Introduction to Systems Maps and Causal Loop Diagrams

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QUEEN'S UNIVERSITY BELFAST

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

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Outline of the day

Recap of session 1 (10 min) – Ruth

What causal loop diagrams are (15 min) – Leandro

Q&A (10 min)

Building a causal loop diagram (50 min) – Leandro

Public health applications (15 min) – Ruth

Q&A (10 min)

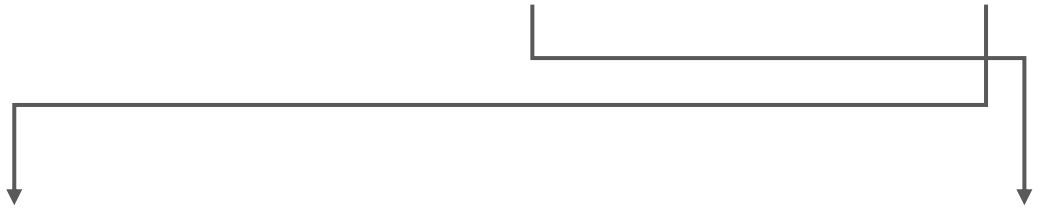
Closing (5 min) – Ruth

Recap of session 1

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’

Systems Map



Visual representation…

…of the interdependencies between a set of elements.

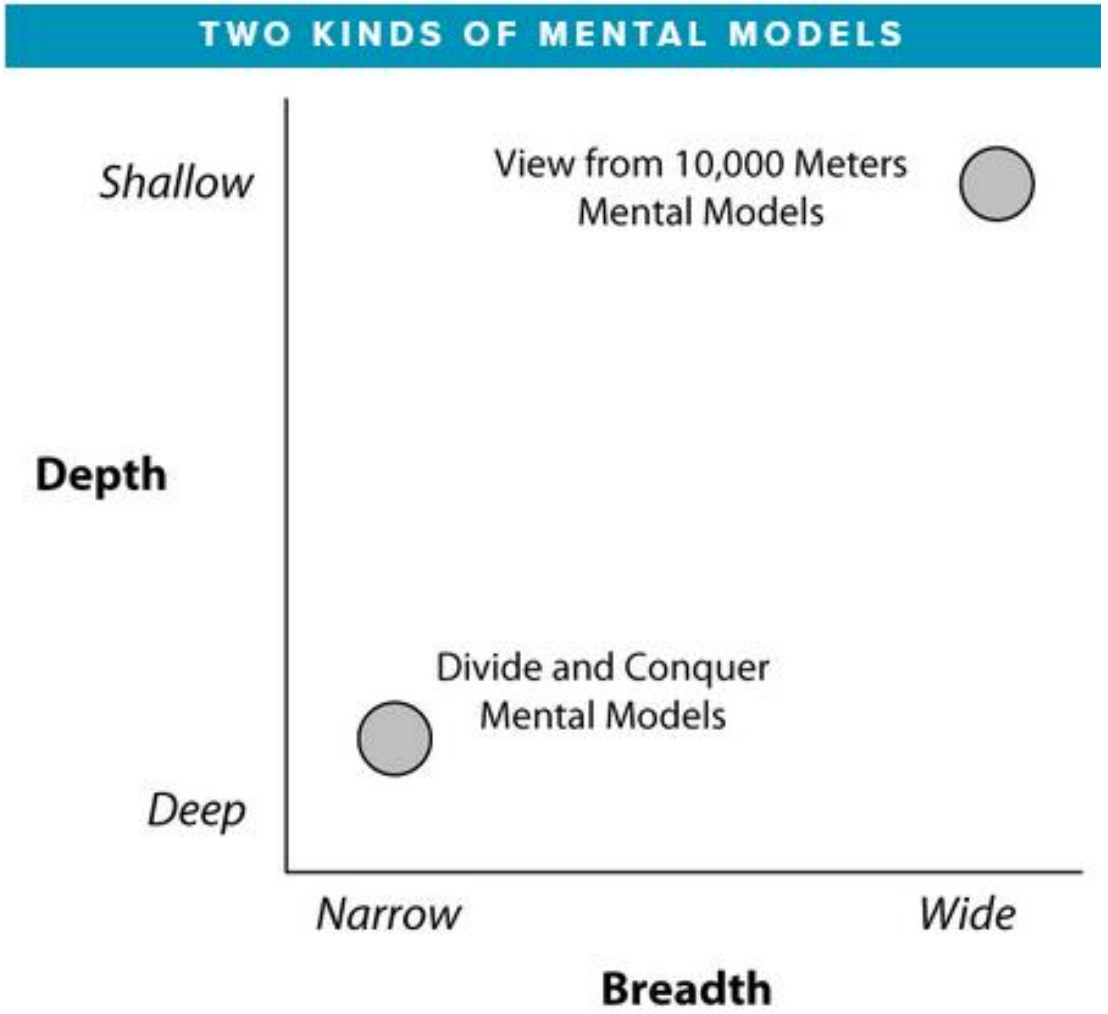
Modelling is creating fit-for-purpose metaphors

‘All models are wrong, but some are useful.’

Box G. Robustness in the strategy of scientific model building. In: Launer R, Wilkinson, G (eds.), Robustness in statistics. 1979.
Thompson E. Escape from model land: how mathematical models can lead us astray and what we can do about it. 2022.

The most common mistake

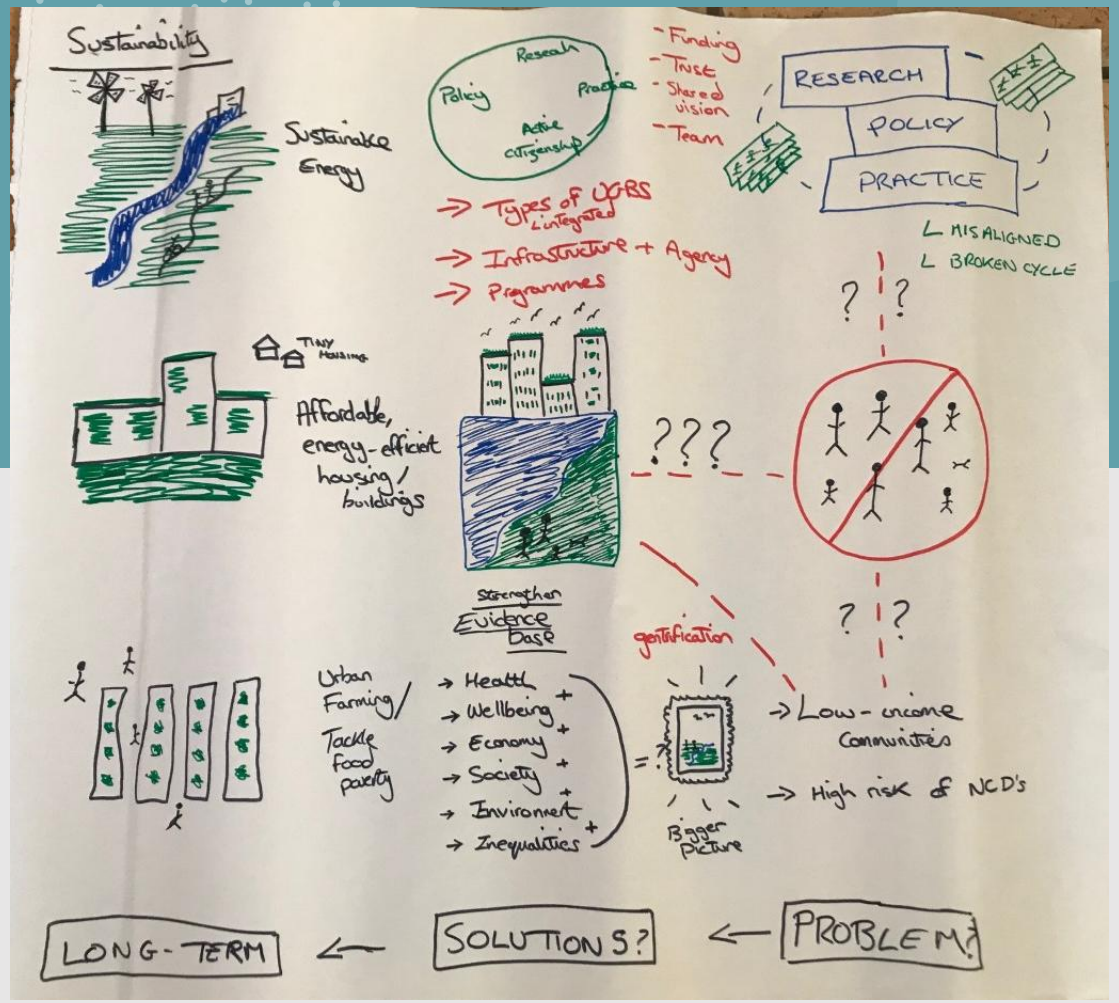
"I am drawing a model about a complex thing. Hence, I need to put everything about the problem in my model, otherwise it will be incomplete, too simple, insufficient."



Richmond B. Systems Thinker. 2010;21(3):2-9.

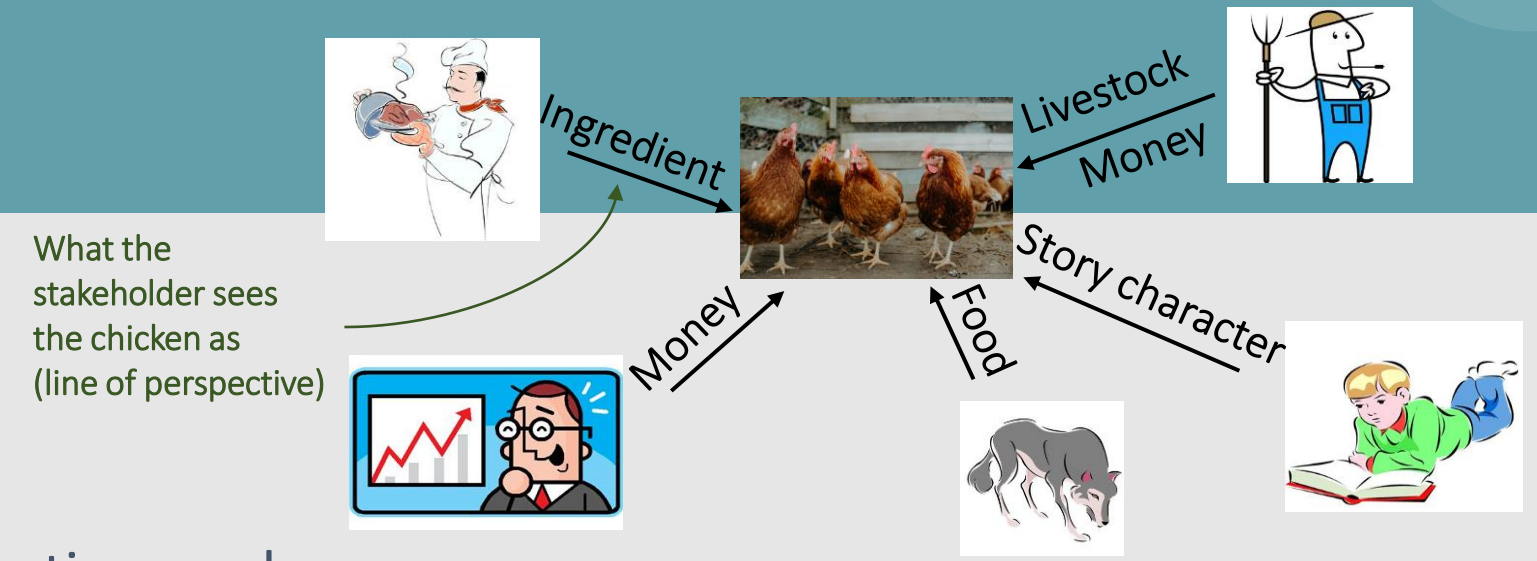
Rich pictures

Drawing or picture of a system or “situation”



