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and Air Sensing for Asian Pollution (AI on Hi-ASAP)
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Systems Thinking and Systems Approach

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17 Sustainable Development Goals (SDGs) [UN, 2015]

https://sustainabledevelopment.un.org/?page=view&nr=1021&type=230&menu=2059

■Needs solution-oriented sustainability science

Core Concept of the Risks of Climate-related Impacts

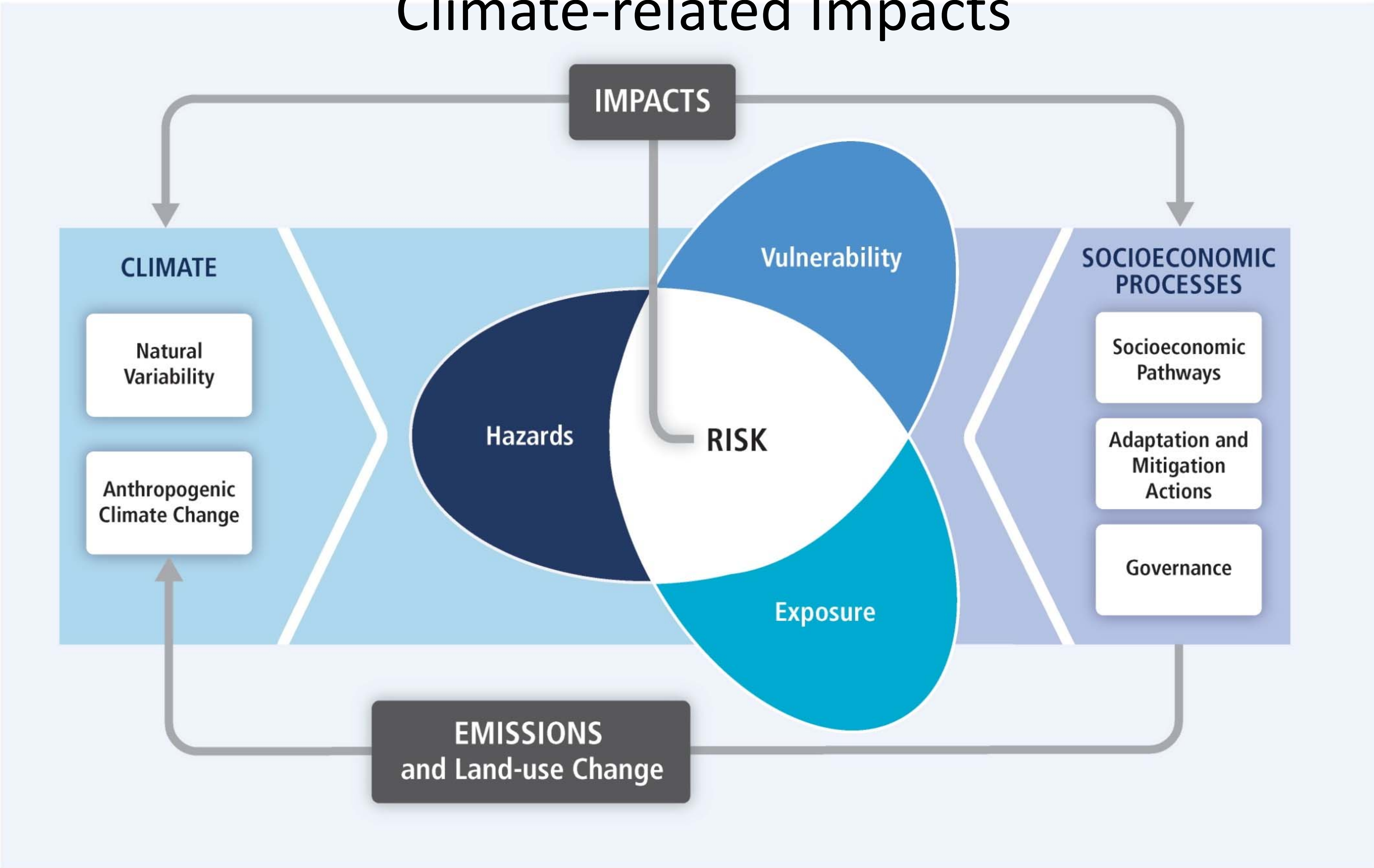


Figure SPM.1 | Illustration of the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1] [IPCC, AR5, SPM]

Integrated Adaptation Strategies to Minimize Impacts

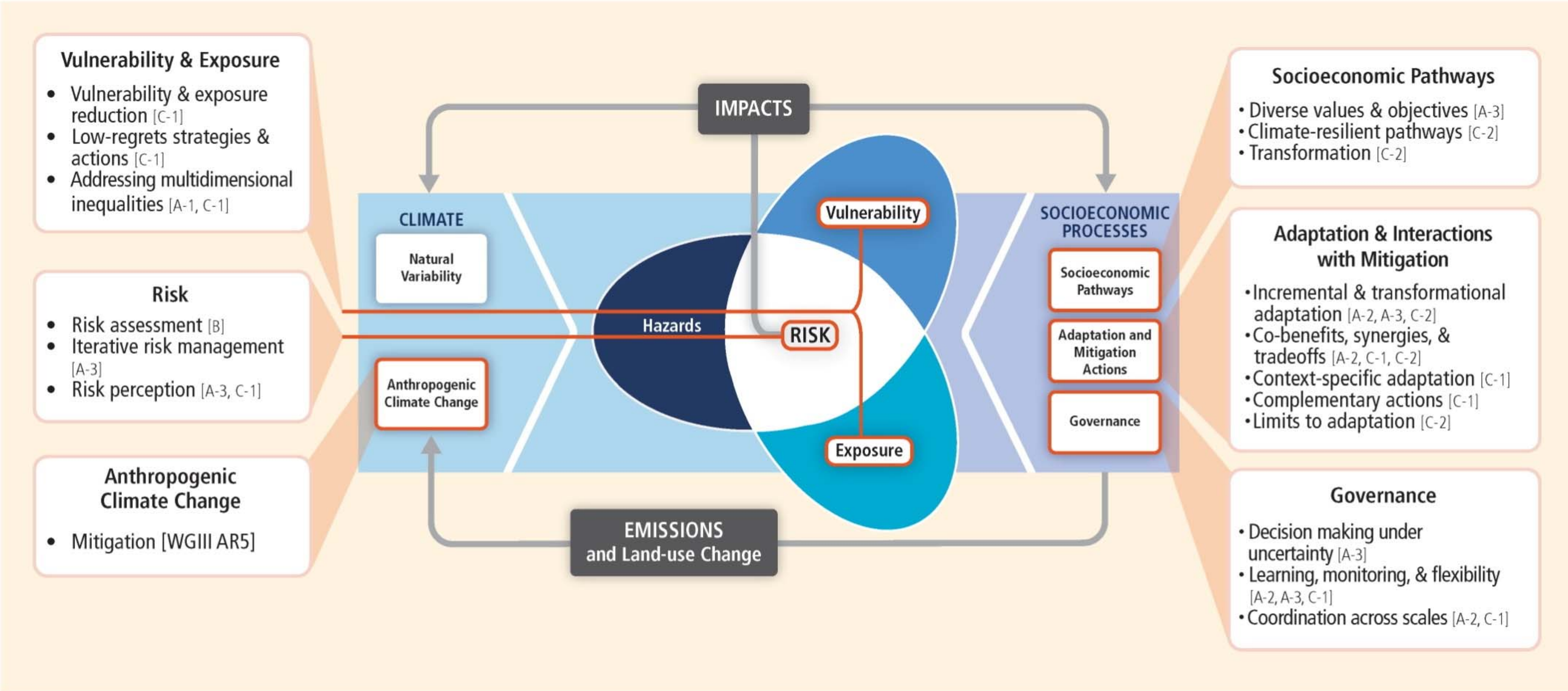
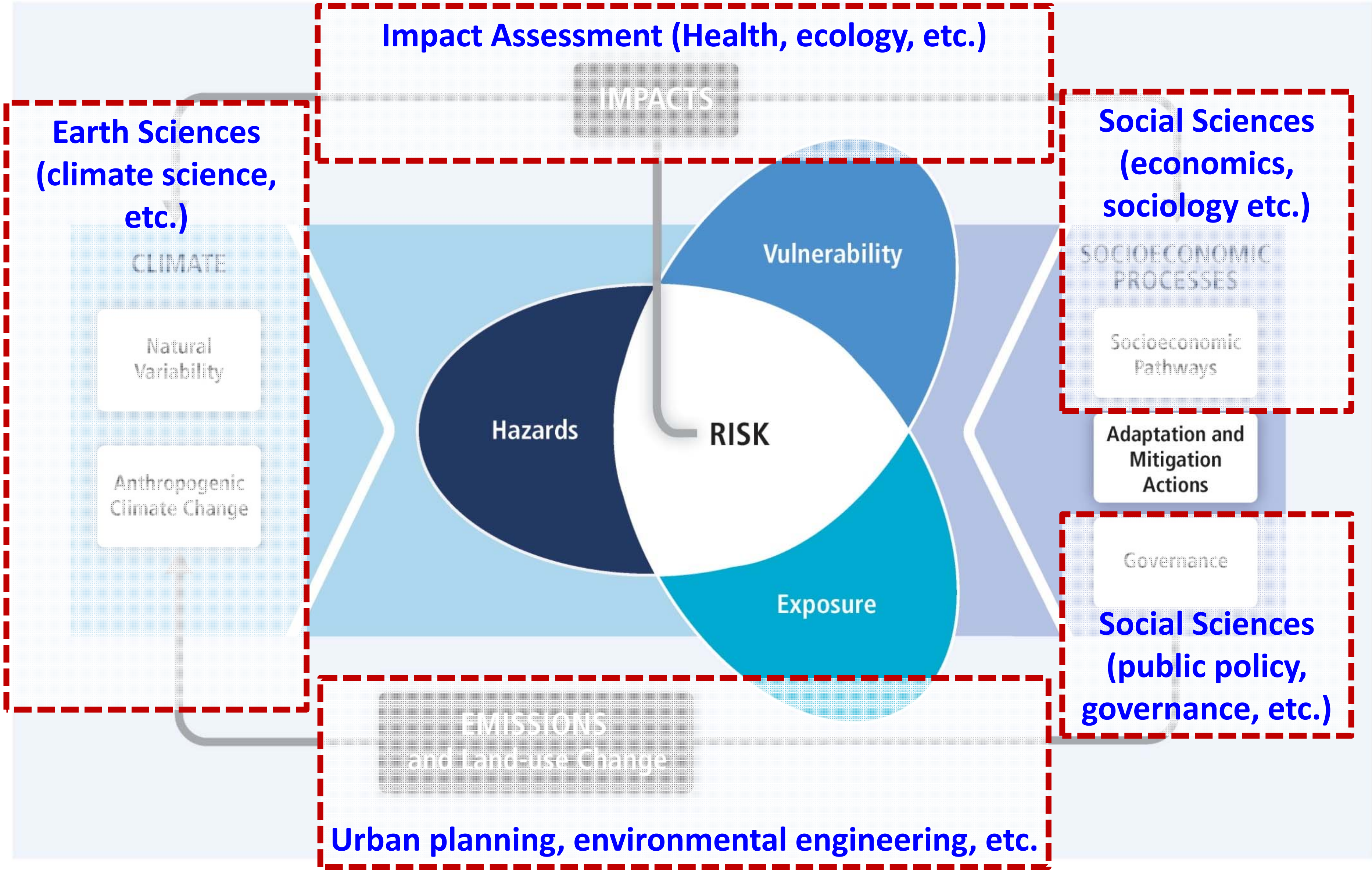


Figure SPM.8 | The solution space. Core concepts of the WGII AR5, illustrating overlapping entry points and approaches, as well as key considerations, in managing risks related to climate change, as assessed in this report and presented throughout this SPM. Bracketed references indicate sections of this summary with corresponding assessment findings.

[IPCC, AR5, SPM]

Disciplines Involved in Integrated Assessment



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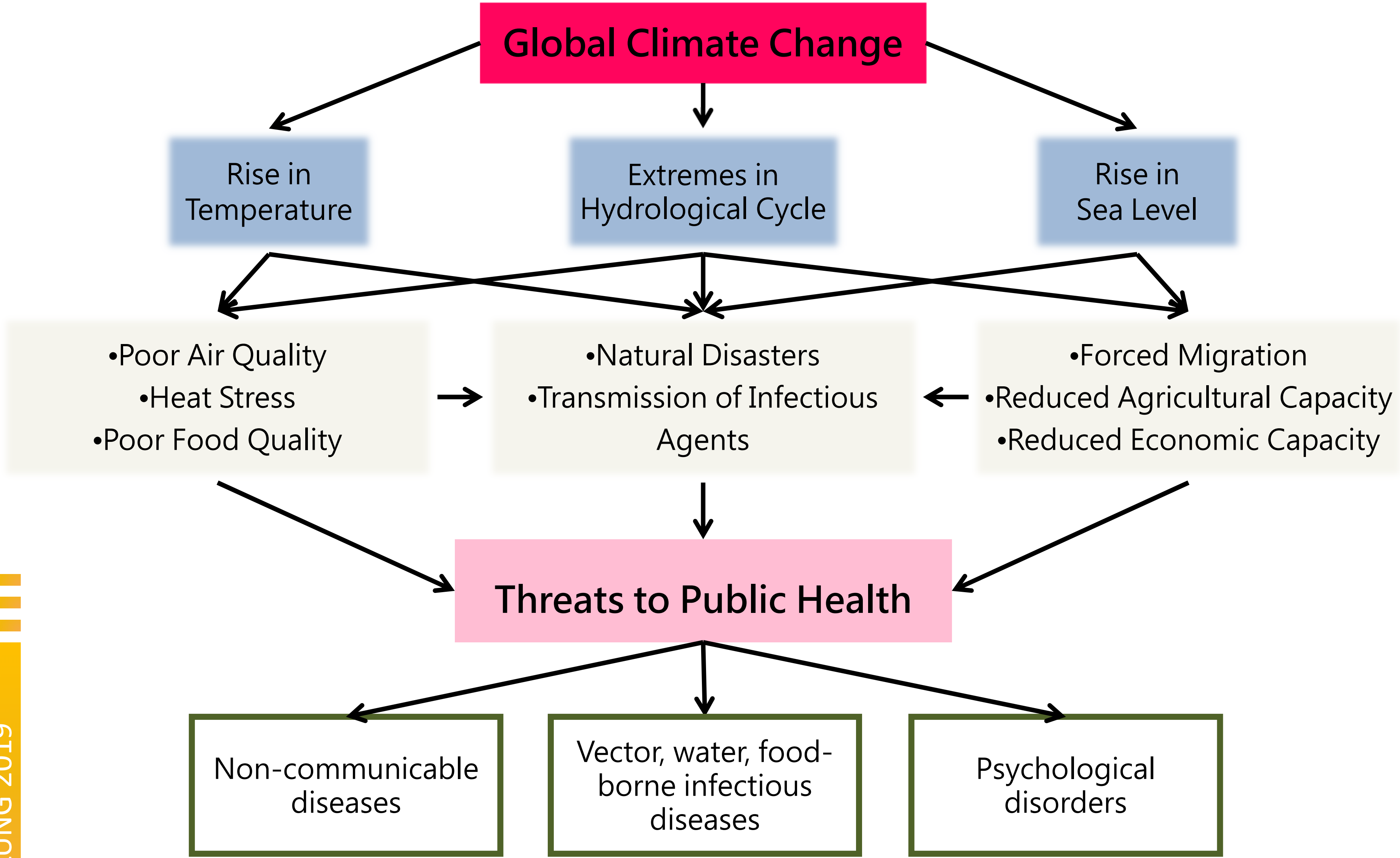
Pathways of Potential Health Threats from Climate Change

[modified from Patz & Balbus, 2001]



Air Pollution may be worse under climate change

- Emission may be higher
  - Higher temperature, higher emissions of volatile organic compounds (VOCs) and bioaerosols
    - (1) VOCs are precursors of $PM_{2.5}$
    - (2) biogenic emission may be higher and the duration of biogenic emission may be longer
  - Higher chances of forest fire
- Photochemical reactions may be faster
- Pollutant accumulation under stagnant conditions
  - Wind speed may be lower under certain condition
  - Boundary layers may be lower under certain conditions

