Are we there yet?
Saturation analysis as a foundation for confidence in system dynamics modeling

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ISDC 2024 Theme, Bridging Perspectives for New Insights

- We have **4 related papers** contributing to the theme.
- **Current Parallel Session:**
  - Are we there yet? Saturation analysis as a foundation for confidence in system dynamics modeling
  - Rigorously interpreted quotation analysis for evaluating causal loop diagrams in Late-Stage conceptualization
- **Work-in-Progress Session later today at 2PM:**
  - CLD Synthesis for Resolving Diverse Perspectives: Principles, Methods and a Case Illustration
  - Advancing System Dynamics Modeling's Integrative Paradigm: A Holistic Approach

Background

The parent study (Tomoaia-Cotisel, 2018)

- Used system dynamics modeling to understand challenges in transforming primary care in a medical center.
- Stakeholder preferences and their mental models determined the system's behavior
- Qualitative data played a key role in defining the model structure

Key Question Addressed in this Paper

- How do we know, with confidence, that we can move from one phase of the modeling process to the next?

What is Saturation?

The point at which, upon purposeful reflection, one feels satisfied or confident, for the time being, that the effort expended at one phase has met its desired aim and more effort would not generate new results. *(Crabtree and Miller, 2022).*

- Concept widely used in qualitative research to inform the decision to move from one phase of the research to the next
- Sometimes numerical measures or visualization tools are used to track saturation

Saturation can be useful for SD Modeling

Challenge 1: How to Navigate the Iterative Process of Modeling?

- Without a clear guidance, one may stay in one phase longer than needed, or one may stop short of capturing important structures contributing to dynamic complexity

Challenge 2: How to Uncover Structural Flaws Sooner than Later?

- Formal model testing focuses heavily on the quantitative aspects of modeling. They tend to focus on the model behaviors. They take place later in the modeling process.
- Structural flaws discovered too late can be costly. Undiscovered flaws are even worse.

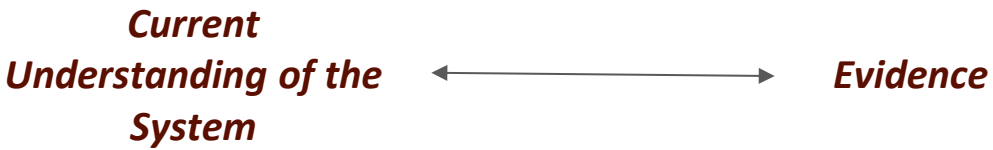
Defining Saturation for System Dynamics Use

A metaphor describing the point at which the current understanding of a system, for the purpose of a modeling project, no longer requires modification when exposed to additional evidence about the problem, thus indicating that additional data gathering and analysis would likely be redundant.

Are we there yet?

