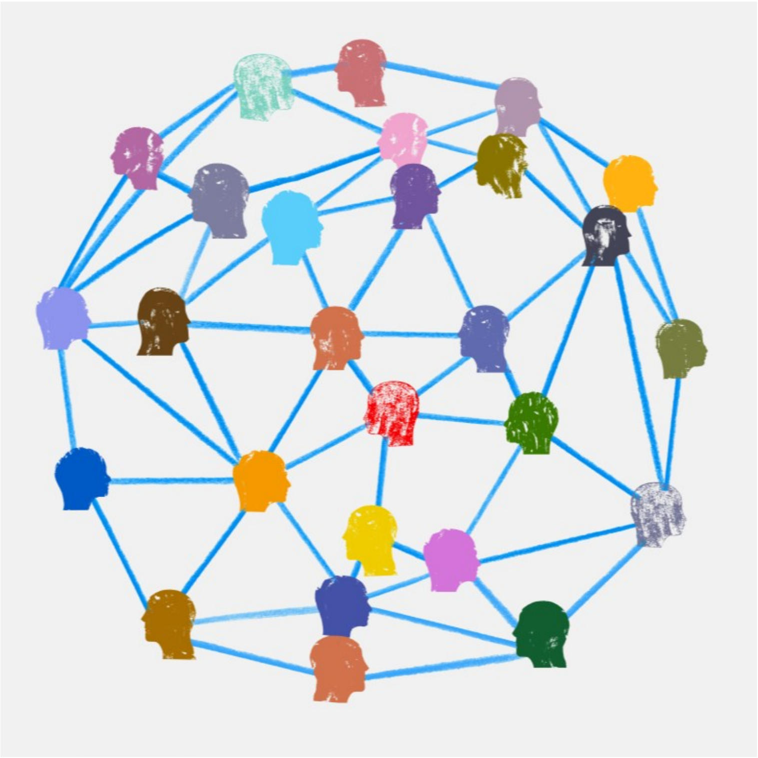
Member group: WHOCC for Research and Training on Complex Systems and Network Science for NCDs

Private Listed

https://www.linkedin.com/groups/13214019/

Foundations of systems thinking

Systems thinking in public health



What is systems thinking?

- Way of thinking and doing based on systems concepts and methods
- **Core principle:** breaking the system down to its parts does not allow us to fully understand the whole system
- Active focus on structures, interconnections, processes, mechanisms, and context
- It is about seeing the 'bigger picture'



What is a system?

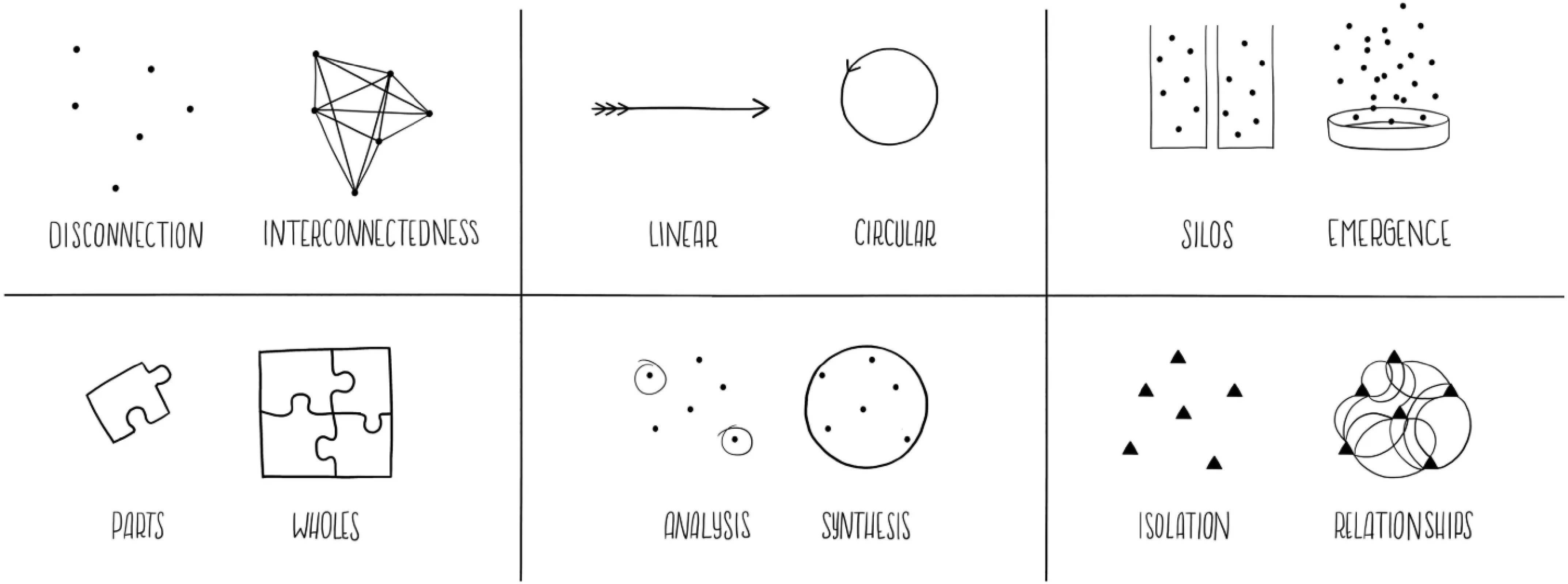
Integrated whole (defined by the observer)

- With structure (interconnected parts)
- New behaviour(s) at the system’s scale
- Porous boundaries (interaction with context)

The system's structure determines its behaviour
(system as cause)

A system's boundaries is given by the observer

Mindset of a systems thinker



https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a

Why use systems thinking?

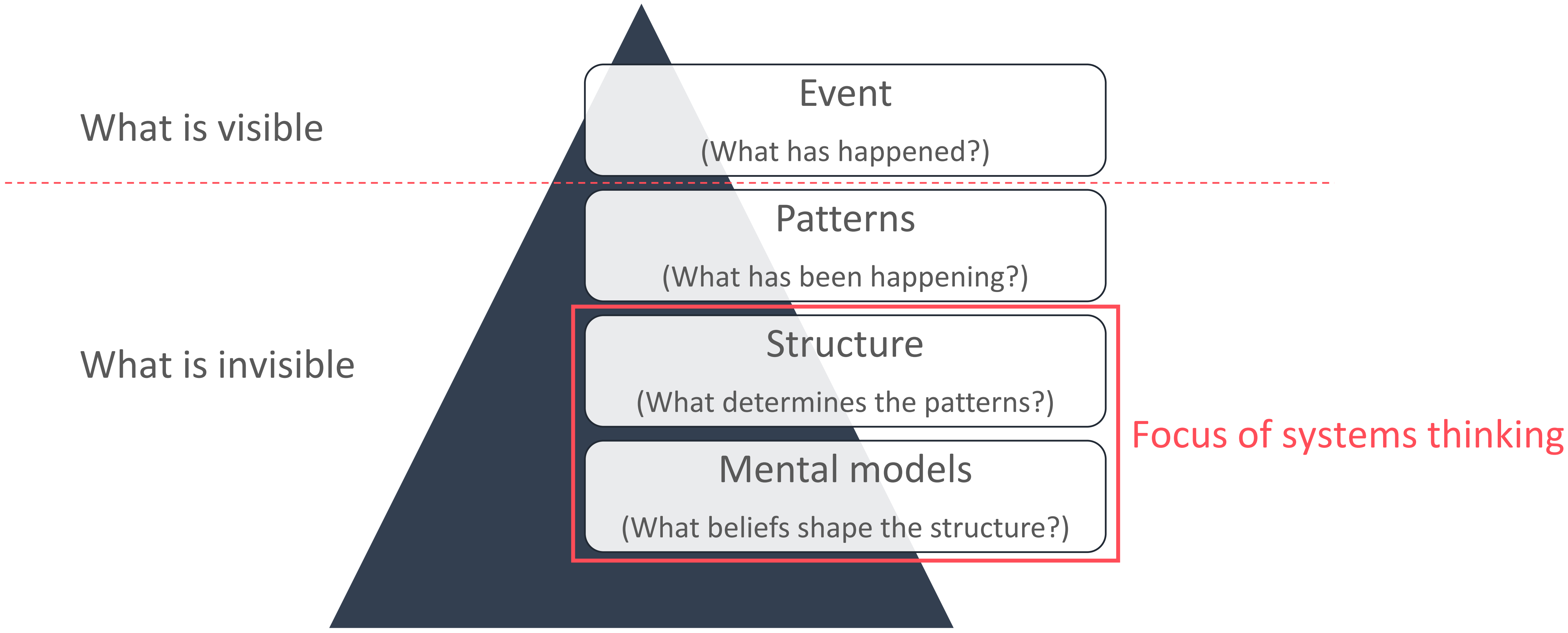
- Investigate systems problems
- Identify ways to address systems problems
- Broadening perspectives

Why systems-based public health?

Proposition: Modern societies are complex systems

Implication 1: Many public health challenges emerge from how modern societies (complex systems) are organized

Implication 2: Interventions are actions within a complex system



"Instead of asking whether an intervention works to fix a problem, we should aim to identify if and how it contributes to reshaping a system in favourable ways."

Rutter H et al. The need for a complex systems model of evidence for public health. Lancet. 2017;390(10112):2602-4.
https://durmonski.com/self-improvement/iceberg-model-systems-thinking

Foundations of system dynamics

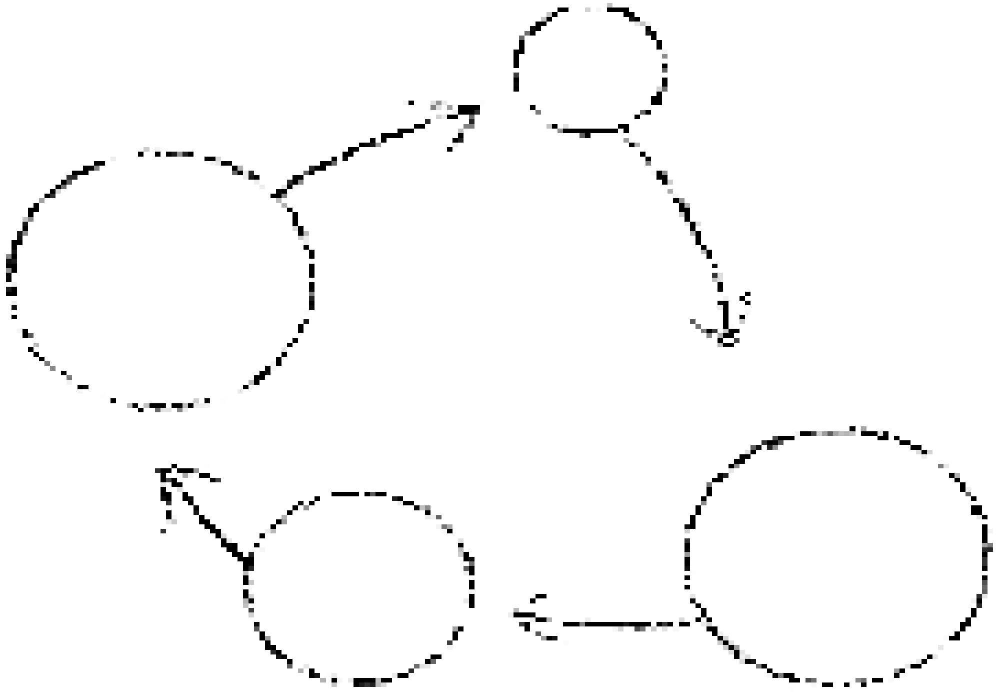
Foundations of systems thinking

Introduction to System Dynamics

(history and foundation)

Qualitative System Dynamics

Quantitative System Dynamics



With acknowledgements to Dr Natalie Clewley and the Cranfield teaching team
Course Director of Systems Thinking Practice at Cranfield University

HISTORY

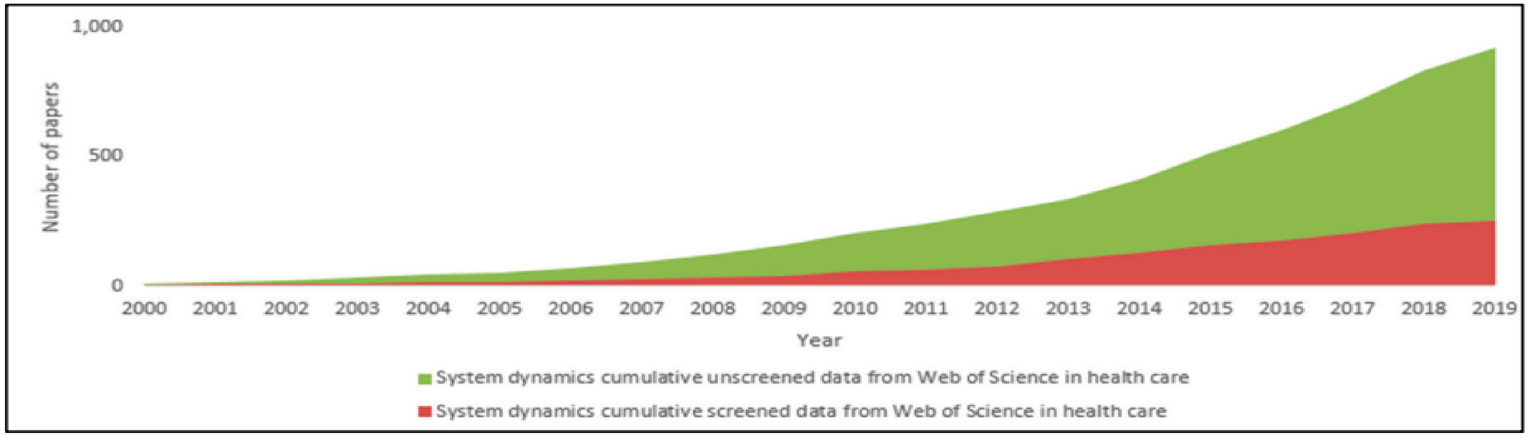
They had noticed the company were struggling with costly stock and resource fluctuations, so Forrester applied some modelling to identify a three-year cycle caused by a variety of factors, including some more social variables (i.e. management knowledge) that were often overlooked.