Health Impacts of Climate Changes and Potential Intervention Points

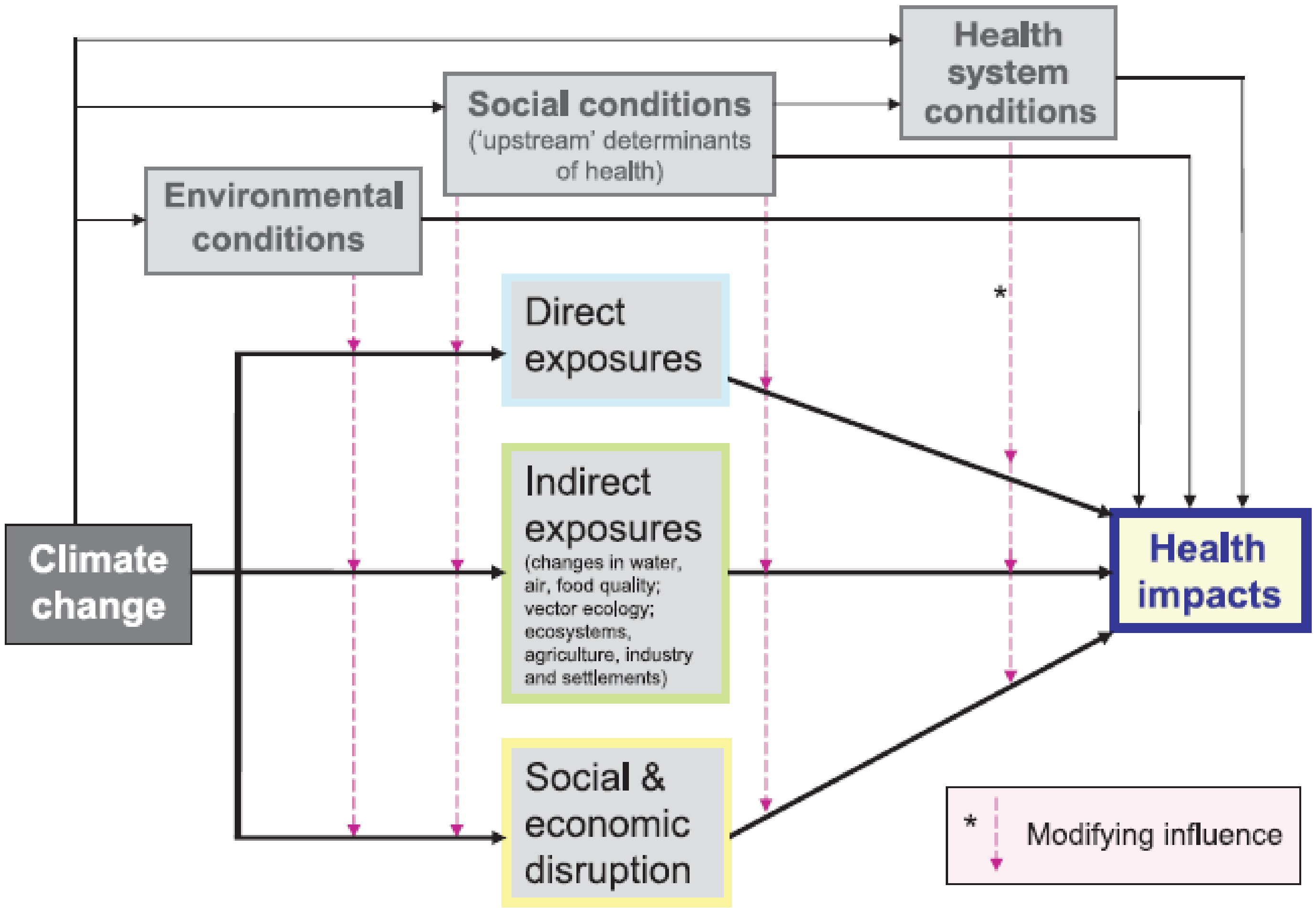


Figure 8.1. *Schematic diagram of pathways by which climate change affects health, and concurrent direct-acting and modifying (conditioning) influences of environmental, social and health-system factors.*

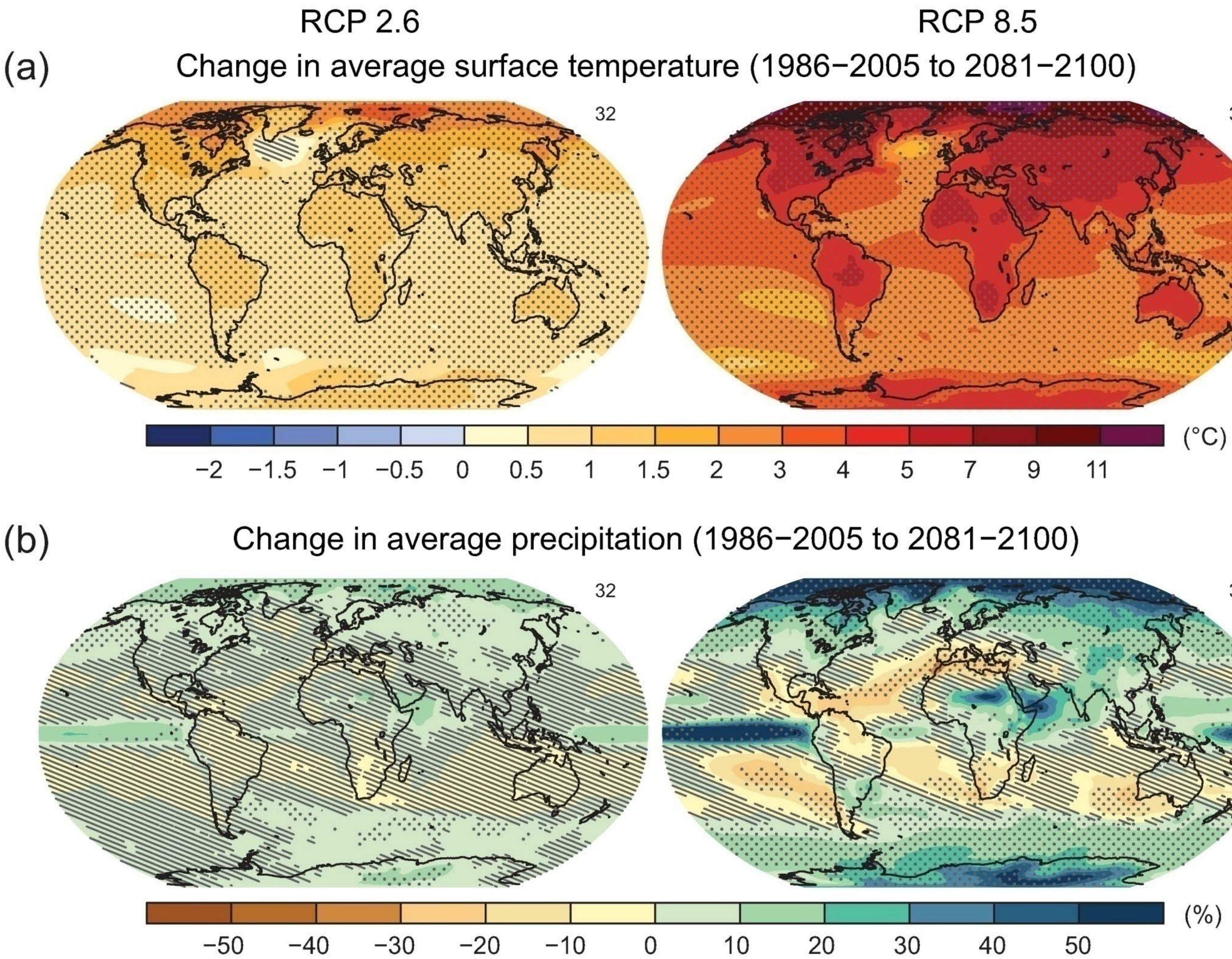
[IPCC, 2007]

Research Features for Health Adaptation

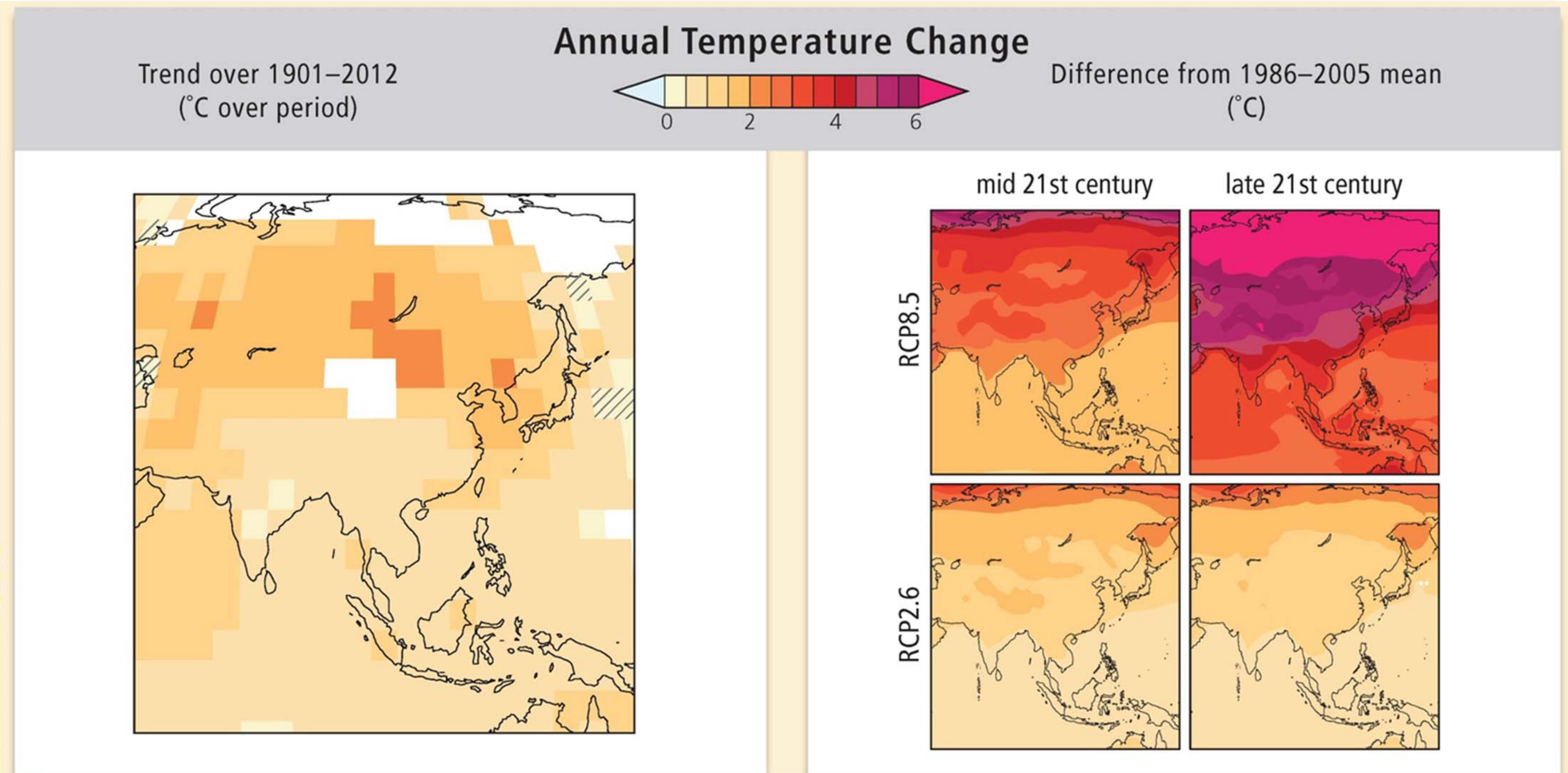
- Integration of multidisciplinary collaboration
  - Challenges:
    - (1) communication is difficult with different jargons
    - (2) it is impossible to learn other expertise within a short period of time
- Solution-oriented science
  - Challenges:
    - (1) solutions need to be feasible in the real world (policy or industry)
    - (2) specific pathways and indicators are needed to measure progress toward the goals
- Innovative thinking
  - Challenges:
    - scientists need to jump out of the box and look for intervention points
- Clear tempo-spatial scales
  - Challenges:
    - (1) focus on one country, region, or city (local context)
    - (2) hope to be realized in the near future
    - (3) tempo-spatial resolution in all disciplines should be consistent

Why Systems Thinking Is a MUST for Sustainability Science

- Real world is networks of complex systems; to find solutions for adaptation and mitigation strategies needs systems thinking to find intervention points within the complex systems
- Advantages of Systems Thinking
  - Identify study focus within complex systems with multidisciplines expertise
  - Pinpoint feasible intervention points and pathways systematically in the complex systems
  - Examine consistence and feasibility of tempo-spatial resolution of the adaptation strategies


RCP 2.6
RCP 8.5
(a)
Change in average surface temperature (1986−2005 to 2081−2100)
32
39
(°C)
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(b)
Change in average precipitation (1986−2005 to 2081−2100)
32
39
(%)
−50 −40 −30 −20 −10 0 10 20 30 40 50

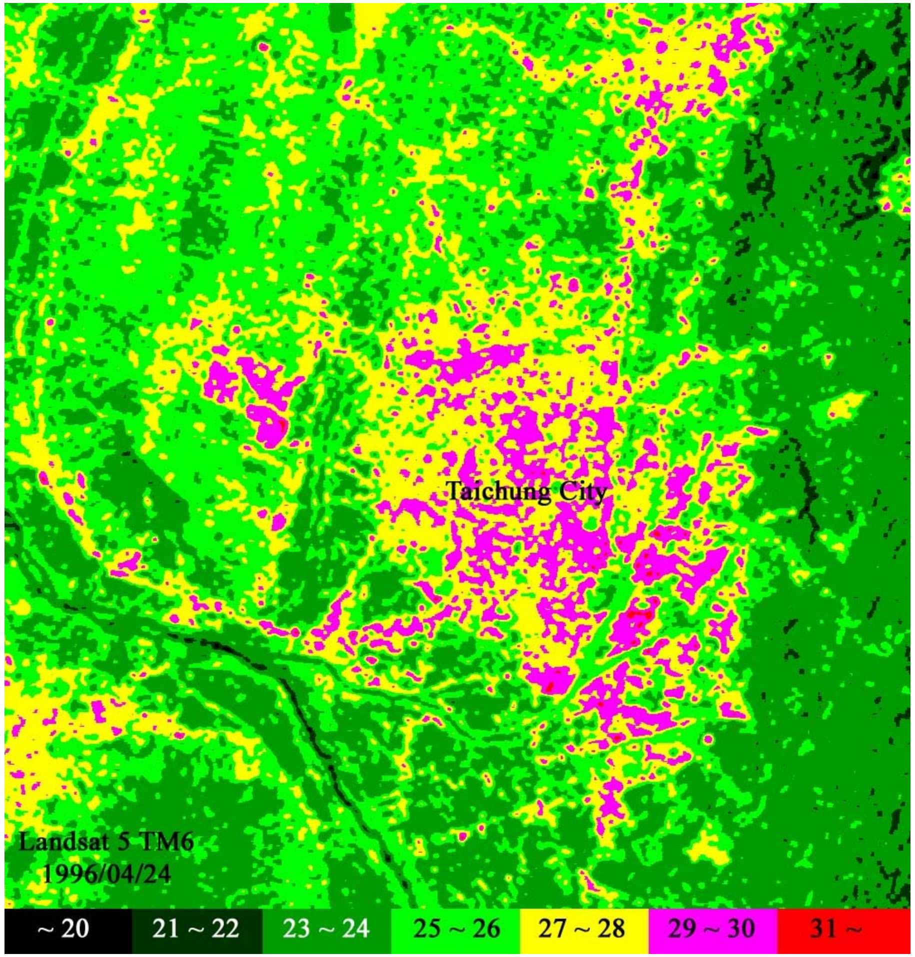
Climate Projection for Asia--Temperature