https://groundswelluk.org/

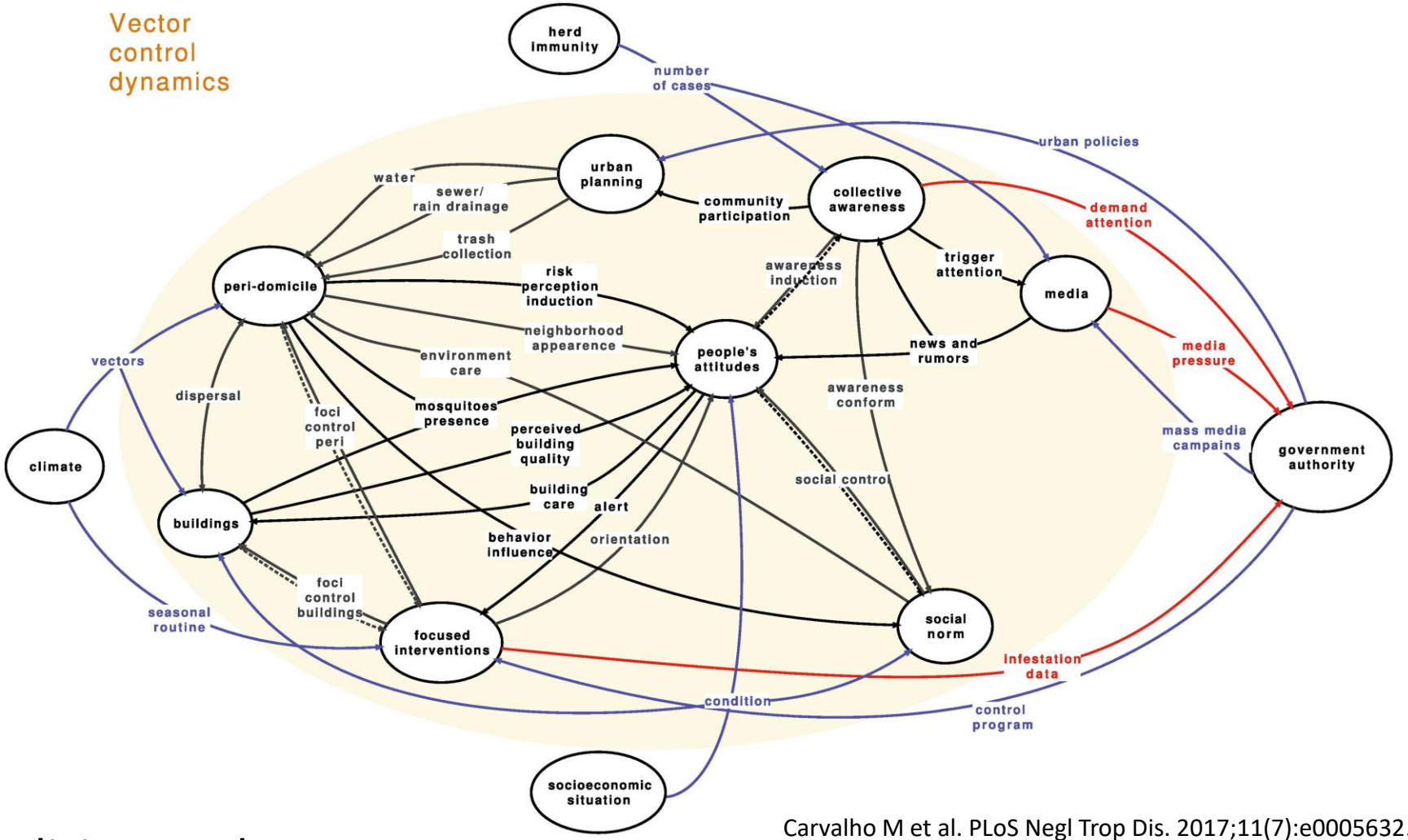
Multi-perspective model



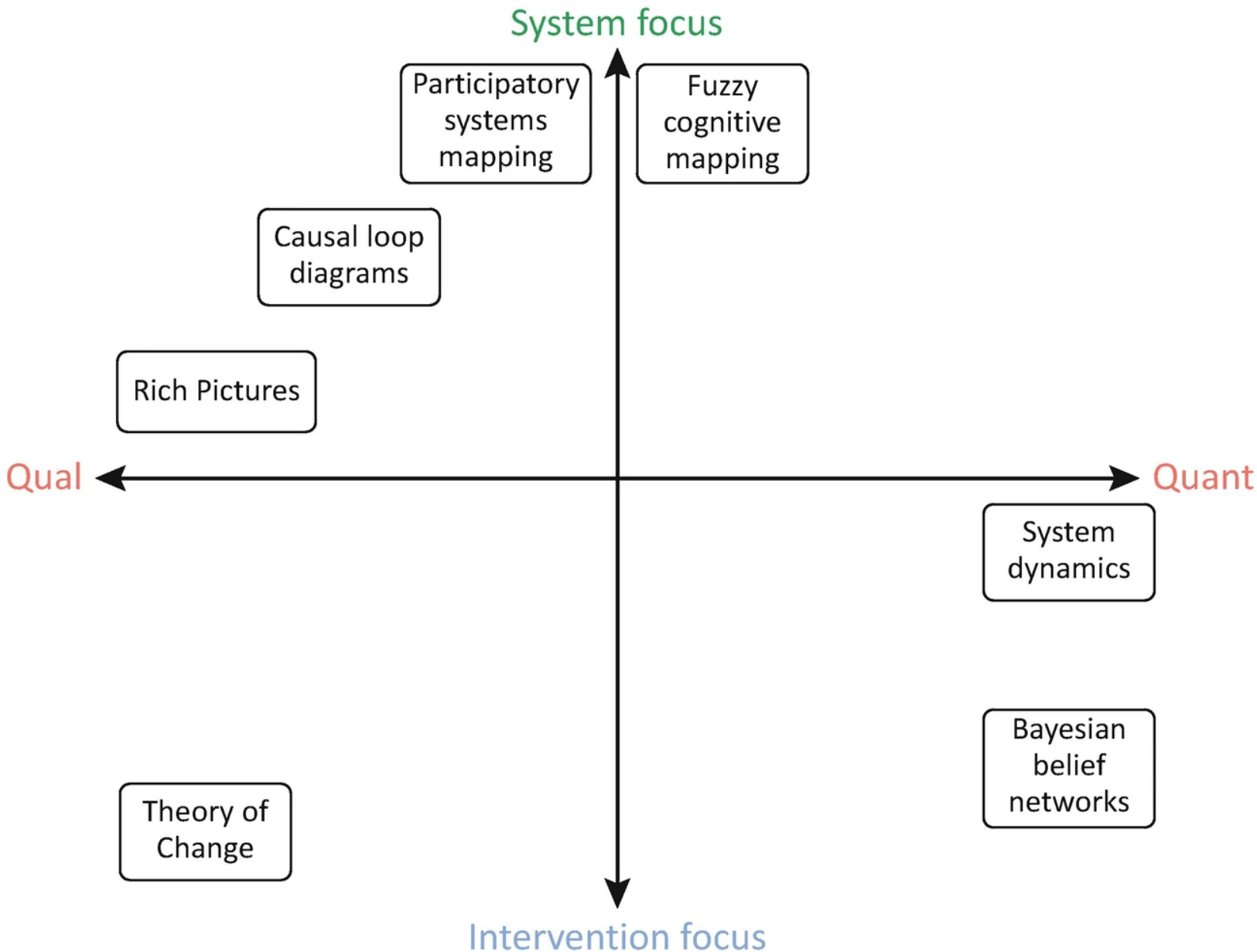
Used to explore different perspectives and agents within a system

Concept mapping

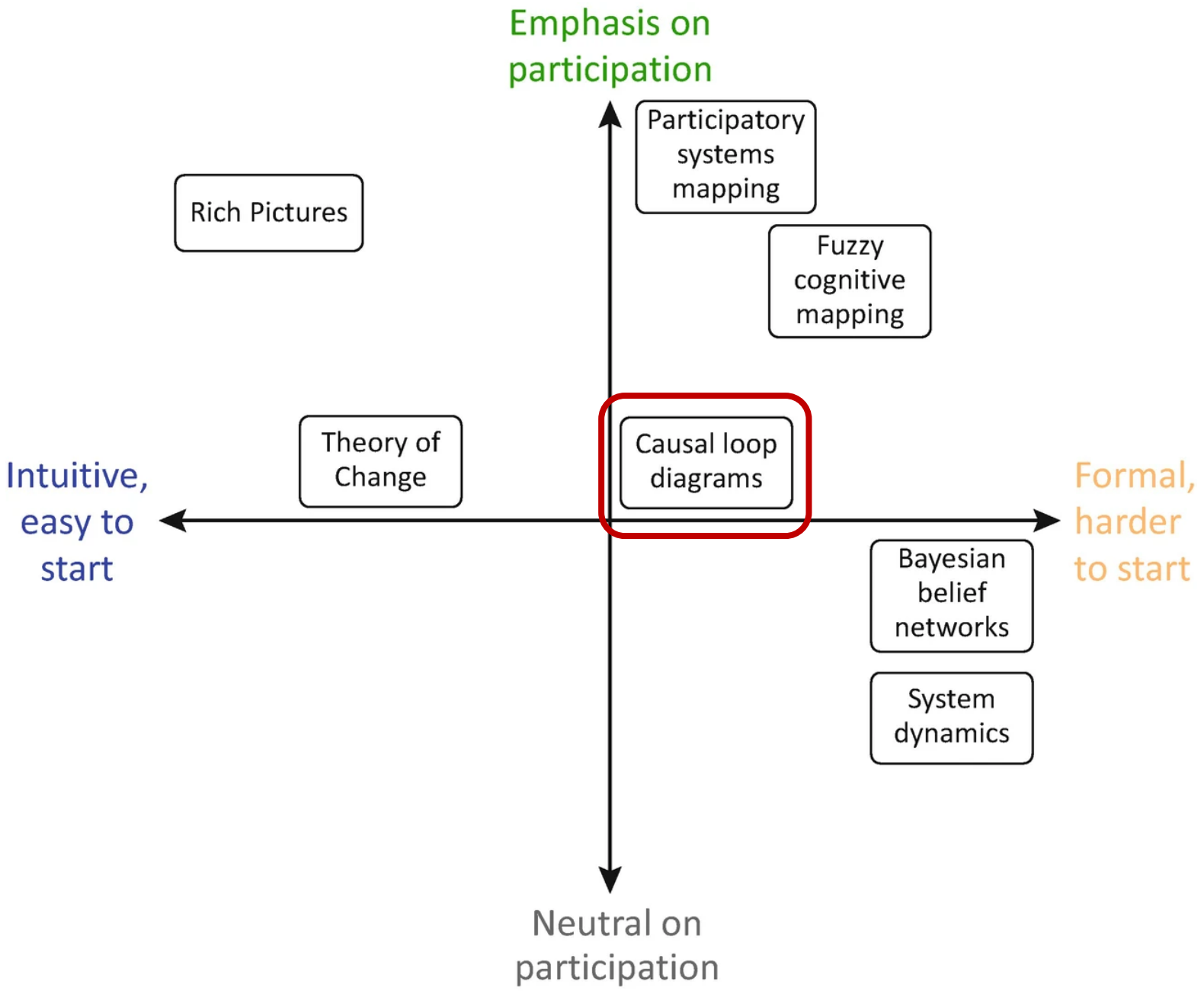
Used for organising, visualising, and linking concepts and ideas



