Making and using large models of complex systems:
The Poverty Reduction Model

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Author's declaration

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Photo credits

Modelling a complex system is a bit like untangling the copper wires on the front cover and throughout this report. Photos of wire are by Alana Boltwood, with blow-torching by Adam & Thomas Price, in the California sunshine.

Abstract

A system model is an abstract representation of a complex social system, which can be useful for facilitated sensemaking and decision support. This study presents a causal model format adapted from causal loop diagramming to integrate more knowledge of complexity, with higher comprehension.

As a case study, a Poverty Reduction Model was developed with over 1100 cause-and-effect relationships between more than 550 factors. Staff of the Yonge Street Mission social services agency used this model to find interventions to reduce poverty in Toronto, which were prioritized using the system model in combination with rating, scoring and discussion.

A framework is provided to balance model scope and quality requirements with the time and resources available to an organization. Modelling and option-comparison methods are documented for potential re-use by other organizations.

Keywords

complex social system; system model; causal model; causal loop diagram; modelling methods; diagram notation; diagram comprehension; large model; modelling software; resource constraints; Kumu; sensemaking; decision support; facilitation; comparison; prioritization; poverty reduction; housing; employment; Toronto

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I learned from my mother, Lee Boltwood, that everything is connected; from my aunt, Patricia Kennedy, that everything should be organized; and from my father, Paul Boltwood (RIP), that only the best will do. I also learned to question everything.

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1 Introduction

In *Gödel, Escher, Bach*, a monumental work on mathematics and cognition, Douglas Hofstadter writes about representing knowledge of real-world complexity: "It seems that a large amount of knowledge has to be taken into account in a highly integrated way for 'understanding' to take place" (Hofstadter, 1999, p.569). This study is about integrating what we know, to understand the mysterious interactions between people, using the photographic metaphor of intermeshed strands and loops of wire, clouded in obscurity.

1.1 The study in brief

This study contributes to the methodology for understanding complex social systems, and for considering how to intervene in their problems.

The study's aim was to adapt Causal Loop Diagrams to be more useful in supporting decisions, by designing a "causal model" information structure that is easier to understand and captures more information. Developing a causal model helps people to visualize and make sense of complex systems of cause and effect. People can use causal models to find the root causes of situations that happen in the system, and find leverage points where interventions could make change in the situations. A case study was conducted by developing and using the Poverty Reduction Model with the Yonge Street Mission, a Toronto charity.

The case study prototyped and tested methods to make large causal models comprehensible for sharing collective knowledge. In the case study, more challenges emerged: designing a process to generate ideas for interventions, and to compare those many options, across a very broad scope with limited time and other capacities. The causal model was combined with facilitated group discussion and methods for rapidly sorting, rating, scoring and voting for options, to make prioritization decisions with awareness of complex systemic effects.

It was found that developing a causal model can help a group of experts make sense of a complex social system. A large model can provide comprehensive coverage of a broadly-scoped system, and can be useful for decision support if combined with facilitation, option comparison and expert discussion.

1.2 Methodology research question and answer

Methodology research question	What modelling format and process would an organization find useful for making sense of a complex social system, and for finding & comparing potential interventions in it?
Answer	A large causal model was shown to be useful as part of a facilitated process for making sense of a complex social system, and finding interventions in it. A causal model can be combined with option-scoring methods to compare and prioritize those interventions.

1.3 Hypothesis, argument and findings

This study begins with the hypothesis that a causal model can be a **useful** abstract representation of a **complex social system**, which is a large number of people and organizations interacting in multiple ways, with many indirect, non-linear, unknown and changeable effects (section 2.2).

Section 2.3 defines a **causal model** as a structure that stores information about cause-and-effect relationships, and visualizes them in notation adapted from Causal Loop Diagrams. The model is an abstraction that conveys some and hides some complexity, which is appropriate for sensemaking and decision support in a complex social system.

Section 3.7 presents practices for **comparing options** with various amounts of research and expert discussion, including some rapid prioritization techniques: dot-voting, rating on scales, and an options matrix that scores how well each option meets pre-set criteria.

