CUNY SPH GRADUATE SCHOOL OF PUBLIC HEALTH & HEALTH POLICY

CUNY SPH CENTER FOR SYSTEMS & COMMUNITY DESIGN

The Use of System Dynamics Modeling and Simulation to Address Complex Public Health Challenges

Nasim S. Sabounchi, PhD

Research Associate Professor

Department of Health Policy and Management

Center for Systems and Community Design

COPRH Con 2022

May 24th 2022

Outline

1. **Systems Thinking**

   What is complexity - Why we care about systems thinking

2. **System Dynamics Modeling**

   Understanding endogenous sources of system behavior

3. **Community System Dynamics Portal**

   Opioid Epidemic in New York State

4. **What can we do**

   Designing systems change strategies

Learning Objectives

- Understanding systems theory and the potential utility of system dynamics for research and action in public health
- Applying basic concepts of systems thinking: Drawing ‘balancing’ and ‘reinforcing’ loops
- Learning how systems science can be applied to complex public health challenges

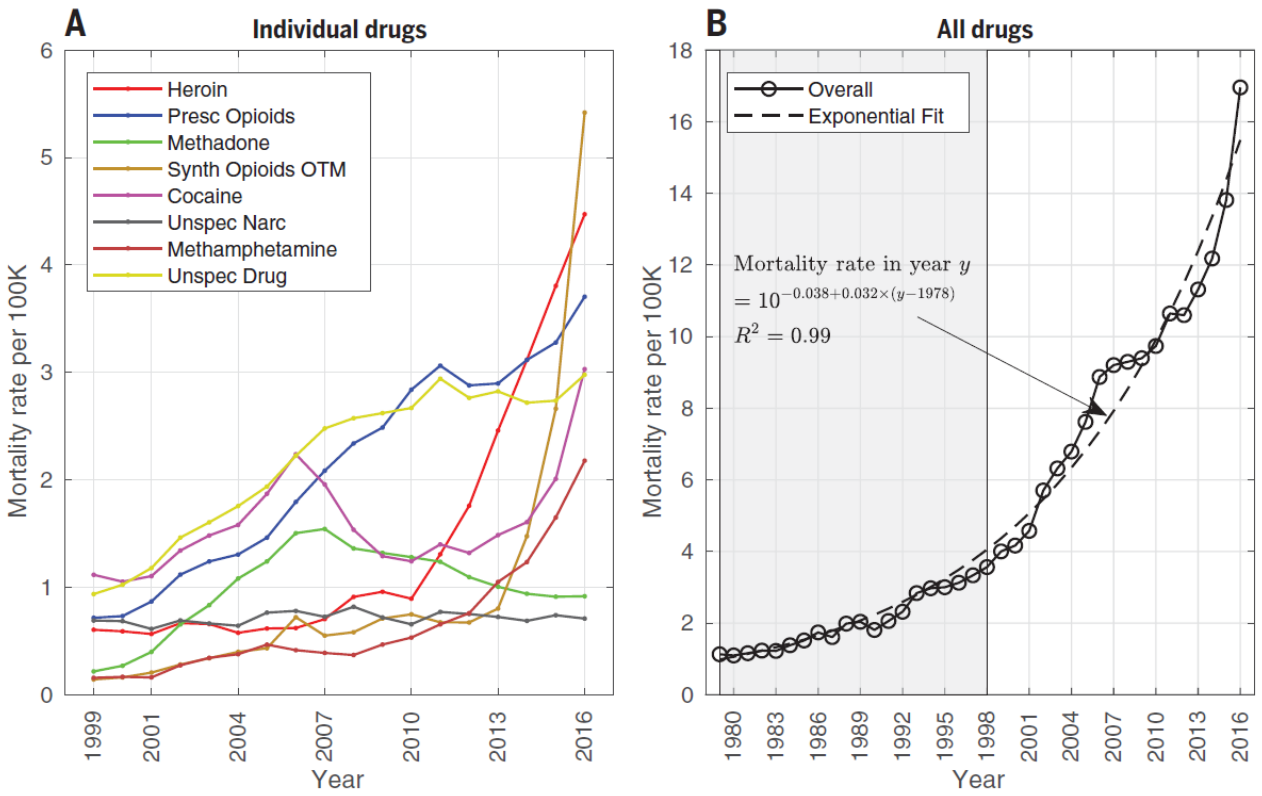
By the end of the workshop, participants will appreciate how to shift the mindset towards systems thinking and how system dynamics modeling is a novel, participatory, and ‘mixed methods’ research methodology well-suited to understanding and addressing diverse, complex problems in public health.

Systems Thinking

What is complexity?

Why we care about systems thinking

The Opioid Crisis: A Complex Challenge Nested Within and Impacting Multiple, Often Siloed Systems (GHPC, 2019)



Jalal et al. (2018) Changing dynamics of the drug overdose epidemic, *Science*

Why Systems Science Methods?

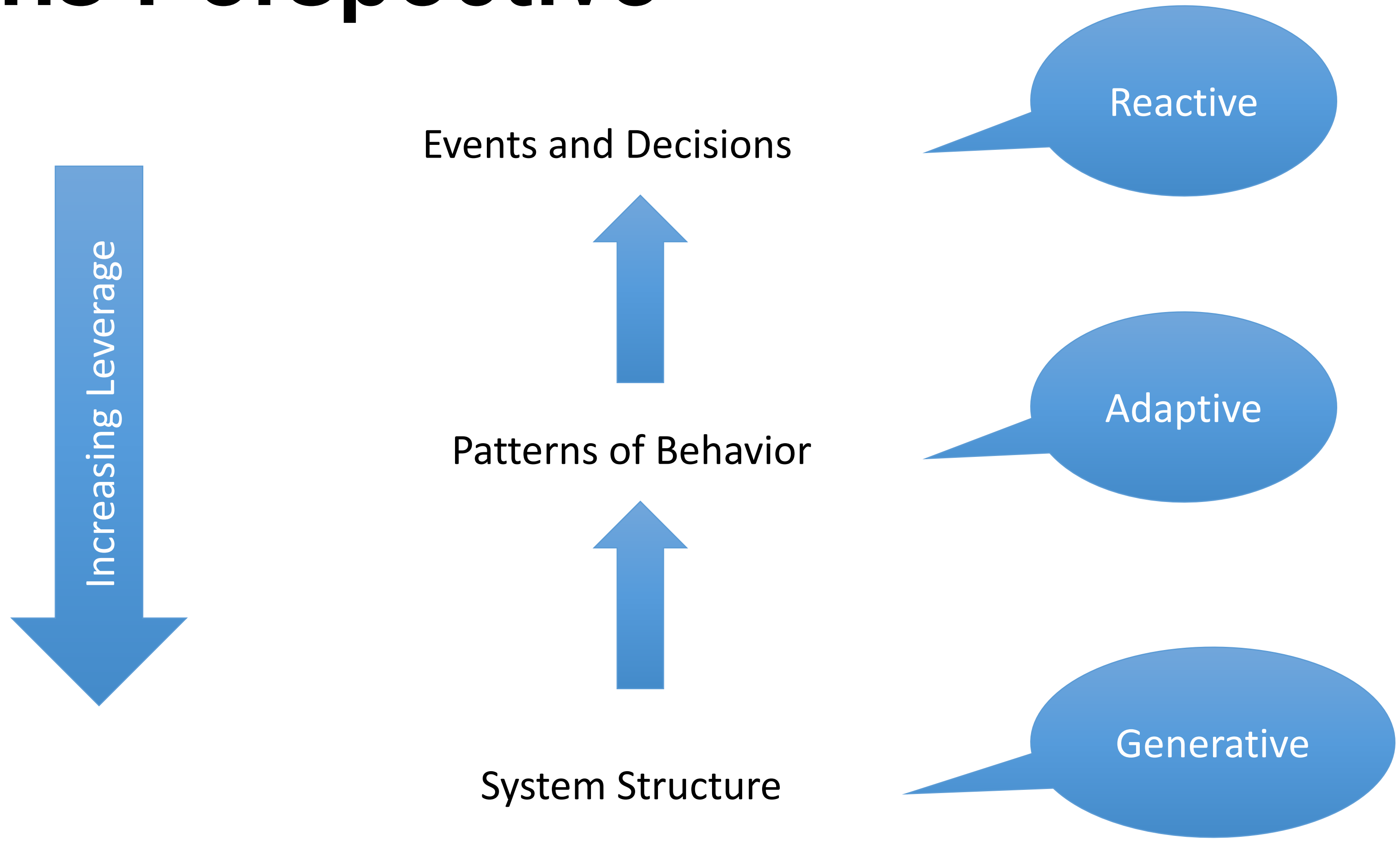
We need better tools for solving complex dynamic problems:

- Intractable, long-term, persistent problems that are not solved with singular solutions
- Singular solutions may worsen the problem because they fail to appreciate the way that these problems are embedded in larger systems
- To address these problems, there is a need for methods that can examine the system structures that impede and contribute to robust, sustainable change

Unintended Consequences

- Cutting cigarette nicotine levels leads to compensatory smoking
- Road building to combat traffic leads to more traffic
- Shrinking leisure time has been the result of working harder to make more money, to be happier
- War on drugs has contributed to higher profit margins for drug traffickers
- Reducing the number of opioid prescriptions, is not effective in reducing prescription related mortality
- Targeted anti-smoking programs lead to disproportionate targeting coupon programs by tobacco industry
- Antibiotic/pesticide overuse leads to pathogen resistance

A Systems Perspective



How to get people to that perspective?