Carvalho M et al. PLoS Negl Trop Dis. 2017;11(7):e0005632.



Barbrook-Johnson P, Penn A. Systems mapping: how to build and use causal models of system. 2022.

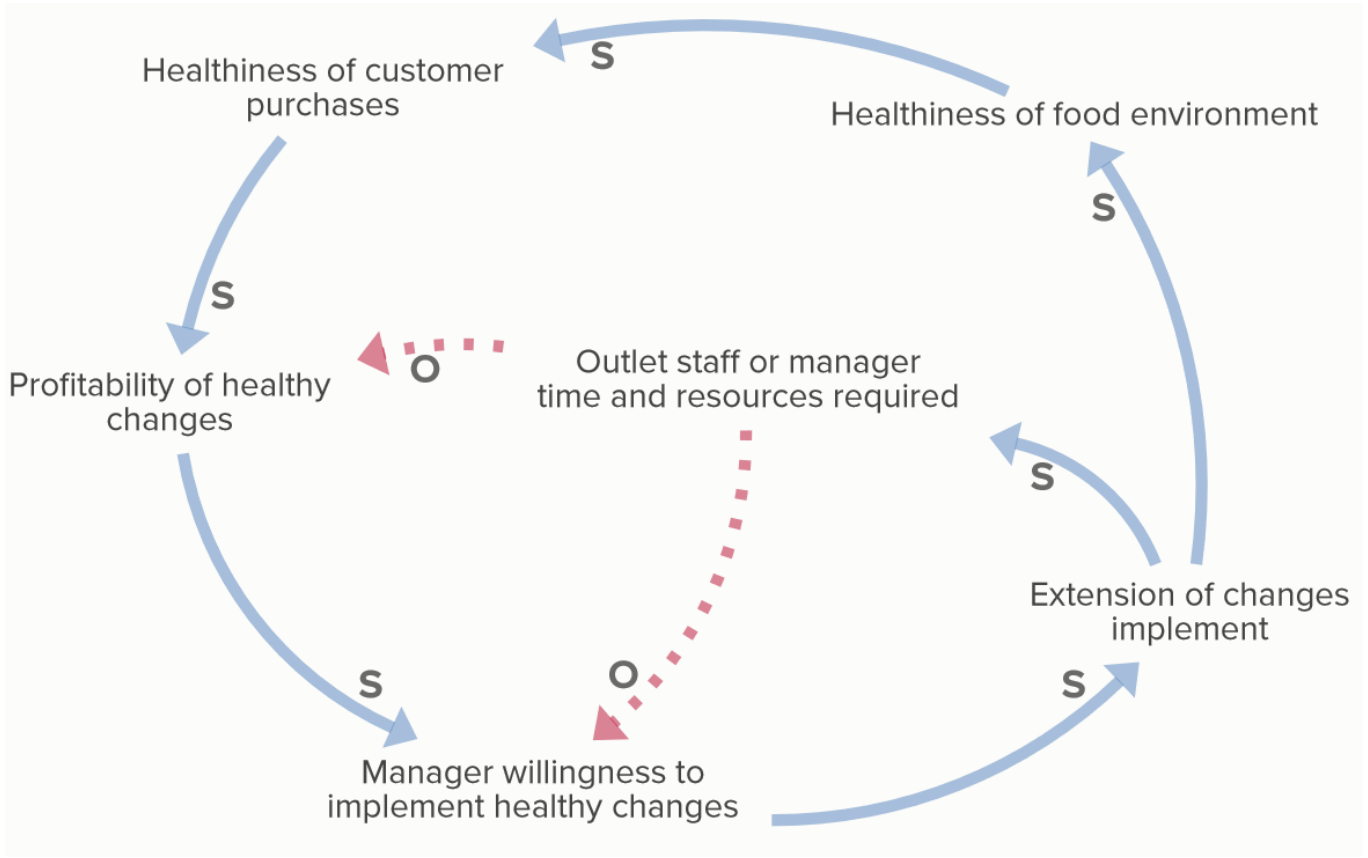


Barbrook-Johnson P, Penn A. Systems mapping: how to build and use causal models of system. 2022.

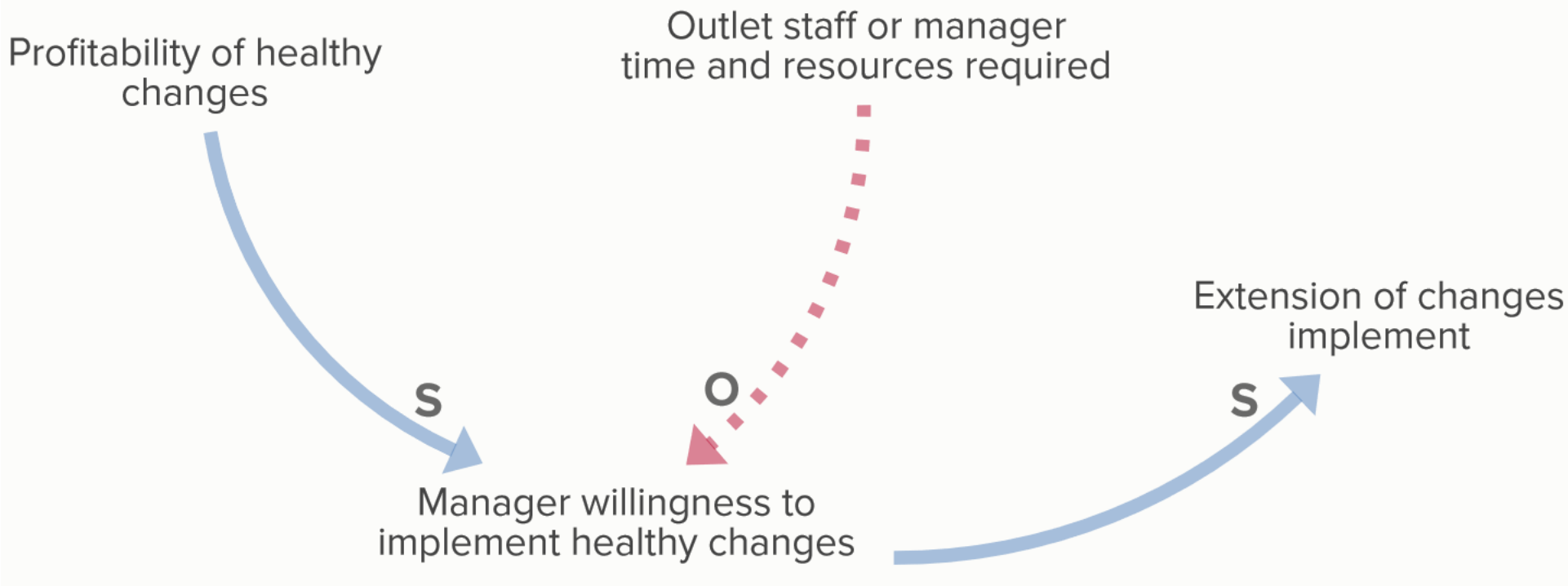
What causal loop diagrams are

Causal Loop Diagram

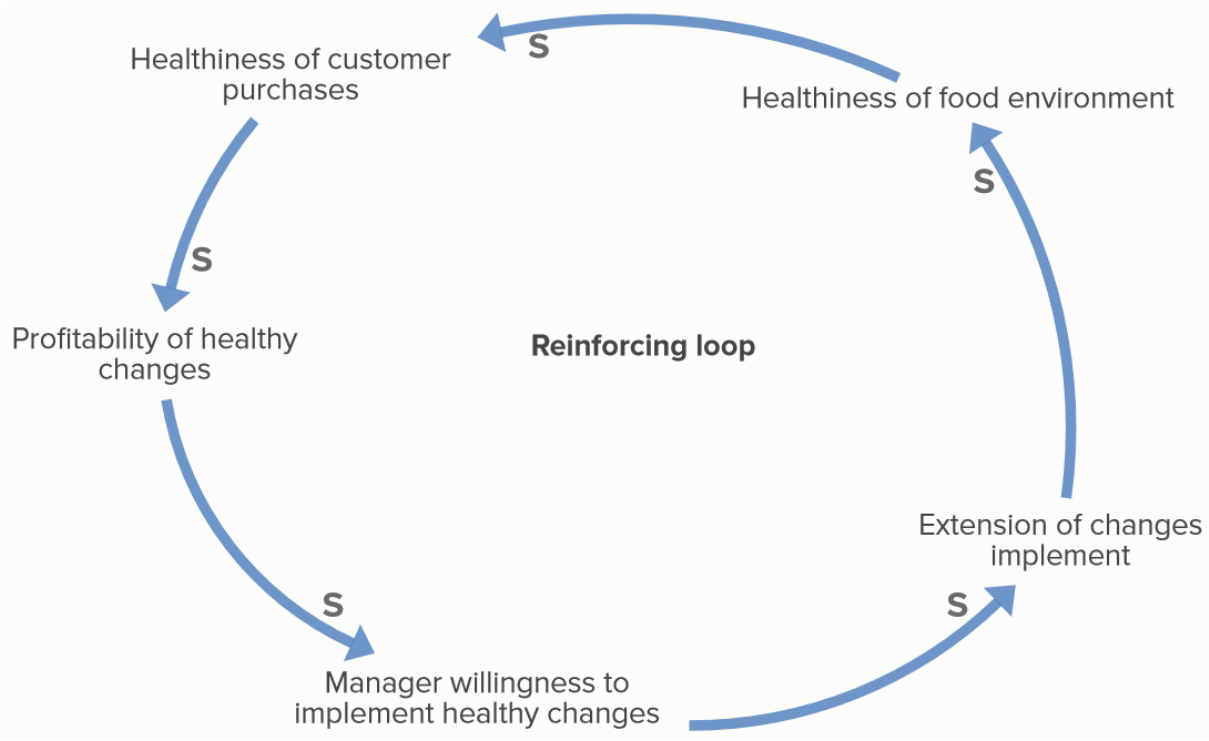
Visual representation… …of causal relationships… …that can be cyclic.