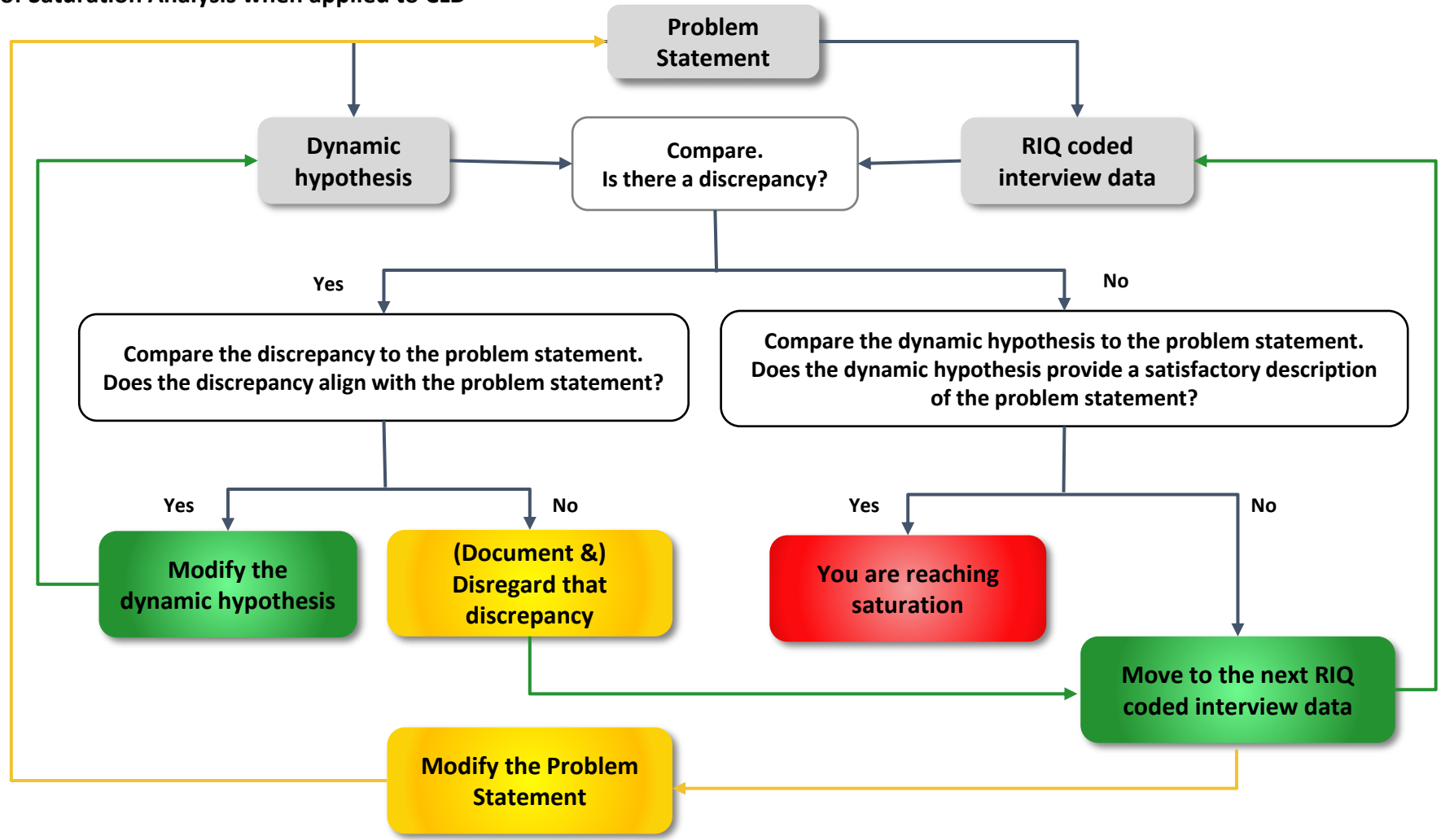
- **"yet":** Are we likely to have ceased identifying errors in our understanding? (saturation sufficiency)
- **"there":** Have we identified everything that is relevant to the problem? (setpoint for saturation)