[IPCC AR5 P1335 fig 24-2]

Urban Heat Island

(Landsat IR image,25 km X 25 km) (from CSRSR NCU)



Taichung, Taiwan

Health Impacts of $PM_{2.5}$

- Depends on the PM compositions
  - Acute effects: ex. acidic irritation on upper respiratory tracts
  - Chronic effects: ex. lung cancers (carcinogenic components such as polycyclic aromatic hydrocarbons (PAHs)); neurologic effects due to heavy metals
- Higher mortality and morbidity of respiratory and cardiovascular diseases
- Impacts on cognitive ability: ex. lower test scores, lower cognitive scores
- Impacts on next generation
- Vulnerable populations: elderly and people with pre-existing diseases (lung, heart, kidney diseases and diabetes)

Summary

- **Systems thinking** is essential for health adaptation research
- Impact assessment is not enough; identifying intervention points are essential
- Research to reduce health risks of air pollution under climate change are urgently needed
  - Identify exposure sources, behaviors, and factors
- Behavior change and policy choices requires solid scientific evidences to support

Introducing "Collaborative Conceptual Modeling "

developed by Barry Newell and Katrina Proust from Australian National University

Why Collaborative Conceptual Modeling Is One of the Preferred Tools for Sustainability Science

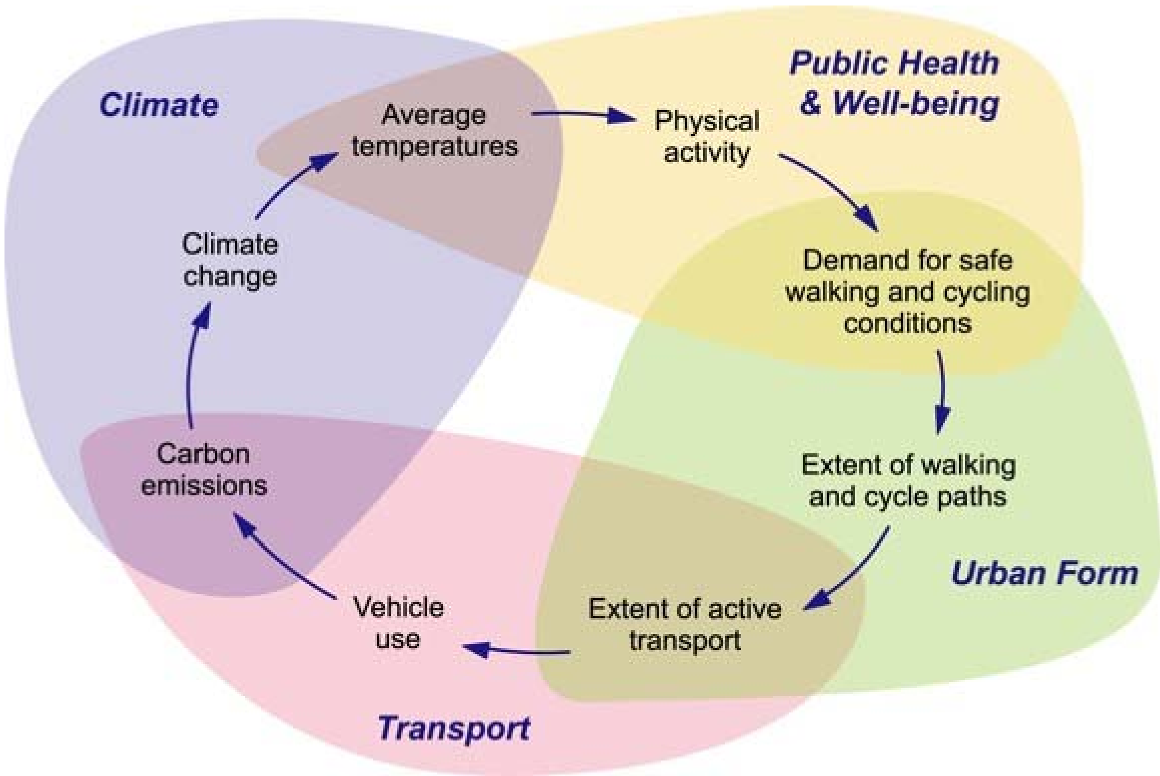
- Collaborative Conceptual Modeling (CCM) is one of the systems thinking approaches to provide systems diagrams for pathways and interactions among complex systems

  [Proust et al., 2012]

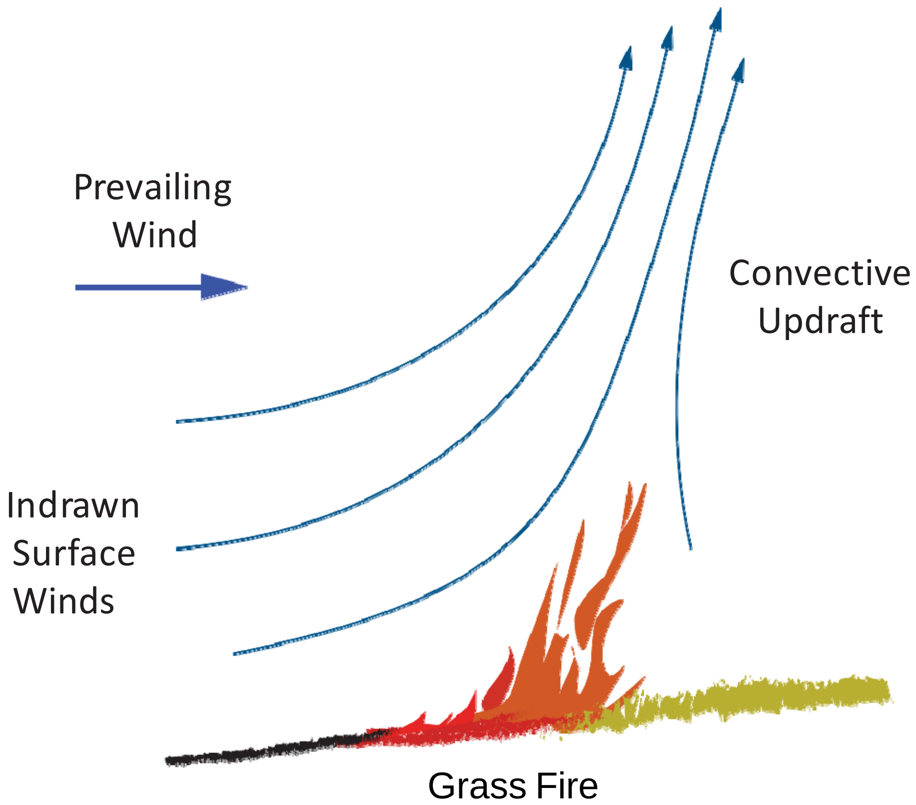
- Advantages of applying CCM (from SC Lung)
  - Simplify complex interactions with systems diagrams in order to communicate with stakeholders and among scholars
  - Stimulate innovative thinking and pinpoint feasible intervention points and pathways systematic ally
  - Specify clear indicators and examine consistence and feasibility of tempo-spatial resolution of the adaptation strategies

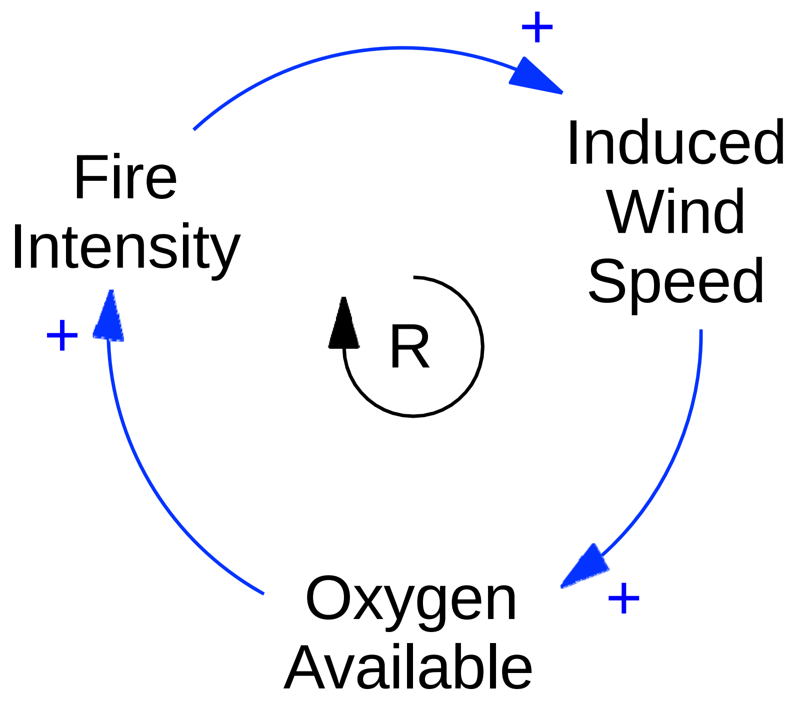
What is a System?

In our usage the word ‘system’ will always mean ‘feedback system’. A *feedback system* is something composed of separate parts that interact to affect each others' behaviour over time.



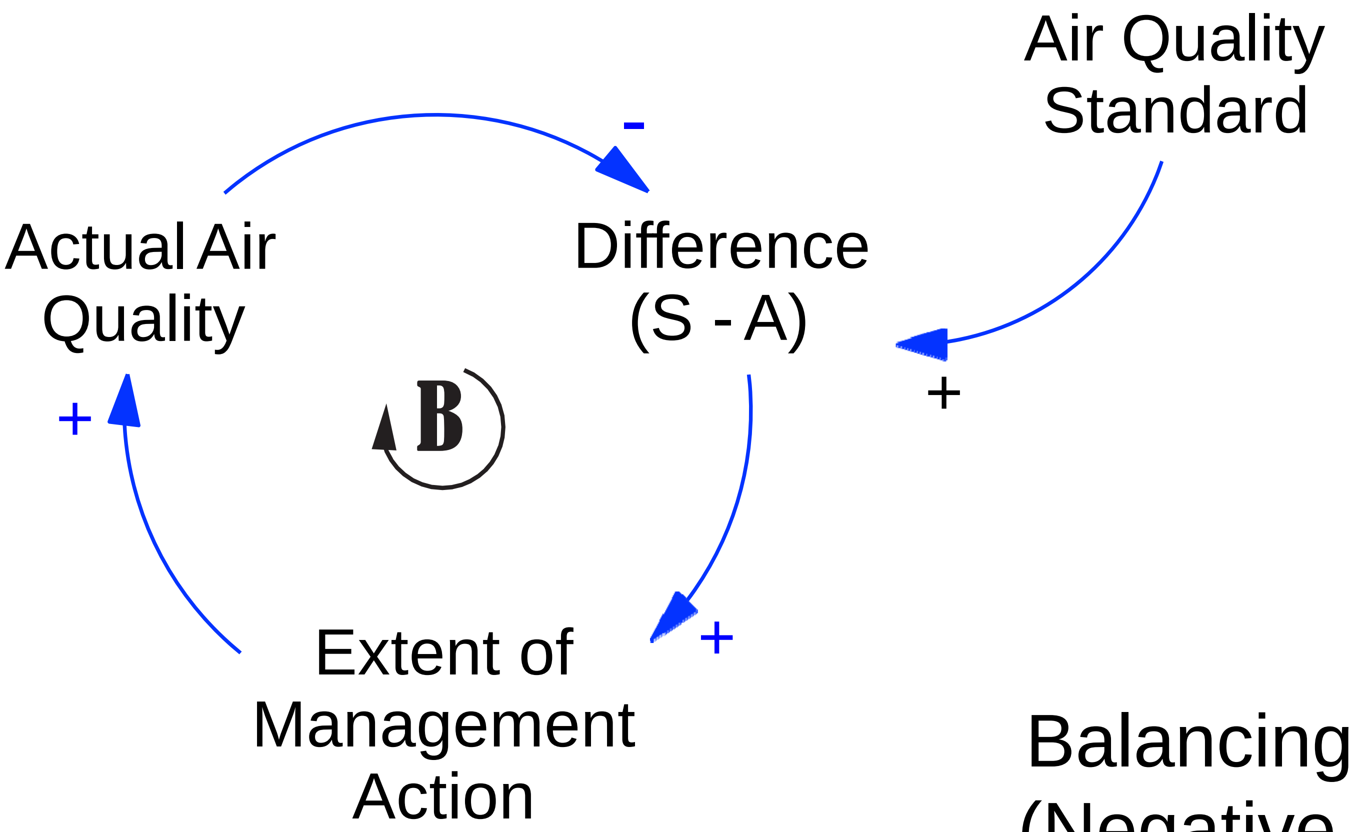
Two Types of Feedback





Reinforcing Feedback (Positive Feedback)

Two Types of Feedback



Balancing Feedback
(Negative Feedback)

Collaborative Conceptual Modelling

Aims of CCM

To provide practical ways for members of a cross-sector group:

- to compare and mesh their cause-effect models (from mental to formal) using a shared visual language
- to develop integrated understandings of the dominant dynamics of a specific system-of-interest
- to design effective cross-sector research projects and guide integrative policy-making efforts

Theoretical Foundations of CCM

Cognitive Science

- Cognitive linguistics (Lakoff, Johnson, Reddy)
- Frame reflection, conflict resolution (Schön, Rein)

Dynamical Systems Theory

- *System Dynamics* community (Forrester, Sterman, Senge, Meadows, Vennix)

Complexity Science

- Santa Fe Institute, Resilience Alliance (Axelrod and Cohen, Walker and Salt)

Applied History

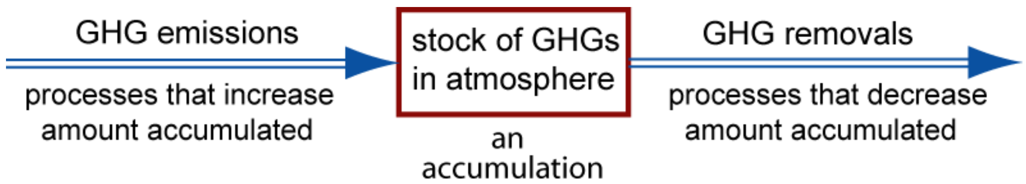
- History that informs policy making (Stearns, Graham, Reuss, Proust), Historical Data Gathering

CCM Systems Thinking Principles

1. *The Feedback Principle*: Feedback effects are dominant drivers of behaviour in any human-environment system.

2. *The Holistic Principle*: The behaviour of a human-environment system emerges from the feedback interactions between its parts, and therefore cannot be optimised by optimising the behaviour of its parts taken one by one.

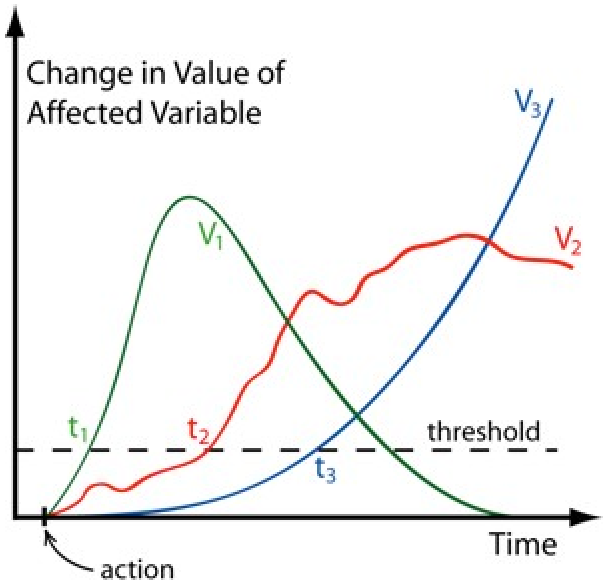
3. *The Inertia Principle*: The filling and draining of stocks is a pervasive process in human-environment systems. The presence of stocks causes delayed responses, thereby giving rise to system inertia.



CCM Systems Thinking Principles

4.The Surprise Principle: Any action taken in a human-environment system will have multiple outcomes, some expected and some unexpected. The expected outcomes might occur—unexpected outcomes will always occur. The unexpected outcomes are usually unwanted and delayed—the delays make it difficult to identify the triggering actions.