Boelsen-Robinson T et al. Food Policy. 2021;101(2021): 102032.



Boelsen-Robinson T et al. Food Policy. 2021;101(2021): 102032.



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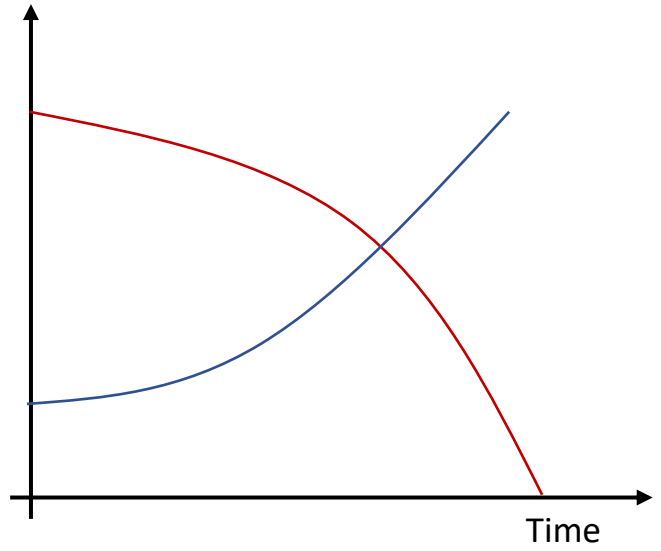

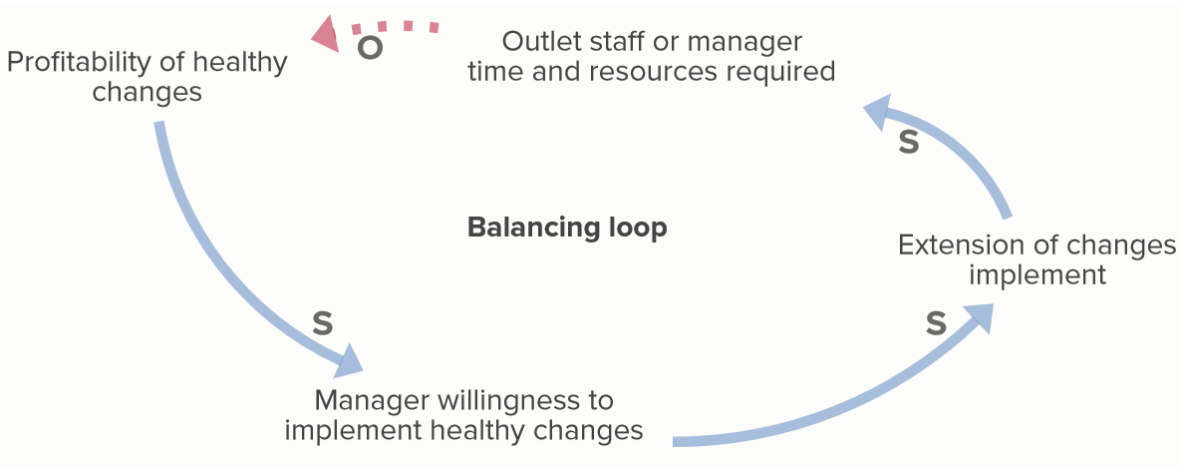

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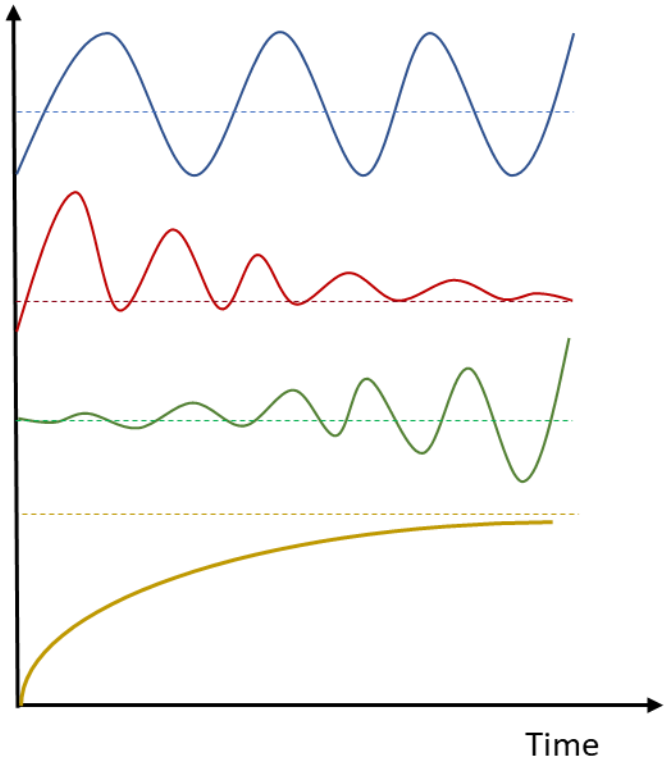
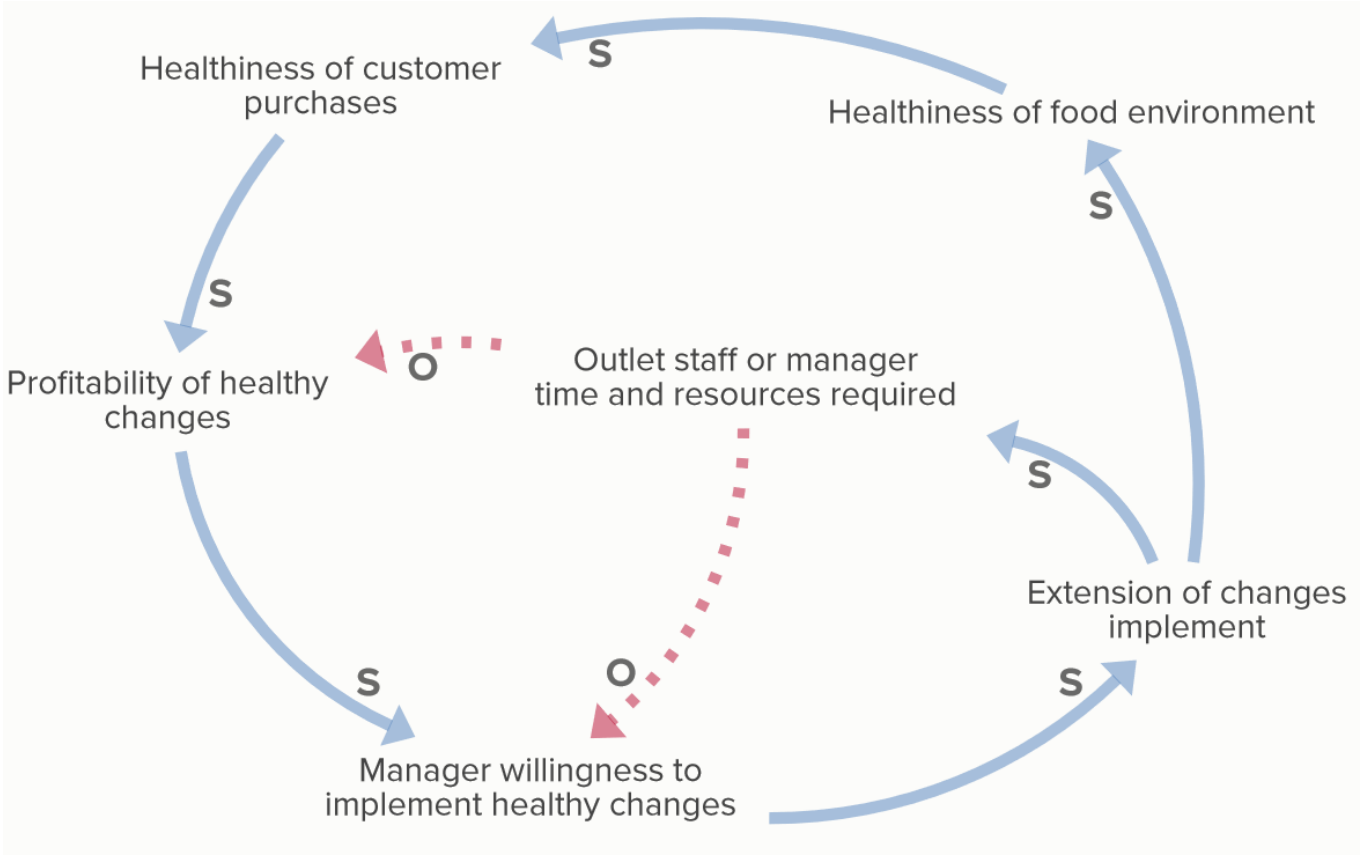


The system's structure governs its behaviour (system as cause)