General Process of Saturation Analysis

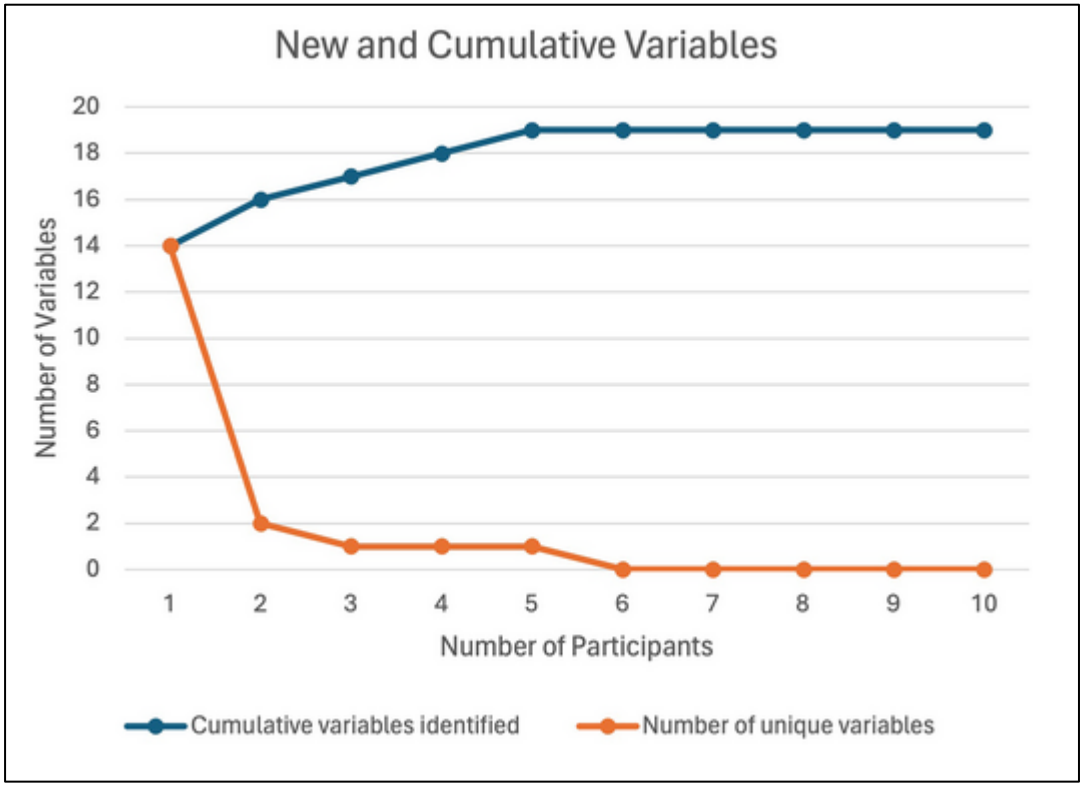


- Compare the current understanding of the system with evidence and modify understanding until comparison no longer requires modification
- The initial problem statement will guide the need for this modification
- In some occasions, new evidence may modify the current understanding of the system to the point that the problem statement must be refined.
- In the following example, we illustrate how saturation can be applied to system conceptualization where CLDs are used before focusing more heavily on simulation modeling.