George Richardson (1998)

Distancing

A systems view requires standing back just far enough to…

- Deliberately smooth discrete events into patterns of behavior
- A focus away from one-off event-oriented thinking to systems thinking about policy implementation and longer term benefits and risks

Systems Science Methodologies

- A broad class of methods to create tools and skills for **systems thinking**
  - Social Network Analysis
  - Micro-simulation Modeling
  - Agent-based Modeling
  - **System Dynamics Modeling**
- What is **system dynamics modeling**?
  - A computer-aided approach to policy analysis and design characterized by information feedback (i.e., circular causality) (Richardson, 1996)
  - [mathematically] A set of differential equations representing hypothesized time-dependent inter-dependencies among specified variables
  - [philosophically] A methodology intended to foster in-depth understanding about the 'structure' and 'behavior' of complex problems
  - [procedurally] **Group Model Building**: Stakeholder-driven, iterative deliberation

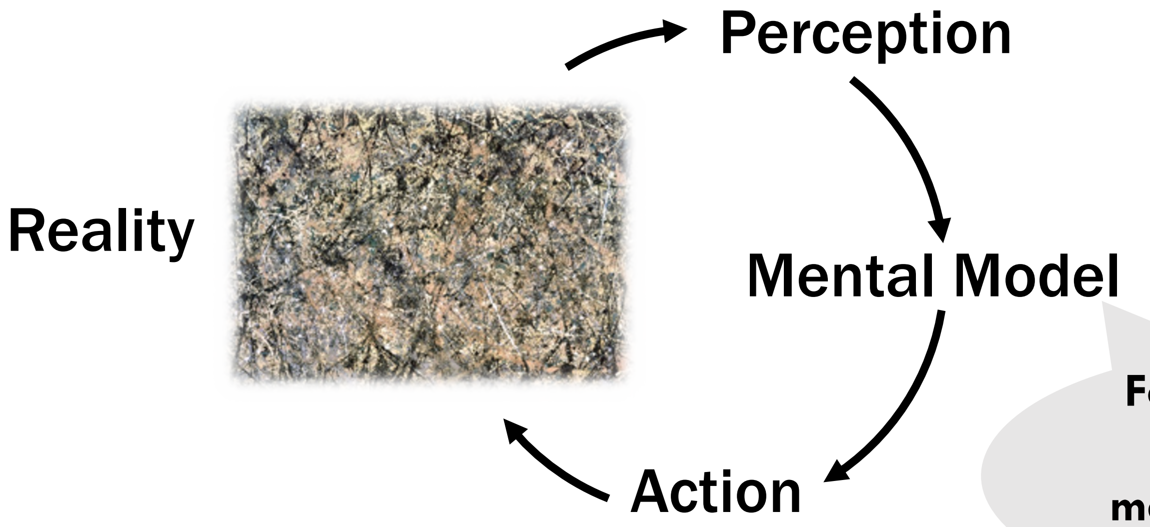
Systems Thinking Skills

Systems Thinking	Definition
Complex	**Forest not trees.** Relationships among two or more variables (wait times, improvement rate), or two or more settings (primary care, general mental health).
Feedback	**Loop not line.** Not simple cause and effect. The end of the story often influences the beginning, and is strengthened (reinforcing) or reduced (balancing) around the loop.
System Behavior	**Movie not snapshot.** Trends over time. Systems cause their own behavior through feedback.
Time	**Short and long term.** Better understanding of change over time (e.g., worse before better, better before worse).

Maani & Maharaj (2004); Sweeney & Sterman (2007).

System Dynamics Modeling

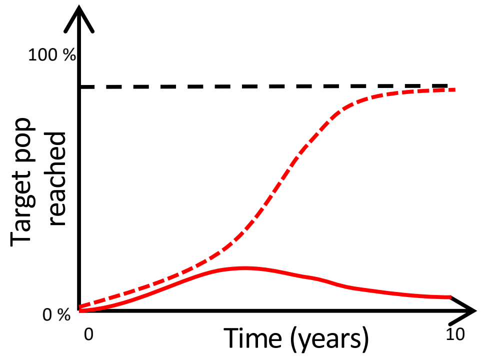
Mental models and systems thinking in a dynamically complex world



Focus in SD is on improving the mental models we use

- Doyle, J. K., & Ford, D. N. (1998). Mental models concepts for system dynamics research. *System Dynamics Review, 14*, 3-29.
- Johnson-Laird, P. (1983). *Mental models: Towards a cognitive science of language, inference and consciousness*. Cambridge, MA: Harvard University Press.
- Axelrod, R. (Ed.). (1976). *Structure of decision: The cognitive maps of political elites*. Princeton, NJ: Princeton: Princeton University Press.

Three general systems science tools for studying complexity

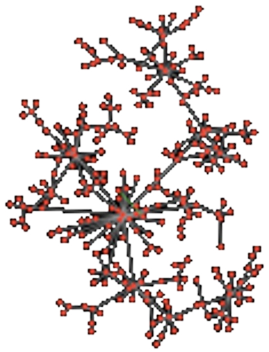


H1

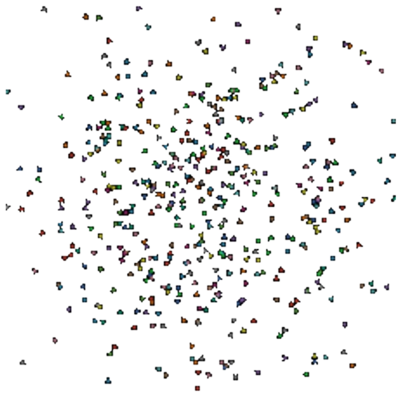
H2

H3

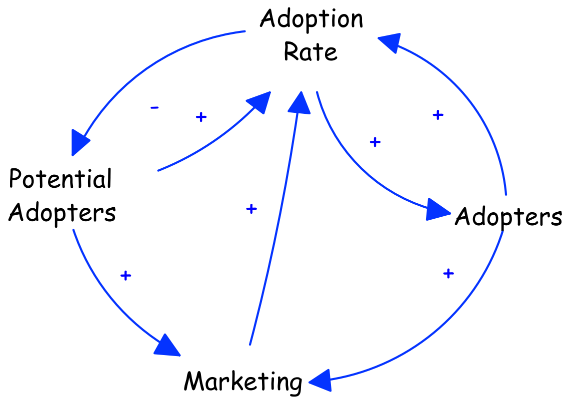
Social networks



Rules of actors



Feedback mechanisms

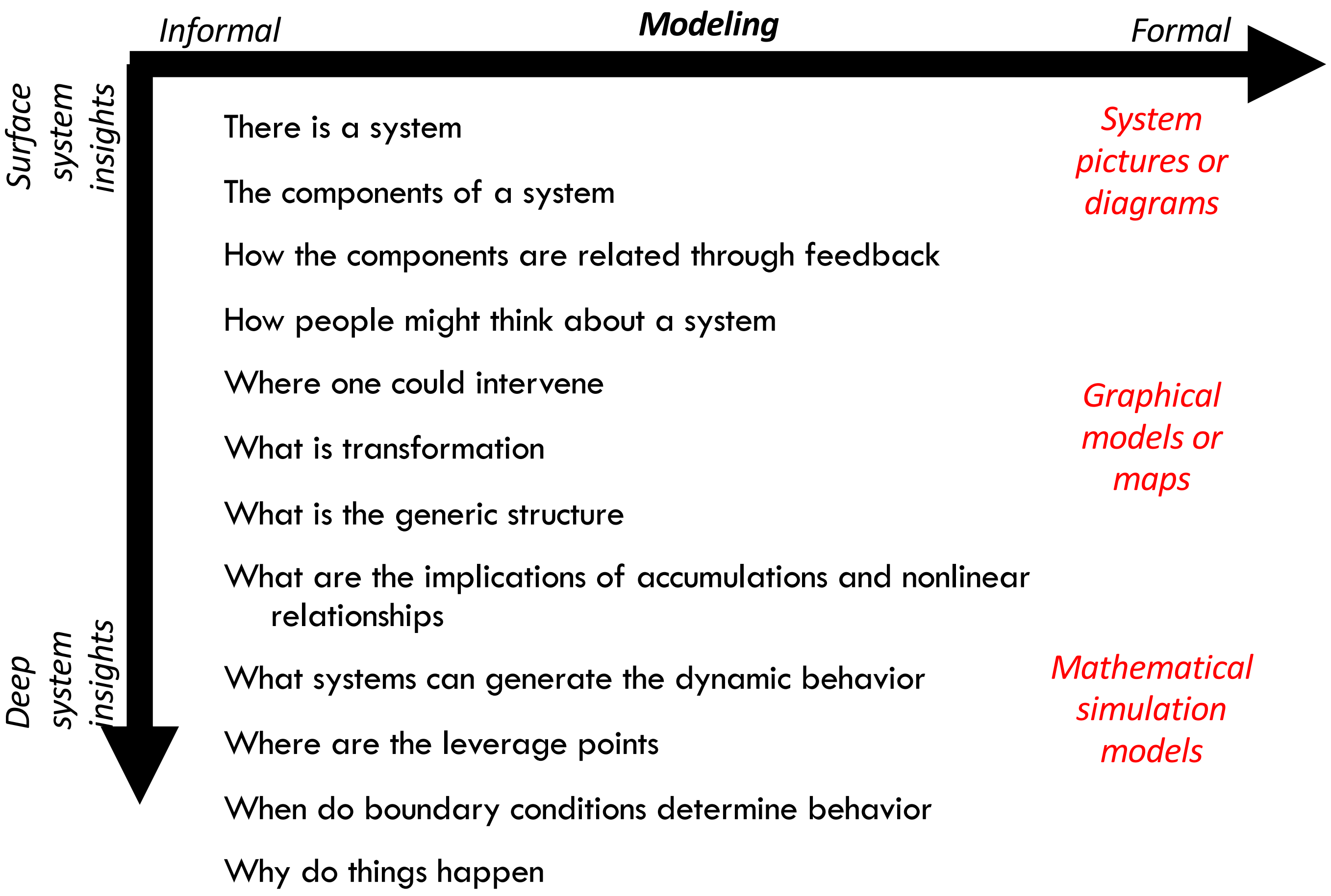


System Dynamics

- Field invented by Jay W. Forrester at MIT in 1958
- System dynamics:
  - "The use of informal maps and formal models with computer simulation to uncover and understand *endogenous sources* of system behavior" [emphasis added] (Richardson, 2011, p. 241)
- Foundations of system dynamics:
  - Endogenous or feedback perspective
    - Stock or level (state) variables representing accumulations
      - Flow or rate variables representing activity
        - Using computers to simulate more realistic mathematical model