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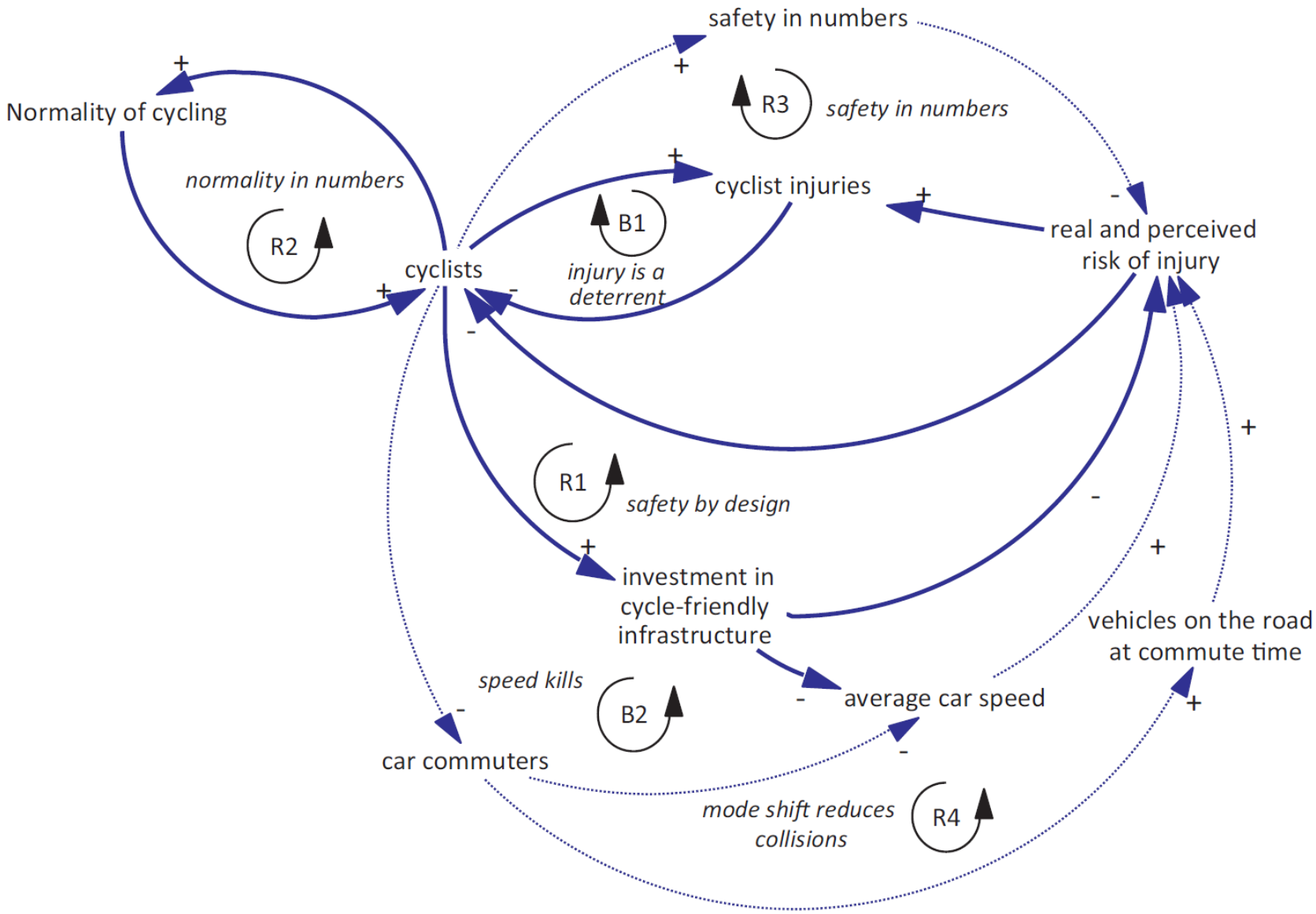
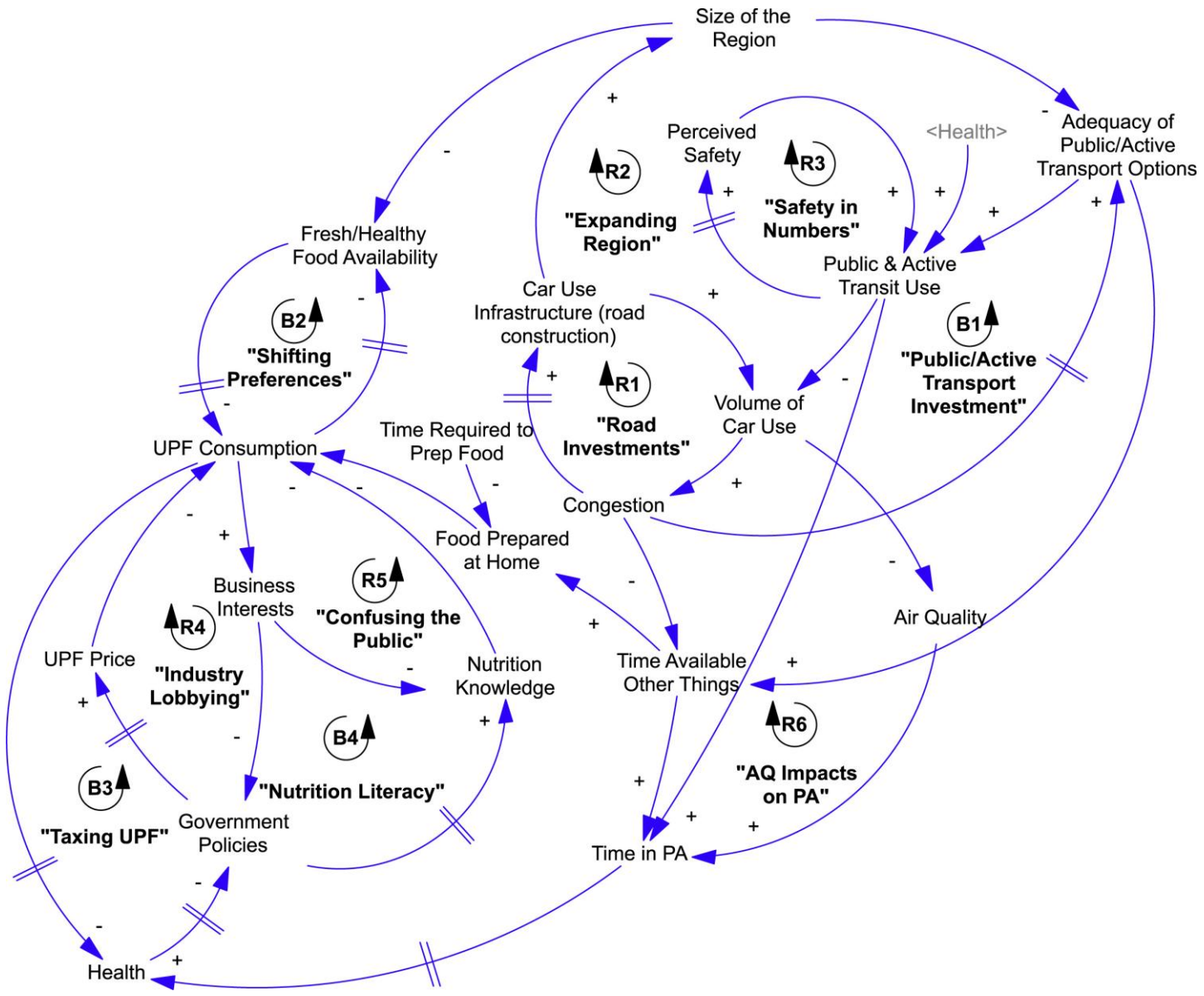
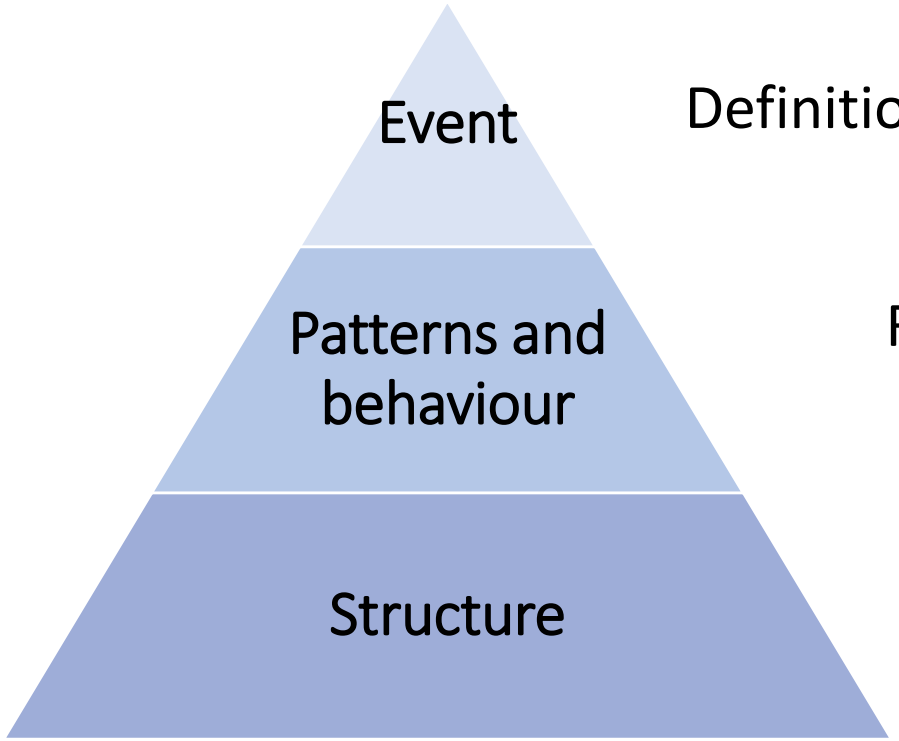


Macmillan A, Woodcock J. J Transp Health. 2017;7(Pt B):269-79.



Langellier B. et al. Health Place. 2019;60:102215.

Building a causal loop diagram



Definition of problem of interest

Reference mode

Variable elicitation

Structure elicitation

Causal loop diagram

Defining a problem of interest

Mechanistic question ('how', 'why') whose answer is likely to involve feedback loops

Why are cycling levels among women in Ireland persistently low?

Does bike scheme *X* increase cycling among women?

Step 1 – Defining the problem of interest

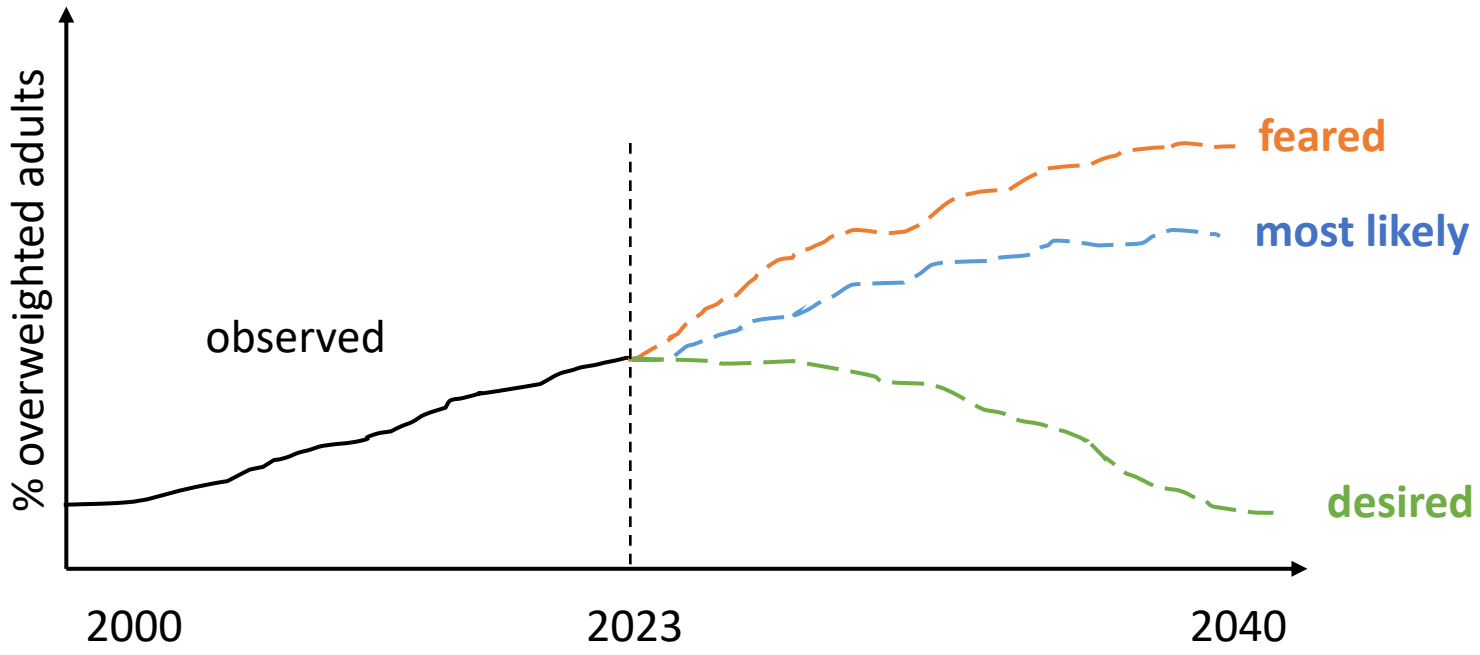
Mechanistic question ('how', 'why') whose answer is likely to involve feedback loops

Examples:

- Why are cycling levels among women in Country A persistently low?
- How individual, social, environmental and economic factors interact and shape levels of obesity in City B?
- What are the drivers and consequences of vaccine hesitation and how do they contribute to outbreaks of disease C?