Chapter 4 presents the study's **process** of model development and use for integrative sensemaking, including understanding, synthesizing and sharing that knowledge to find and compare interventions in a complex social system. This process uses a causal model **format** (section 6.2) and software (section 6.4) that can integrate more **knowledge** of complexity, with higher **comprehension**, than classic causal loop diagrams. The process combines the model with option-scoring methods in a series of facilitated workshops and online activities (section 4.4).

The case study (section 4.1) develops a causal model, the Poverty Reduction Model, and uses it for finding and prioritizing interventions to reduce poverty in Toronto. Results from the case study (section 5) show that the combination of the causal model format and the facilitated process was useful for these purposes. The case study also shows that limited **capacities** (time, skill and resources) can constrain the **scope** and quality of a system model and its usage in sensemaking and decision support.

This study found that a causal model can be a **useful** abstract representation of a complex social system (chapter 6), in combination with facilitated activities for sensemaking and decision support (chapter 7). This is achievable if **capacities** are sufficient to develop a **comprehensible** model of comprehensive **scope** that integrates enough **knowledge** about the complexity of the system, and sufficient to make use of that large-enough model.

1.4 Uses of causal models and option comparison

Causal models can be useful for making sense of a complex system, prior to taking actions within it. Option-comparison methods such as scoring can also be used to make sense of choices for action within a complex system. The model and the option scores are both simplified representations of reality, to be used within facilitated discussion amongst knowledgeable people. They are complementary tools to support decision-making, but should not be used to make decisions in an automatic or deterministic fashion.

The case study showed that a causal model can be used for **integrative sensemaking:** Contributors to a causal model develop their understanding of the system while collaboratively synthesizing their expert knowledge with evidence from source documents to develop the model. The recorded knowledge is conveyed to future readers of the causal model to learn about the system.

Finding interventions: The case study found that a causal model, along with other systemic design tools (section 3.6), can be used in a facilitated process for finding new, modified or additional interventions to improve upon the problems in a complex social system.

Comparing interventions: The case study found a successful combination of methods to make informed and reasoned choices of interventions. The methods included using a causal model to compare the systemic effects of interventions in a system, and rating and scoring the intervention options according prioritization criteria including systemic effects (section 3.7). More labour-intensive comparison methods were not tested.

This study develops methods that could increase the usefulness of causal models, and lead to their wider adoption. Causal models are useful not only for making sense of complex systems but as a support for making decisions, as discussed in section 3.5.

1.5 Benefits of causal modelling

The following direct and indirect benefits of causal modelling (in combination with facilitated option comparisons) are posited, but not tested by this study:

If people develop and use a causal model to better understand a system, they can hold clearer and more informed discussions about its complexity. That understanding, along with option comparison methods, might influence them to make better (more beneficial) decisions within that system. If people use a causal model to find leverage points and compare opportunities for intervention in a system, it might lead them to choose or advocate for more effective intervention actions. If these better decisions and effective actions are implemented, it might lead to improvement upon the problems within the social system.

Any organization considering modelling would define what better decisions and effective actions might mean in the context of their mission and goals.

1.6 Challenges and practices

A causal model must be carefully designed to ensure it is useful for its intended purposes. This study develops methodology and practices to address the following challenges in modelling and in the process of sensemaking and decision support: The **Knowledge** modelling challenge (section 2.4)**:** Working collaboratively in a social system requires sharing knowledge, debating multiple perspectives, and recognizing unknown factors that are difficult to measure or predict.

> Findings (section 6.3.1): A causal model can synthesize qualitative and quantitative knowledge and evidence about a system, and articulate multiple perspectives in a common language.

The **Scope** modelling challenge (section 2.5)**:** A model of a system's complexity can become very large and detailed, with no clear boundary on the scope.

> Findings (section 6.3.2): A comprehensive causal model can capture the breadth of a social system, and rich detail about its complexity.

The **Comprehension** modelling challenge (section 2.6)**:** System models can be difficult to understand, due to their size, format or clarity.

> Findings (section 6.3.3): A large causal model can be understandable, if it has a summary, is structured, is written clearly, is visualized with flexible notation, and can be viewed in small pieces.