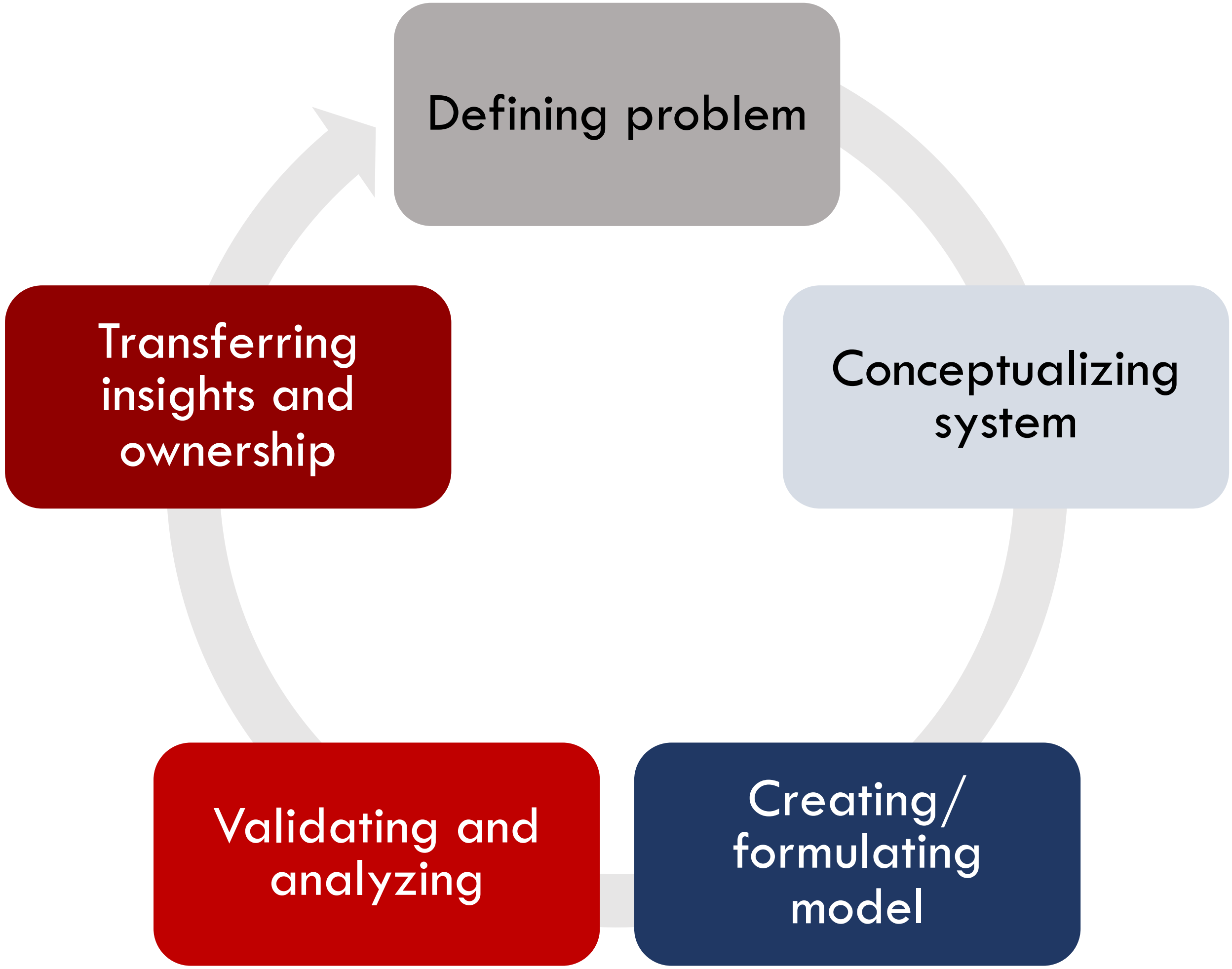
Richardson, G.P. (2011). Reflections on the foundations of system dynamics. *System Dynamics Review, 27*(3), 219-243.

Different types of models for different types of system insights

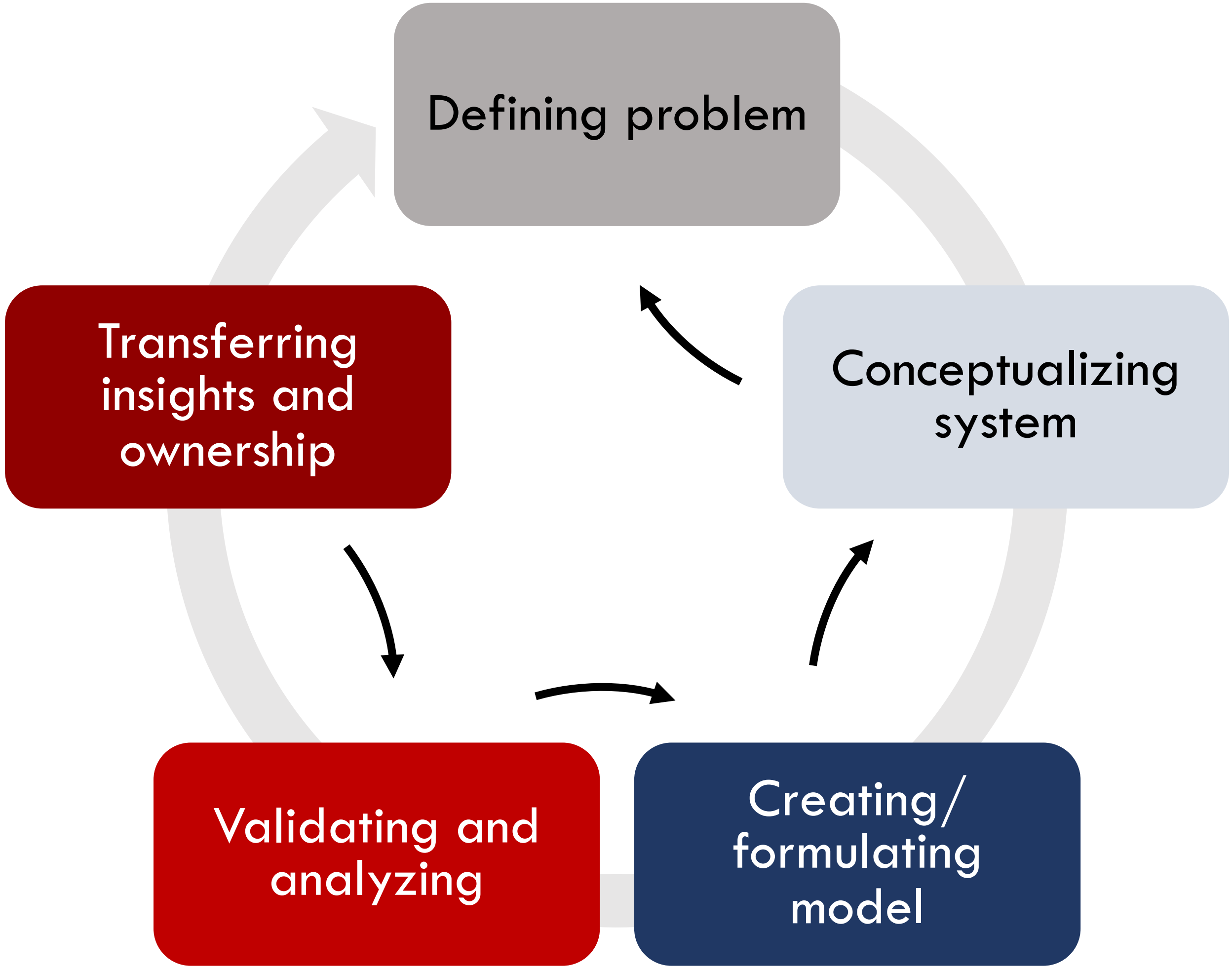


Hovmand, P. S. (2014). Community based system dynamics. Springer.