Reference mode

Chart showing the system's behaviour (trajectory) over time



Step 2 – Creating a reference mode

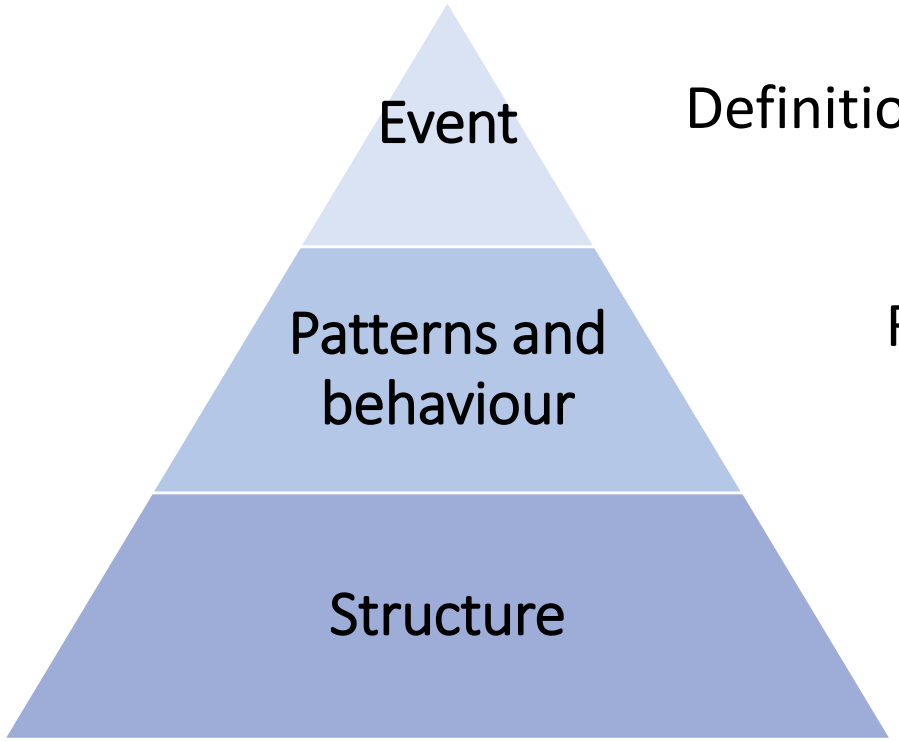
Define a key variable or indicator that can show how the situation is evolving

- Ask yourselves: "If we wanted to know whether the situation is improving or not, what is the one key variable/indicator we should monitor?"
- The variable/indicator should be something that can vary over time
- Examples:
  - Number of women who commute by bicycle
  - Percentage of the population with overweight or obesity
  - Percentage of the population that is vaccinated against disease C

Step 2 – Creating a reference mode

Define a time horizon and draw a behaviour-over-time chart (reference mode)

- Determine a time horizon long enough to see the dynamics underlying the situation play out
- Draw a behaviour-over-time chart using the variable/indicator you selected
  - First, draw the observed behaviour of the variable/indicator until present
  - Next, draw the most likely (if nothing changes), hoped, and feared behaviour of the variable/indicator into the future
- This is your take on the macro behaviour of the system, and will guide your thinking on the structure of the feedback loops shaping this behaviour
- It is fine if you don’t have quantitative data to inform the graph. The most important is to have an idea of the past and possible future trajectories (macro behaviour) of the system



Definition of problem of interest

Reference mode

Variable elicitation

Structure elicitation

Causal loop diagram

Tools for systems mapping

- Kumu (https://kumu.io/)
- Loopy (https://ncase.me/loopy/)
- Qualitative Systems Exploration Model (https://www.systemssciencelab.com/)
- Mural (https://www.mural.co/) or Miro (https://miro.com/)
- Whiteboard applications
- Power Point

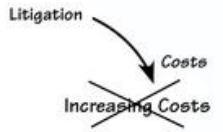
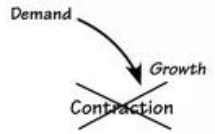
You can always use pen and paper!

Variable elicitation

"What are the key contributors to, and consequences of, your reference mode?

1) Refer to your reference mode

2) Variable elicitation
   - Identify possible contributors and consequences
   - Clarify and refine meaning
   - Reach accommodation
   - Place the selected variables in a list or circle

	Guideline	Example
Selecting Variable Names	1. When choosing a variable name, use nouns. Avoid verbs and action phrases since the action is conveyed in the arrows. For example, "Costs" is better than "Increasing Costs," since a decrease in Increasing Costs is confusing. The sign of the arrow ("s" for same or "o" for opposite) indicates whether Costs increase or decrease relative to the other variable.	
	2. Variables should be something that can be measured—quantities that can vary over time. It does not make sense to say that "State of Mind" increases or decreases. A term like "Happiness," on the other hand, can vary.	
	3. Choosing the "positive" sense of a variable name is preferable. An increase or decrease in "Growth" is clearer than an increase or decrease in "Contraction."	

Remember, you are not trying to draw out the whole system – only what is critical to understand the situation being addressed!

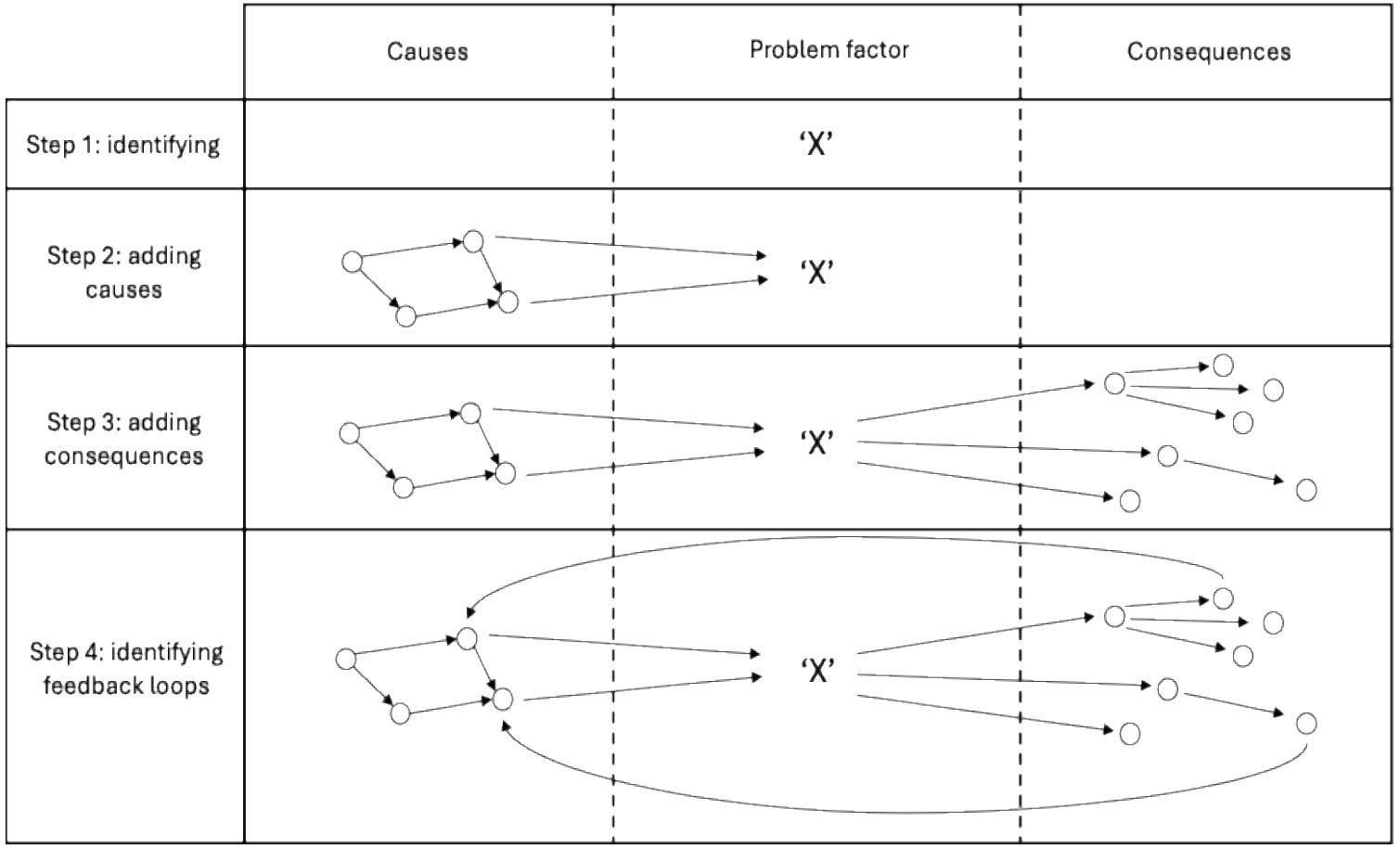
When in doubt about including something, ask "If I were to double or halve this variable, would it have a significant effect on the situation I am mapping?" If not, it probably can be omitted.

Kim D. Systems Thinker. 1992;3(1):5-6.

