Challenges and Considerations in Validating Causal Loop Diagrams for Complex Systems

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Causal Loop Diagram

- Middle child of system dynamics
  - Underappreciated yet crucial role in the modeling process

- Less attention compared to Stock and Flow Models
- Seeking validation and importance
- Independence and versatility

- Connect, adapt, and navigate dynamics within a family

Agenda

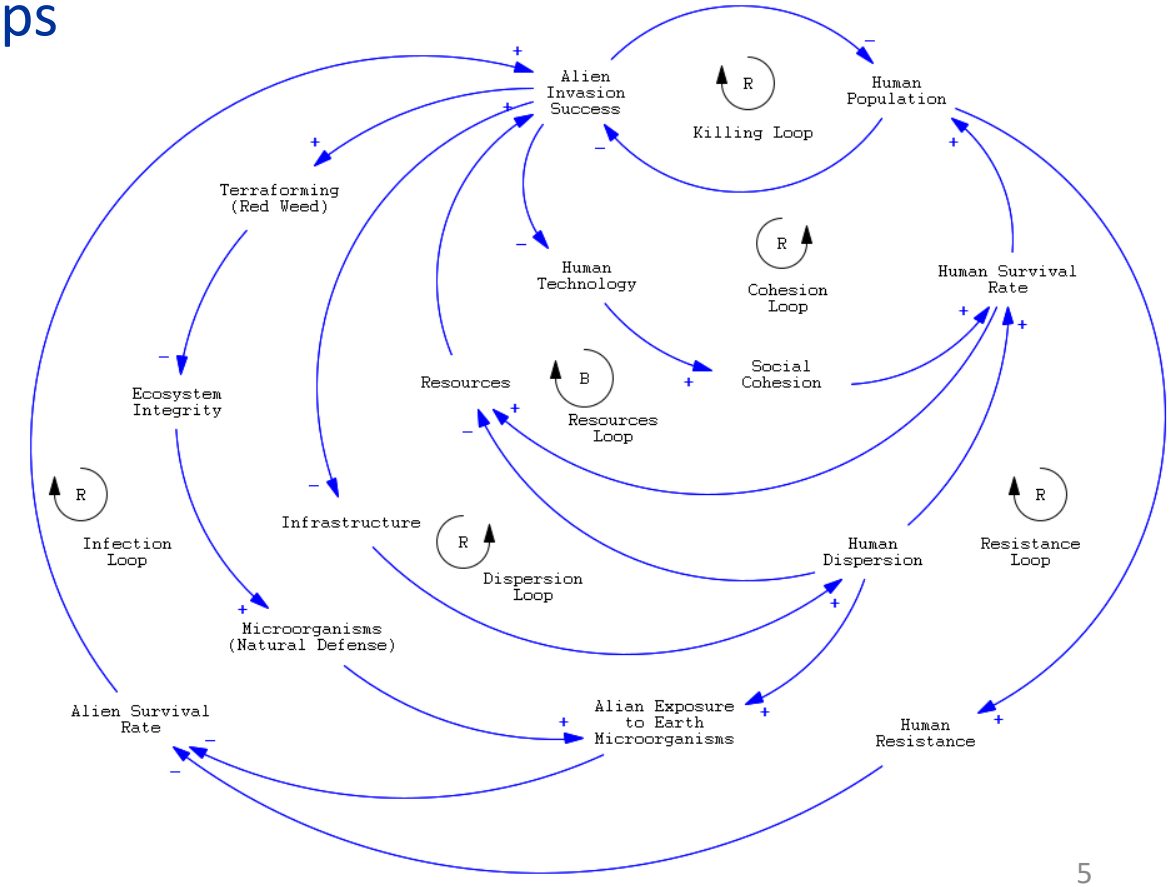
- Causal Loop Diagram (CLD) Uses
- Development of Causal Loop Diagrams
- Causal Loop Diagram Validation Methods
- Measures of Causal Loop Diagram Validation
- Conclusion

Background

- Widely used in systems thinking to visualise and analyse dynamic relationships in complex systems
  - Robust tool for complex and wicked problems across various domains
- Validation remains a critical challenge
  - Simplified representations of reality
  - Complexity of the modelled system
  - Accuracy vs utility
  - Iterative nature of problem solving

Causal Loop Diagrams

- Represent and analyse complex systems to facilitate understanding and communication across various domains
  - Non-linear interactions with feedback loops
- Require rigorous validation to ensure they are reliable and effective
  - Despite their simplicity and ease of use
- Validating systems thinking models can become problematic