- 1950s and 60s: **Jay Forrester** analysed industrial processes like business cycles at GE, focusing on the Appliance Plant. His paper, 'Industrial Dynamics – A Major Breakthrough for Decision Makers' (Forrester, 1958), paved the way for a whole new research domain.
- In 1968, an international group of academics and scientists met to discuss the 'present and future predicament of man'. Their book, 'Limits to Growth' (Meadows et al, 1972), controversially presented some early ideas of computational modelling.
- In the 70s, Forrester was invited to help with the system dynamics approach to develop models of global resource constraints -> WORLD1,2
- In 1990, Peter Senge published the 'Fifth Discipline' (Senge, 1990). Also at MIT, Senge promoted the idea of more Qualitative SD with the goal of creating 'Learning Organisations'.
- First simulation packages SIMPLE and later DYNAMO

HISTORY

Nowadays, System Dynamics is a thriving research and consultancy domain, and software with a Graphical User Interface allows easy access to model development.

The most popular are probably STELLA and VENSIM



a total of 253 scientific papers written by 940 authors, applied to **Healthcare** published between 2000 to 2020 !! *

* Ref: Davahli, M. R., Karwowski, W., & Taiar, R. (2020). A system dynamics simulation applied to healthcare: A systematic review. *International journal of environmental research and public health*, *17*(16), 5741.

WHAT IS A SYSTEM?

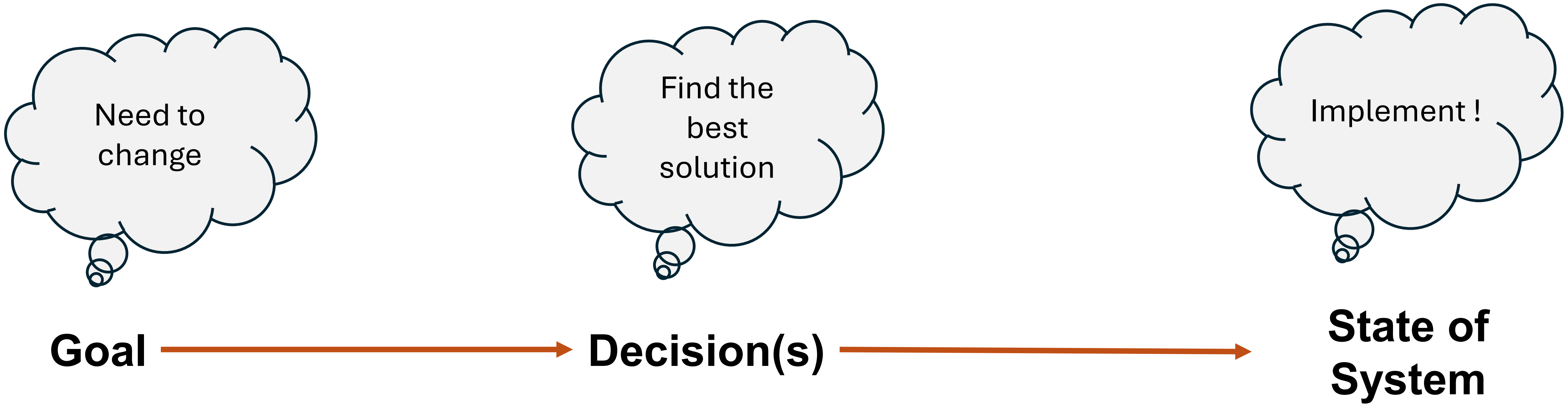
For this session and from System Dynamics view, we define a ‘system’ as:

A network of interdependent components connected by feedback relationships, whose structure generates its dynamic behaviour over time.

Jay W. Forrester, Industrial Dynamics (1961)

DYNAMIC THINKING

Closed (Dynamic) vs Linear Thinking



Event-oriented view of the world

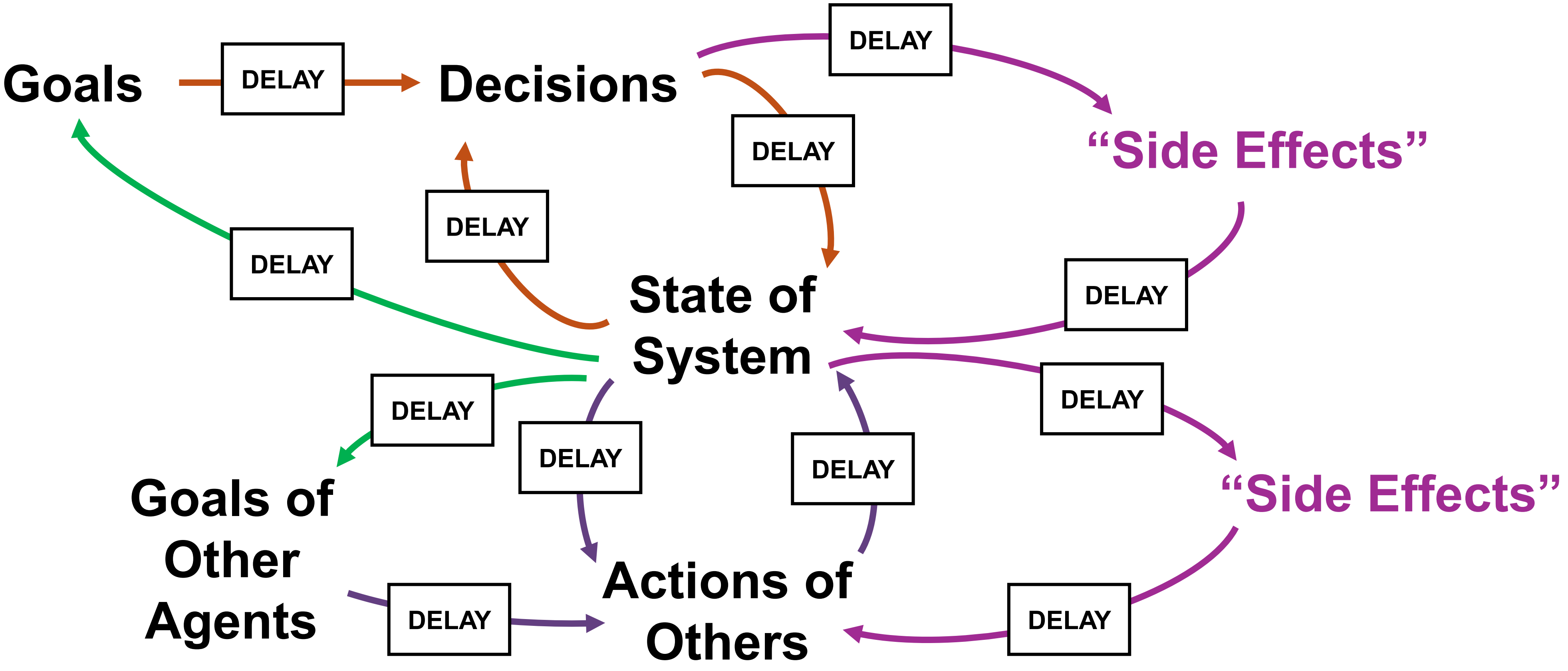
Closed loop VS. Open loop

Goals → Decisions → State of System

Event-Oriented (Linear) Thinking

Adapted from Sterman (2000)

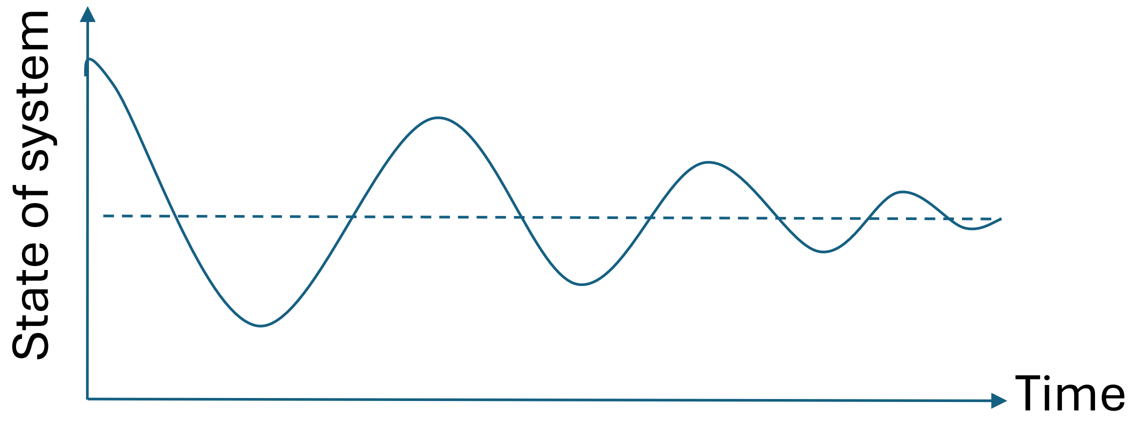
System (Dynamic) Thinking

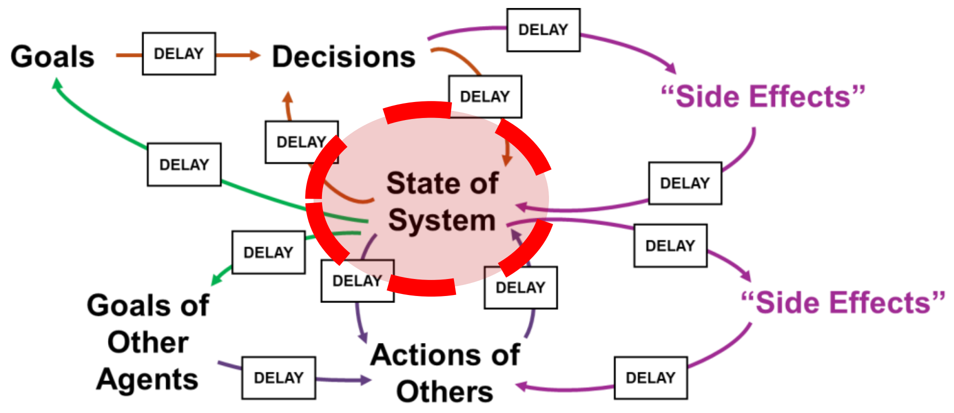


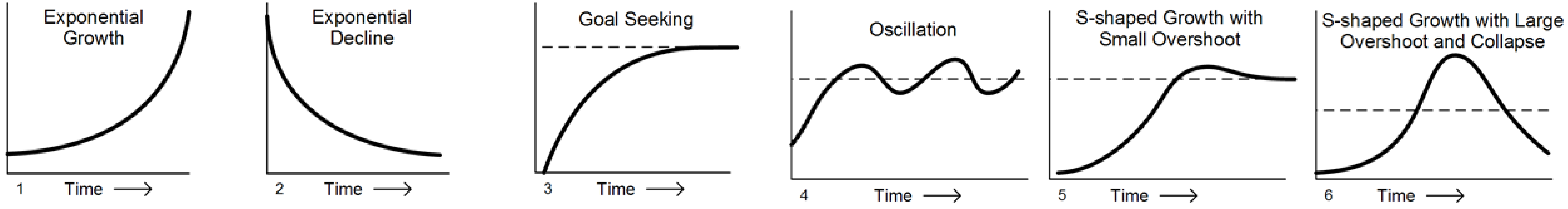
Closed loop Thinking

Adapted from Sterman (2000)

Closed (Linear) vs Open (Dynamic) Thinking







The above six graphs adopted from:
John Sterman's Business Dynamics: Systems Thinking and Modelling for a Complex World, page 108.

Closed (Linear) vs Open (Dynamic) Thinking

Concept	Event-Oriented Thinking	System Dynamics Thinking
Focus	Single events	Patterns and structures
Causality	One-way cause → effect (A → B → C → D)	Circular feedback loops (A ↔ B ↔ C ↔ D ↺)
Focus	Isolated events	Interconnected structure
Time	Static snapshot (short time)	Evolving over time (Long-term)
View of Change	Quick fixes	Sustainable solutions

SD FUNDAMENTALS

SD is not a tool but rather an approach ….

Social, health and economic systems are:

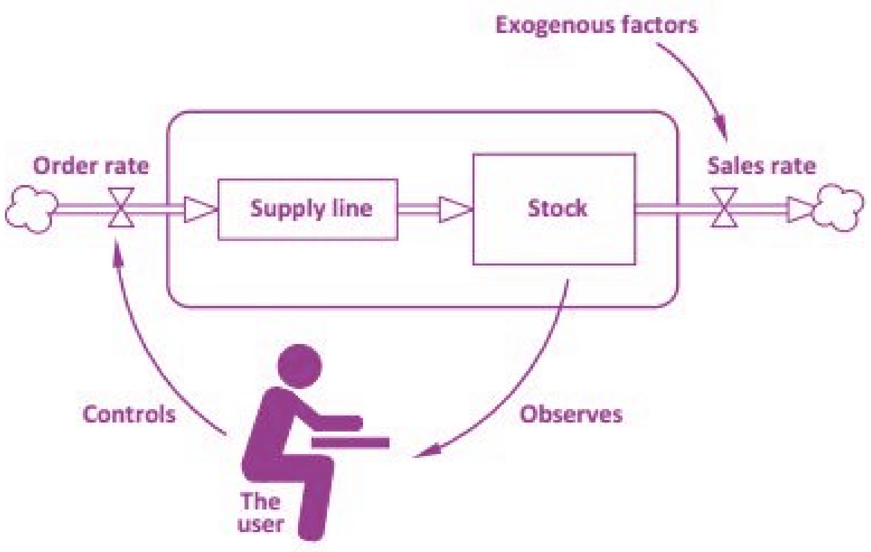
- Dynamic
- Tightly coupled
- Nonlinear and Governed by feedback
- Delays in cause and effect

- **No system exists in isolation**
- **Mental models are key drivers**

WHEN DO WE WANT A SYSTEM DYNAMICS SIMULATION MODEL?