5.The History Principle: Knowledge of past activities and patterns of behaviour is essential in any attempt to understand how a human-environment system works.



CCM Systems Thinking Principles

6. *The Myopia Principle*: No one person can see the whole of a human-environment system.

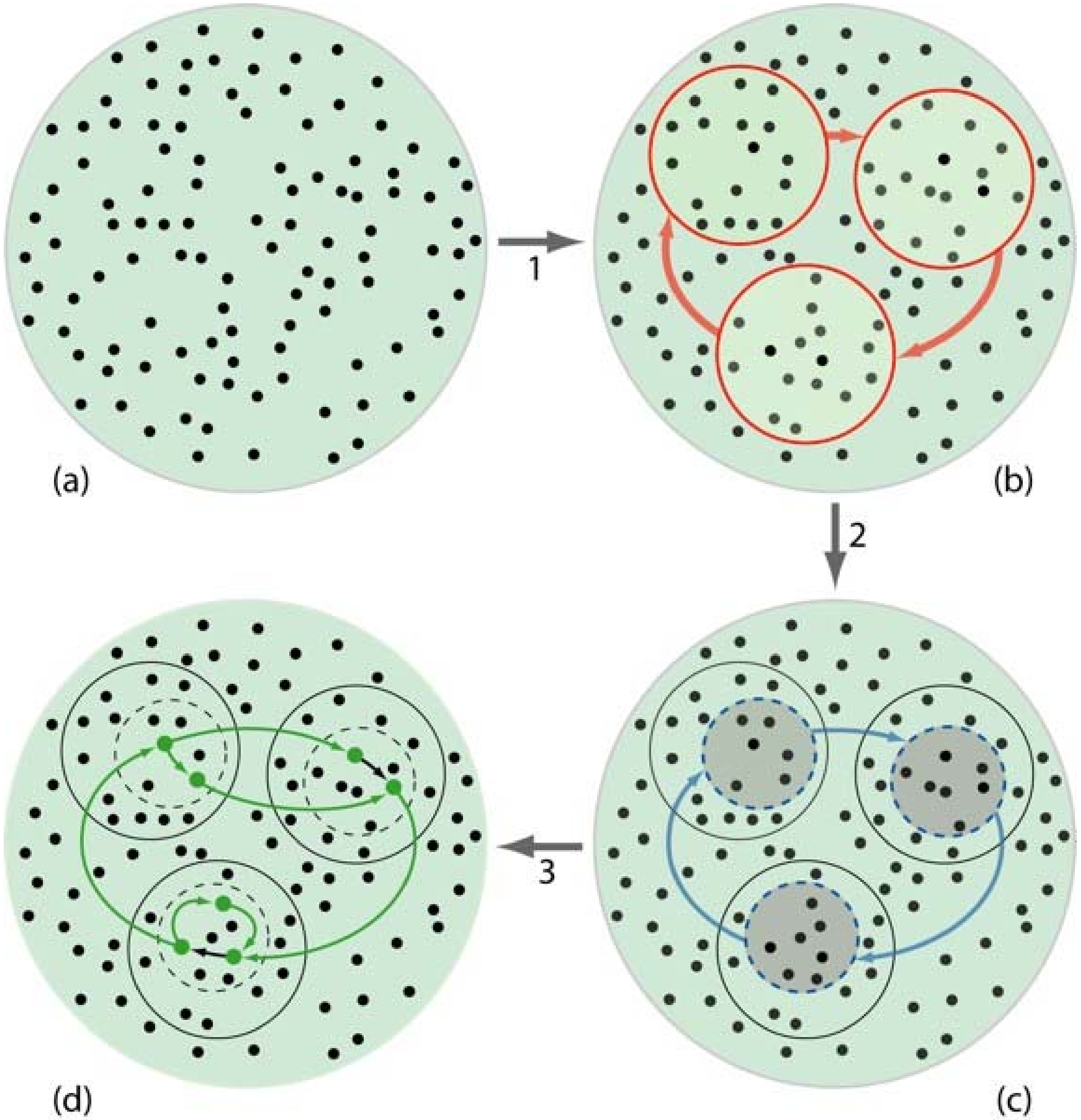
7. *The Collaboration Principle*: The boundaries of a human-environment system cut across the boundaries of traditional disciplines, organisations, governance sectors and sub-cultures. An effective systems approach therefore requires deep collaboration between people with different backgrounds, worldviews, values and allegiances.

The need for cross-sector approaches is clear when you look at the world through system eyes.

Feedback Guided Analysis

Whole System

System Overview Template



Specific System of Interest

SSoI

Problem Space

Collaborative Conceptual Modelling (CCM)
(SC Lung modified from Proust et al., 2012)

- **Step 1:** Identify studied systems, ex: public health, atmospheric environment
  - Identify several systems which are related to climate-related disasters
  - Identify disciplines related to these systems
- **Step 2:** Select studied variables, ex: cardiovascular mortality
  - Select focused and measurable variables within the studied systems
- **Step 3:** Clarify interactions among systems
  - Clarify interactions of these studied variables among different systems
  - Brainstorming potential intervention points in the interfaces of these studied systems

- Reminders:
  - Systems diagrams of CCM are conceptual and are a collaborative outcome of brainstorming from multidisciplinary scientists
  - The focus is the interfaces and interactions among different systems (discipline); the scientific context within each system should be kept to the experts in that system to avoid confusion and streamline communication among different disciplines
  - The interactions among systems could be quantitative or qualitative; it is helpful for the collaboration between social scientists and natural scientists

Interactions among Systems

BOX 1

Causal Link Polarities

In System Dynamics terminology a causal link can have one of two polarities [13]. In the diagram below, the letters **A** and **B** represent system variables and the arrows represent causal links. The "polarity" of a link is indicated by a plus sign (+) or a minus sign (−) attached to the arrow representing the link.

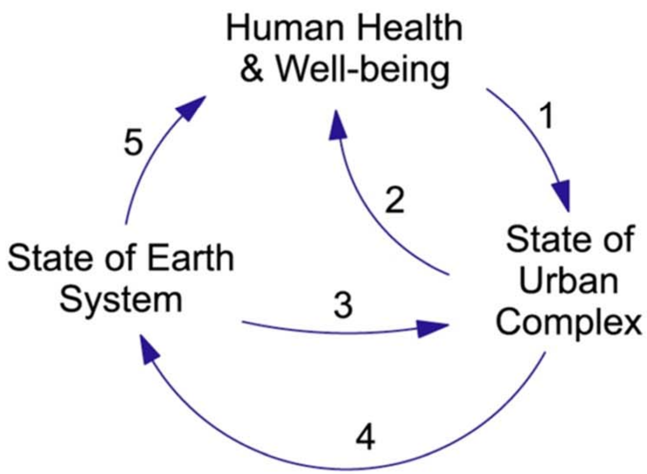
Positive polarity means that an increase/*decrease* in the level of variable **A** will cause the level of variable **B** to eventually rise above/*fall below* the level that it otherwise would have had (all else being equal). Similarly, negative polarity means that an increase/*decrease* in the level of variable **A** will cause the level of variable **B** to eventually fall below/*rise above* the level that it otherwise would have had (all else being equal). Diagrams where polarities have been assigned are called causal diagrams or causal-loop diagrams.

REF: *Int. J. Environ. Res. Public Health* ***2012, 9, 2134-2158; doi:10.3390/ijerph9062134***

Step 1: Identify Studied Systems

- Identify several systems which are related to climate-related disasters and health adaptation
- Take Co-Effects Template as an example
  - A template shows how to slow down climate change and reduce health risks

Figure 4. The Co-Effects Template. The blocks of text in this influence diagram represent system stocks (state variables) grouped into three high-level sub-systems. Examples of these stocks are given in Table 1. The arrows represent bundles of causal links. Examples of the flows (state-change processes) associated with each link are given in Table 2.



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Stocks in the Co-Effect Template

Stocks	Description
State of Urban Complex	Stocks that define the state of a city and its inhabitants. Both physical and social variables are required. Examples include area of city, area of green space, kilometres of roads, size of car fleet, quality of infrastructure, extent of infrastructure, street permeability, energy consumption, albedo of urban region, size of population, population density, security of food supply, affluence, social cohesion, alienation, equality and visual amenity.
State of Earth System	Stocks that define the physical and ecological state of the planet. Must include variables that measure the physical state of the planet and those measuring the health of ecosystems at all scales from local to global. Examples include atmospheric energy content, GHG concentrations, ocean acidity, biodiversity, species abundance, extent of native vegetation, condition of soils, and condition of fresh water.
Human Health & Well-being	Stocks that define the physiological, psychological and social health of an urban community. Examples include incidence of specific diseases, extent of obesity, physical fitness, stress levels, level of mental health, acclimatisation to weather extremes, sense of purpose, sense of belonging, sense of security.

REF: *Int. J. Environ. Res. Public Health* ***2012, 9, 2134-2158; doi:10.3390/ijerph9062134***

Casual links in the Co-Effect Template

Link	Processes represented by the link
1	Human activities. The design and implementation of formal and informal social and public health policies.
2	Human behavioural patterns influenced by the state of the urban complex. Processes whereby the state of the urban complex directly affects individual physiological, psychological and social functioning.
3	Human activities. The design and implementation of formal and informal environmental protection policies.
4	Extraction of natural resources and pollution (dumping of wastes). Conservation and restoration activities.
5	Processes whereby environmental conditions directly affect human physiological, psychological and social states.

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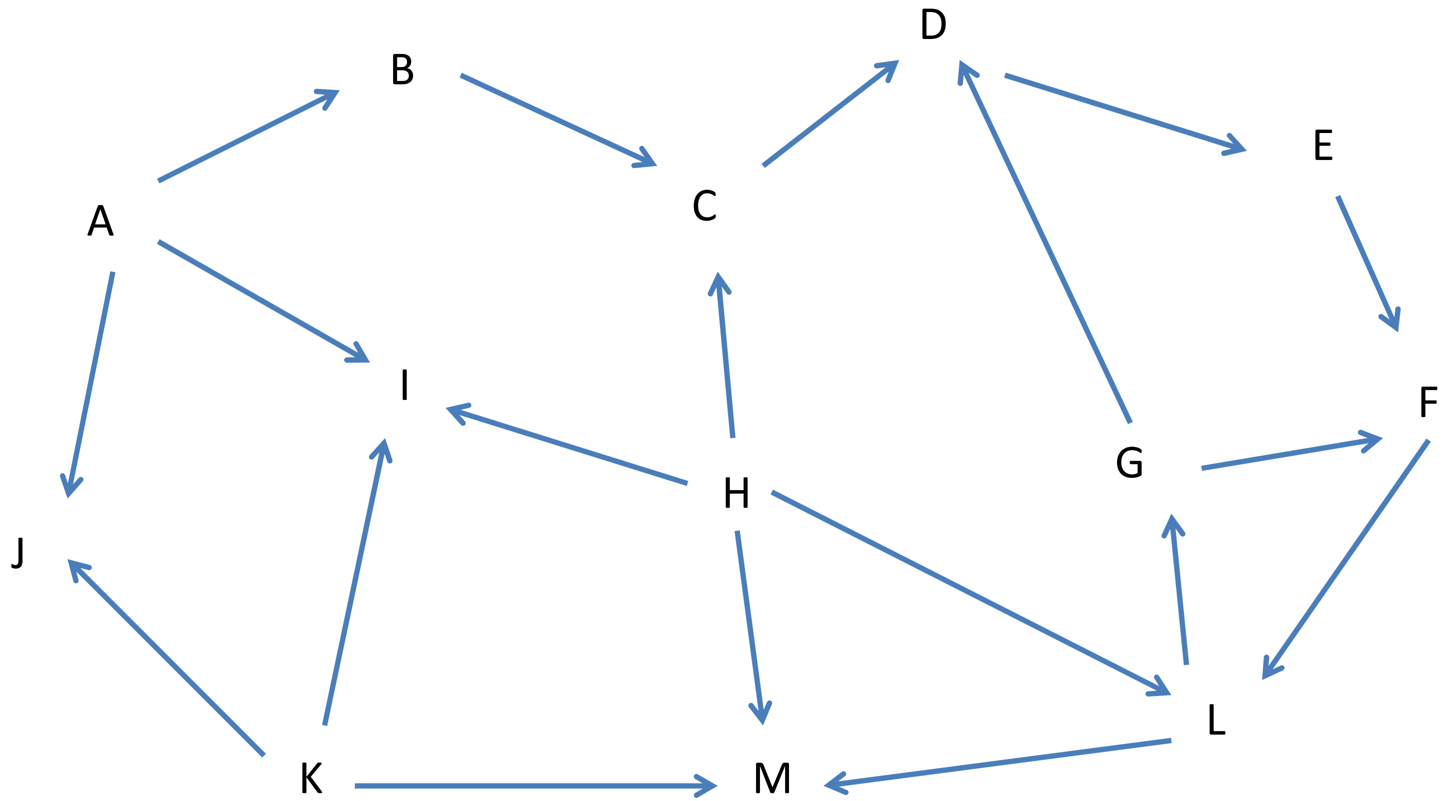
Special Features of CCM

- CCM diagrams are different from typical diagrams of climate change and health adaptation
  - Emphasizes “feedback loops” which is essential to identify intervention points to provide solutions for health adaptation strategies
  - Feedback loops are not necessarily quantitative processes; a policy-pressure process is also acceptable. However, a quantitative variable to measure the change of this system is required to assess the effectiveness of the intervention program

How many feedback loops?



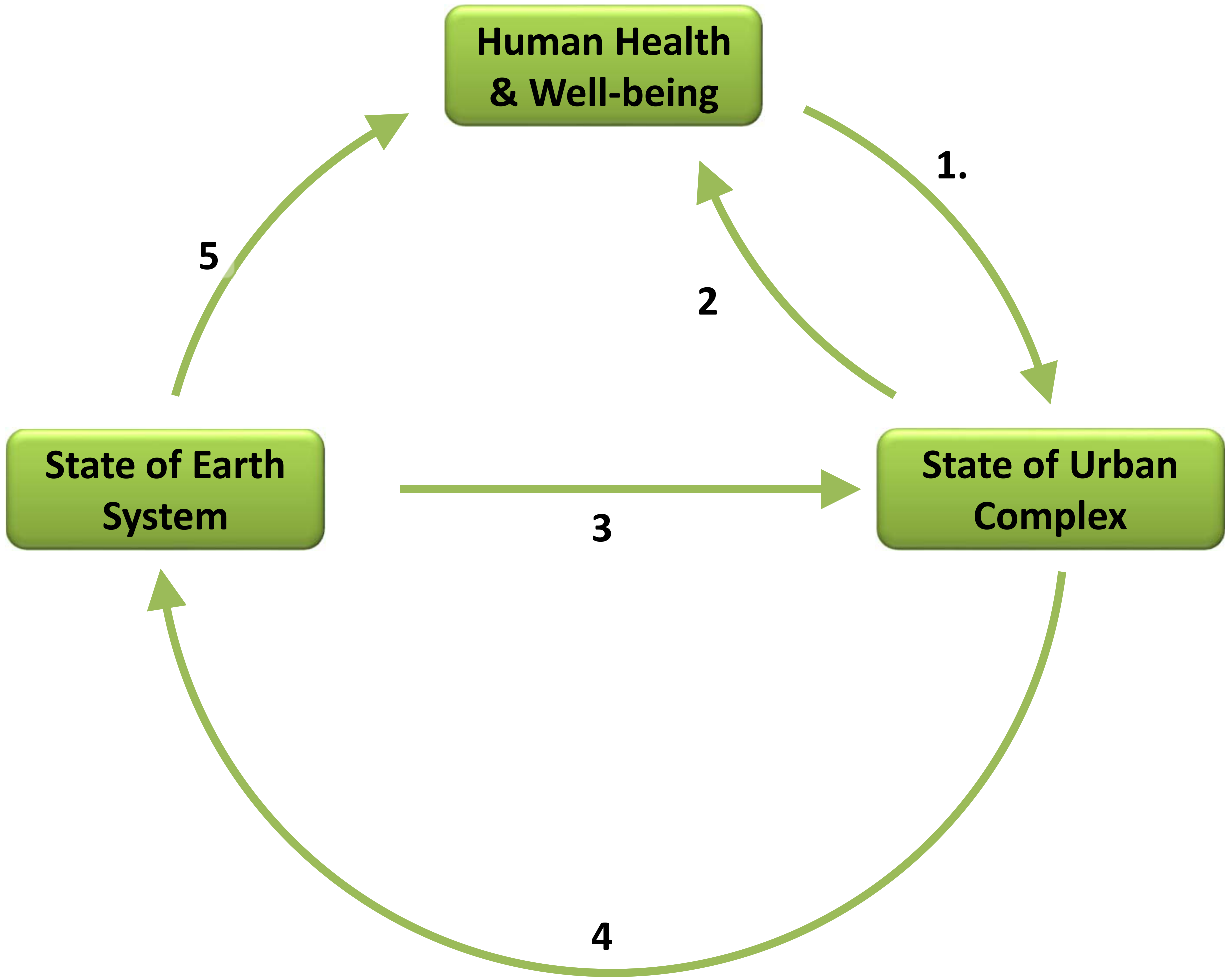


Figure 1 Problem space (Step 1: identify studied systems)