SD Modeling Process



SD modeling process is iterative



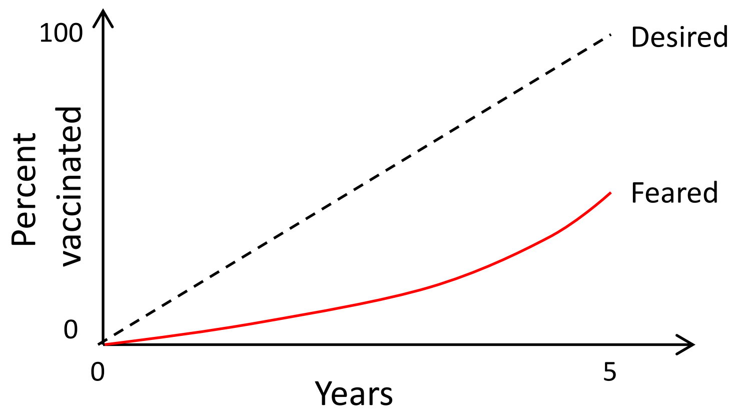
Defining Problem

In system dynamics, **we start** with a **dynamic** problem (i.e., “We model problems, not systems”)

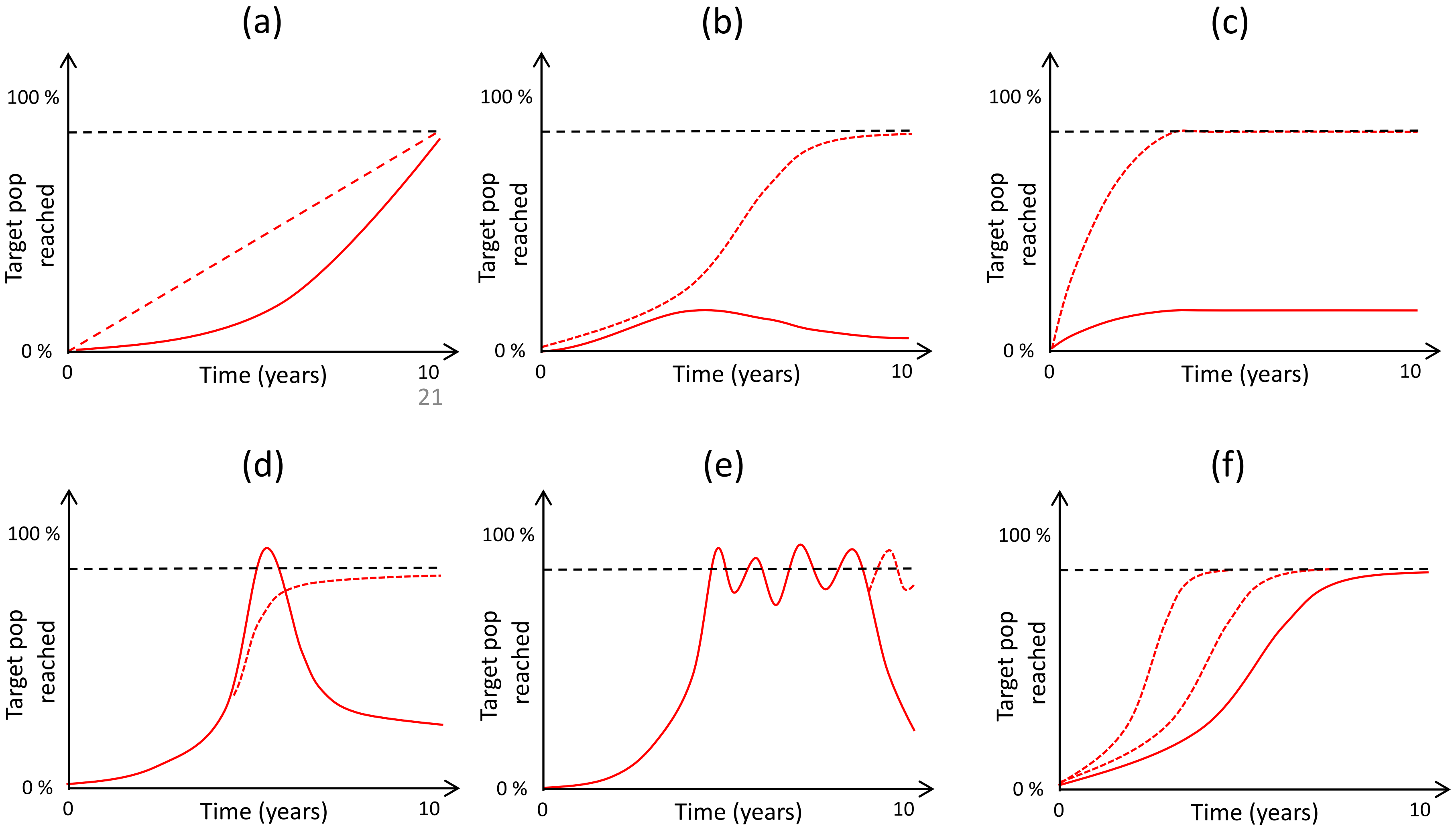
(A) Scaling up as a static problem

- The partnering organizations might not be ready
- There might not be enough vaccines
- We don’t have enough trained staff
- We’re worried about demand for the vaccine and whether or not they will families will want to have their children vaccinated
- We are not sure how many children a community health worker vaccinate each year
- There are problems with transportation

(B) Scaling up as a dynamic problem



Examples of different system dynamics behavior (dashed line represents desired trajectory)

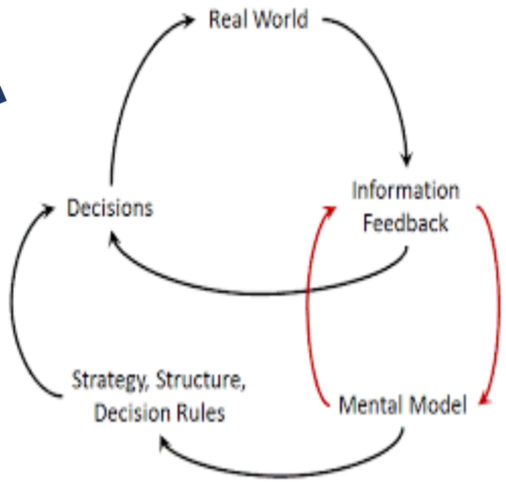


Group Model Building

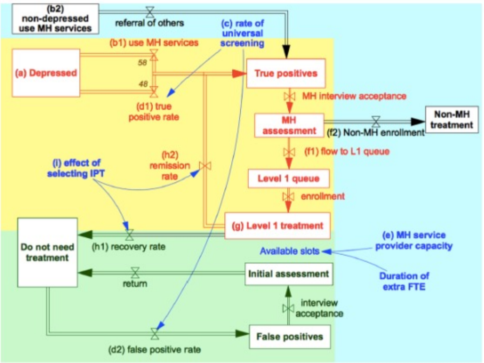
System Dynamics Modeling is Participatory

Stakeholder engagement

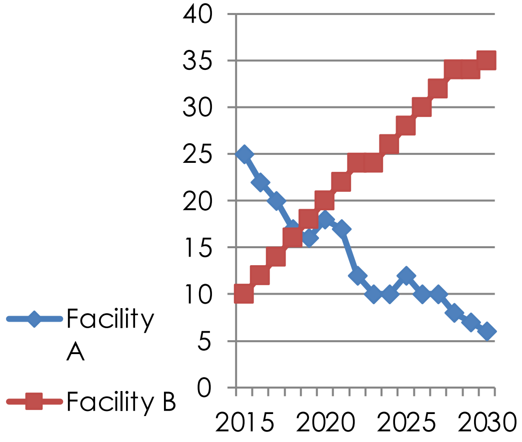
Mental models made explicit



System 'structure' formulated and calibrated

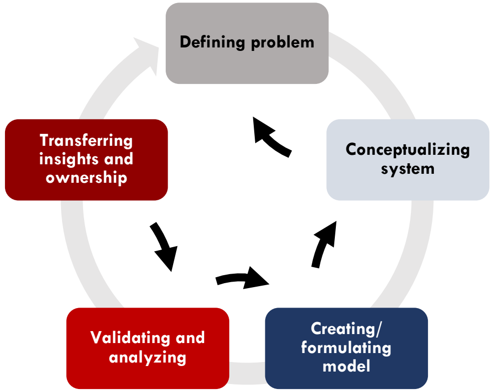


Model 'behavior' evaluated



Group Model Building (GMB) as a strategy to tackle the persistent problem

- Method of involving participants and other stakeholders in the process of building **system dynamics** models:



- **Reasons for using**
  - Taking a fresh look at current efforts
  - Identifying and sharing insights
  - Building shared capacity for systems change
  - Improving design and implementation of interventions and policies

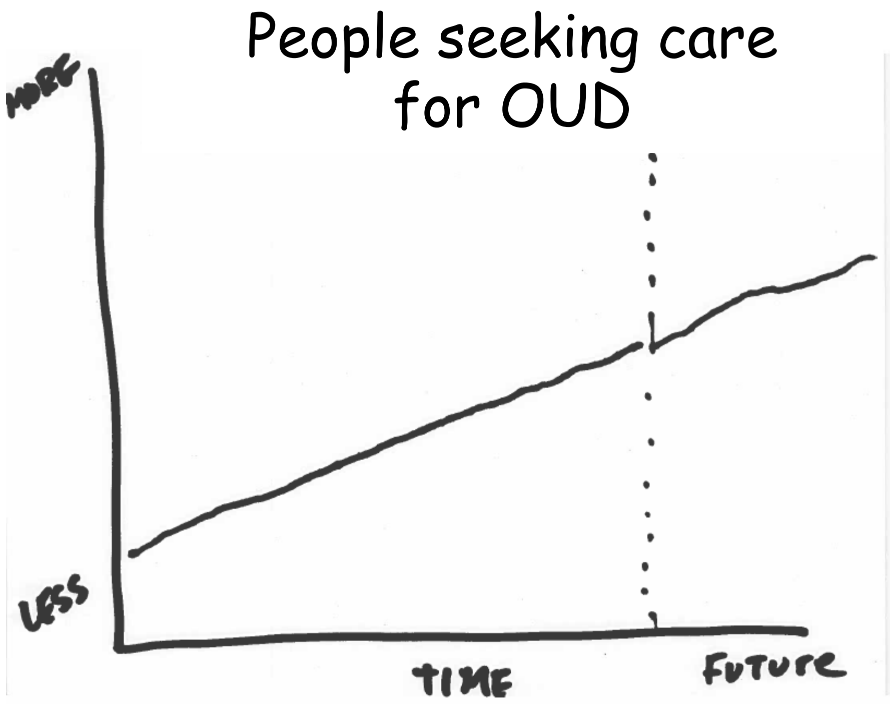
Hovmand, P. S. *Group model building* [PowerPoint slides].