Structure elicitation

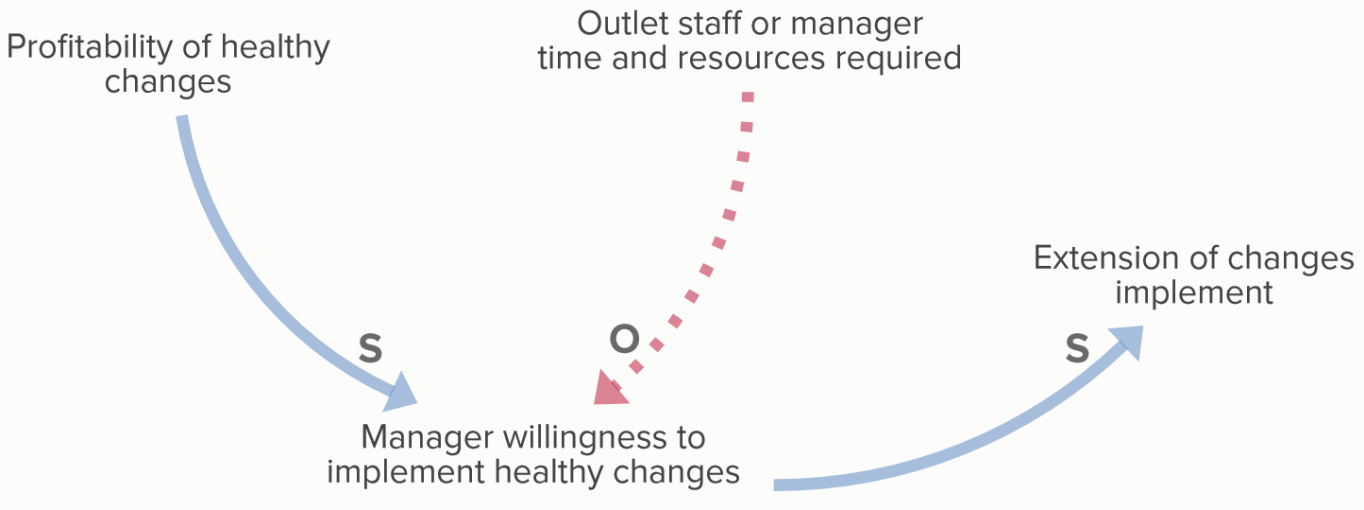
- Starting from your list of variables, draw arrows between pairs of variables
  - Only ***causal*** and ***critical*** connections
  - Add polarity to arrows
  - You do not need to use all variables
  - As you build the diagram, new variables can be added
  - Consider how the consequences also contribute to shape the problem (cyclic nature of the problem)
  - If it is a bi-directional connection, you can (a) draw two opposite arrows, or (b) check whether there is already a feedback loop linking the variables
  - If an arrow can have both polarities, draw two arrows, one for each polarity

Based on the reference mode and the variables identified, construct a causal loop diagram that describes a hypothesis about the system that shapes *[the situation you are investigating]*.



Vennix, Jac. Group model building: facilitating team learning using system. 1996. p.120.

Assigning polarity to arrows



Boelsen-Robinson T et al. Food Policy. 2021;101(2021): 102032.

Profitability ↑, Willingness ↑: **S**ame direction (+)

Profitability ↓, Willingness ↓: **S**ame direction (+)

Resources ↑, Willingness ↓: **O**pposite direction (-)

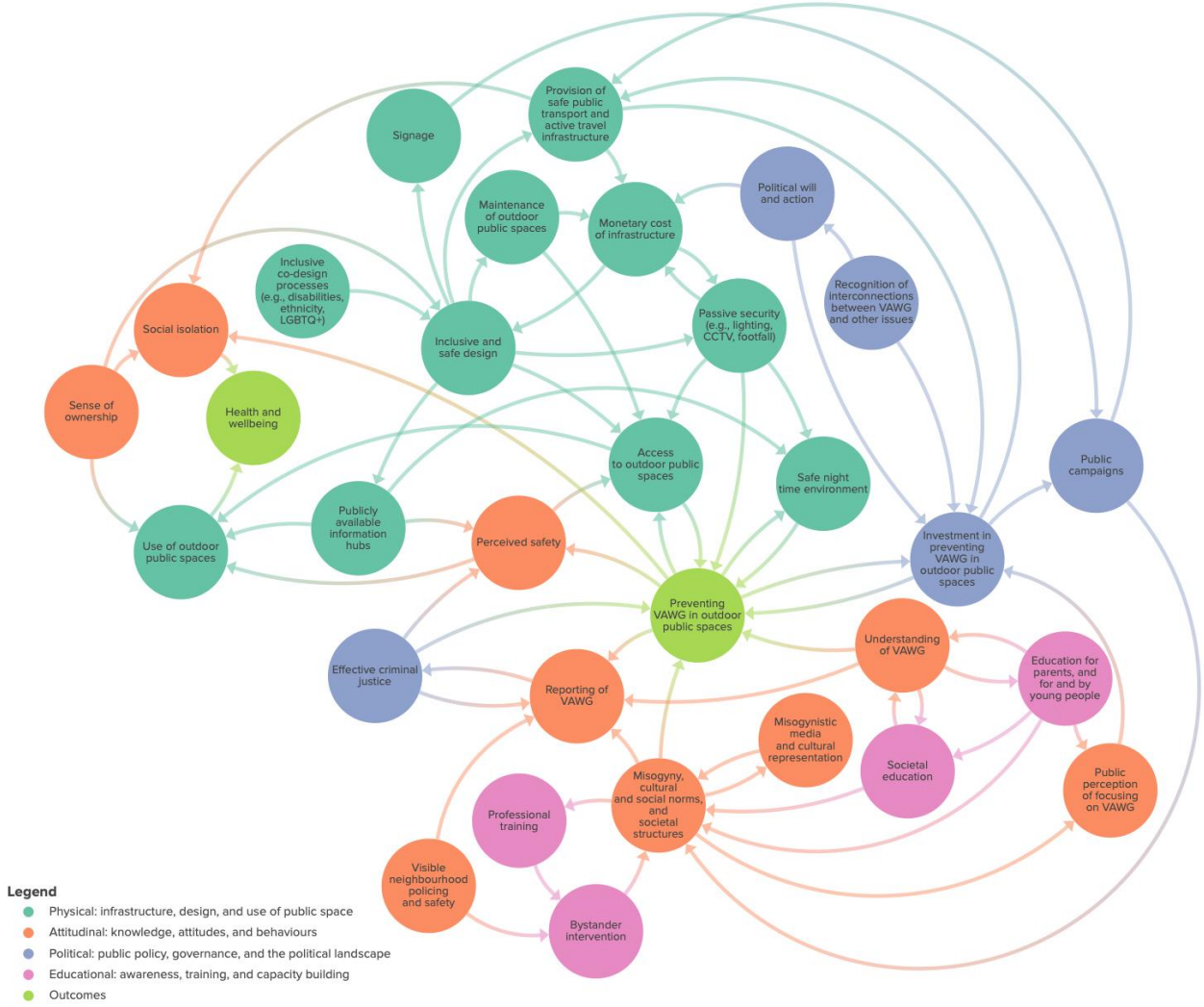
Resources ↓, Willingness ↑: **O**pposite direction (-)

Model review

- Are there variables in excess or missing to explain the key system dynamics?
- Are the variable names correct and clear?
- Are there connections in excess or missing to explain the key system dynamics? Are there any redundancies that can be deleted?
- Are the connections' polarity correct?
- Have you considered whether and how the consequences are also drivers of the problem (cyclic nature)?
- Do the causal pathways and feedback loops make sense?
- Does your diagram tell a coherent story?
- Is there anything you can do improve the diagram presentation?

Public health applications

Preventing VAWG in outdoor public spaces



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Jones S et al. Preventing violence against women and girls in outdoor public spaces in Belfast: a systems map. 2025.

Preventing VAWG in outdoor public spaces

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Purpose: to co-develop a systems map that represented a shared vision and identified pathways with the potential to prevent VAWG in outdoor public spaces in Belfast.

The two workshops involved:

Day 1: Identification of factors shaping VAWG in outdoor public spaces, and initial development of the systems map.

Day 2: Refinement of the systems map, and identification of key actions and priorities for future interventions and policies.

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Preventing VAWG in outdoor public spaces

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Outputs from these workshops were:

(1) A systems map visualising the factors, and their interrelationships, which could contribute to preventing VAWG in outdoor public spaces in Belfast.

(2) A list of eight action and priority points with the capacity to prevent VAWG in outdoor public spaces in Belfast

THEME	ACTION POINTS FROM PARTNERS	DEFINITION	EXAMPLE
Improving societal education about VAWG in outdoor public spaces	• Improving societal education about VAWG in outdoor public spaces • Societal education in sport • Education	Promote inclusive, age-appropriate education and public engagement across schools, communities, and sports to challenge harmful norms, improve awareness, and foster a culture of respect and accountability in outdoor public spaces and transport.	Public campaign posters in public transport.
Improving design of outdoor public spaces	• Inclusive and safe design • First principles	Ensure outdoor public spaces and transport are inclusively designed and well-maintained through participatory, data-informed approaches that promote safety, visibility, community use, and confidence—especially for women and girls.	Adequate street lighting and visible sight lines.
Improving operation of outdoor public spaces	• Park design and operation • Standards around reporting in relation to VAWG • Investment in neighbourhood policing	Encourage safer outdoor public spaces and transport by improving the function of outdoor public spaces, and how they are used and maintained.	Increased investment in neighbourhood policing.

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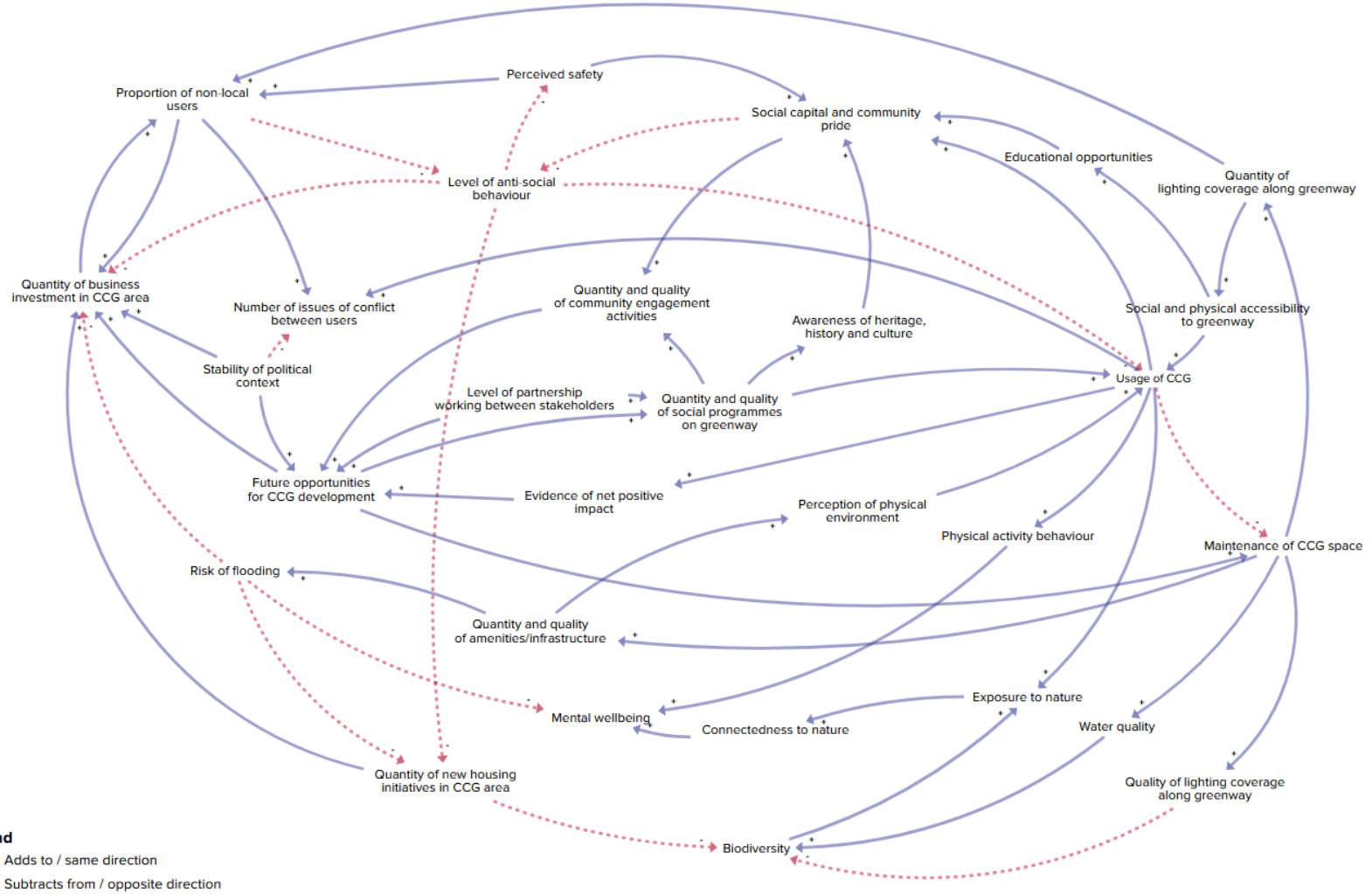
Jones S et al. Safer Streets, Shared Voices: insights from public workshops on preventing violence against women and girls in outdoor public spaces in Belfast. 2025.