[Lung SCC, 2015]

Example:

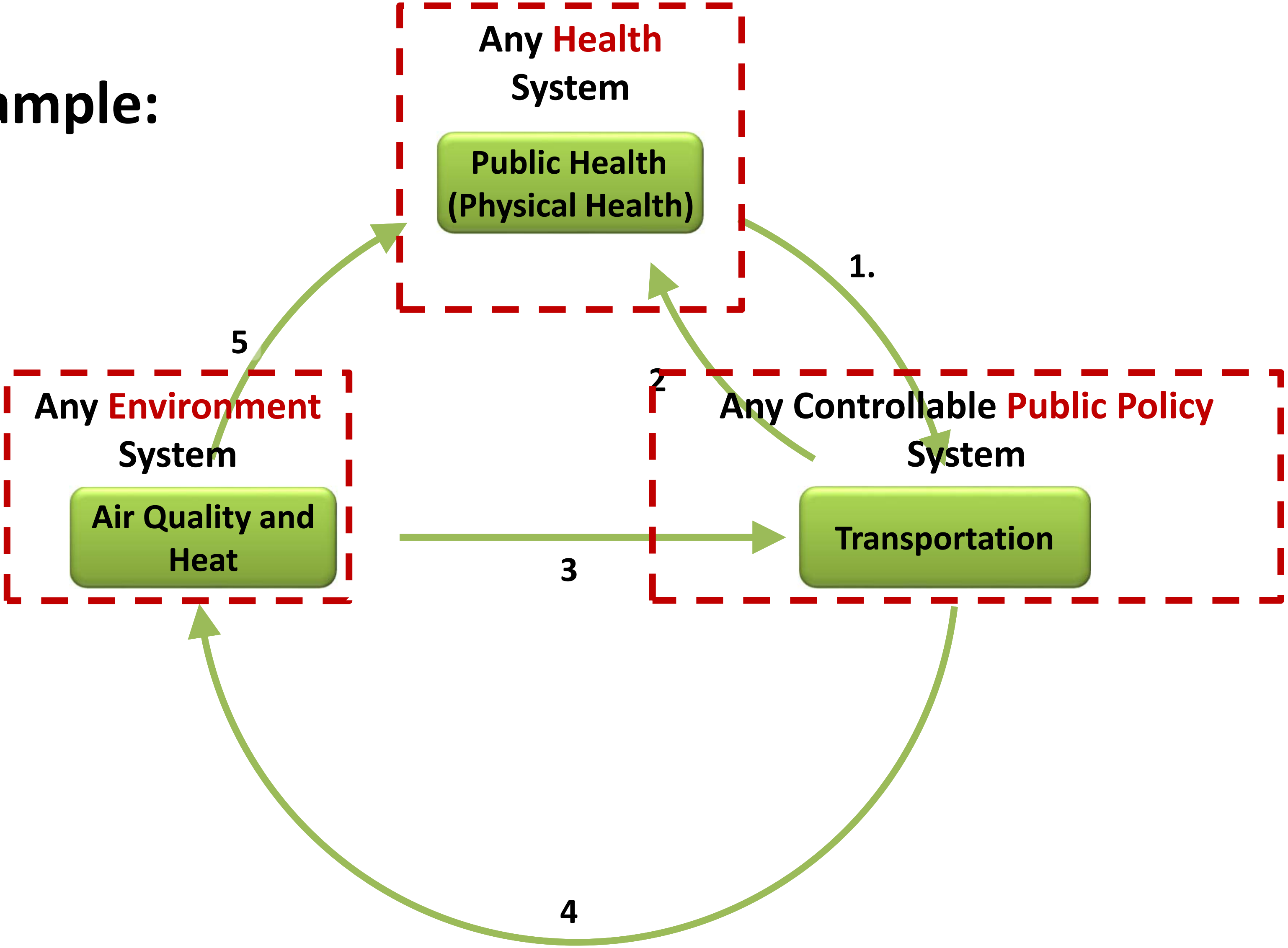


Figure 2 Problem space (Step 1: identify studied systems)

[Lung SCC, 2015]

Step 2: Select Studied Variables

- Select the focused variables within the studied systems
  - Select the main measurable variable in each system
- Criteria
  - This variable interacts with other main measurable variables in other studied systems
  - There are measurable change of this variable occurring within the focused tempo-spatial scales
  - This variable is changeable or controllable by governmental policies, industrial innovations, and/or human behavior changes. In other words, it could be used to measure the effectiveness of the adaptation strategies

Step 1: Identify Studied System

Identified problem space based on CCM

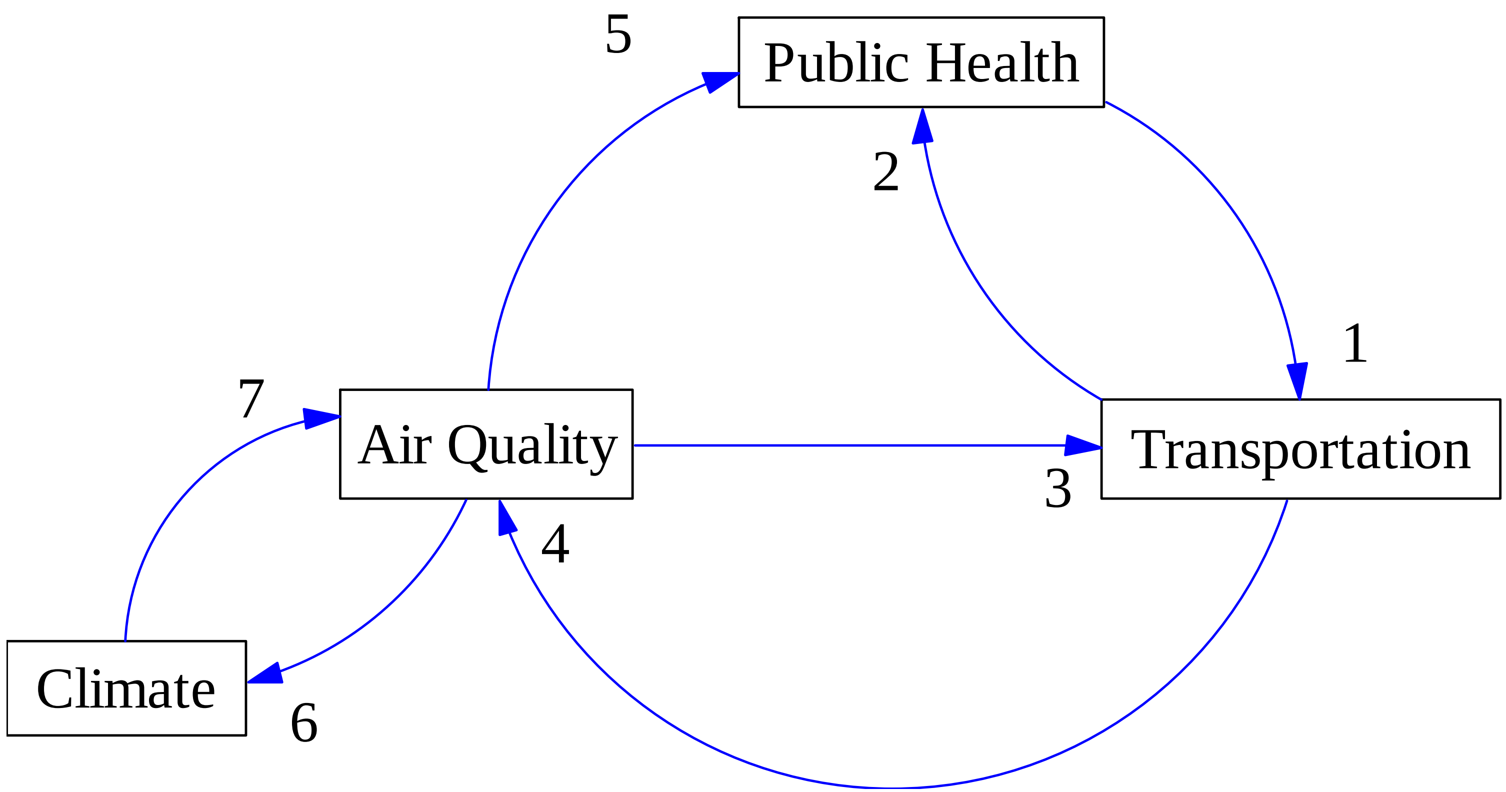


Figure 1. The conceptual interactions among transportation, air quality (and climate), and public health

[Lung et al., 2013]

Step 2: Identify Studied Variables
The specific stocks and processes

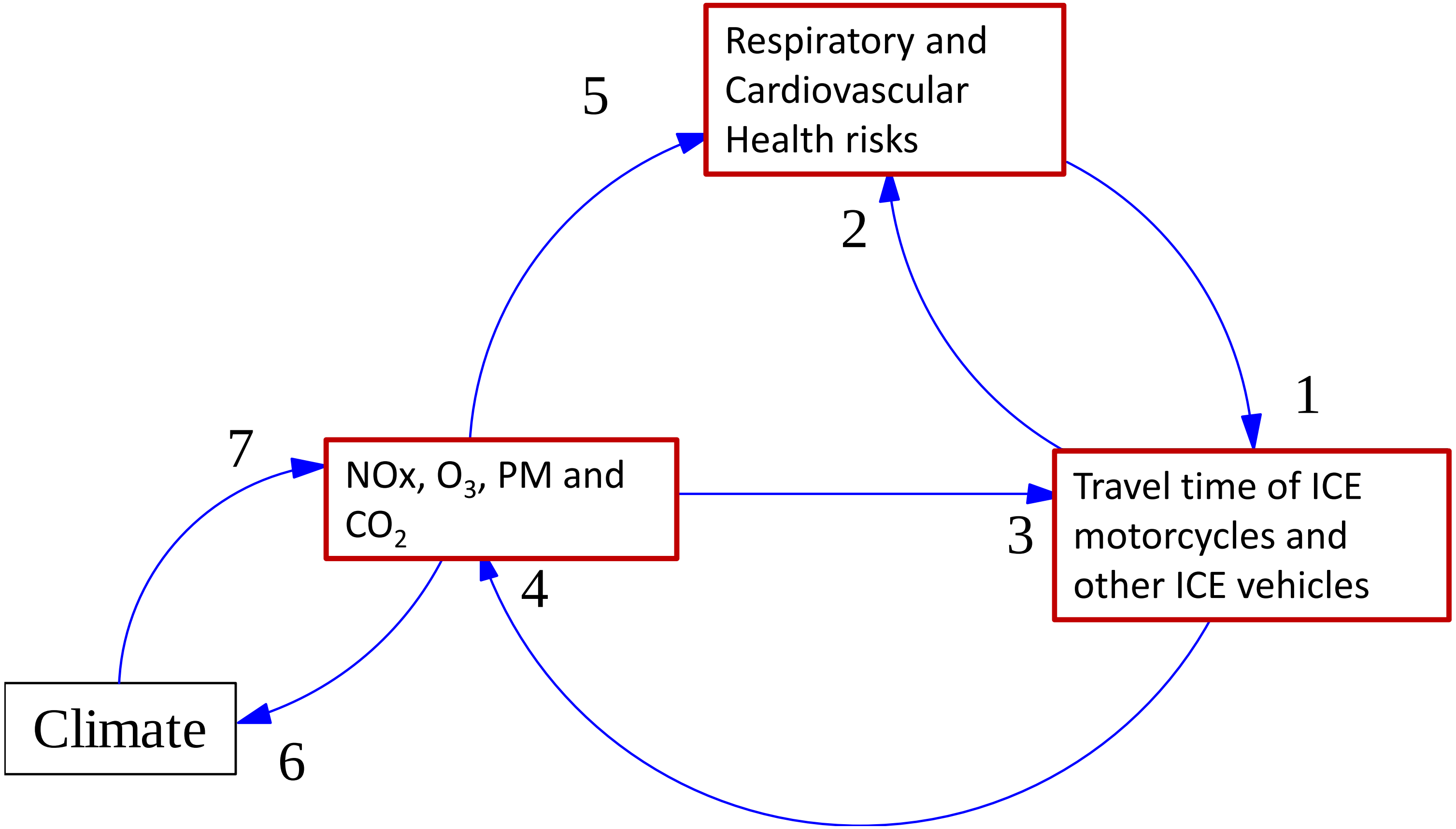
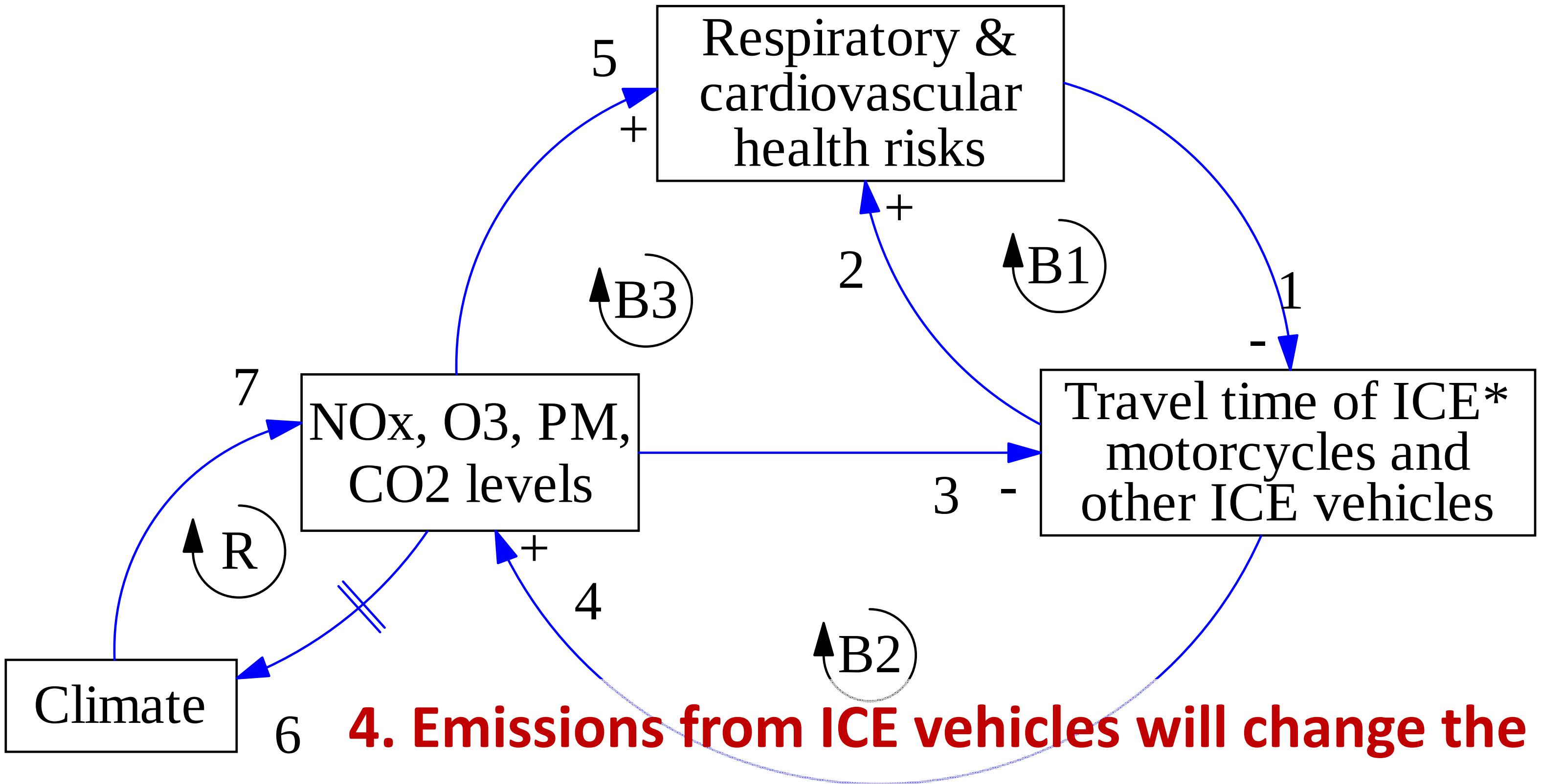