Stakeholders in the Room

- Westchester Commissioner
- Community SUD coalitions and SUD committee groups
- SUD treatment, recovery, and prevention providers-SUD, MH and PC agencies - Directors
- Peers, advocates, and family members
- Housing and homeless shelter providers - directors
- Social services - senior staff
- Health Department - senior staff
- Outpatient and methadone clinics - senior staff

Drawing Behavior Over Time Graphs (BOTGs)

- ***What are the drivers that contribute to your implementation challenges?***
- Probe: Indicate the past, the present, and your expected (near) future in your graph
- For example:
  - # of people seeking care for OUD
  - # of primary care doctors trained in medication-assisted treatment (MAT) for OUD
  - Use of remote technology for OUD support



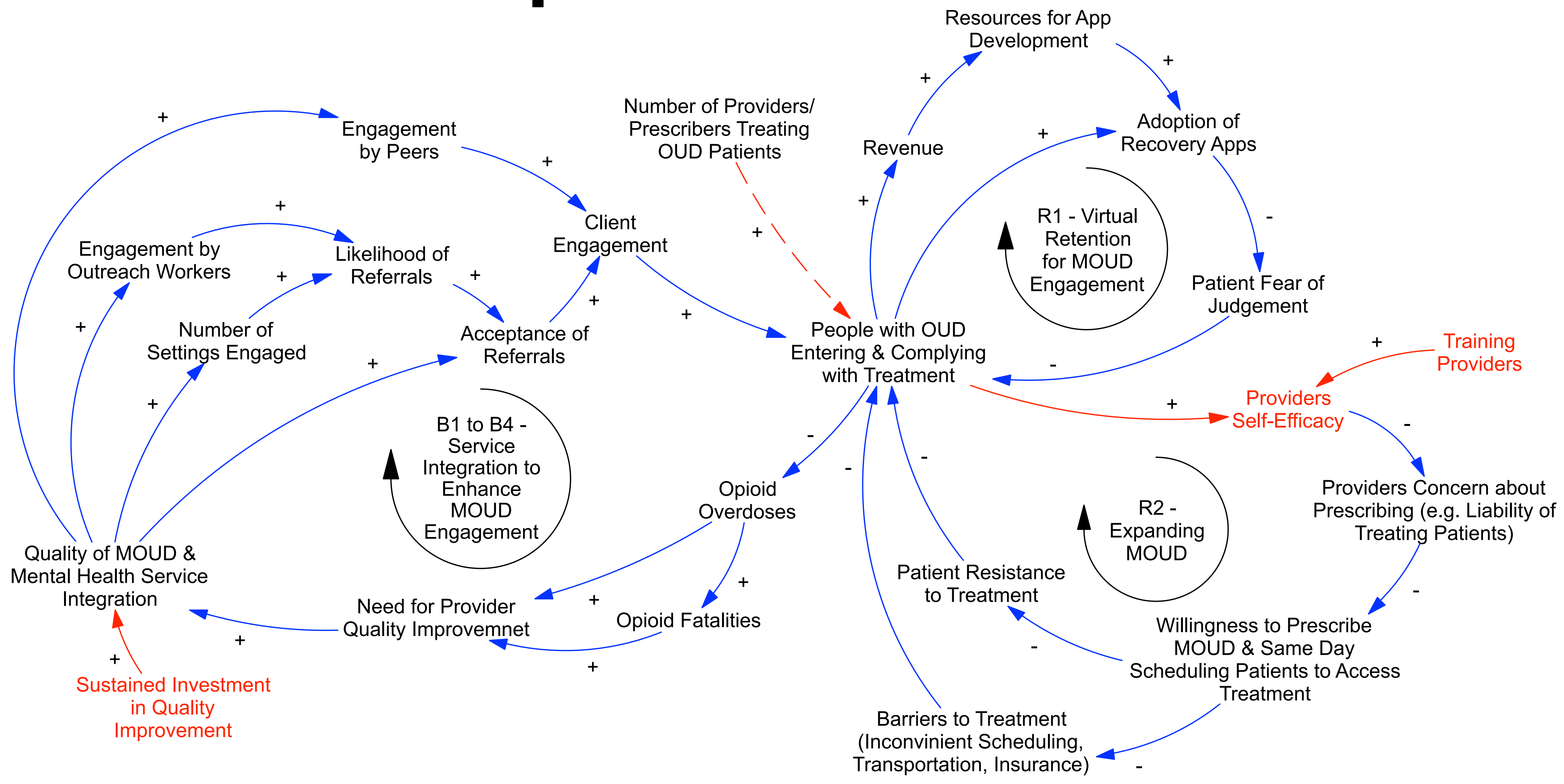
Drawing Causal Loop Diagrams (CLDs)

Goal: To create CLDs depicting causal linkages between variables identified during the BOTG exercise. The CLDs will be used to identify feedback loops that will describe dynamic hypotheses on the basis of which formal modeling will start.