There is a challenge, and we want to:

- increase our understanding of a problem
- Improve existing systems
- Improve behaviours
- Reduce complexity
- Avoid black-box decision making



DEFINITIONS OF SYSTEM DYNAMICS

"…the investigation of the information-feedback characteristics of [managed] systems and the use of models for the design of improved organisational form and guiding policy." (Forrester, 1961)

"A rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organisational boundaries and strategies; which facilitates quantitative simulation modelling and analysis for the design of system structure and behaviour." (Wolstenholm, 1990)

"A method of analysing problems in which time is an important factor, and which involve the study of how the system can be defended against, or made to benefit from, the shocks which fall upon it from the outside world." (Coyle, 1979)

"Systems dynamics deals with the time-dependent behaviour of managed systems with the aim of describing the system and understanding, through qualitative and quantitative models, how information feedback governs its behaviour, and designing robust information feedback structures and control policies through simulation and optimisation." (Coyle, 1996)

QUALITATIVE VS. QUANTITATIVE SYSTEM DYNAMICS

Qualitative SD

- Causal Loop, feedback or Influence Diagrams
- Feedback Loops
- Structure Generating Behaviour

Quantitative SD

- Stock and Flow Modelling
- Feedback and Delay
- Underpinning Mathematics
- Simulation

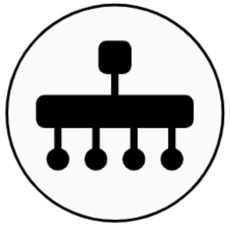
Two equivalent models that describe a system

A STRUCTURED APPROACH TO SYSTEM DYNAMICS

<u>Qualitative</u> System Dynamics

Problem Definition

Formulate and scope the problem for dynamic modelling

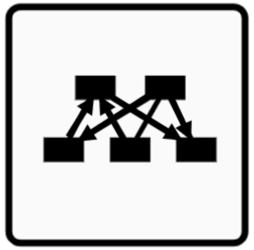


Variables

Recognise and identify the key variables and underlying factors

Behaviour over time

Recognise and estimate the behaviour of key variables over time

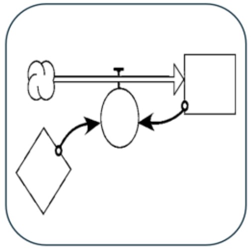


Feedback diagram

Identify cause and effect, draw feedback diagrams
<u>(Causal loop diagram)</u>

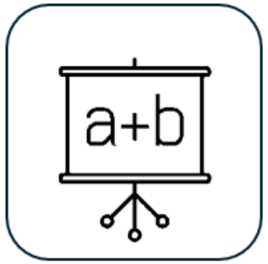
A STRUCTURED APPROACH TO SYSTEM DYNAMICS

Quantitative System Dynamics



Stock and Flow Diagramming

Identification of stock and flows and their interrelationships



Model formulation

Integrations of stocks and policies of flows

Simulation

Generate model behaviour over time

Analysis and implementation

Compare real and simulated behaviour, test structure, identify and test policy alternatives, and implement changes in the real system

SD MODELS

A model structure should **(Forrester, 1961):**

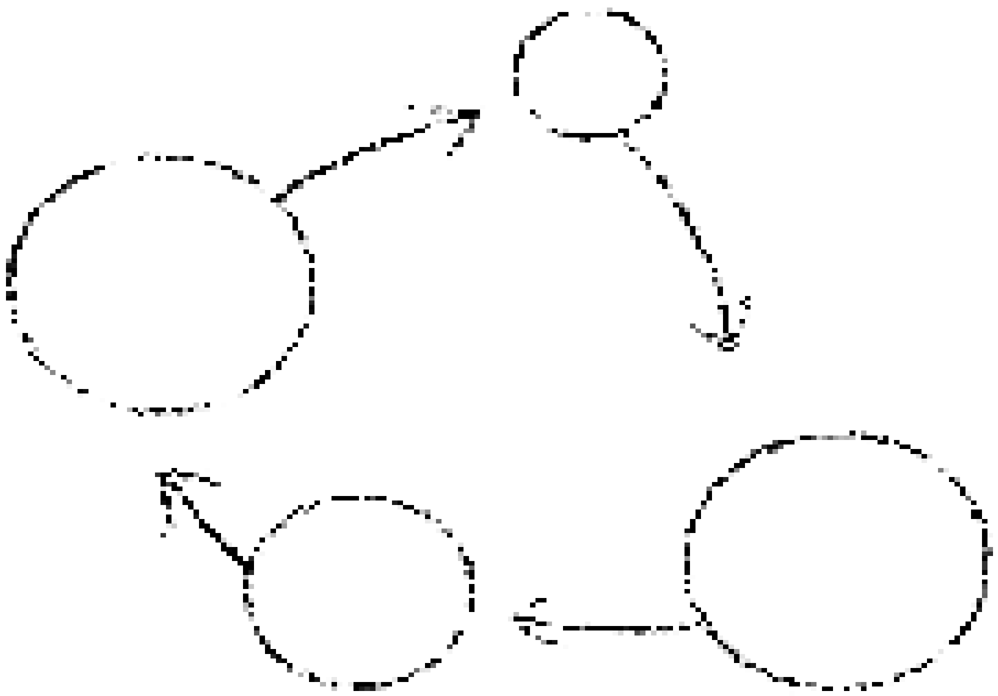
- Be able to describe any statement of cause-and-effect relationships across the system.
- Be simple (practical) in mathematical nature.
- Be able to incorporate feedback and delays within a system
- Be extendable to large numbers of variables without exceeding practical computing limits.
- Be able to handle ‘continuous’ interactions.

Foundations of systems thinking

Introduction to System Dynamics

Qualitative System Dynamics (CLD)

Quantitative System Dynamics



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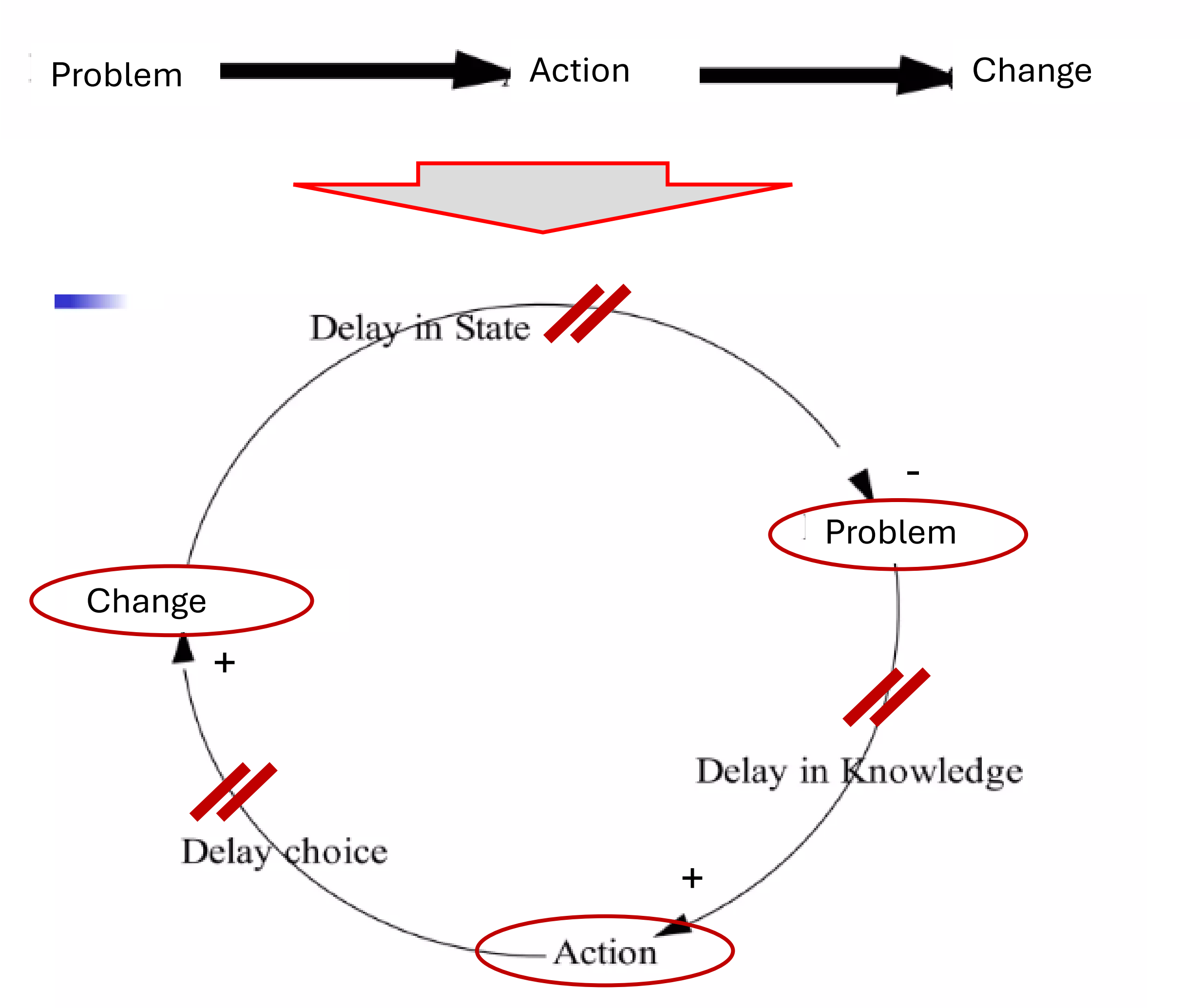
Causal loop diagrams

FROM LINEAR TO DYNAMIC

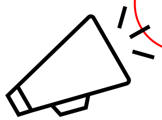


CAUSAL LOOP DIAGRAMS

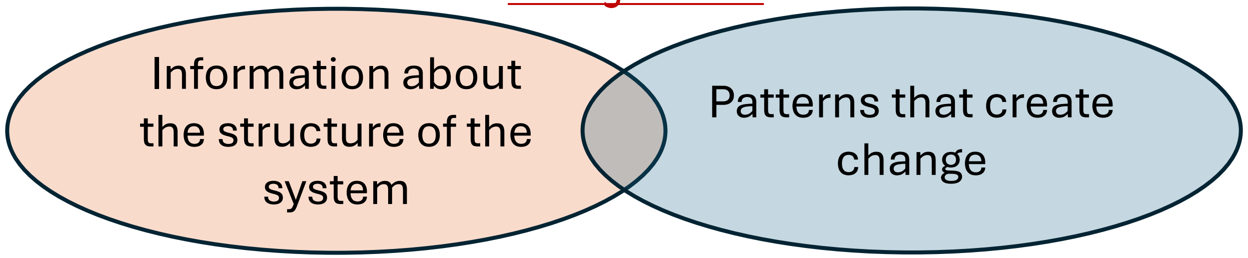
- CLDs are maps that show links between variables with arrows that signify cause and effect.
- CLDs describe the hypothesis about the causes of the dynamics
- In a CLD, variables are connected with arrows that represent a cause-and-effect relationship.
- An arrow pointing from a variable, say ‘A’, to a variable ‘B’, indicates that A causes B
- Each causal link is labelled with a polarity – indicated with a plus or a minus sign.
- The polarities represent how the independent variable affects the dependent variable

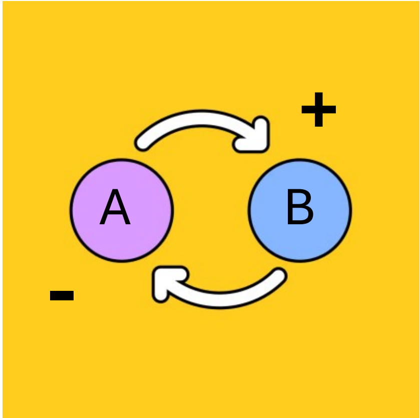
CLD Variables are:

- Clear
- Objective
- Unambiguous



CLDs give us …





CAUSAL LOOP DIAGRAMS

- **Variables:**

These are the key elements or factors within a system that change over time.

- **Arrows (Causal Links):**

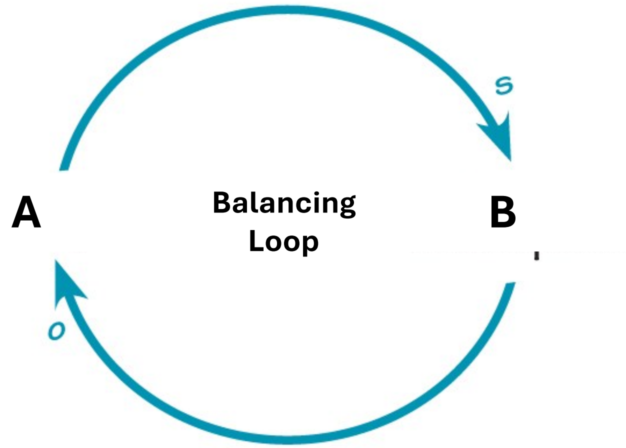
Arrows connect the variables and show a causal relationship, indicating that a change in one variable affects another.