The **Capacity** process challenge (section 3.8)**:** Developing and using system models draws upon costly and limited resources: the time and skills of subject-matter experts, modellers, researchers and facilitators (the modelling team).

> Findings (section 7.5): Developing and using a causal model is a worthwhile use of limited time and resources. Scope and quality requirements should be determined in advance to plan the best use of available capacities. Software, tools and training can supplement the skills of the modelling team.

1.7 Case study in brief

1.7.1 Case study purpose and methods

A case study was conducted to test whether a causal model could be useful for sensemaking and decision support in a complex social system. In this study, the Yonge Street Mission charity (YSM) used systems thinking and modelling to select a short-list of policy innovations for a demonstration project to reduce poverty in Toronto.

A comprehensive causal model of systems surrounding poverty was developed and summarized in collaboration with YSM. A Working Group of YSM staff and partners participated in five facilitated workshops to use the model to make sense of the system and find and prioritize interventions. YSM found the system modelling activities to be useful enhancements to their decision-making process, as described in section 7.1. The case study is further described in section 4.1 and its results are in chapter 5.

Case study research question	What might be the most effective system interventions (potential policies or programs) to reduce poverty in Toronto?
YSM answer	The Yonge Street Mission has selected this short-list of interventions that meet their effectiveness and other criteria: *Life skills education* *Wraparound support for path to employment* *Portable Housing Benefit*

1.7.2 Overview of Poverty Reduction Model

In cooperation with the Yonge Street Mission, this study has developed the Poverty Reduction Model (PRM), a causal model with over 550 elements and over 1100 connections related to poverty in Toronto. Most of the PRM content is also relevant to Ontario, and large multicultural cities in developed countries.