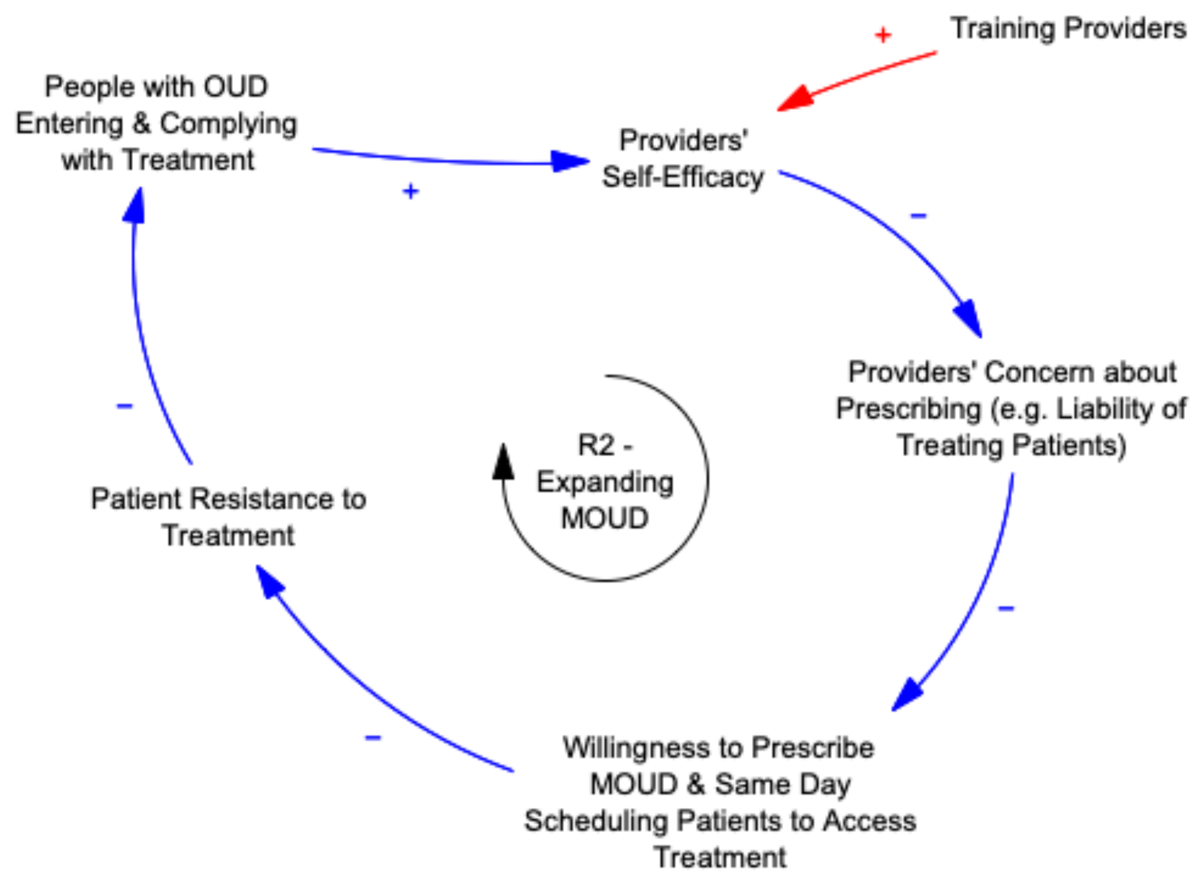
Merging CLDs

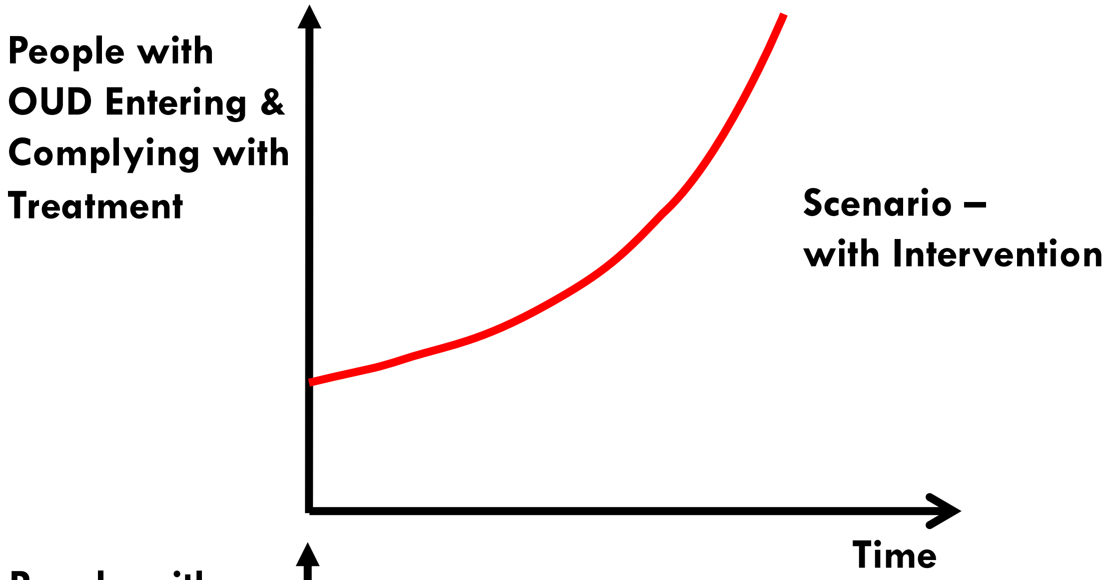
- The teams created three CLDs around the following:
  - service integration to enhance MOUD engagement
  - virtual retention for MOUD engagement
  - expansion of MOUD.

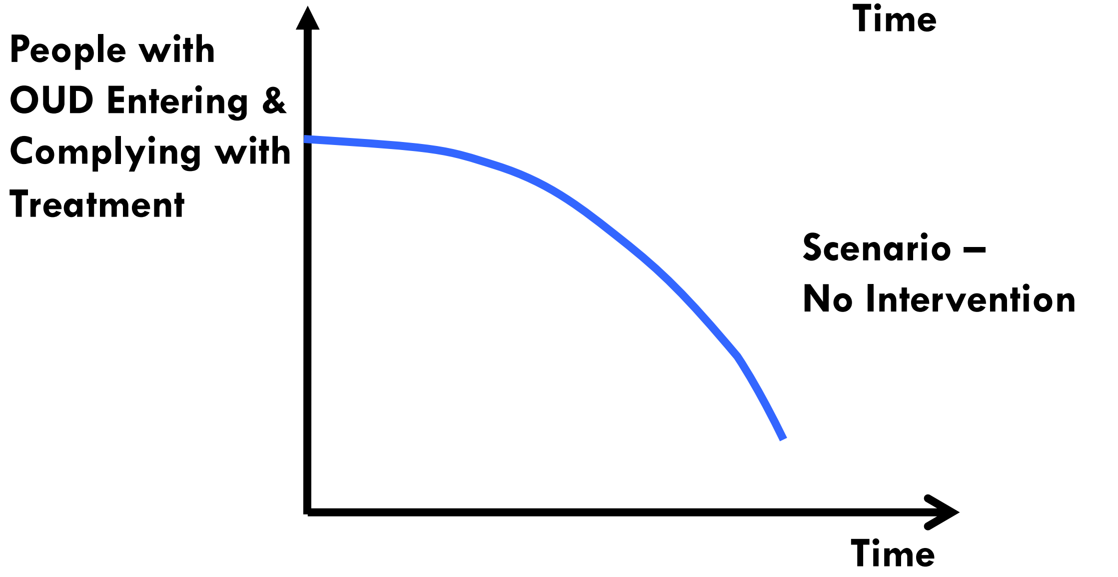
Merged CLD Presented on Day 2: Goal is to keep clients within treatment