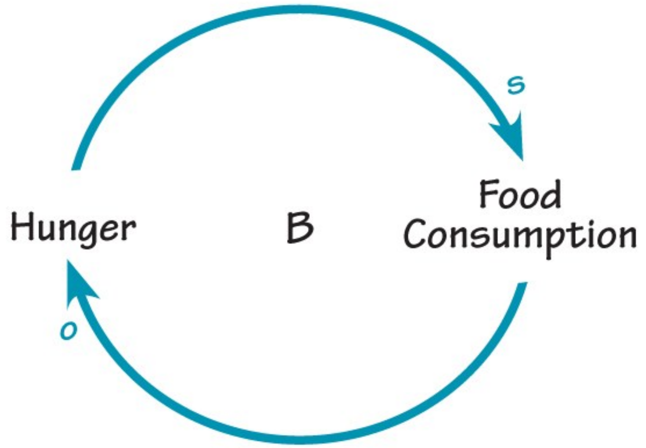
- **Feedback Loops:**

A feedback loop is created when causal links **form** a closed circle or loop.

- **Time Delays**

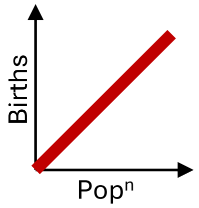
These are often represented by a symbol on a link and indicate that a causal relationship takes time to manifest its effect.





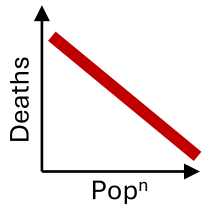
CLD - ARROWS

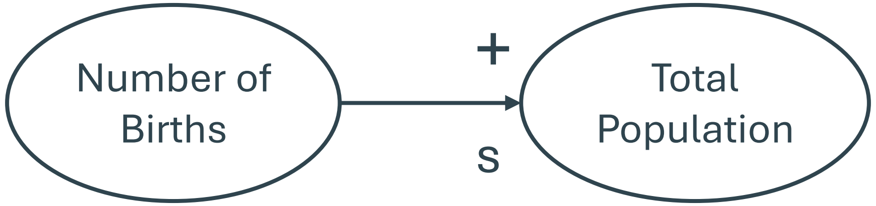
The connecting arrows between variables or nodes within the system indicate a **positive or negative correlation between variables**, signifying how a change in one variable will affect another.

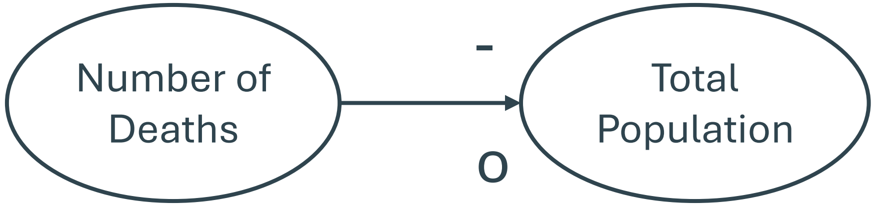


A **positive correlation/coupling** moves the variable values in the same direction. This can be represented by '+' or 's' for the same direction.

A **negative correlation/coupling** moves the variable values in opposite directions. This can be represented by '-' or 'o' for opposite direction



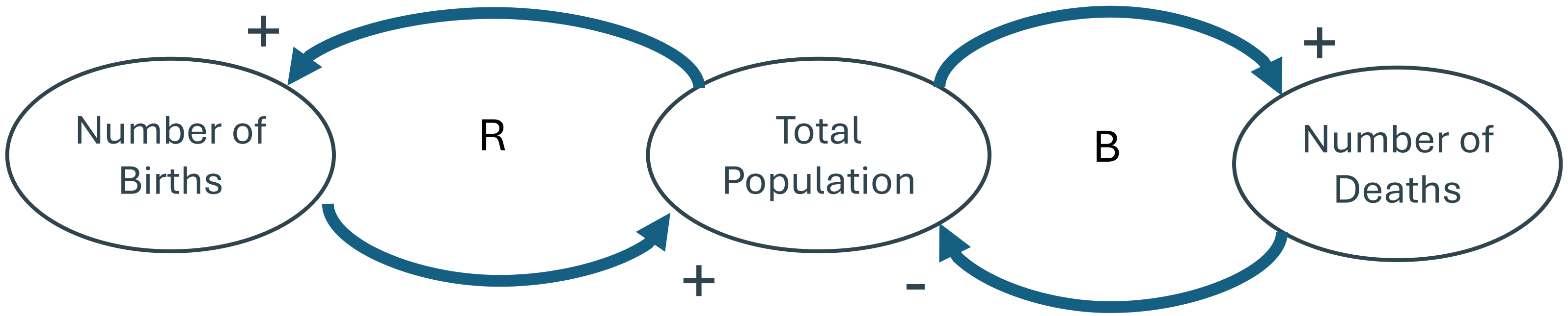




For example, an *increase* ↑ in births causes an *increase* ↑ in the population (+ positive coupling) whereas an *increase* ↑ in deaths causes a *decrease* ↓ in the population (- negative coupling).

CLD - FEEDBACK LOOPS

Causal loops enable us to think about feedback, delay and non-linearity in the behaviour of a system.

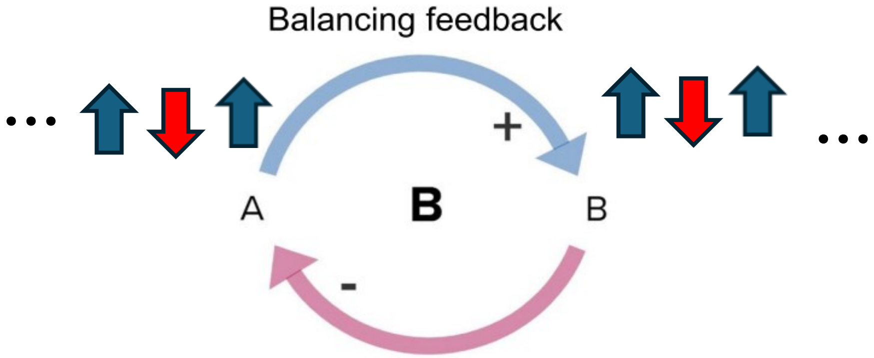


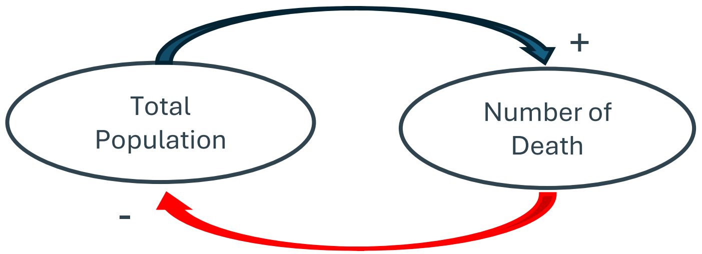
CLD - FEEDBACK LOOPS

Feedback loops can be **balancing** or **reinforcing** in nature.

- **Balancing (B) behaviour**, where the initial change is counteracted, also referred to as negative feedback or goal seeking. Balancing loops can calibrate a system and enable it to stay in equilibrium.

Balancing loops are created when there is an odd number of negative couplings!

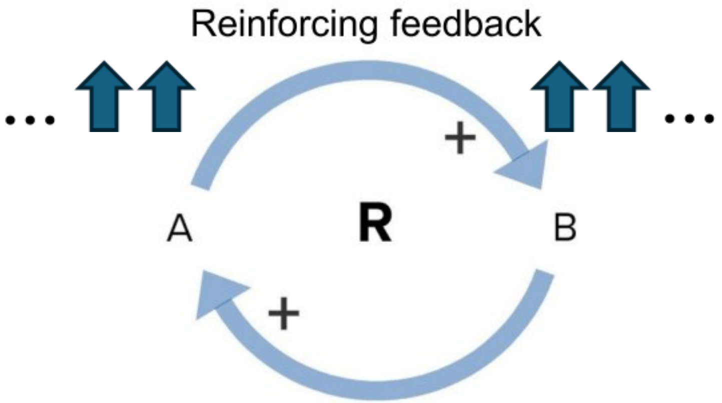


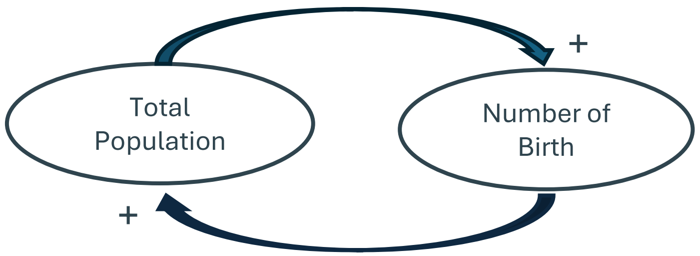


CLD - FEEDBACK LOOPS (2)

Reinforcing (R) behaviour, where an initial increase in the first component is further increased, also referred to as positive feedback, growing action.

Reinforcing (R) behaviour, where an initial decrease in the first component is further decreased, also referred to as declining, decaying.



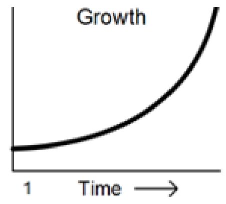


Reinforcing loops are created when balancing loops are not created!

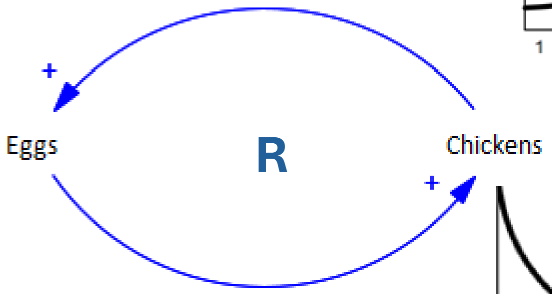
EXAMPLE (1)

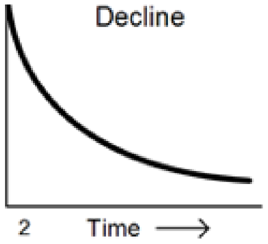
Chickens, eggs, and road crossing dynamics

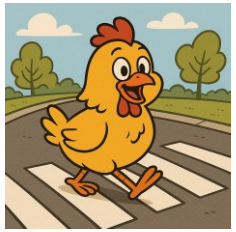
Problem: **How is the chicken population affected by egg-laying and the threat of cars on the road?**



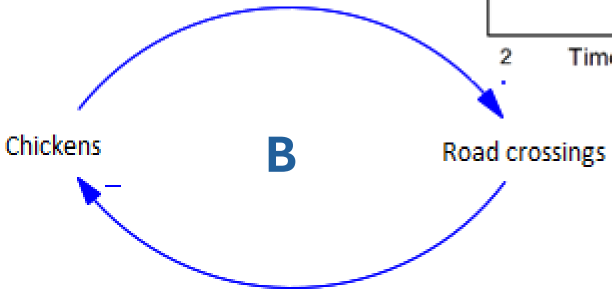
What happens with the number of chickens over time if we consider only this part of the system?



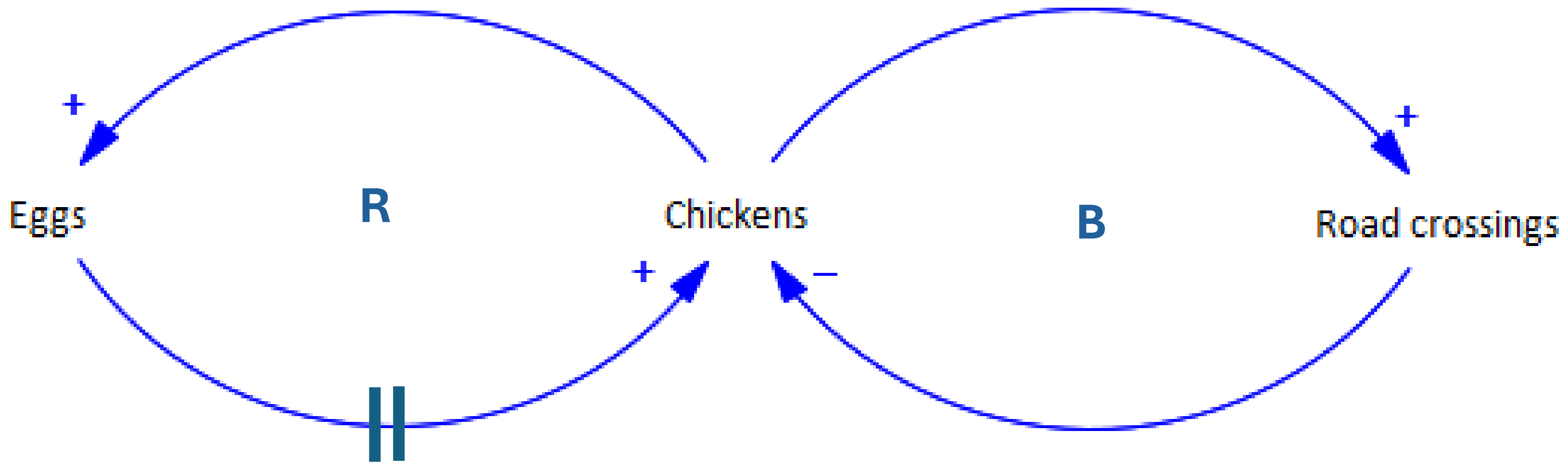




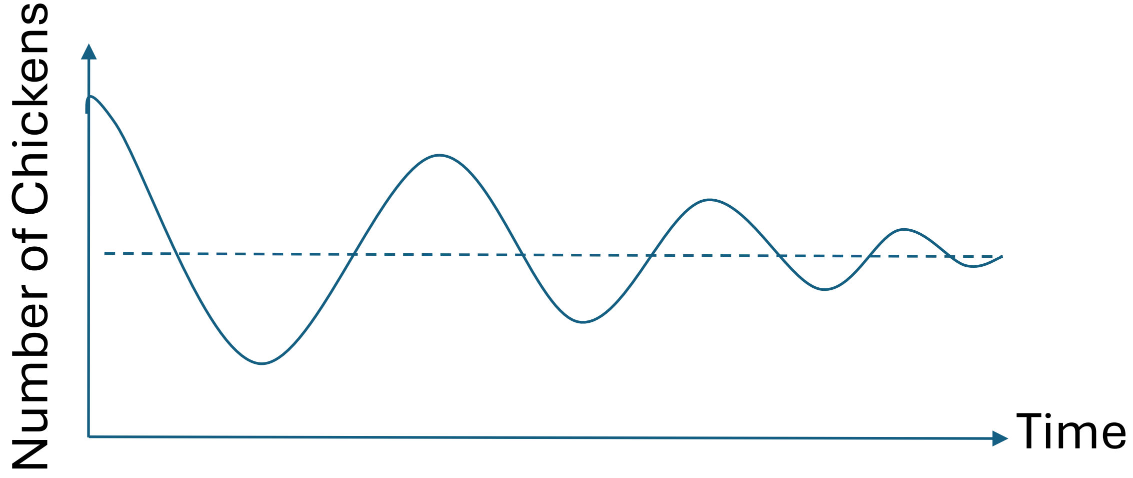
What happens with the number of chickens over time if we consider only this part of the system?