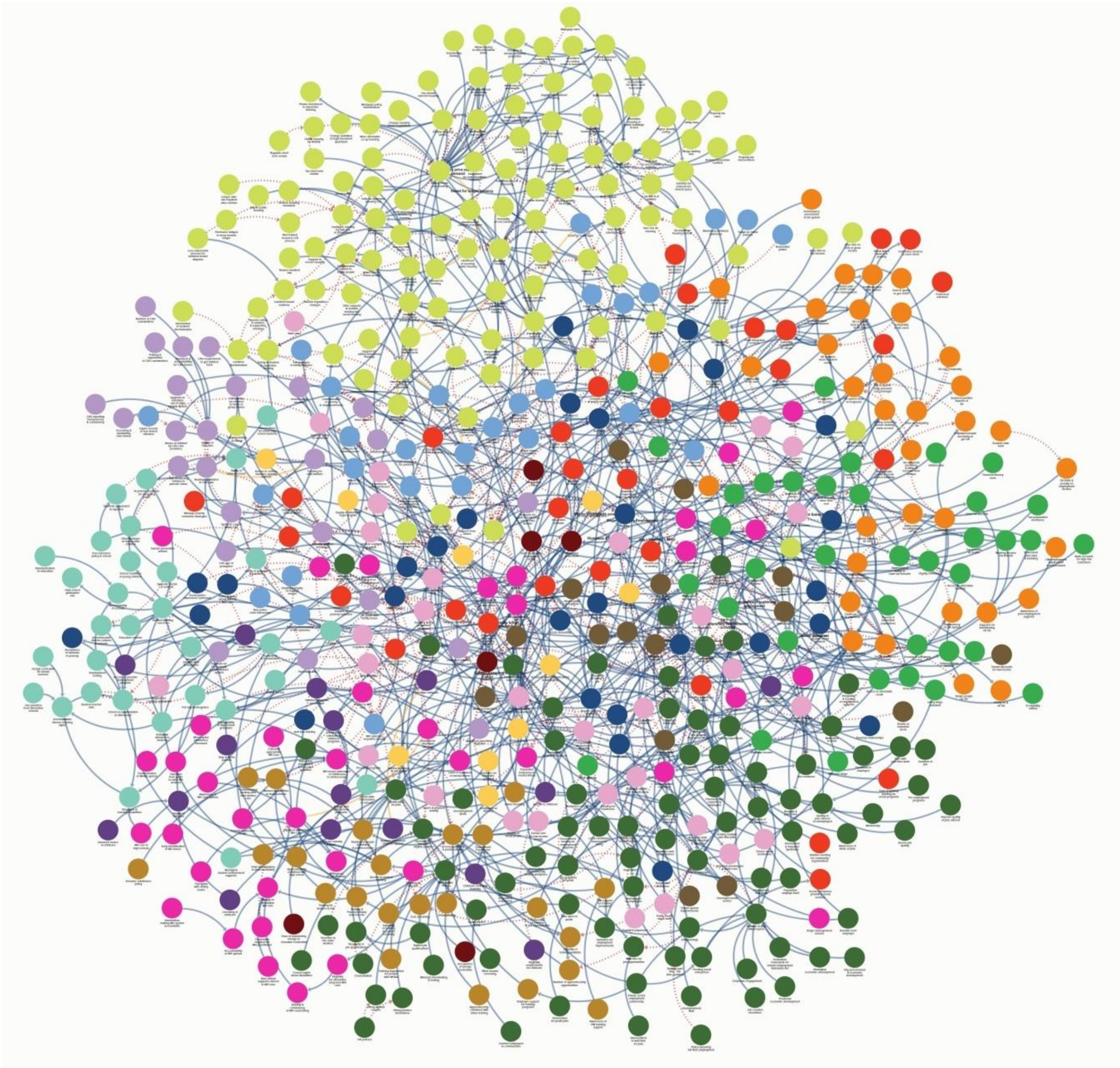

Figure 1: PRM: all elements and connections

The PRM has comprehensive coverage of housing and employment issues, and light to moderate coverage of 14 more subject areas as listed in section 5.3.1. In this overview diagram, Figure 1, the housing elements are apple green near the top, and employment elements are forest green near the bottom (see legend of subject area colours, Figure 13).

The following sample illustrates some typical elements and connections in the PRM, and explains how to read the causal model notation. In Figure 2 the blue arrows mean that increasing the first factor may increase the related factor, for example, *Job retention* increases *Employment income*. The red dashed arrows indicate an opposite causal relationship, for example, when a person's *Employment income* goes up, their *Social Assistance income* goes down.