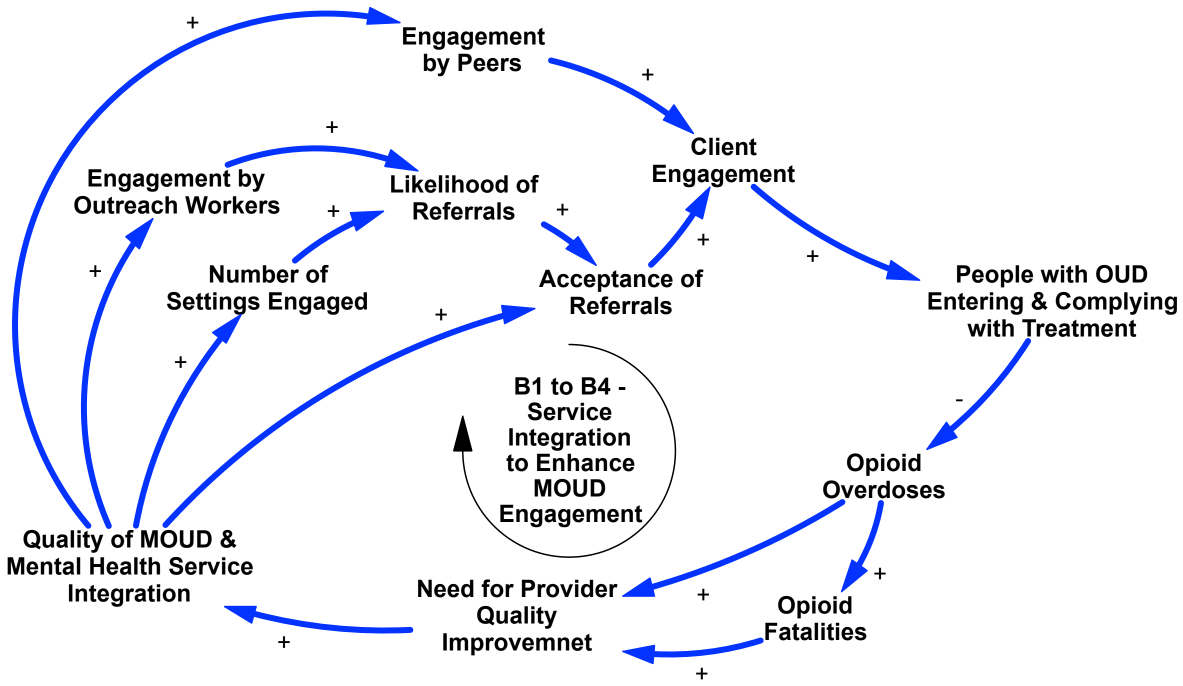
Reinforcing Loop

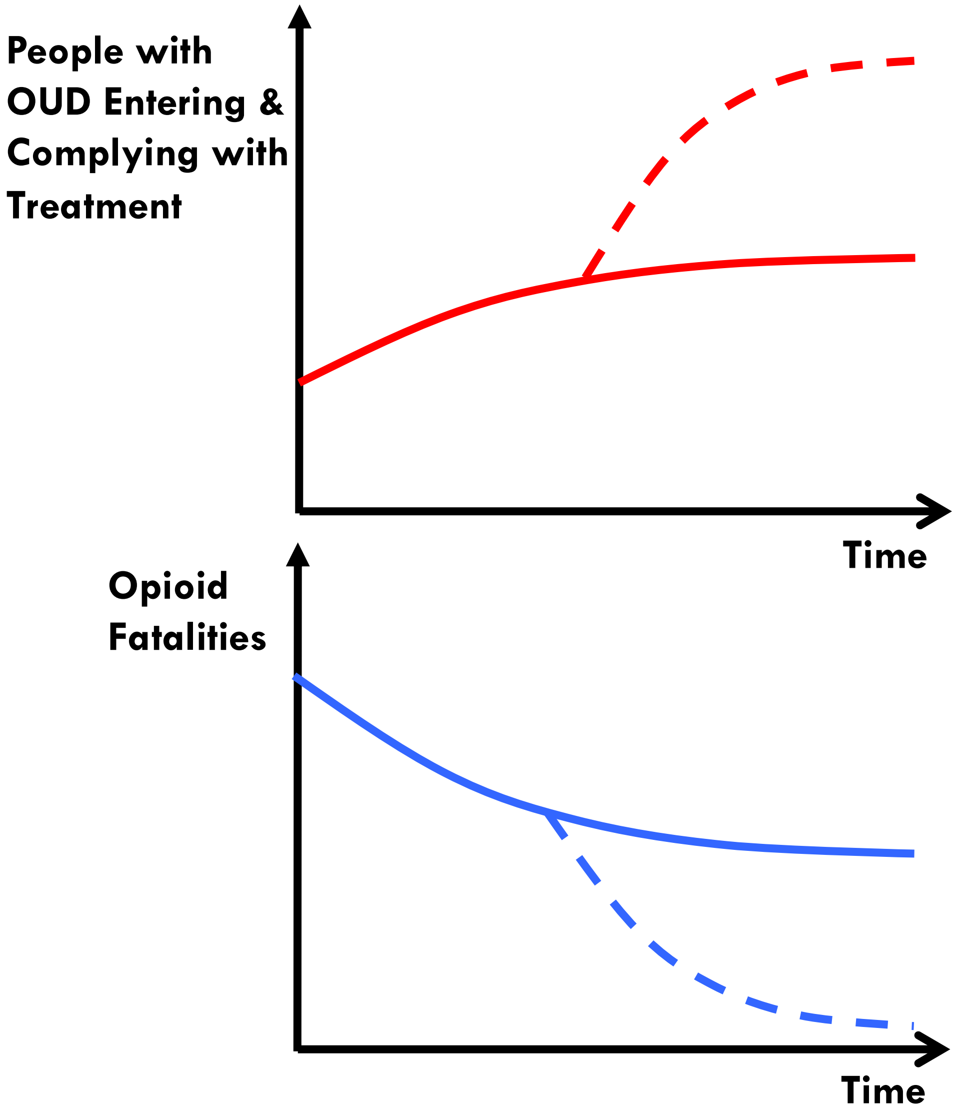






Series of Balancing Loops

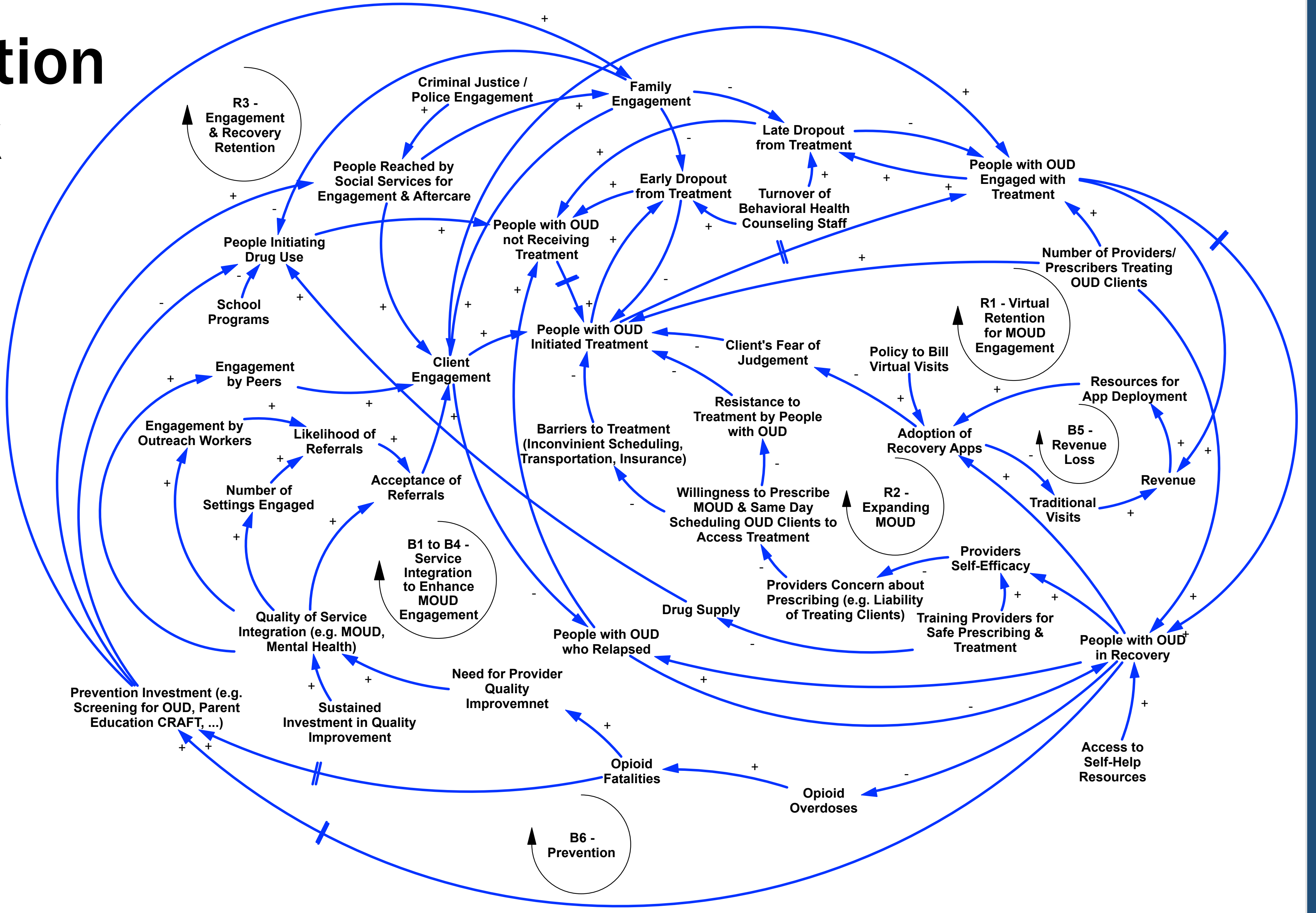




Final CLD after Reflection & Feedback

Moving to upstream and focusing on prevention to reduce the susceptible to OUD

Successful treatment and recovery necessitates the involvement of various sectors of society (e.g. family members, schools, peers, law enforcement, health care providers, and social services)

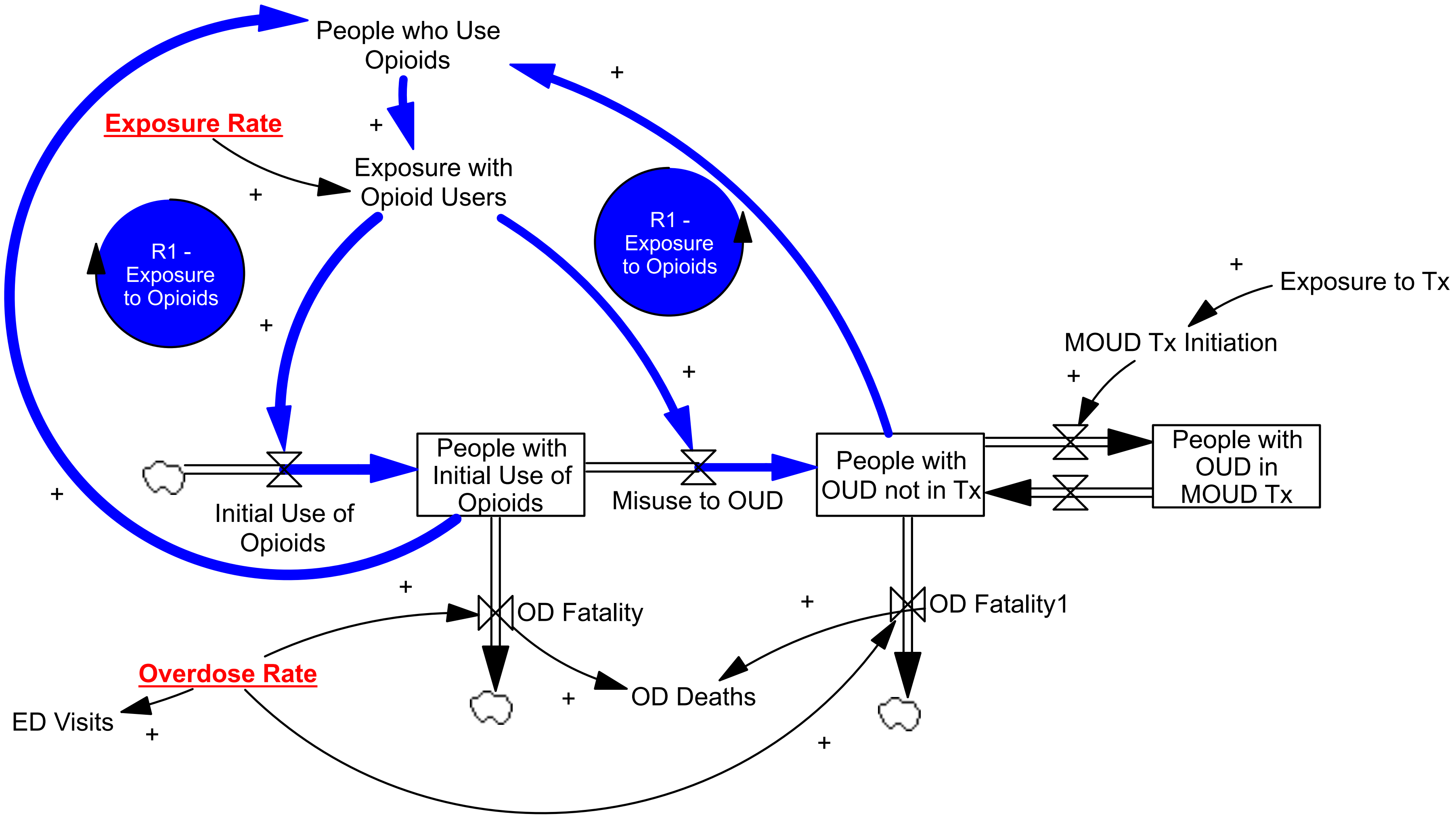


Summary and Next Steps

- The final CLD enhanced the group's shared understanding of important challenges associated with implementation of EBPs
- We produced and shared a summary report
- We invited on-going dialogue about future modeling to guide implementation strategies

Community System Dynamics Portal

System Dynamics Model – Core Structure



Community System Dynamics Portal

- Using **simulation modeling:**
  - Examine outcomes of local implementation strategies
  - Foster critical deliberation about local capacity/feasibility to implement strategies that can further enhance the implementation of Opioid Overdose Reduction Continuum of Care Approach

What can we do?