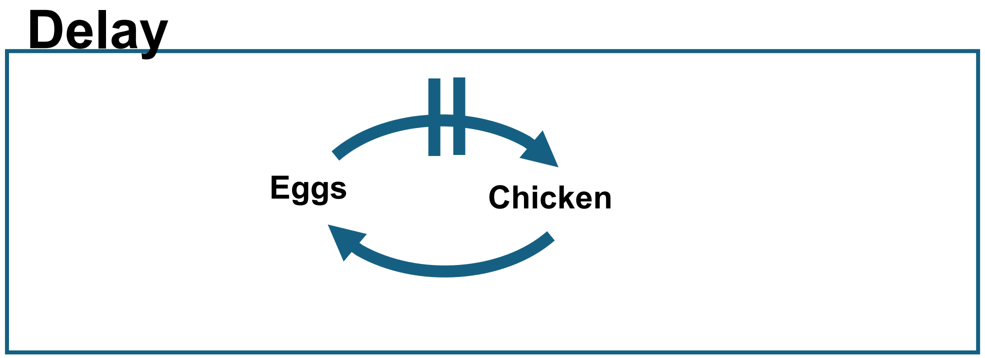
EXAMPLE (1)



+
Eggs
R
+
Chickens
B
+
Road crossings
−



Number of Chickens
Time



Delay
Eggs
Chicken

EXAMPLE (2)*

The Real Estate Game
Available houses

1. Problem Definition:

To estimate the available houses within a region in the next 100 months.

NEXT: Variables and Feedback diagram (CLD)

Try to think about developing a Qualitative SD model
Causal Loop Diagram (CLD)

* https://www.vensim.com/documentation/20760.html

EXAMPLE (2)*

The Real Estate Game

1. Problem Definition:

To simulate ***the available houses*** within a region in the next 100 months.

2. Variables Identification

Key Variables

- ✓ Available Houses
- ✓ Gap in Houses
- ✓ Replacement Houses
- ✓ Demolishing
- ✓ Average House Life
- ✓ Planning and Approvals
- ✓ Planned Houses
- ✓ Construction
- ✓ Houses in Construction
- ✓ Completing

Delays

- ✓ Time to Plan to Build
- ✓ Time to Build Houses
- ✓ Time to Respond to Gap

* https://www.vensim.com/documentation/20760.html

Causal Loop Diagram

EXAMPLE (2)*

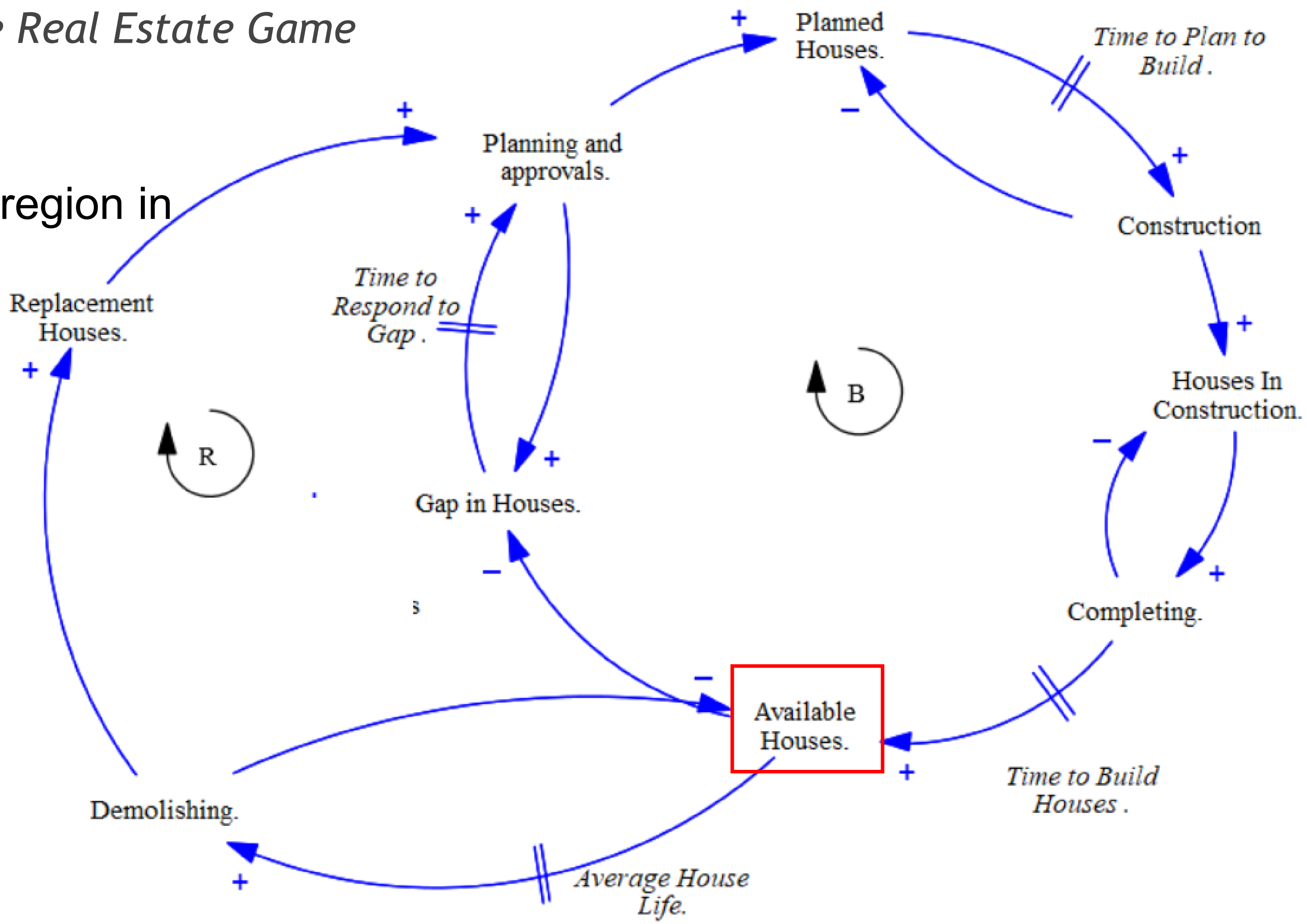
The Real Estate Game

1. Problem Definition:

To simulate ***the available houses*** within a region in the next 100 months.

2. Variables Identification

3. Feedback diagram

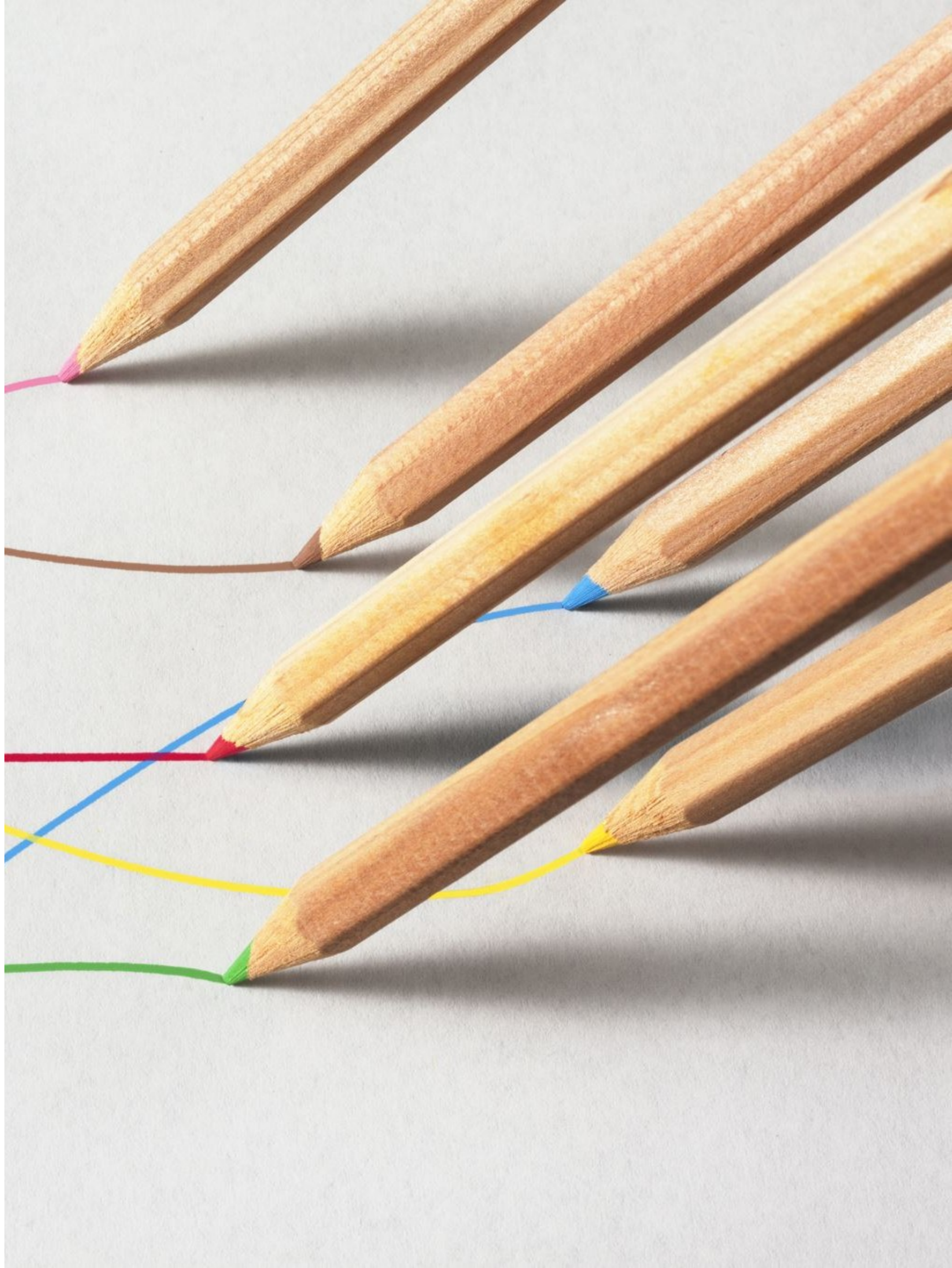


Causal Loop Diagram

* https://www.vensim.com/documentation/20760.html

Example of a public health CLD

Let’s build a simple CLD!



Building a CLD

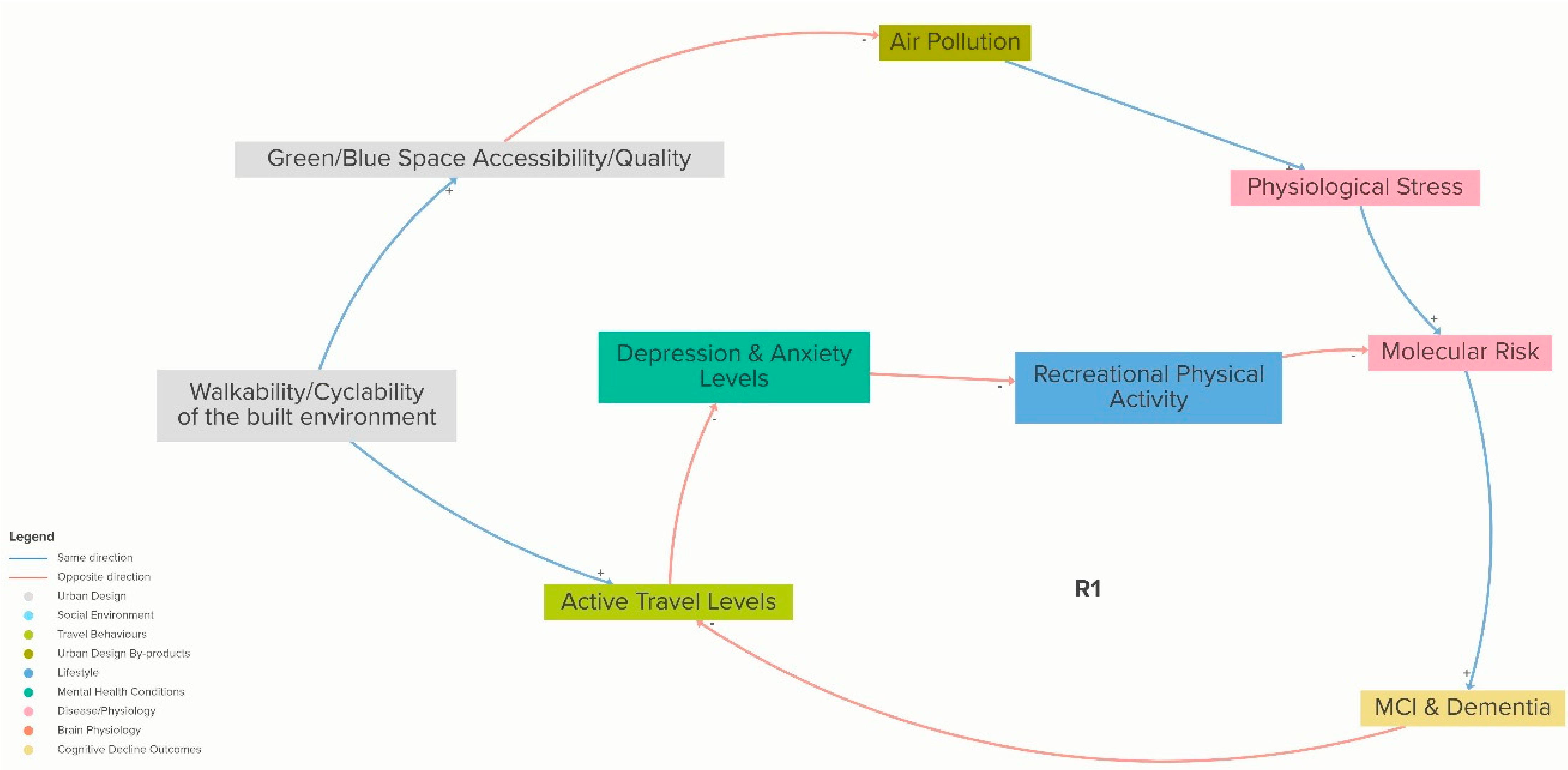
Problem definition: how the built environment contributes to the onset of mild cognitive impairment (MCI) and dementia?