Evaluation of an urban greenway



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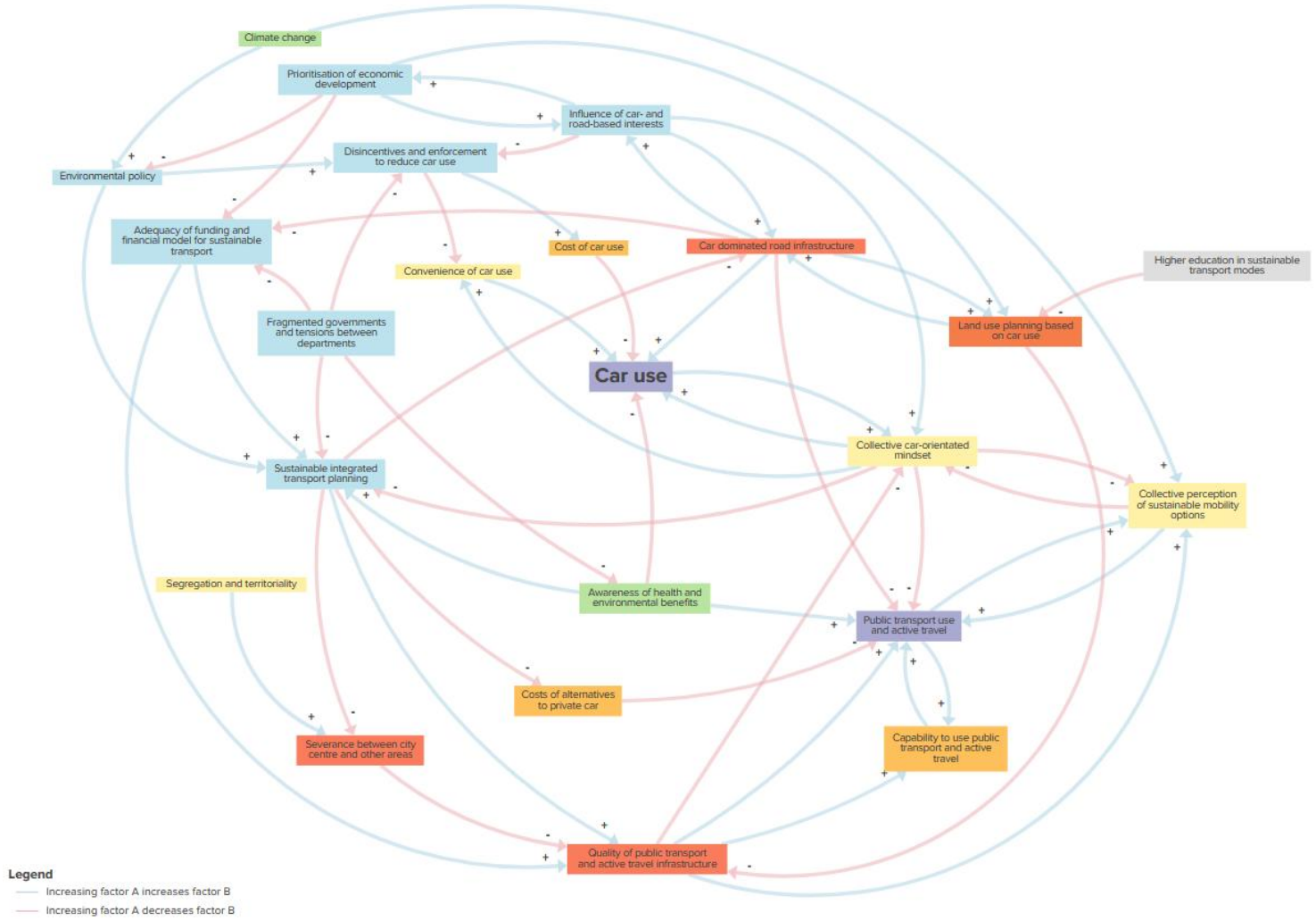
Hunter RF et al. Investigating the long-term public health and co-benefit impacts of an urban greenway intervention in the UK… BMJ Open. 2025;15:e09753.

Reducing car dependency in Belfast



Holly W et al. Group model building for developing systems-oriented solutions to reduce car dependency in Belfast, United Kingdom. Cities & Health. 2024;8(3):374-89.

Leverage points: actions that influence how the system functions

Table 3

Examples of coherent actions across the ASM

	Events	Structures	Goals	Beliefs
What we observe	These are the issues (behaviours and outcomes) that can be observed around us in the modern world, and are symptoms which arise from the system functioning as designed (both intentionally and unintentionally).	This relates to the underlying structures and patterns that cause the events to occur. This includes the organisation of the system; the structures, information flows, processes and relationships between parts of the system.	These are the goals, targets or ambitions that the system – or parts of the system – is working to achieve. Goals often drive the system to be structured as it is and therefore to work as it does.	These are the deeply held beliefs, norms, attitudes and values (i.e. the mindset) of the individuals and organisations within the system. They are the foundations that cause the system to keep functioning as it does, and are reflected in the system goals.
Actions at this level	Aim to suppress the *immediate* event. They do this by reacting quickly to the visible issues – i.e. 'quick fixes'. Quite often these actions are needed, but will not address the underlying issues which cause the issue to arise (i.e. the structures, goals and beliefs).	Aim to reduce the number or severity of the events occurring. They do this by reshaping or redesigning the organisational or relational system structures, and therefore require an understanding for how the system works.	Aim to re-orientate the goals that the system is working towards. They do this by changing the beliefs of those people setting the system goals.	Aim to change how individuals and organisations (who influence how the system works) think about the problem. They do this by challenging and changing the deeply held beliefs, norms, attitudes and values within the system.

Nobles J et al. Perspect Public Health. 2022;142(6):328-37.

Leverage points: examples

Table 3

Examples of coherent actions across the ASM

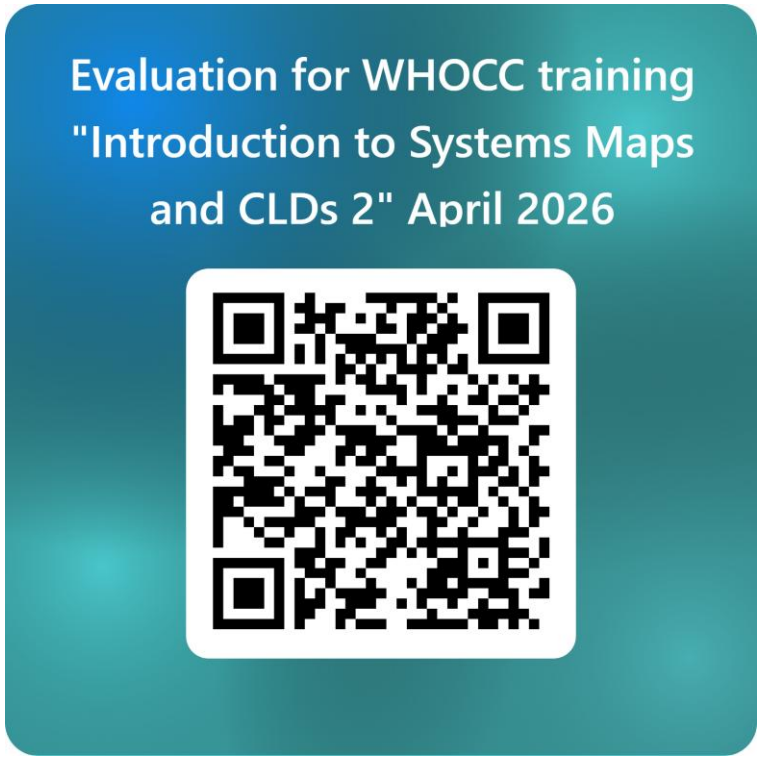
	Events	Structures	Goals	Beliefs
Example actions	1.1. LAs provide cycling training to school children.	1.2. The LA assesses and improves the walkability of the environment surrounding the schools.	1.3. Schools work with parents and community to set a shared goal to reduce short car journeys to school by 20% in next 5 years.	1.4. LA creates a working group to champion and promote active transport to senior leaders in the council.
	2.1. Families can attend free workshops to learn how to cook healthy food.	2.2. Regulations are introduced that require food manufacturers to reformulate ready meals.	2.3. Supermarket chains set mandatory targets for suppliers on the nutritional quality of products.	2.4. Supermarkets work with suppliers to demonstrate that healthier food options can maintain company profits.
	3.1. GPs refer adults with obesity to commercial weight management programmes.	3.2. Medical students receive mandatory training about the complexity of obesity.	3.3. Ensure that everyone, regardless of their health status, has access to a GP within one week.	3.4. Senior clinicians reinforce across healthcare settings that obesity is the product of complex adaptive systems.

Nobles J et al. Perspect Public Health. 2022;142(6):328-37.

Closing

Short feedback survey

https://forms.cloud.microsoft/e/dGRYH0MudW



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Introduction to Systems Maps and Causal Loop Diagrams

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