Causal Loop Diagram Uses

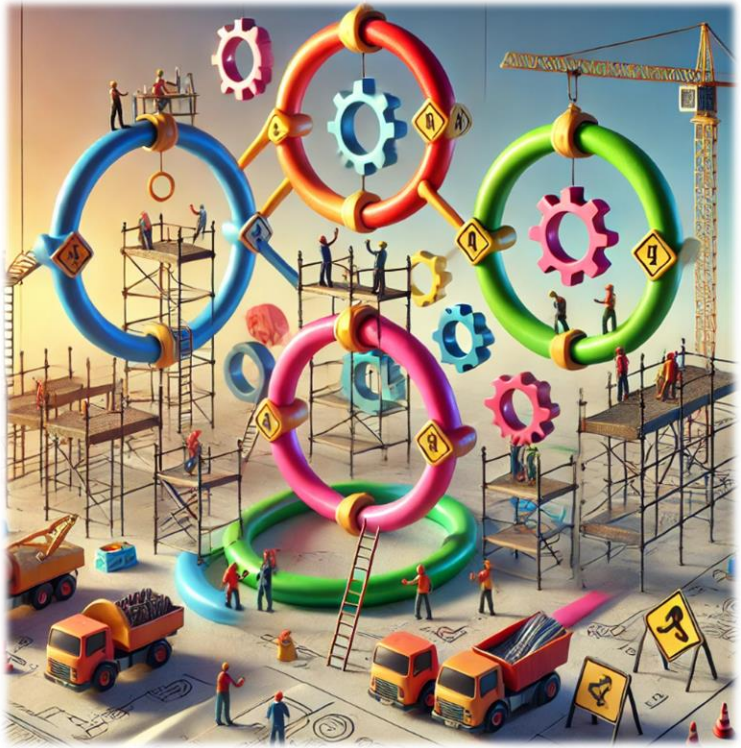
- Public health, environmental science, business management, and sustainability
- Stakeholder engagement and collaboration
  - Visualise “mental models” for understanding
  - Understanding of system dynamics
    - Show how changes in one part of a system can propagate to other parts
  - Communicate hypotheses about system dynamics

Causal Loop Diagram Uses

- Identify leverage points
  - Interventions that target the root causes rather than only symptoms
  - Could yield significant improvements
- Inform policy
  - Reveal unintended consequences and systemic impacts of policy decisions
- Support for research and evaluation
  - Formulate hypotheses and propose practical solutions
  - Bridge to more detailed computational models

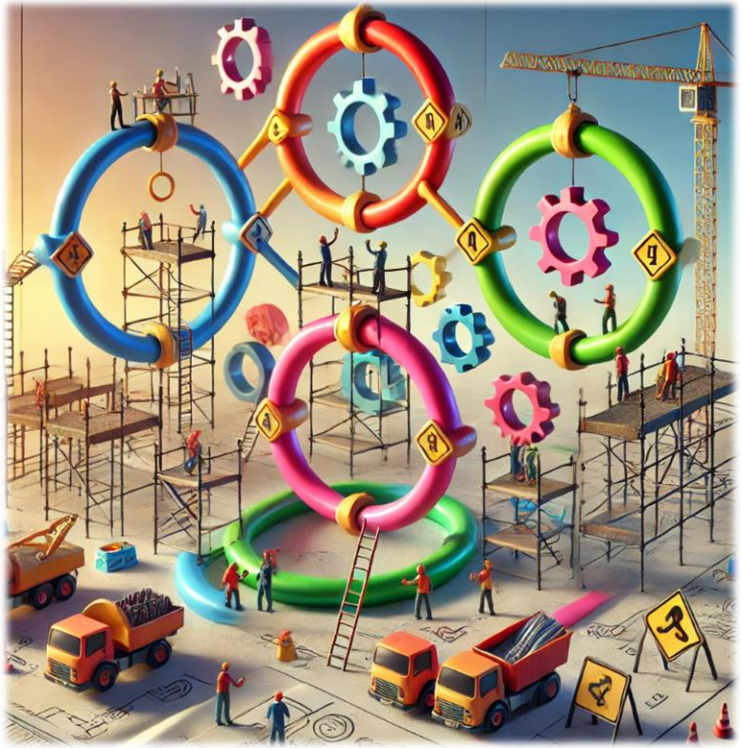
Development of Causal Loop Diagrams

- Conceptual phase of a systems thinking modelling
- Data gathering
  - Qualitative data
  - Primary data
    - Interviews, Workshops, Field Observations, Statistics
  - Secondary data
    - Document and Literature Reviews
  - Grounded theory method
- Identify key variables and their relationships
  - Critical variables that affect or are affected by the problem
  - Concept mapping and Systemigrams organise knowledge
  - Determine how variables cause observed problem behaviour