Variables:

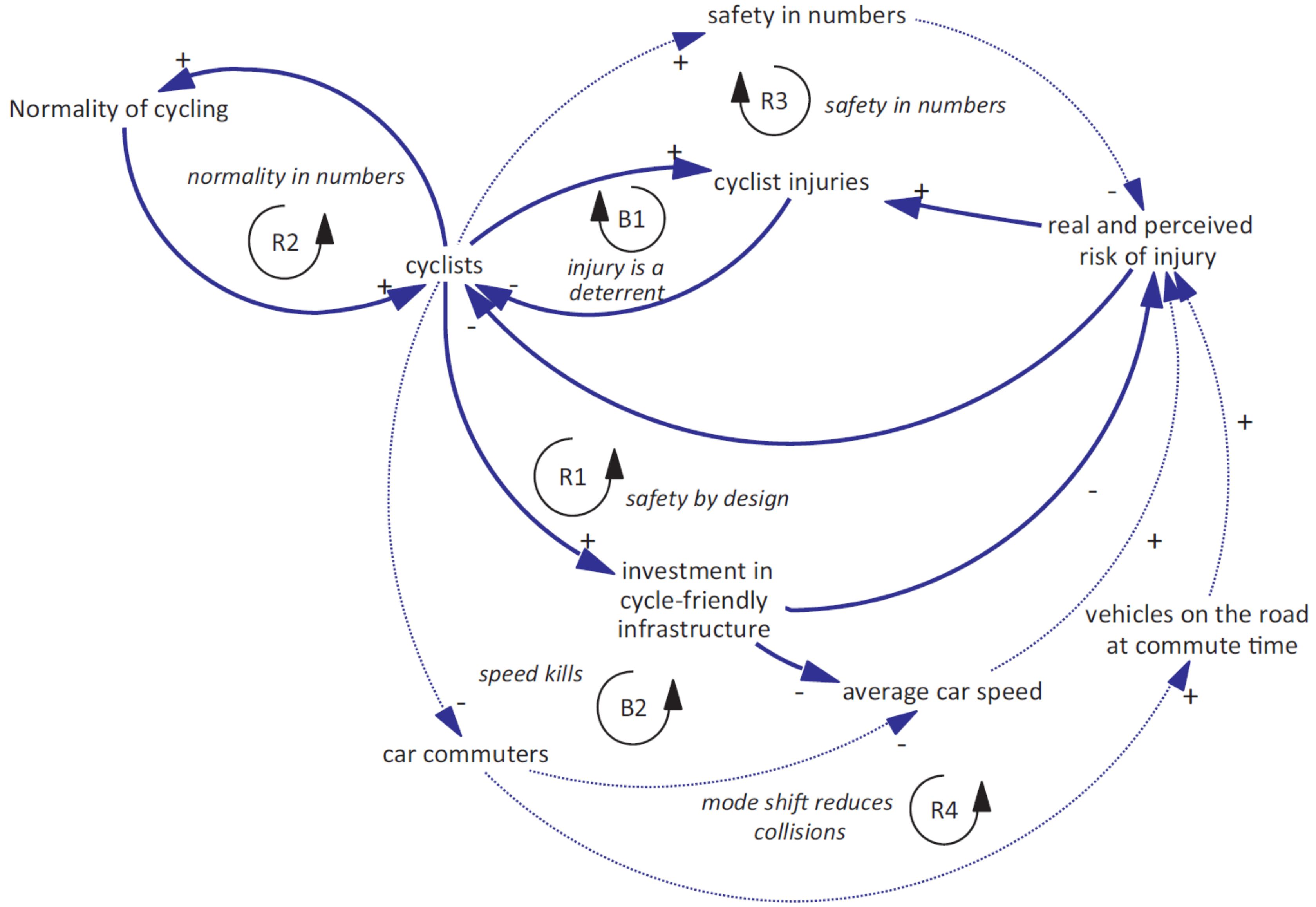
- Walkability/Cyclability of the built environment
- Green/Blue Space Accessibility/Quality
- Air pollution
- Active travel levels
- Recreational physical activity
- Physiological stress
- Molecular risk
- Depression and anxiety levels
- MCI and dementia

Draw arrows between pairs of variables

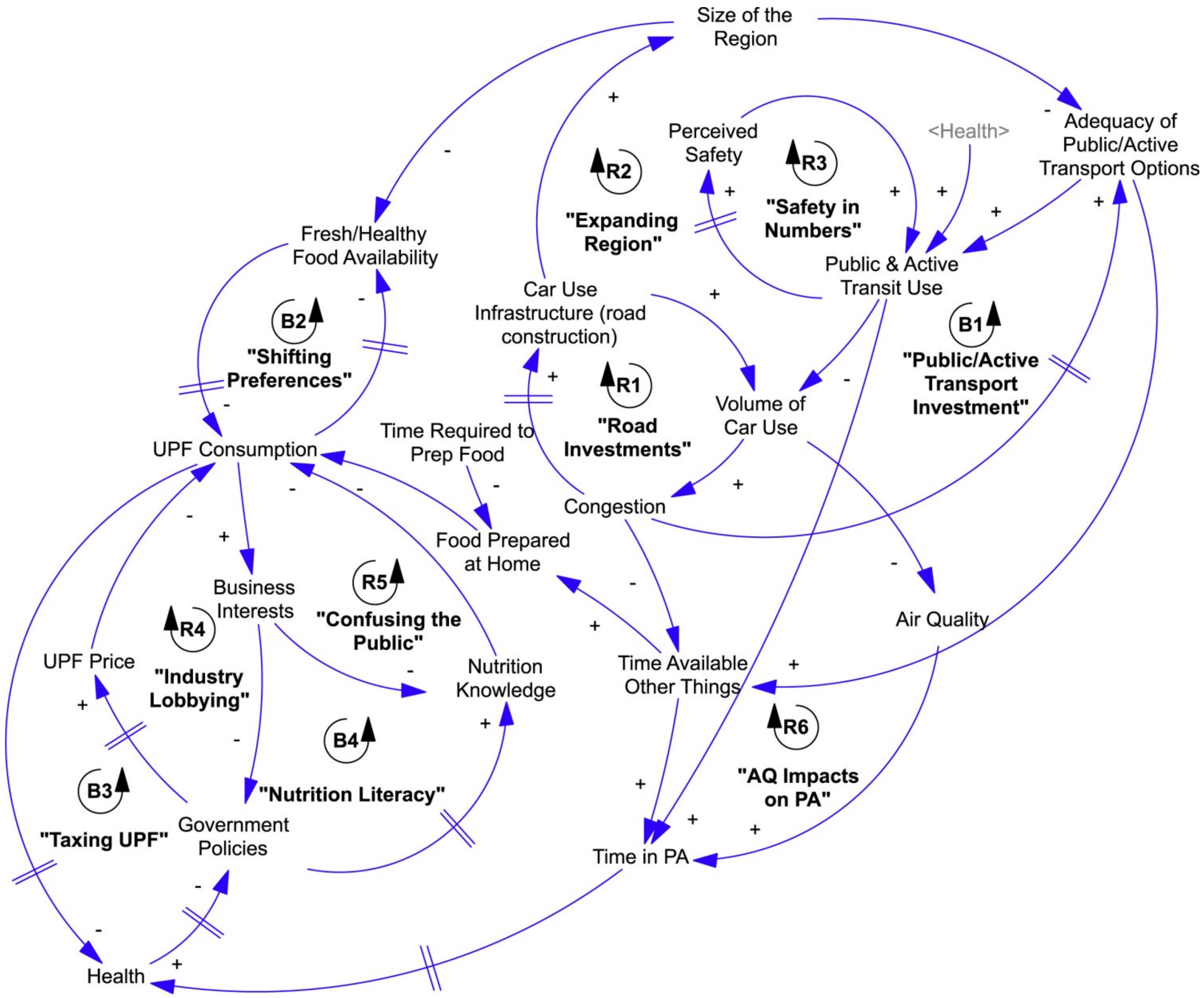
- Only causal and critical connections
- Add polarity to arrows
- Consider key(s) feedback loop(s)



Avila-Palencia I et al. Mapping the complex system that connects the urban environment to cognitive decline in older adults: a group model building study. Systems. 2025;13(7):606.



Macmillan A, Woodcock J. Understanding bicycling in cities using system dynamics modelling. J Transp Health. 2017;7(Pt B):269-79.



Langellier B. et al. Using community-based system dynamics modeling to understand the complex systems that influence health in cities: The SALURBAL study Health Place. 2019;60:102215.

Where do the data to inform CLDs come from?

- Literature
- Data collection and analysis
- Participatory approaches

Applications to build causal loop diagrams

- SD software (Vensim, Stella iThink, AnyLogic)
- Kumu (https://kumu.io/)
- Loopy (https://ncase.me/loopy/)
- Mural (https://www.mural.co/) or Miro (https://miro.com/)
- Other whiteboard applications
- Power Point

You can always use pen and paper!

References and further support

- Waters Center for Systems Thinking. Habits of a systems thinker. Available at: https://thinkingtoolsstudio.waterscenterst.org/cards.
- Richmond B. The thinking in systems thinking: eight critical skills. Systems Thinker. 2010;21(3):2-9. Available at: https://thesystemsthinker.com/%ef%bb%bfthe-thinking-in-systems-thinking-eight-critical-skills/.
- Rutter H et al. The need for a complex systems model of evidence for public health. Lancet. 2017;390(10112):2602-4.
- Sterman J. Learning from evidence in a complex world. Am J Public Health. 2006;96(3):505-14.
- System Dynamics Society. What is system dynamics? Available at: https://systemdynamics.org/what-is-system-dynamics/.
- Sterman J. Business dynamics: systems thinking and modeling for a complex world. Boston: Irwin McGraw-Hill; 2000.
- Bala B, Arshad F, Noh K. System dynamics: modelling and simulation. Singapore: Springer Nature; 2017.
- Barbrook-Johnson P, Penn A. Causal loop diagrams. In: Systems mapping: how to build and use causal models of systems. Switzerland: Palgrave Macmillan; 2022. p.47-59. Available at: https://doi.org/10.1007/978-3-031-01919-7.
- Kim D. Guidelines for drawing causal loop diagrams. Systems Thinker. 1992;3(1):5-6. Available at: https://thesystemsthinker.com/guidelines-for-drawing-causal-loop-diagrams-2/.
- Hovmand P. Community based systems dynamics. New York: Springer; 2014.

References and further support

- Coyle, R.G. (1996). System Dynamics Modelling: A Practical Approach. Springer Verlag.
- Coyle, R.G. (1979). Management Systems Dynamics.
- Duggan, J. (2016) Systems Dynamics Modelling with R, Lecture Notes in Social Networks. Springer: Switzerland.
- Forrester, J. (1961) Industrial Dynamics. MIT Press: Cambridge, Mass.
- Forrester, J. (1958) Industrial dynamics: a major breakthrough for decision makers, Harvard Business Review, 36, pp.37-66.
- Jackson, M. (2019) Critical Systems Thinking and the Management of Complexity: Responsible Leadership for a Complex World.
- Maani, K.E., & Cavana, R.Y. (2002) Systems Thinking and Modelling, Prentice Hall.
- Meadows, D.H, Meadows, D.L., Randers, J. and Behrens III, W.W. (1972) The Limits to Growth. Universe Books: New York, USA. Available:
- Pidd, M. (2009) Tools for Thinking: Modelling in Management Science, 3rd Edition. Wiley: West Sussex, UK.
- Senge, P. M. and Sterman, J. D. (1992) Systems thinking and organisational learning: Acting locally and thinking globally in the organisation of the future, European Journal of Operational Research, 59, pp.137-150.
- Senge, P. (1990) The Fifth Discipline.
- Sterman, J. D. (2000) Business Dynamics: Systems Thinking and Modelling for a Complex World. Irwin McGraw-Hill, ID: USA.
- Wolstenholme, E.F. (1990) System Enquiry: A System Dynamics Modelling Approach, John Wiley & Sons, Chichester.
- Ulrich, W. and Reynolds (2010) Chapter 6: Critical Systems Heuristics in Reynolds, M. and Holwell, S. (Eds) (2010) Systems Approaches to Managing Change: A Practical Guide. Springer: London.