Figure 4. The specific targeted variables in the fields of transportation, air quality (and climate), and public health;
ICE: internal combustion engine; PM: particulate matter;

[Lung et al., 2013]

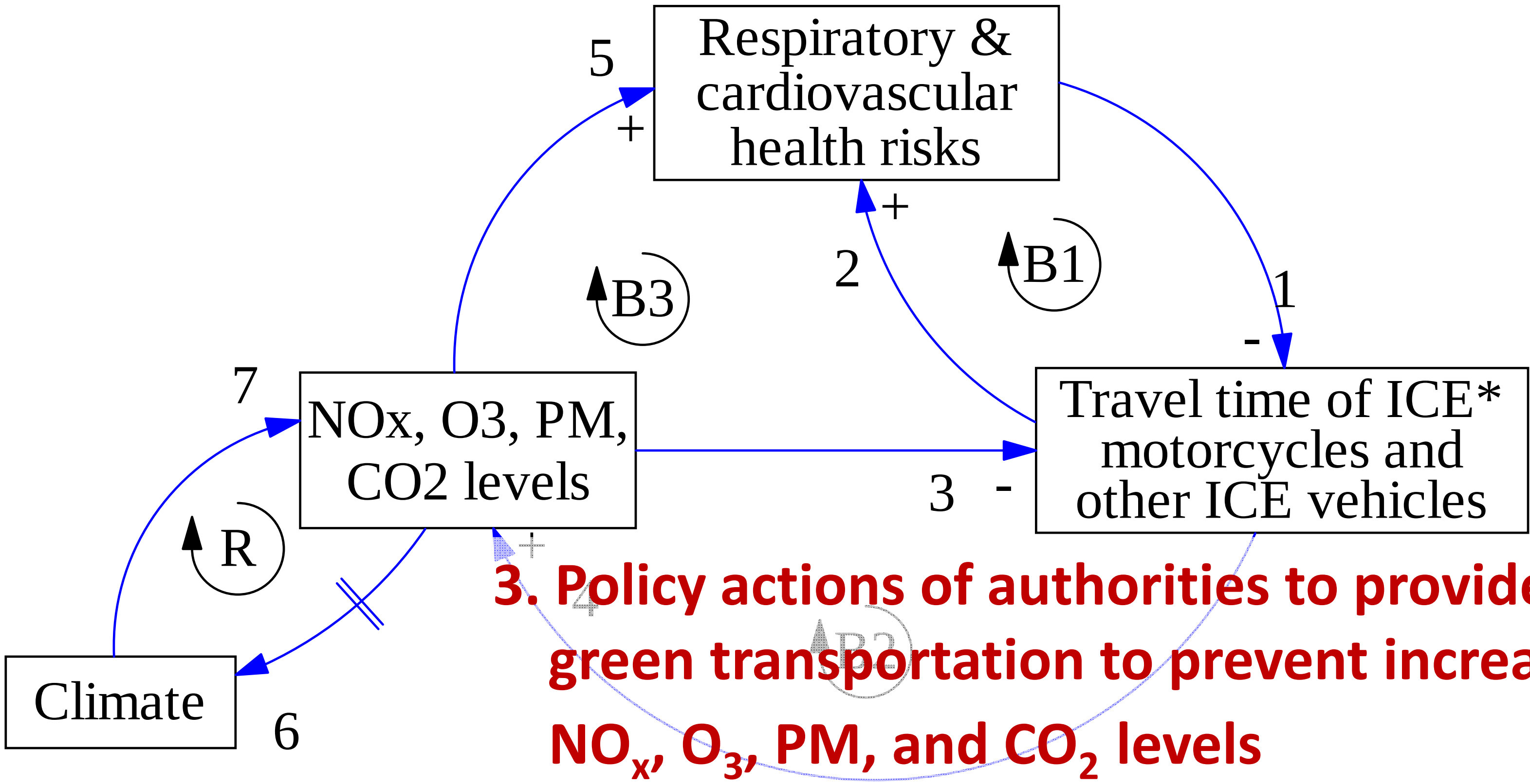
The specific stocks and processes



4. Emissions from ICE vehicles will change the levels of NO_x, O_3, PM, and CO_2 in the urban settings

Figure 2. System of Interest

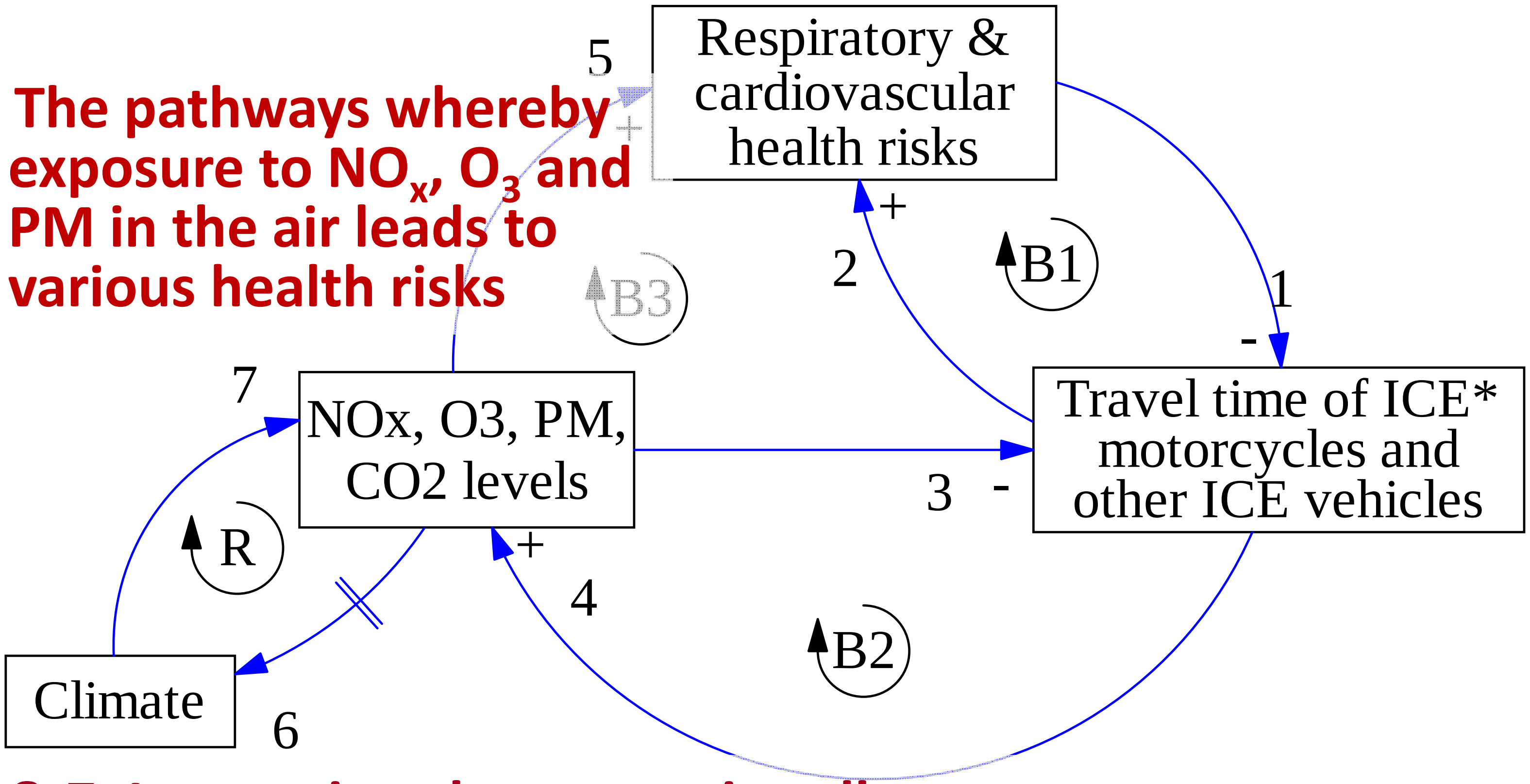
The specific stocks and processes



3. Policy actions of authorities to provide more green transportation to prevent increases of NO_x, O_3, PM, and CO_2 levels

Figure 2. System of Interest

The specific stocks and processes



5. The pathways whereby exposure to NO_x, O_3 and PM in the air leads to various health risks

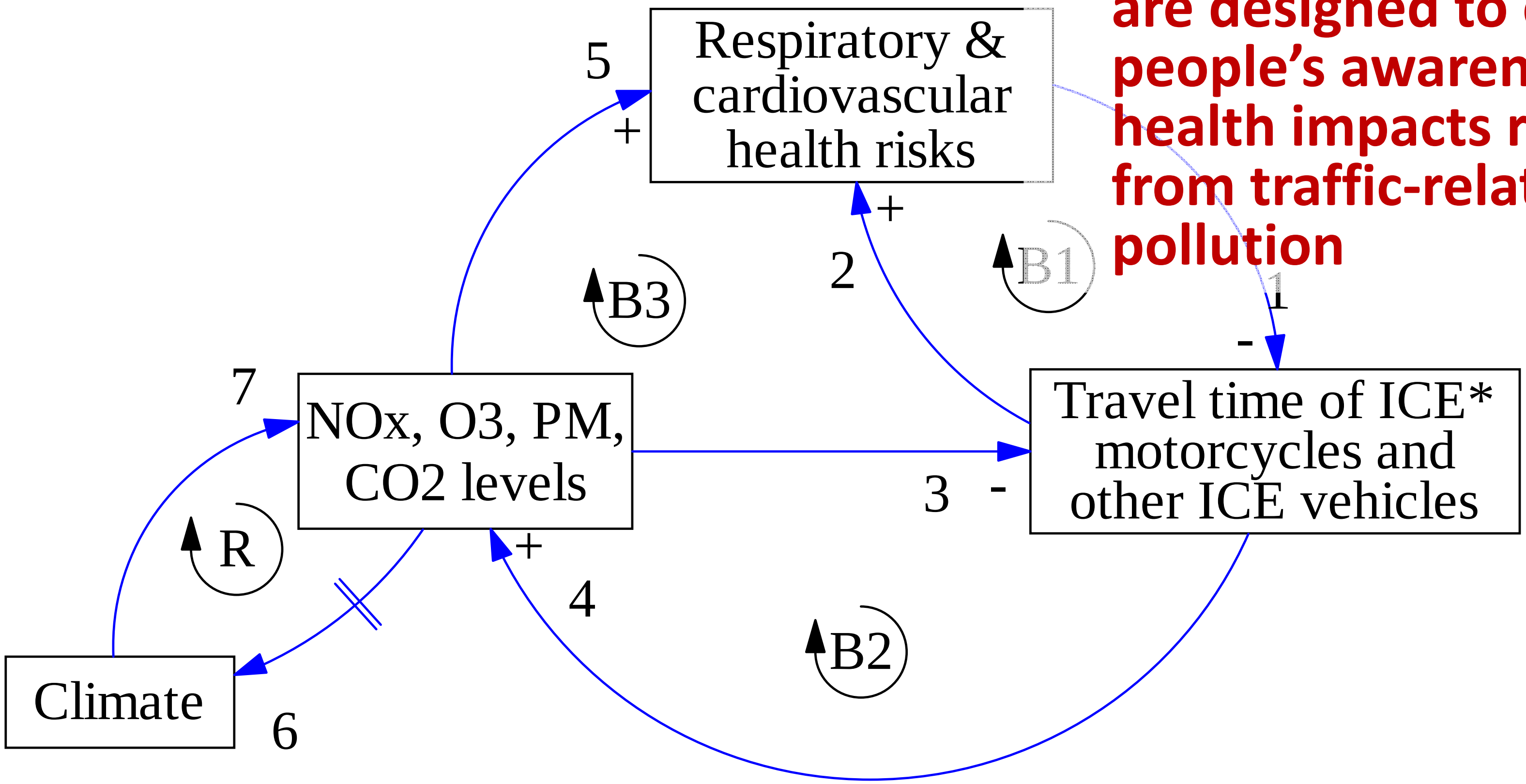
6. & 7. Interactions between air pollutant levels and climate conditions

Figure 2. System of Interest

SC LUNG 2019

The specific stocks and processes

1. Public health programs are designed to enhance people's awareness of health impacts resulted from traffic-related air pollution



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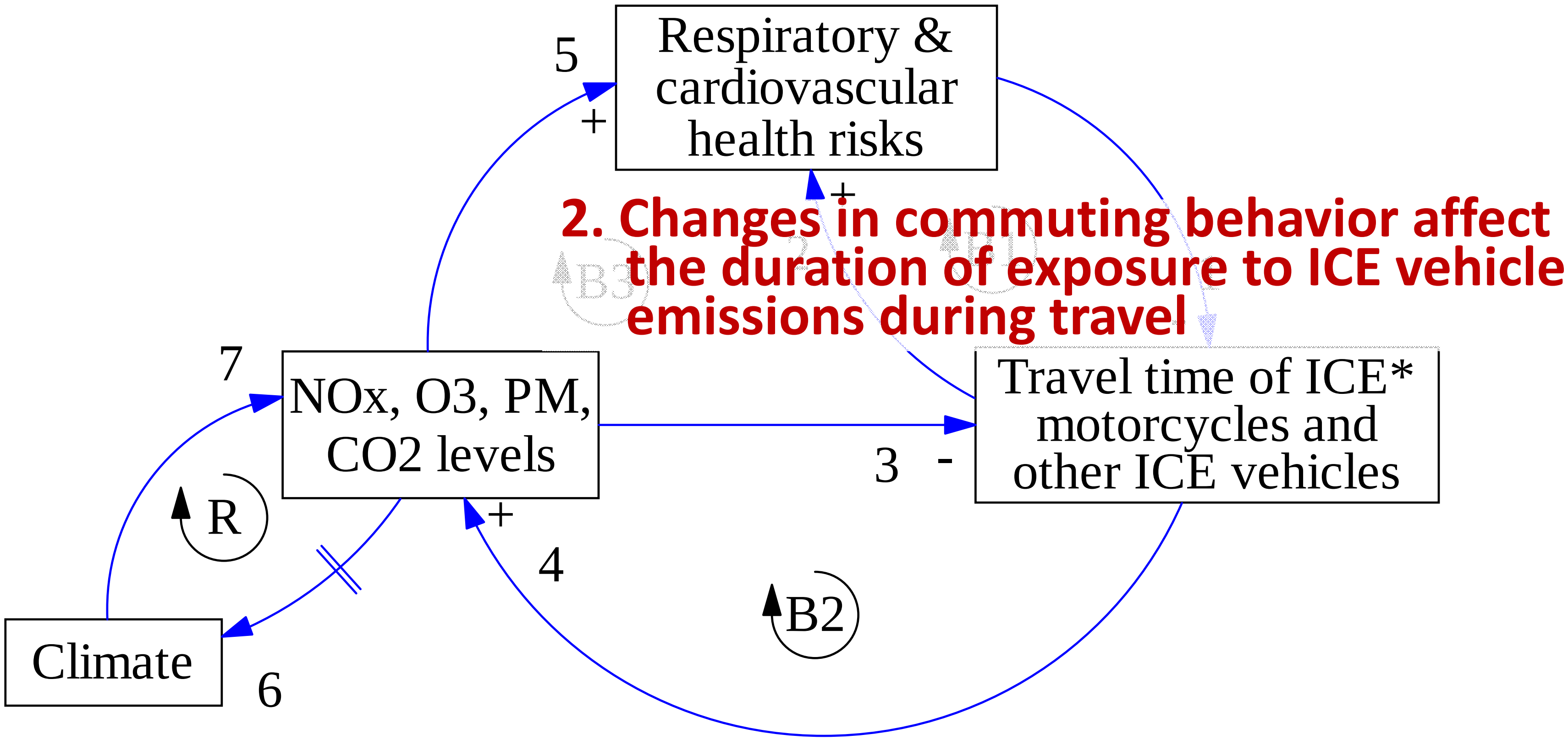