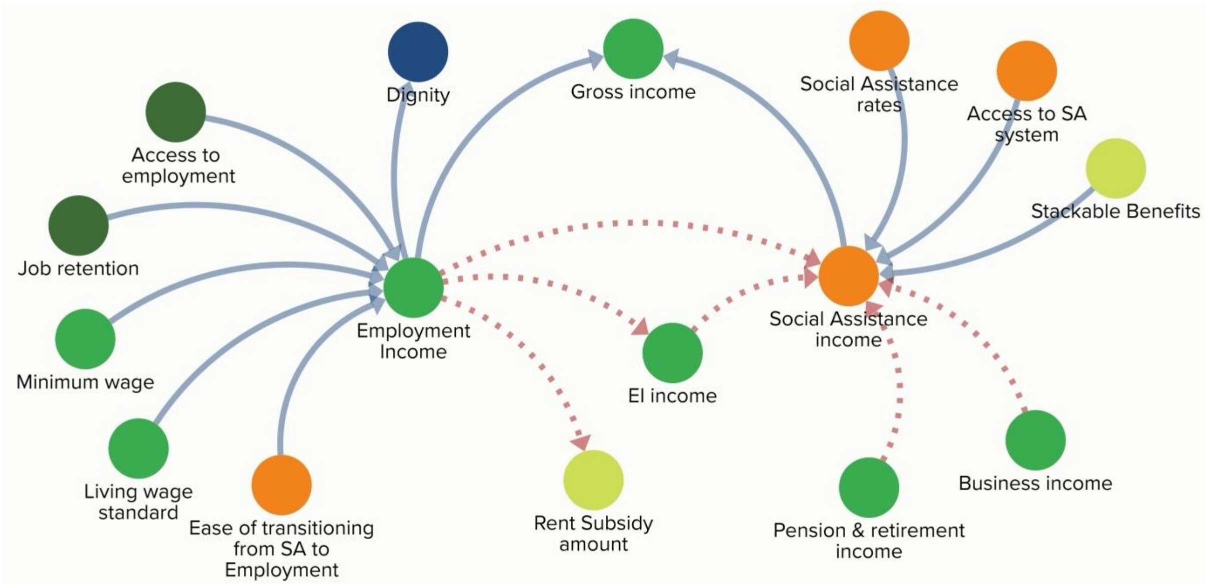

Figure 2: PRM sample: employment and social assistance income

See the Table of Figures to find more samples of the PRM. Please contact the researcher for access to the full content of the PRM, or assistance with adapting or enhancing it.

1.7.3 Summary Model

The Poverty Reduction Model was summarized as a one-page diagram of the subject areas and major goals. The Summary Model, Figure 3, is read as follows: To prevent or exit poverty, a person needs employment or other income. To find employment, a person needs certain capabilities (such as language, training, and childcare) and the absence of limitations (such as a criminal record). There are general factors such as service suitability and transportation that enable people to acquire those capabilities and to access financial benefits. Those enablers, and a person's income level, affect their access to health, housing and other services that can alleviate poverty by improving quality of life.