Next session

- Wednesday 22 October 2025 @ 10:30 (BST)
- Recap of session 1
- Steps involved in developing a system dynamics model
- Analysing and visualising outputs
- Public health application
- Q&A

SAVE THE DATE

COMPLEX SYSTEMS AND NETWORK SCIENCE FOR PREVENTION AND CONTROL OF NONCOMMUNICABLE DISEASES

A WHO COLLABORATING CENTRE FOR RESEARCH AND TRAINING

Join us for a series of online short courses designed to build skills in a range of systems thinking methods for NCD prevention and control. Further details and registration links will be advertised 6 weeks in advance of the training sessions.

Introduction to Systems Dynamics Modelling:
Wednesday 15 & 22 October 2025 10:30 – 12:30 (BST)

Introduction to Agent-based Modelling:
Wednesday 5 & 12 November 2025 10:30 – 12:30 (GMT)

Introduction to Soft Systems Modelling:
Wednesday 21 & 28 January 2026 10:30 – 12:30 (GMT)

Introduction to Viable Systems Modelling:
Wednesday 18 & 25 February 2026 10:30 – 12:30 (GMT)

Introduction to Systems Maps and Causal Loop Diagrams:
Wednesday 25 March & Wed 1 April 2026 10:30 – 12:30 (GMT)

Introduction to Stakeholder Network Analysis:
Wednesday 22 & 29 April 2026 10:30 – 12:30 (BST)

SCAN ME

QUEEN'S UNIVERSITY BELFAST

qub.ac.uk/sites/who

whocc@qub.ac.uk

Outline of the day

- Introduction to the WHO CC (10 min) – Leandro
- Foundations of systems thinking (15 min) – Leandro
- Foundations of system dynamics (20 min) – Mehdi
- Q&A (10 min)
- Causal loop diagrams (CLDs) (15 min) – Mehdi
- Q&A (5 min)
- Hands-on example of public health CLD (15 min) – Leandro
- Q&A (15 min)
- Closing (5 min) – Leandro

Short feedback survey

https://forms.office.com/e/njHB9gvp9Q

bitly

Introduction to System Dynamics Modelling

Dr Leandro Garcia, Queen's University Belfast (l.garcia@qub.ac.uk)

Dr Mehdi Hafezi, Cranfield University (Mehdi.Hafezi@cranfield.ac.uk)

Additional materials

EXAMPLE (3)*

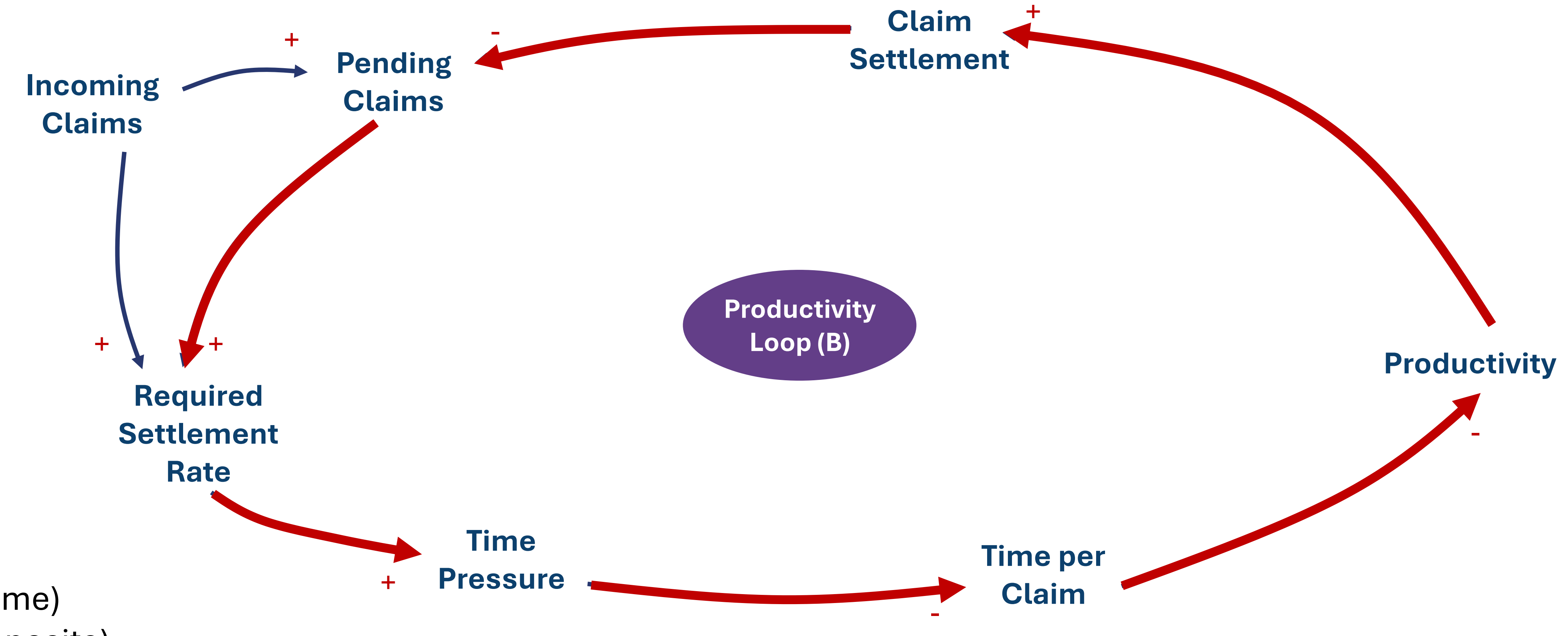
The Hannover Insurance Company

Adapted from:

1) Senge, P. M. and Sterman, J. D. (1992) Systems thinking and organisational learning: Acting locally and thinking globally in the organisation of the future, European Journal of Operational Research, 59, pp.137-150.
2) Maani, K.E., & Cavana, R.Y. (2002) Systems Thinking and Modelling, Prentice Hall.

EXAMPLE (3)*

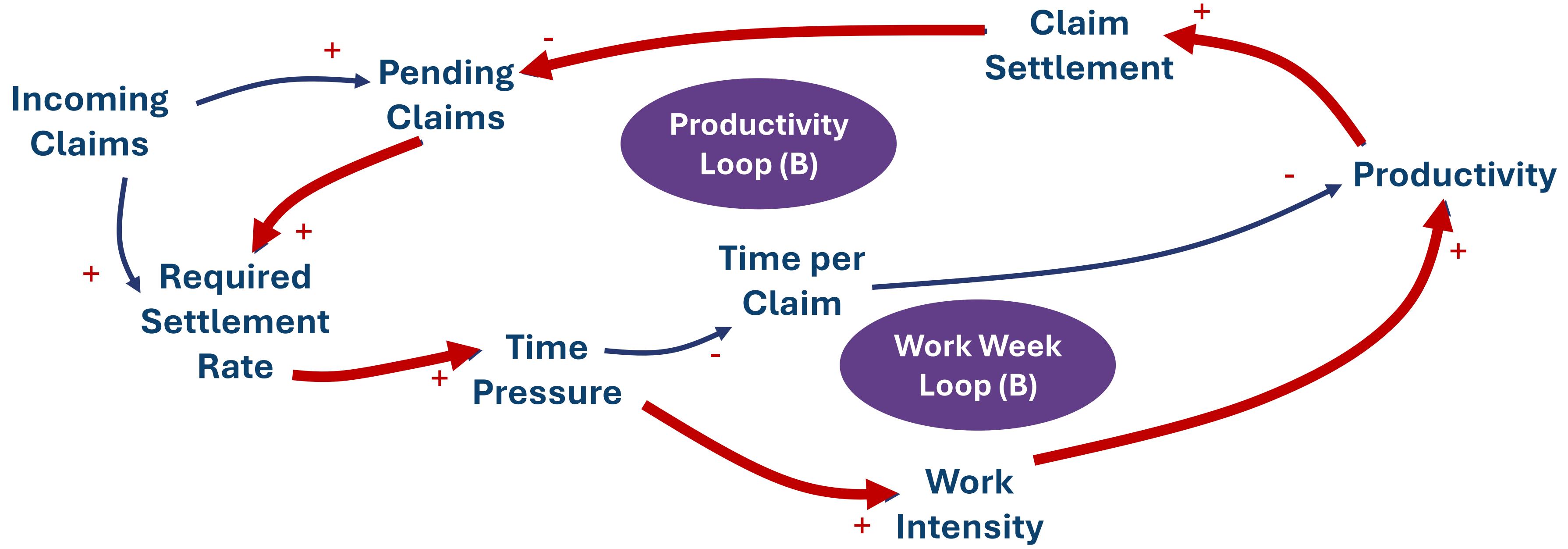
Focus 1: Productivity



+ = **s**(ame)
- = **o**(pposite)

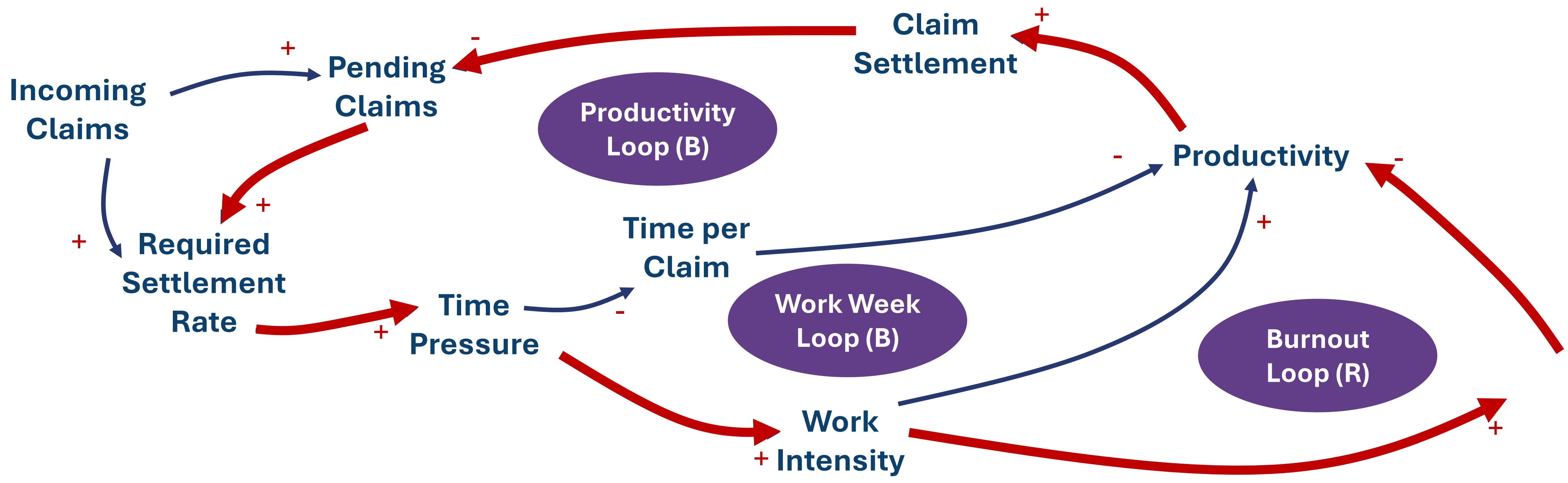
EXAMPLE (3)*

Focus 2: The Working Week



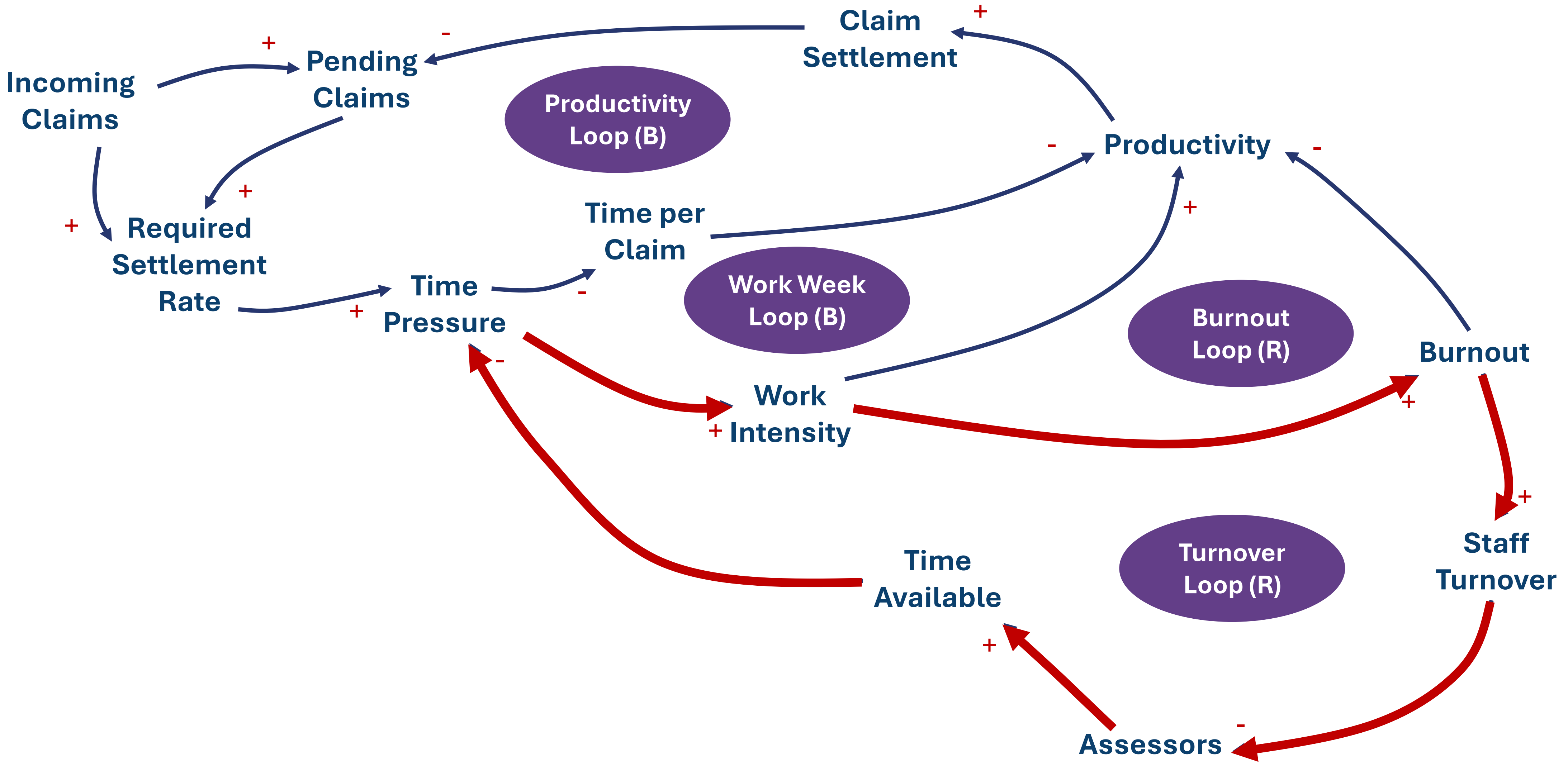
EXAMPLE (3)