2. Changes in commuting behavior affect the duration of exposure to ICE vehicle emissions during travel

Figure 2. System of Interest

Step 3: Clarify Interactions among Systems

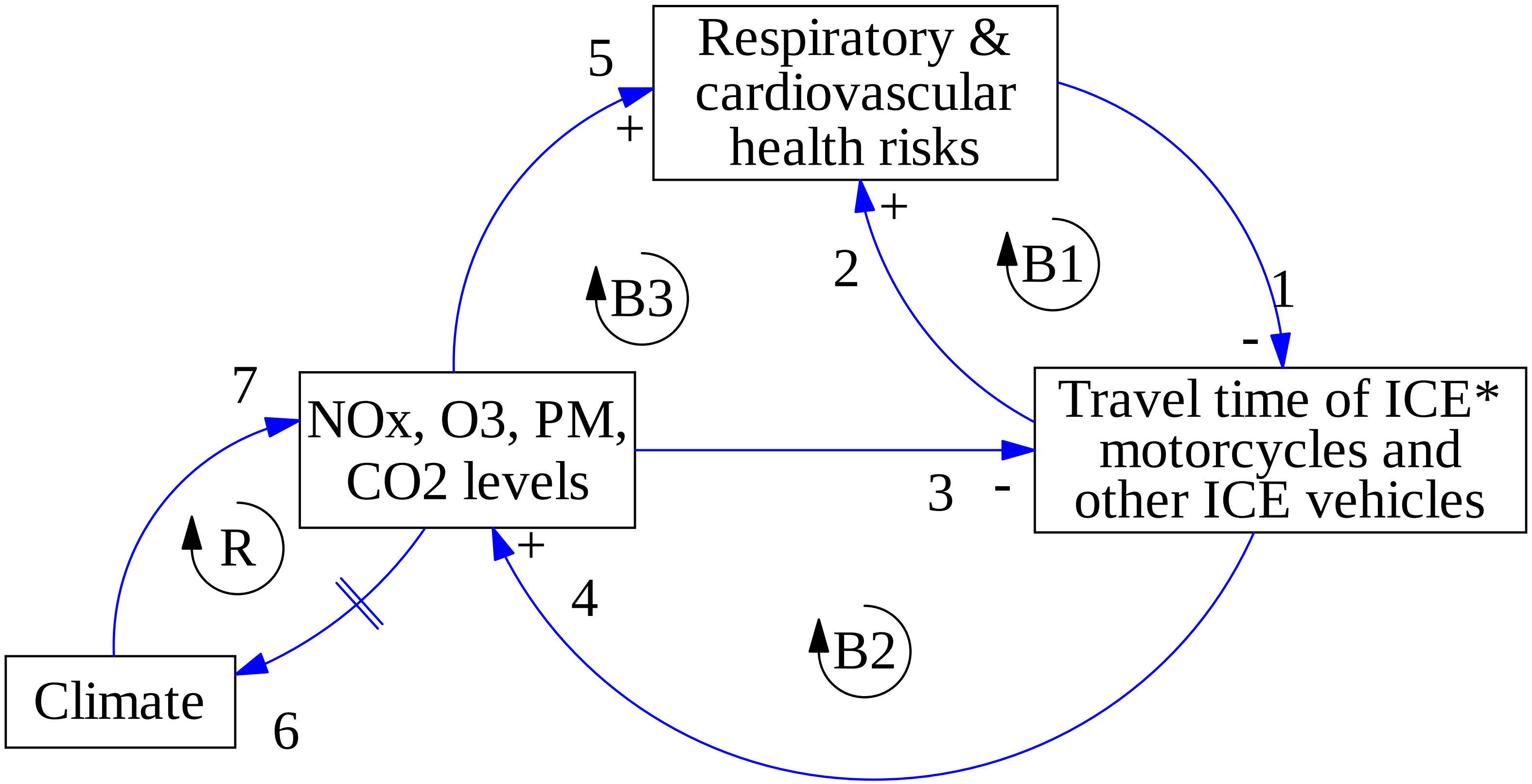


Figure 3. Clarify interactions among System of Interest
ICE: internal combustion engine; PM: particulate matter; B: balancing loop; B1= links 1 and 2; B2= links 3 and 4; B3=links 1, 4, and 5; R: reinforcing loop

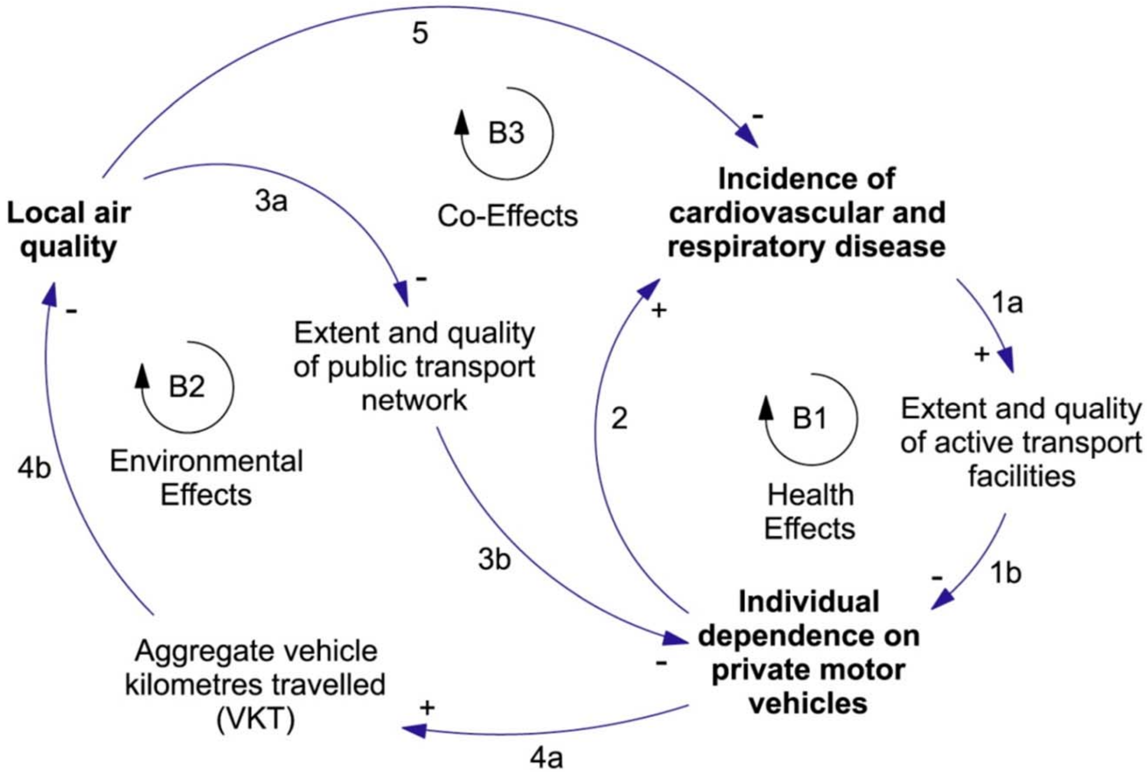
[Lung et al., 2013]

Advantages of applying CCM

- Present reinforcing or balancing relationships among systems based on integration of multidisciplinary knowledge, facilitating communication focusing on the interfaces of systems among experts from different disciplines
- Easier to identify potential intervention points and pathways as options for adaptation strategies
- Easier to examine the consistence in tempo-spatial scales of focused variables in each system which facilitate communication between scholars and stakeholders
- Facilitate the construction of transdisciplinary integration tools for research, policy and industry applications
- Identify interactions among different systems in advance to avoid policy surprises! (unwanted consequences due to unexpected interactions)

Step 4: Complicate CCM diagrams within each discipline

Figure 6. A causal loop diagram concerning selected co-effects of vehicle-dependence in urban settings. The arrows represent causal links and are labelled in accordance with the numbering scheme used in the Co-Effects Template. Each arrow has been assigned a polarity. The state-change processes represented by each arrow are described in Table 5. Links 1, 3 and 4 each have two components, labelled "a" and "b". The encircled symbols B1, B2 and B3 indicate that all three feedback loops are balancing.



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CCM for Cross-sector Collaboration for Health Adaptation (SC Lung modified from Proust et al., 2012)

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- Step 4: Complicate diagrams within your own system

- Reminders:
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Step 1: Identify Studied Systems

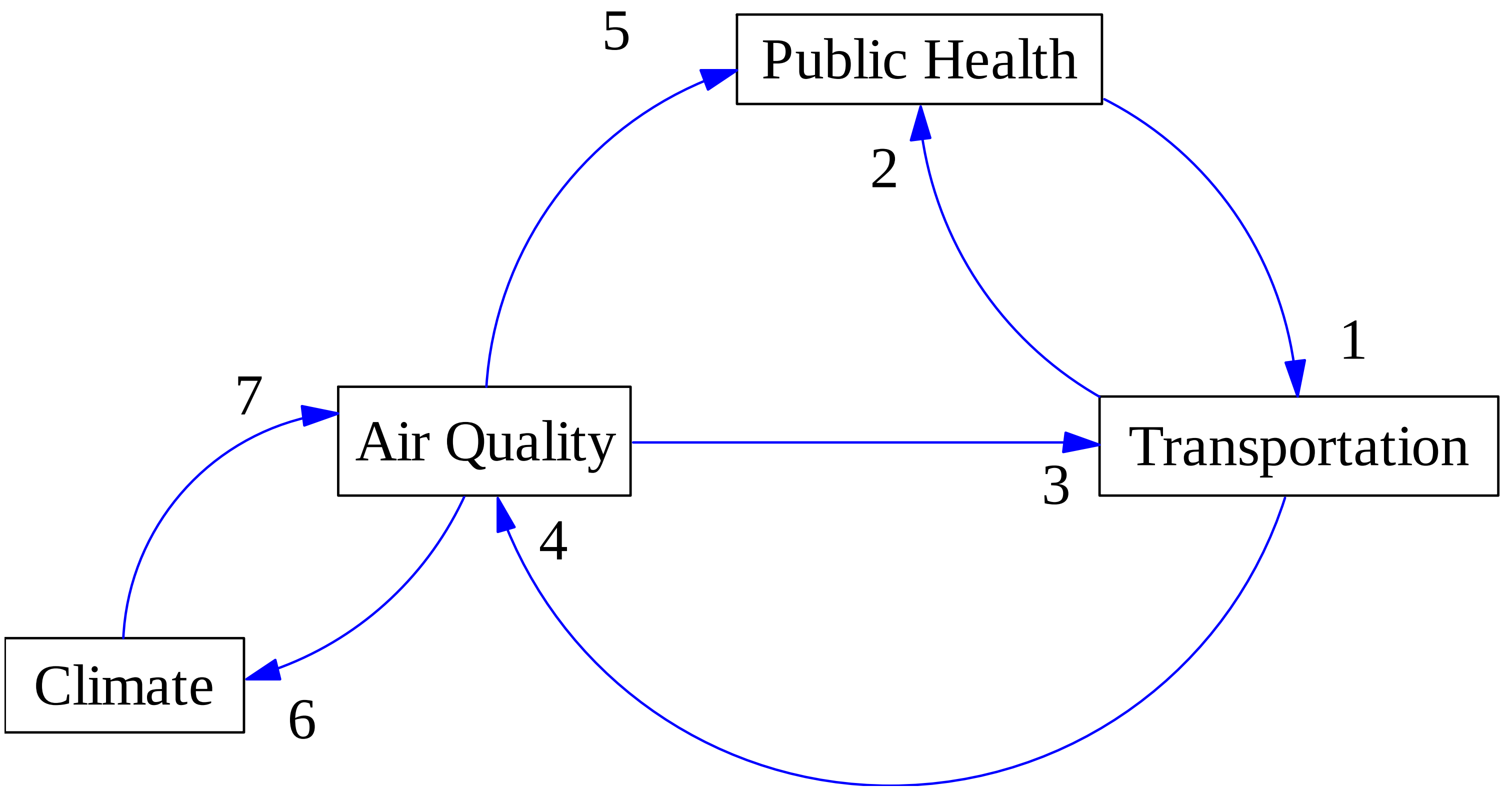
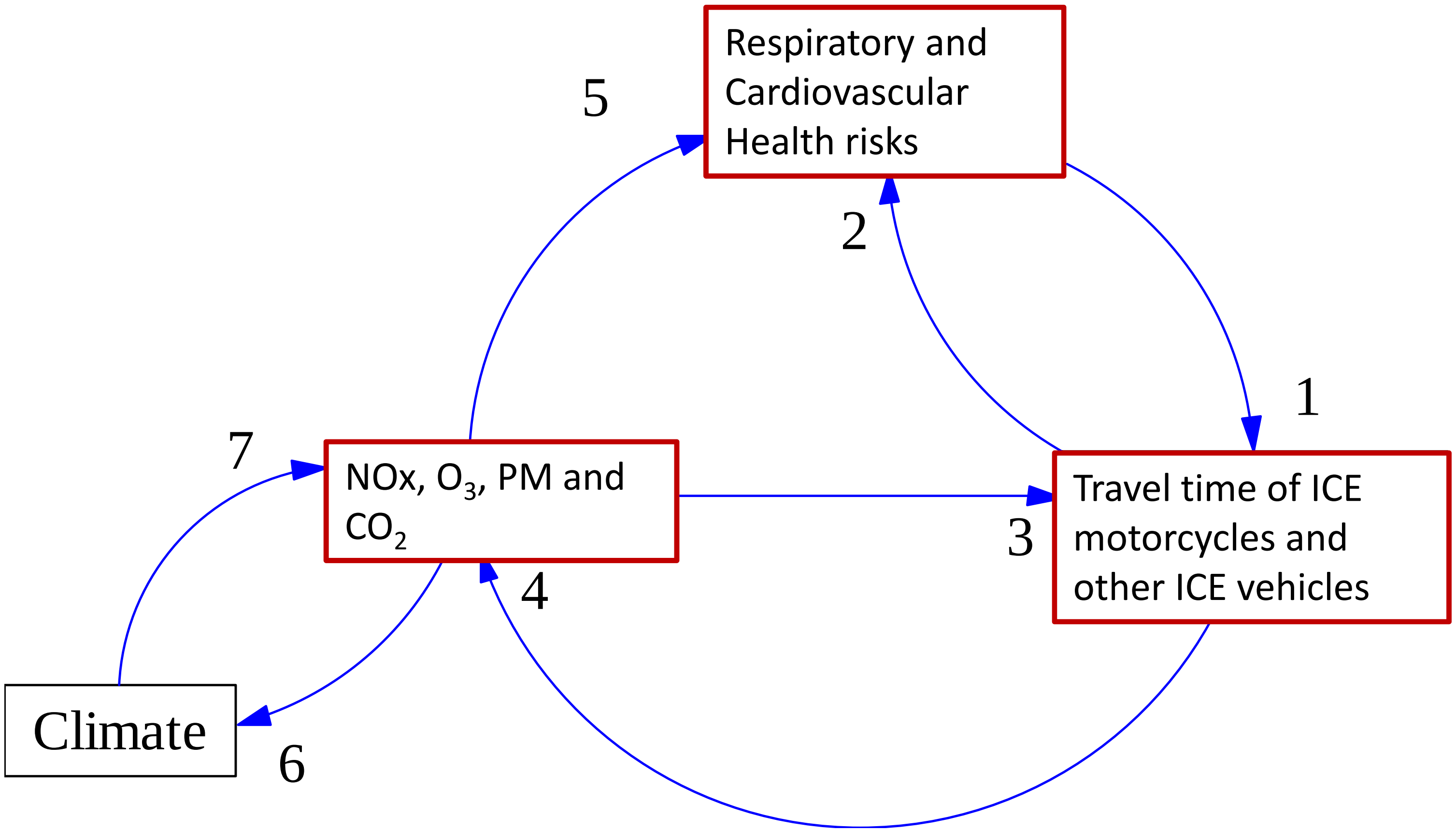