Development of Causal Loop Diagrams

- Draw the diagram
  - Map causal links
    - Use arrows to connect variables, indicating the direction of influence
  - Arrange the diagram to minimise line crossing and make causal relationships clear
  - Analyse the links to identify feedback loops
  - Descriptive names for key loops
- Identify leverage points
  - Reinforcing loops or at junctions of multiple feedback loops
- Stakeholder engagement and iterative refinement



Causal Loop Diagram Validation

- Good CLD accurately represents system dynamics with actionable insights
- Ensure theoretical soundness and practical viability
  - Throughout development to ensure accuracy and utility
  - Structured and auditable process is form of validation
  - Stakeholder feedback and real-world data
- Iterative Improvement

Causal Loop Diagram Validation Methods

- Stakeholder engagement and expert review
  - Verify assumptions, concepts, and structure supporting the model's theoretical and empirical foundations
  - Align stakeholder mental models and reducing bias
  - Different perspectives enhance credibility

- Policy and scenario testing
  - Real-world application confirm decision-making utility various scenarios and policy interventions

Causal Loop Diagram Validation Methods

- Comparison with existing models
  - Ensuring the new model conforms to established knowledge

- Aligning models with real-world data
  - Comparing assumptions and outputs with historical data and literature
    - Behaviour over time graphs
    - Archetypes
  - Triangulation of primary and secondary data sources

Measures Of Causal Loop Diagram Validation

- Completeness
  - Capture all the system's relevant variables, relationships, and feedback loops
    - Ensuring that nothing critical is missing
    - Oversimplification leads to incomplete representation
  - Boundary adequacy ensure essential factors are included
    - Model boundaries may shift as the problem understanding evolves
  - Expert involvement, cross-verification with existing models
  - Not capture every detail, but highlight critical system components and dynamics

Measures Of Causal Loop Diagram Validation

- Accuracy
  - How well CLD represent behaviour, relationships, and feedback loops
    - Reflect correct cause-and-effect mechanisms
    - Abstraction levels of elements
  - Structural validation and real-world relevance
    - Correct signs (+ or -) representing the interaction between variables
    - Variables and relationships generate expected behaviour
    - Feedback loops defined and named

Measures Of Causal Loop Diagram Validation

- Clarity
  - How well the structure and components are visually and logically presented
  - Organized for easy tracing of causal paths and identify of feedback loops
    - Intuitive relationships between variables
  - Free from ambiguity or confusion in its visual representation
  - Facilitate communication by reducing misinterpretation
  - Balancing the complexity and understandability
    - Capture enough complexity to be meaningful but not to be overwhelming

Measures Of Causal Loop Diagram Validation

- Understandability
  - Stakeholders can easily grasp the underlying concepts, dynamics, and insights
    - Simplicity influences understandability
  - Effectively communicates complex ideas accessible to technical and non-technical stakeholders
  - Realism and relevance reflect real-world conditions
    - But not at the expense of user comprehension

Measures Of Causal Loop Diagram Validation

- Consistency
  - Reliable insights across different scenarios, conditions and stakeholders

- Sensitivity
  - How responsive CLD is to changes in key variables or parameter
  - Minor variations in link strength or introducing a new feedback loops have limited effect in overall system behaviour
  - Pinpointing critical leverage points in the system

Measures Of Causal Loop Diagram Validation

- Usefulness for Decision-Making
  - Provide stakeholders with new insights into the system's dynamics
    - Understand the potential impacts of various interventions
  - Identify leverage points and evaluate the potential outcomes of their interventions
  - Provide reliable guidance for sustainable decision-making

Conclusion

- Complexity of the systems is a major challenges in validating CLDs
- Focus in validating CLDs should be on their utility for a purpose
  - Accurate enough to be useful and facilitate effective communication and problem-solving among stakeholders
- Validation happens throughout the modelling process
- Depends on stakeholder engagement and subjective confidence in the model

- "Essentially, all models are wrong, but some are useful"

  - (George Box)

Questions