Focus 3: Staff Burnout



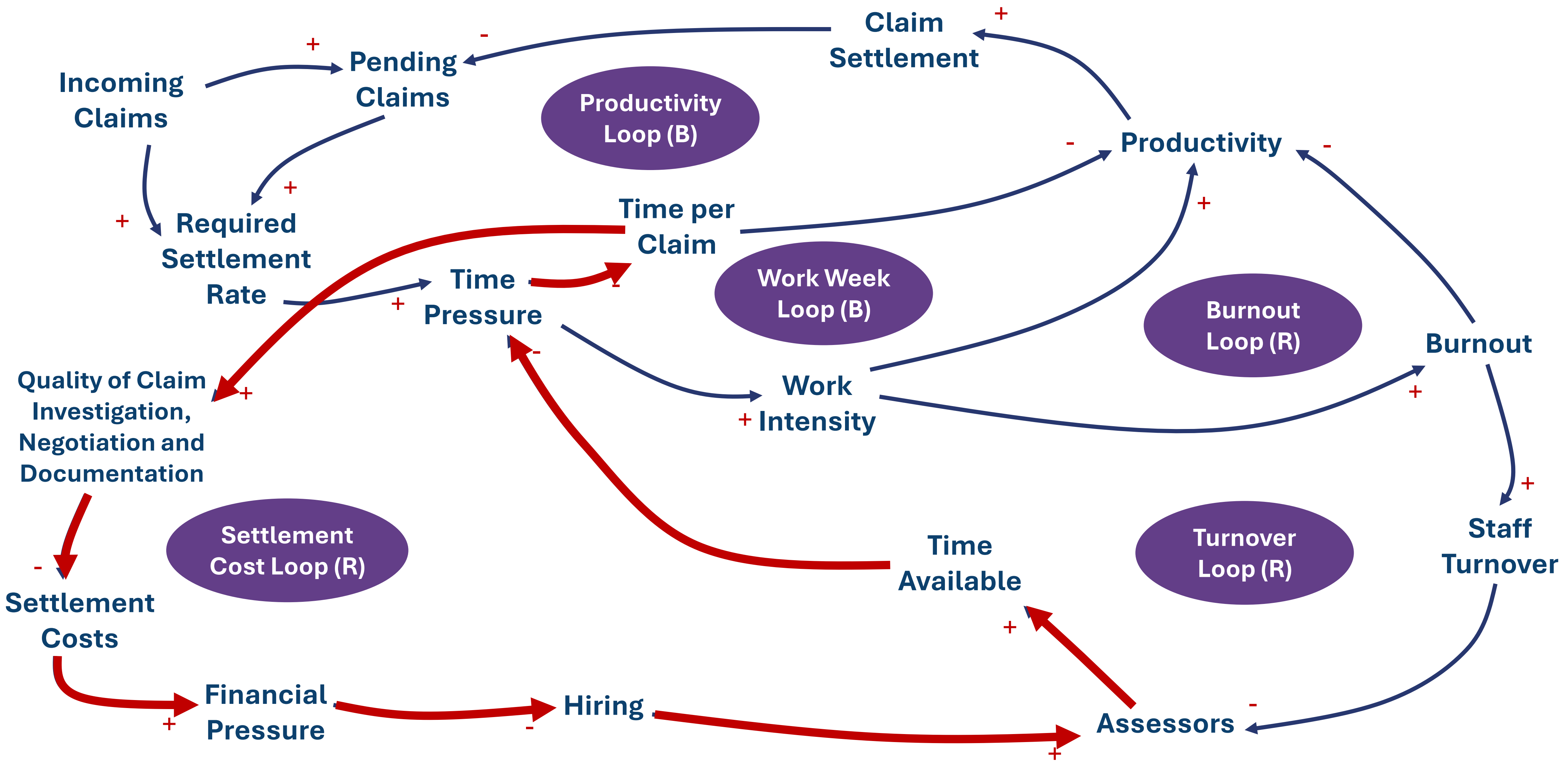
EXAMPLE (3)

Focus 4: Turnover



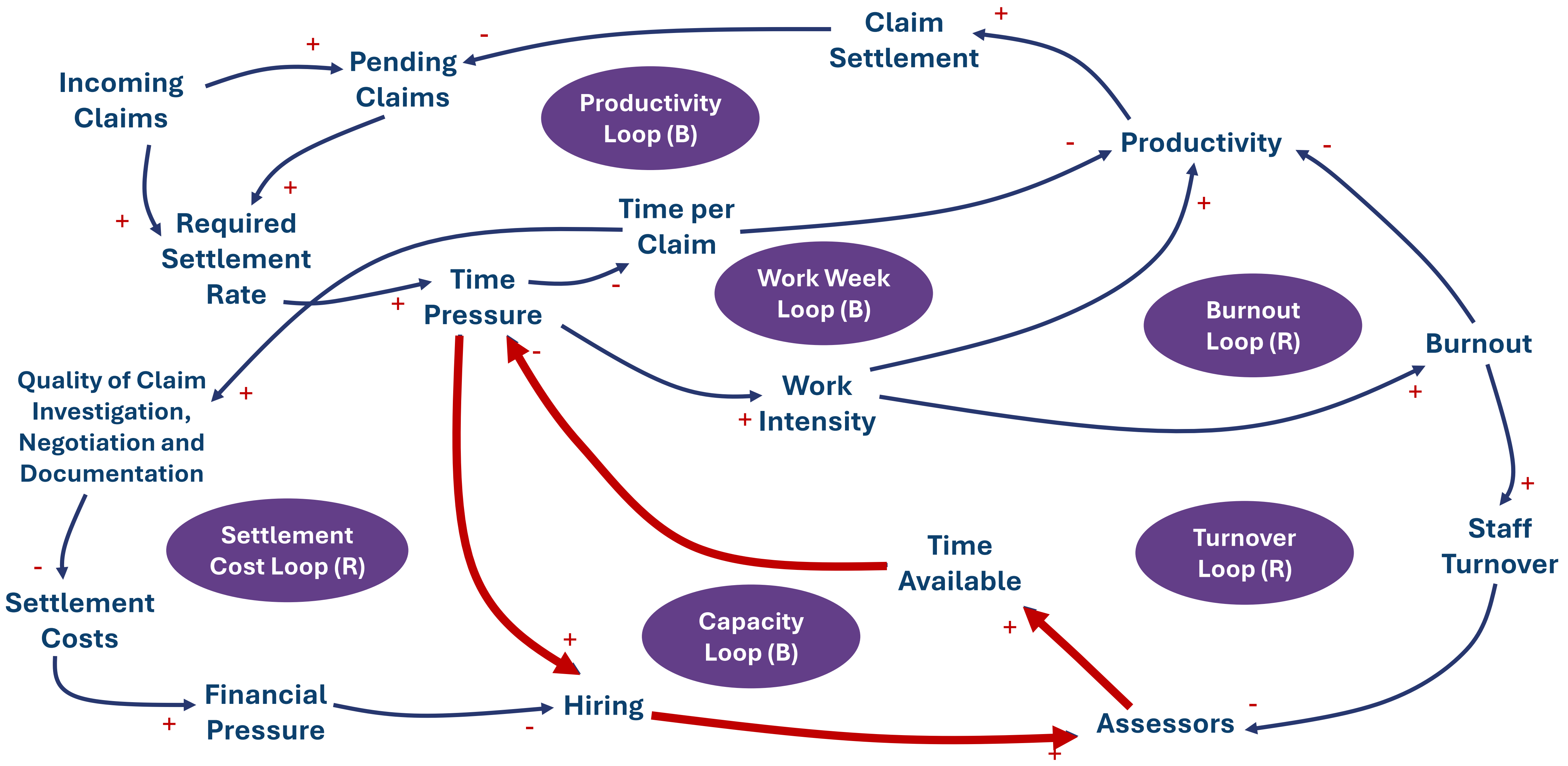
EXAMPLE (3)

Focus 5: Settlement Cost

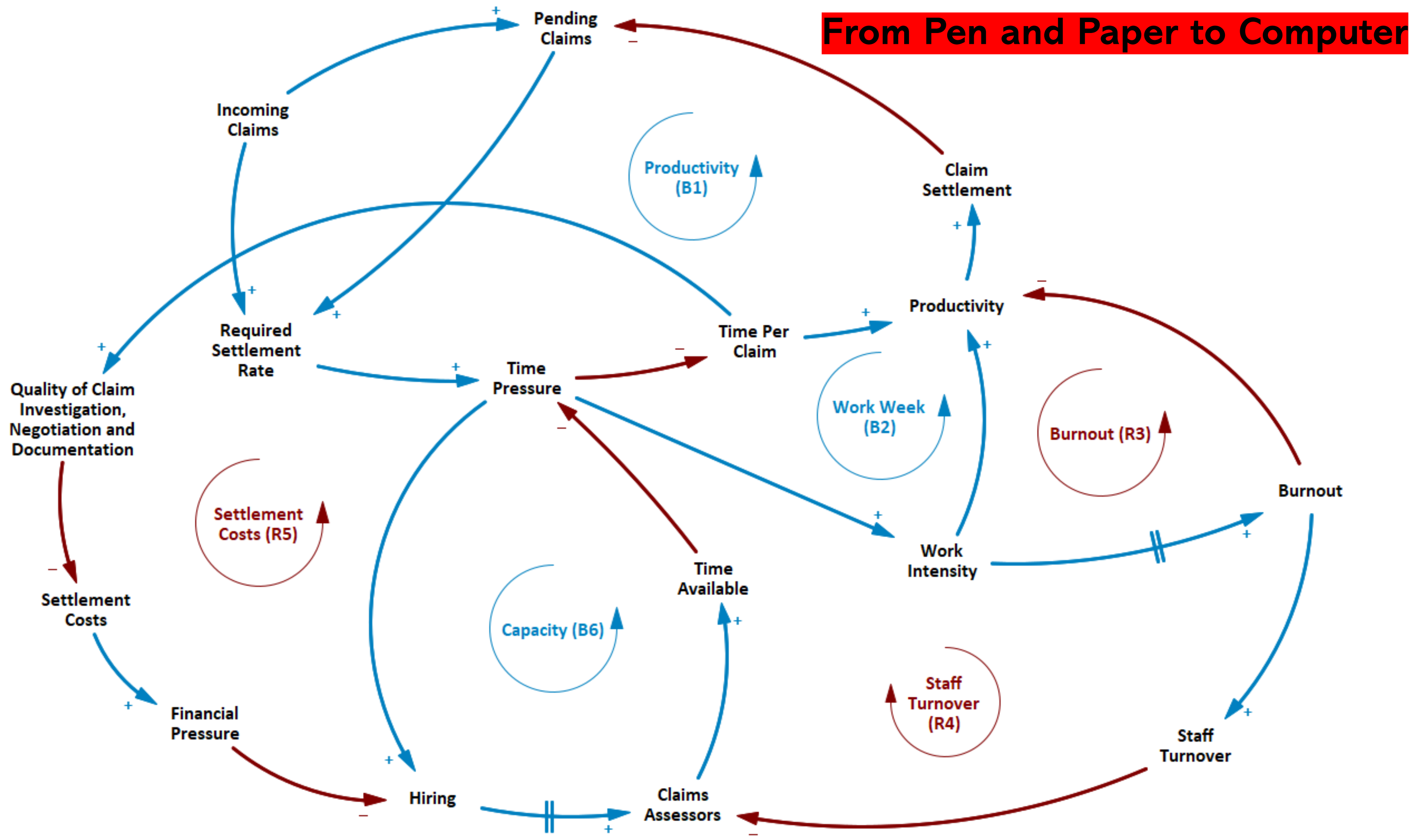


EXAMPLE (3)

Focus 6: Capacity



EXAMPLE (3)*



CLD drawn in Vensim (PLE)

https://vensim.com/vensim-personal-learning-edition

Free for academic purposes