Figure 1. The conceptual interactions among transportation, air quality (and climate), and public health

[Lung et al., 2013]

Step 2: Identify Studied Variables



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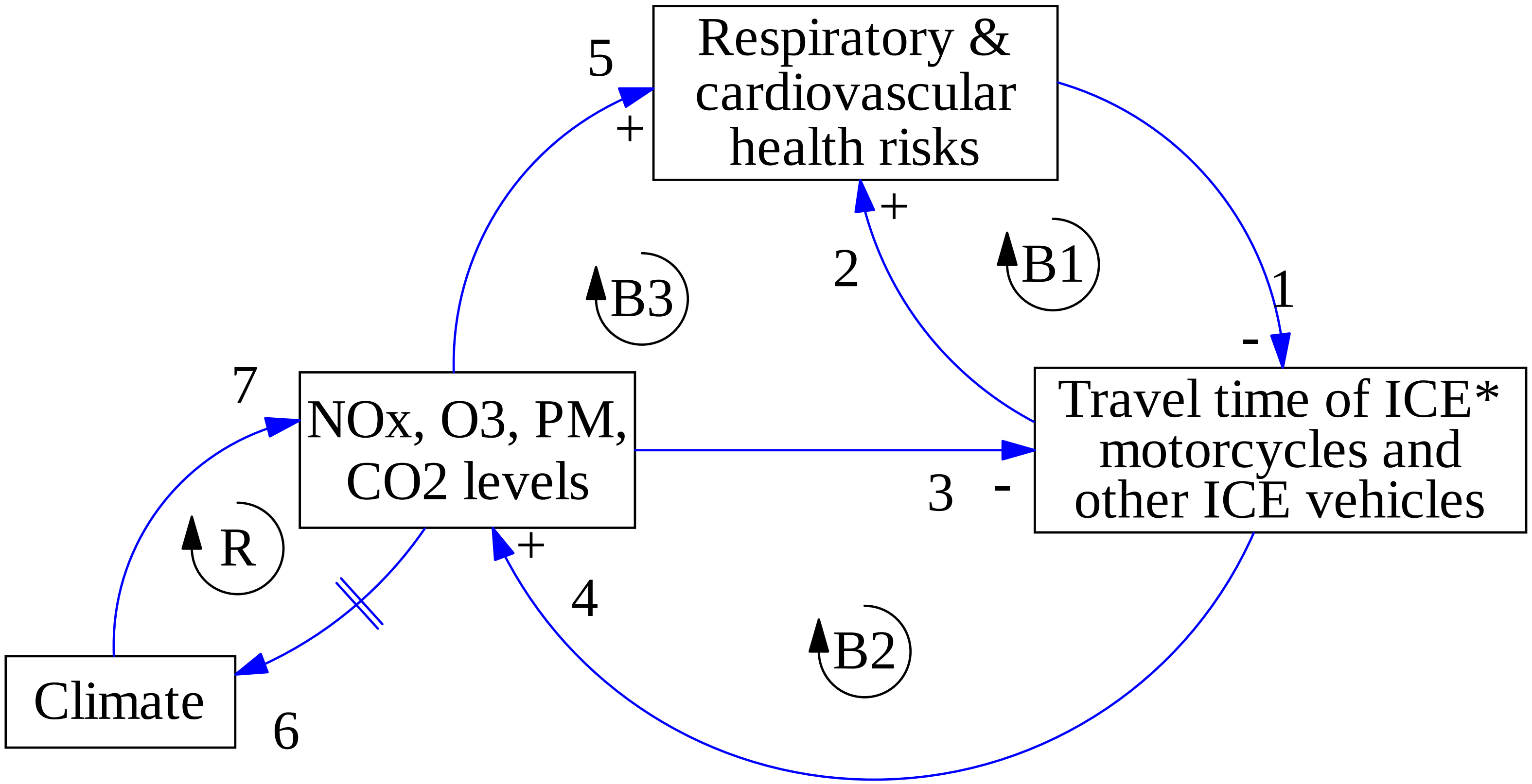

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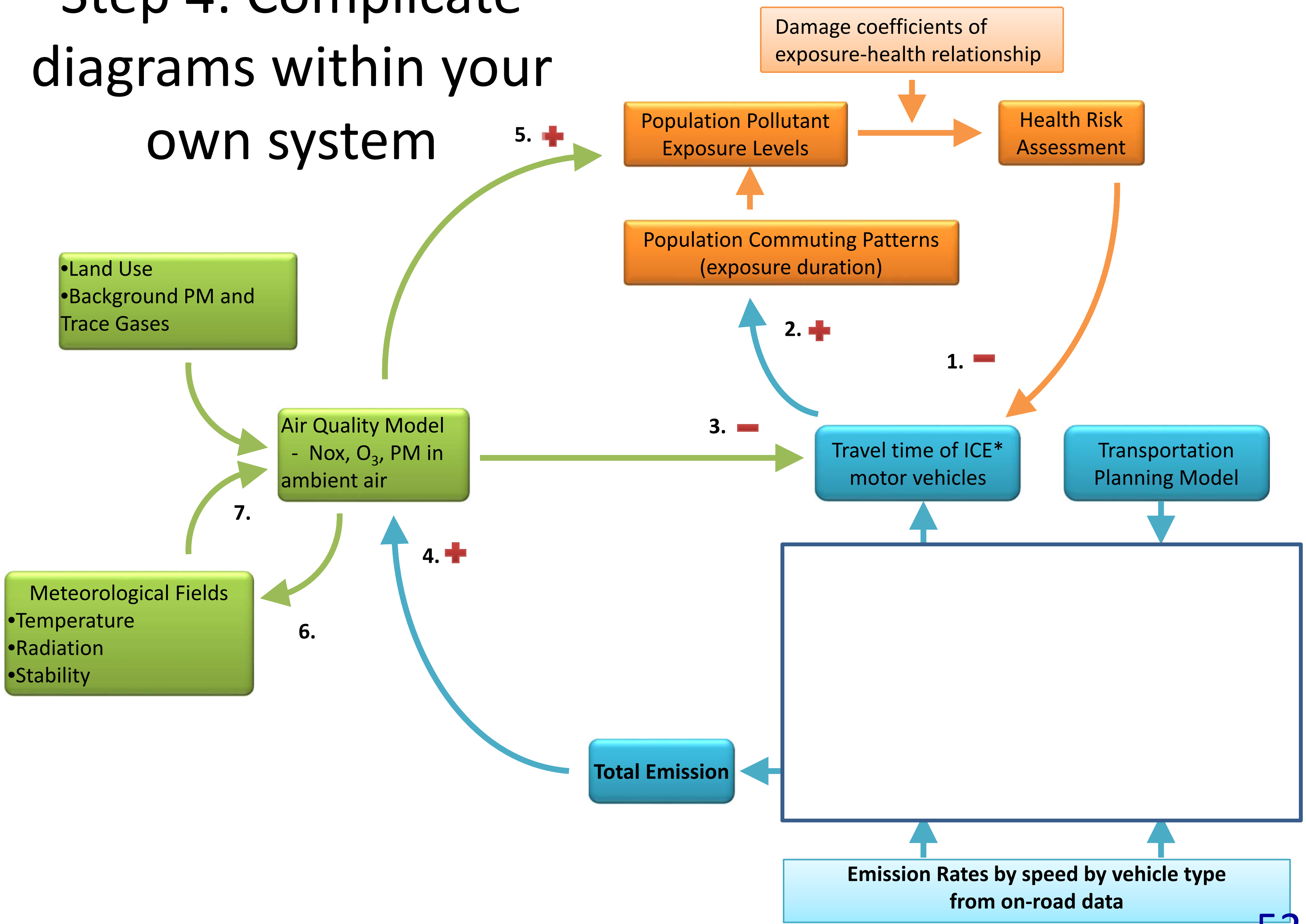
ICE: internal combustion engine; PM: particulate matter; B: balancing loop; B1= links 1 and 2; B2= links 3 and 4; B3=links 1, 4, and 5; R: reinforcing loop
[Lung et al., 2013]

Step 4: Complicate diagrams within your own system



Any Questions?

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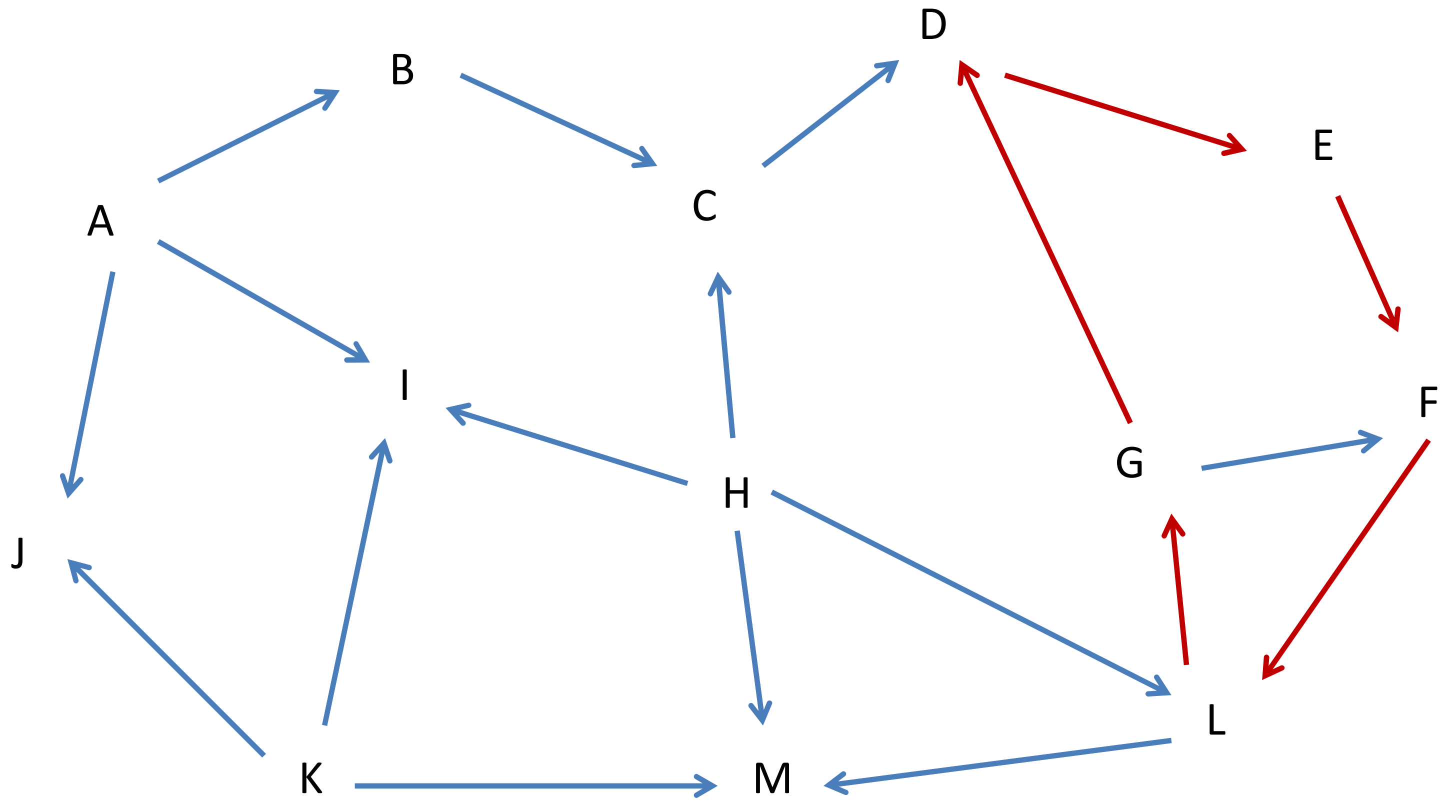
How many feedback loops?



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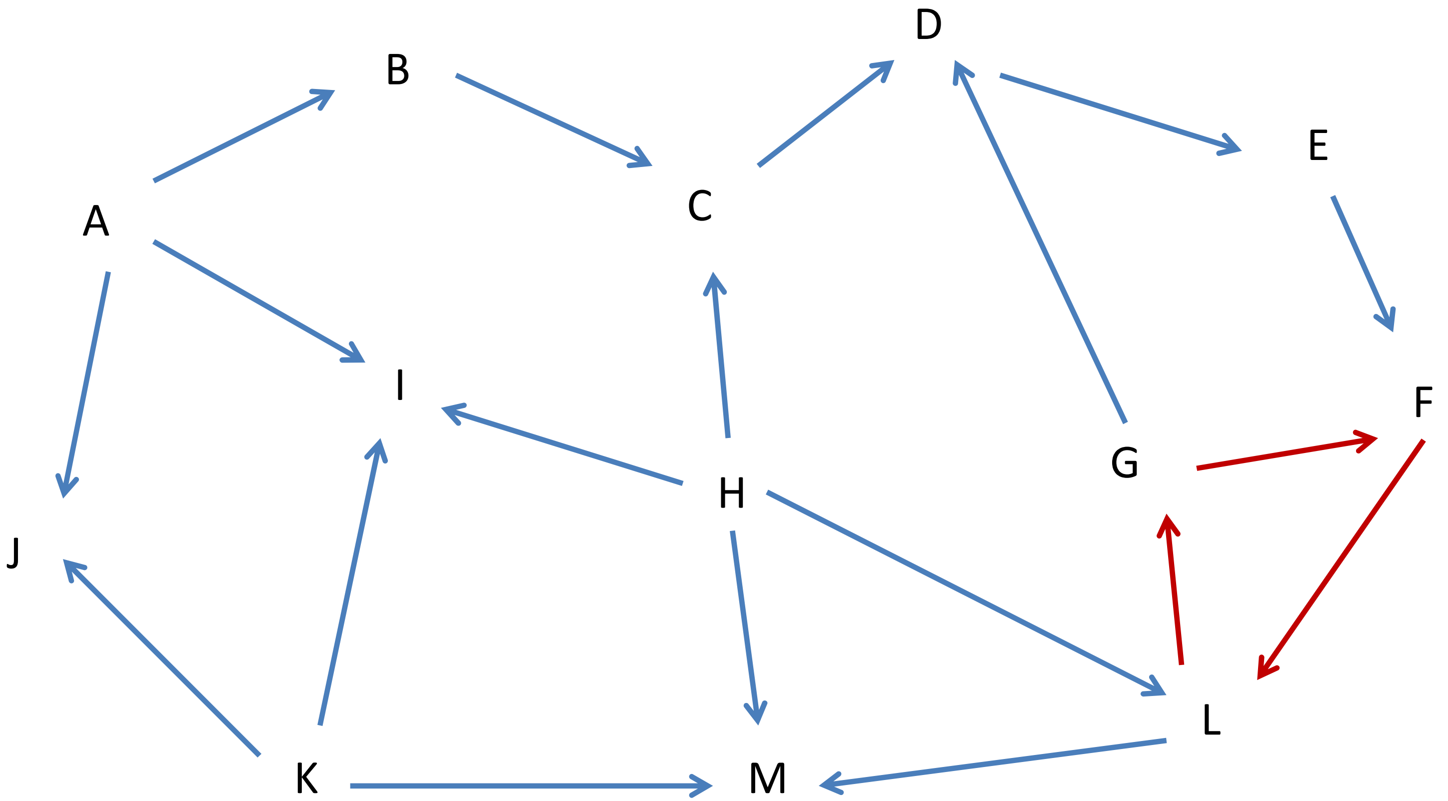

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