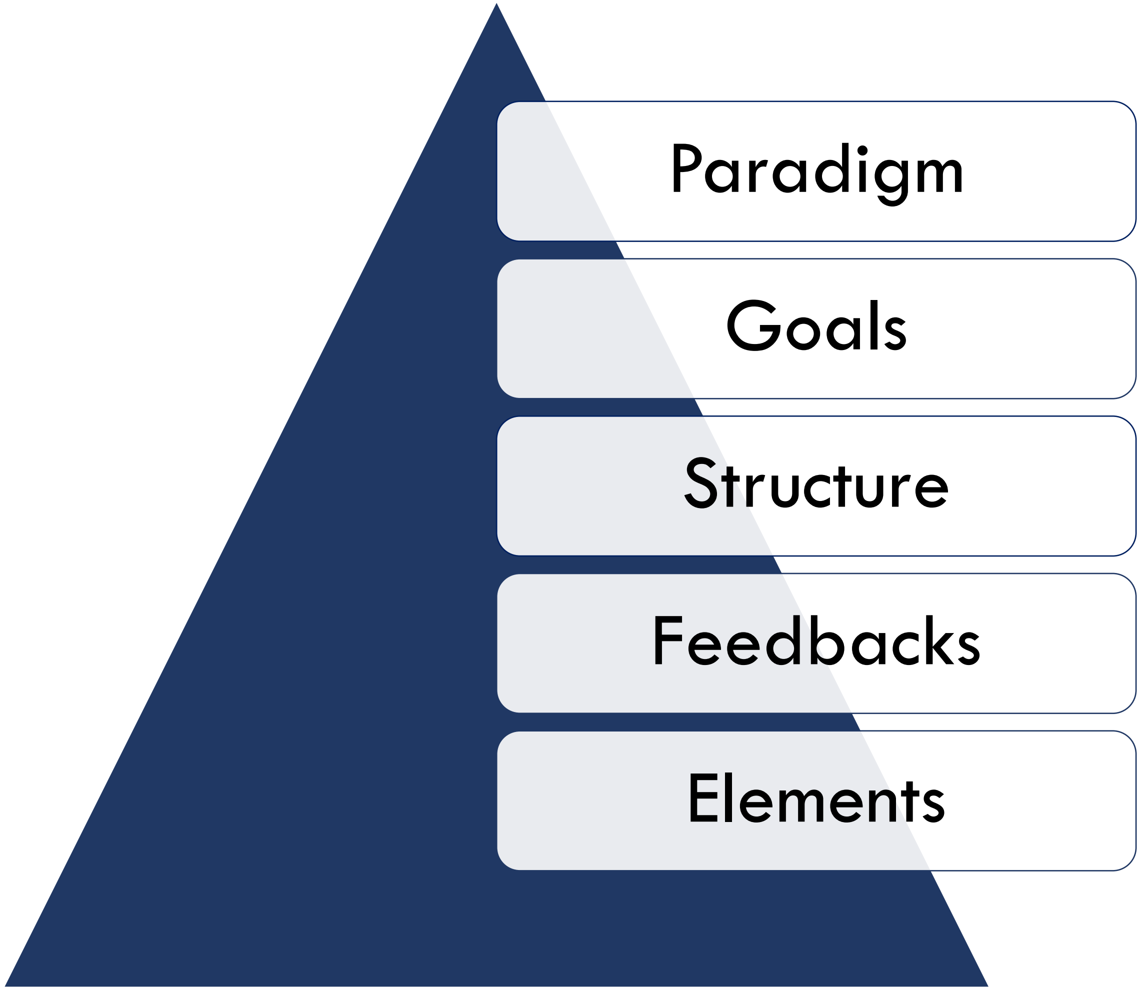
Designing systems change strategies

Places to Intervene in a System – *increasing order of effectiveness*

Adapted from Donella H. Meadows, Dec. 1999

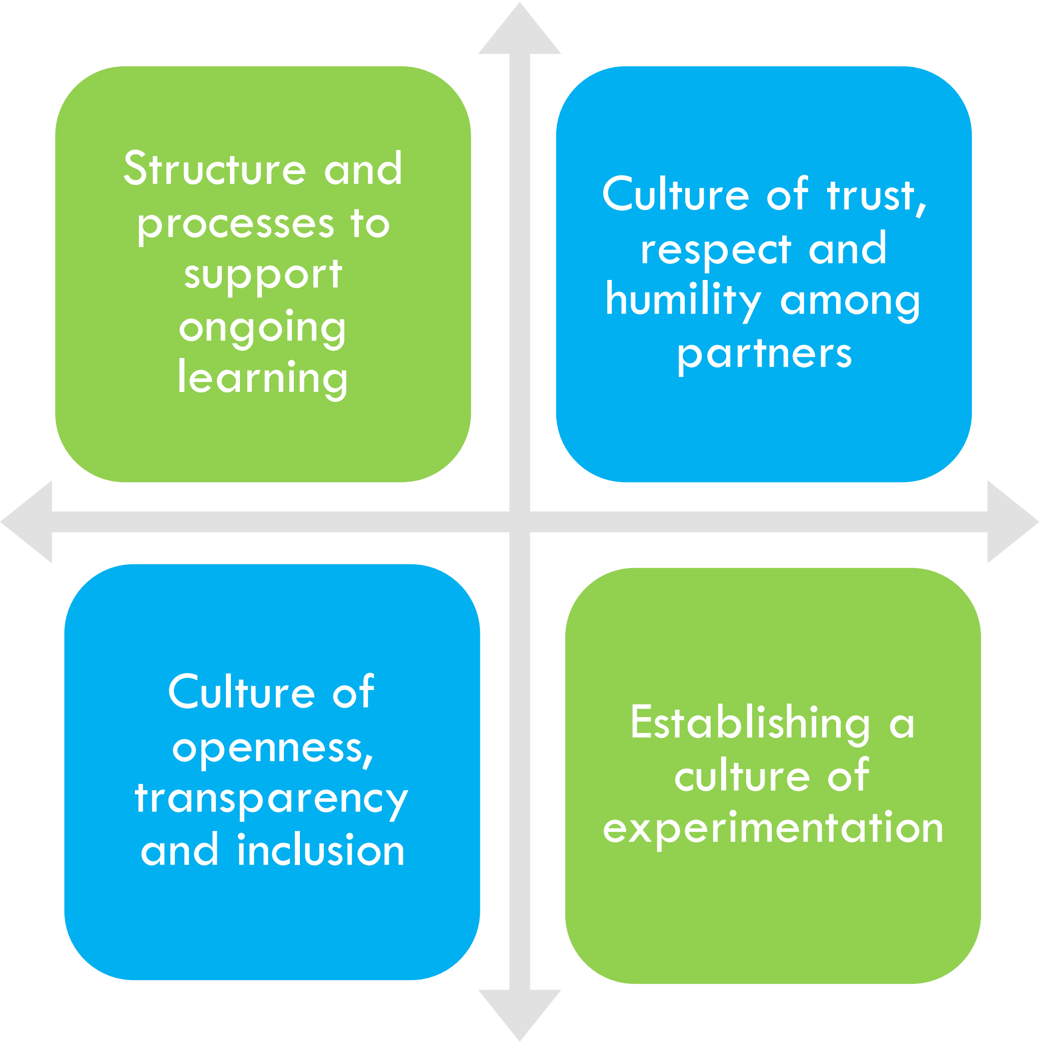
- Constants, parameters, numbers
- The size of buffers and other stabilizing stocks relative to their flows
- The structure of material stocks and flows (such as transport networks, population age structures).
- The length of delays, relative to the rate of system change.
- The strength of negative feedback loops, relative to the impacts they are trying to correct against.
- The gain around driving positive feedback loops.
- The structure of information flows (who does and does not have access to what kinds of information)
- The rules of the system (such as incentives, punishments, constraints)
- The power to add, change, evolve, or self-organize system structure
- The goals of the system
- The mindset or paradigm out of which the system — its goals, structure, rules, delays, parameters — arise
- The power to transcend paradigms

Systems Intervention Levels



Johnston, Matteson & Finegood, AJPH, 2014.

Capacity Building for Systems Change: Promoting a Culture of Systems Thinking <u>and</u> Action



Adapted from:
www.CollectiveImpact.org

SUMMARY

Systems thinking helps us grapple with complexity and yields models that can help guide action to improve public health

Iterative, stakeholder-driven deliberation fosters discovery of innovative solutions to complex problems

Affirming a shared rationale for collaboration will shape stakeholder engagement and lay the foundation for systems change

Systems thinking skills are be easy to learn, but are only mastered with practice

We don't all need to be systems scientists, but we can all be systems thinkers






Our Team at the Center for Systems and Community Design

- **Terry Huang, PhD, MPH, MBA**, Professor, and Director
- **David Lounsbury**, Associate Professor, Einstein College of Medicine
- **Weanne Myrrh Estrada** – Doctoral candidate
- **Rachel Thompson** – Doctoral candidate
- **Priscila Lutete** – Doctoral candidate
- **Pulwasha Iftikhar** – *MPH*

Discussion

What public health problem are you interested in?

Is it a complex systems challenge? Why?