Process of Saturation Analysis when applied to CLD

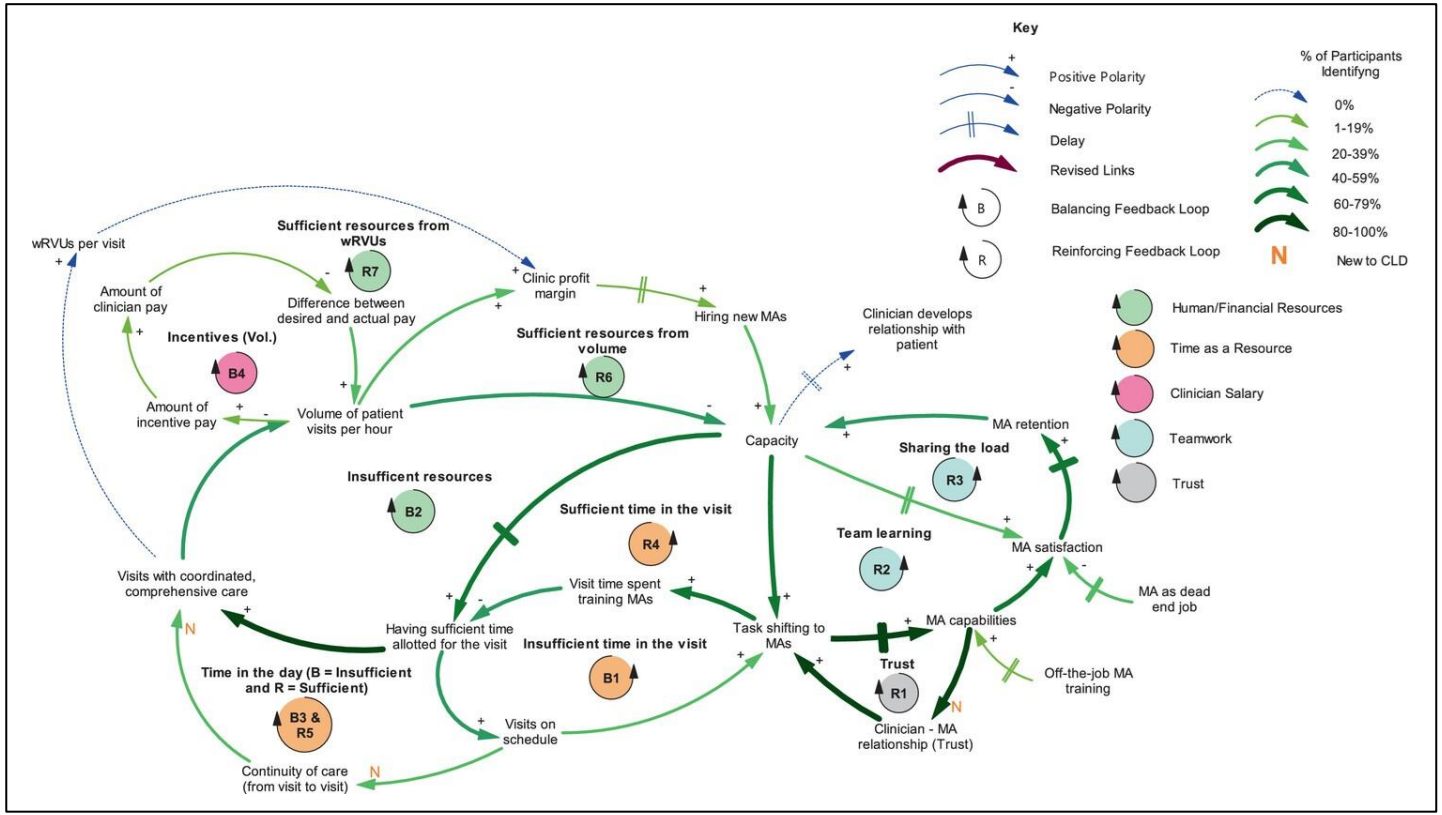


Visual Representations of Saturation Analysis:
Saturation Curve



- Provides a visual support that saturation has reached
- Similar curve can be created for all key CLD elements (variables, links, delays, feedback loops)
- Focuses on the *overall level of saturation* across the key CLD elements

Visual Representations of Saturation Analysis:
Shared Understanding Diagram



- Focuses on the *relative level of saturation* for each link on the CLD
- Identifies links that had a paucity of evidence behind them
- Reflects on the need for additional data collection and analysis.

Benefits of Saturation Analysis

Process of Saturation Analysis

- Continuous evaluation of dynamic hypothesis that includes diverse stakeholder experiences
- Multiple opportunities for reflection that builds confidence in the model
- Documentation contributing to research transparency and replicability
- Early identification of errors and needed revisions

Saturation Curve

- Quick assessment of how much new structure might be surfaced by additional data

Shared Understanding Diagram

- Communication of relative level of evidence in different parts of the model
- Discover subgroups, disagreements, and/or blind spots

Discussion and Future Studies

- In our full paper, we have more discussion on
  - Theoretical background
  - Generalized application of saturation analysis in system dynamics modeling
  - Return on investment
  - Future work

https://doi.org/10.1002/sdr.1781

Thank you!

Questions for Reflection

- Are variables and boundaries of the dynamic hypothesis well-developed and validated to meet the model purpose expressed in the problem statement?
- Are the relationships in the dynamic hypothesis well-supported by the RIQ-coded interviews?
- Are new and relevant data regarding the elements in the dynamic hypothesis likely to have ceased to emerge?
- Are bounded rationality and cultural acceptability evident in the dynamic hypothesis?

Modification of Problem Statement

- In some cases, the dynamic hypothesis resulting from the saturation analysis motivates a revision of the problem statement.
- A revised problem statement can better guide the rest of the modeling process.

Initial problem statement:
"… to better understand challenges faced by primary care practices as they transform into [Patient Centered Medical Homes (PCMHs)]"

Final problem statement:
"Primary care transformation has been and continues to be an elusive target. In the short term, implementation is hard, and failure abounds. In the long term, some practices reach successful implementation. We lack sufficient understanding of the structure of primary care, and of the policies that can impact this structure."

Comparing with Romanenko et al. (2023) SDR.