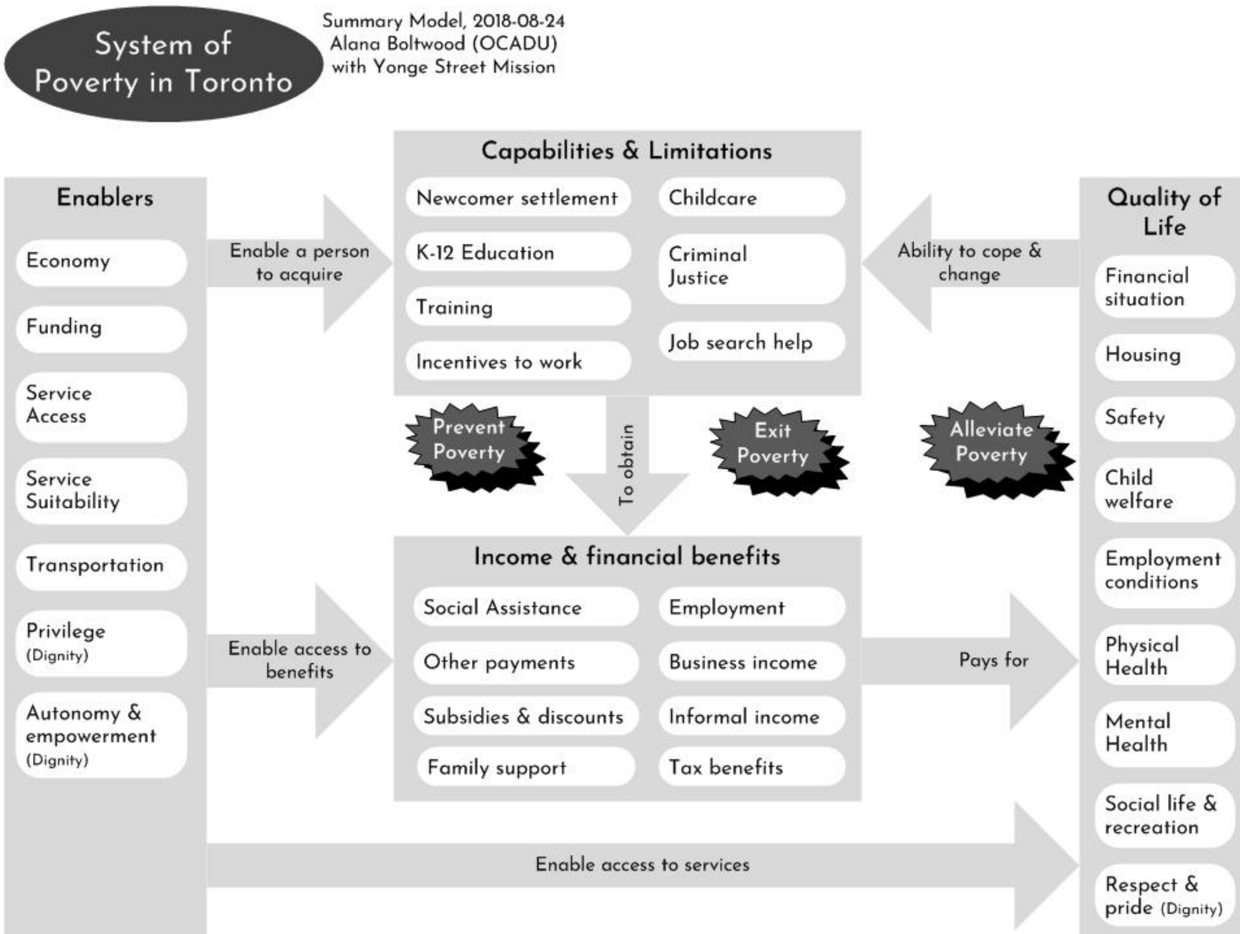

Figure 3: Summary Model (letter size) after Workshop 1

1.8 Contribution of this study to methodology

This study makes the argument for describing a complex social system with a structured, comprehensive model of cause and effect (section 2.3).

To address the challenges in section 1.6, this study has combined existing methods for model development and option scoring. It has adapted the methods for a very large causal model and for limited time with expert contributors. The study documents and evaluates the following adapted methods for use in modelling any complex system:

- A causal model format that organizes and describes many model elements and connections, section 6.2.1
- Customization of Kumu software to visualize dynamic selections from the model with readable, flexible notation, section 6.4
- Procedures and guidance for model development, section 4.3.3

- Facilitated workshop activities for experts to contribute to model development while finding interventions, sections 4.4.5 and 4.4.7
- Methods to analyze a causal model, section 4.5, and find high-leverage interventions in it, section 4.6

The study demonstrates facilitated activities (section 4.4) that use a causal model to compare opportunities for intervention, and then prioritize them with option-scoring techniques, as a support to discussing decisions about how to intervene in a complex system.

The study also makes recommendations, section 7.6.5, for planning modelling projects to balance scope, knowledge and quality requirements with the resources available, to produce understandable and useful models.

1.9 Definitions

Table 1: Glossary

Term	Meaning
Yonge Street Mission	The case study organization, also referred to as "YSM". A non-profit organization that offers social services to low-income people in downtown Toronto. See section 4.1.1.
Model	An abstract structure representing some aspects of reality. See section 2.3.
System model	An abstract structure representing some aspects of a real-world system. See section 2.3.
Causal model	A type of system model. An abstract structure representing a real-world system by showing the cause-and-effect relationships between variable factors. Each variable factor may be related to many causes and many effects. See section 2.3.9. May also be referred to simply as "a model".
Causal loop diagram	A form of cause-and-effect model, described in section 2.3.8. May be referred to as a "CLD". A causal loop diagram depicts variable factors as text blocks (nodes). It shows cause-and-effect relationships as curved arrows between the nodes, with some notation of the relationship polarity (also defined in this glossary). A sequence of relationships may form a reinforcing or balancing loop.
Poverty Reduction Model	The fully detailed causal model, about systems related to poverty in Toronto, developed by the case study. May be referred to as "the model" or "the PRM".
Summary Model	The one-page summarized overview of the Poverty Reduction Model, Figure 3.

Term	Meaning
Variable factor	A node in a causal model may be known as a variable factor, variable, factor, node, or element. It represents some factor (quantitative or qualitative) that can vary up and down, in a complex system of causes and effects.
Changeable factor	A variable factor that someone has the ability to influence or change.
Leverage point	A variable factor in a complex system "where a small shift in one thing can produce big changes in everything" (Meadows, 1999).
Leverage	The relative influence of each factor on all other factors in the system. High leverage includes having stronger influence on a larger number of more fundamental objectives, to push the system towards desirable goals. Comparisons of leverage need to consider the cumulative strength of an intervention's effects, along the chain of causality: the direct and indirect connections from that intervention element out (downstream) to other elements.
Element	A variable factor in the Poverty Reduction Model. Depicted as a bubble (circle) in the PRM, which uses the term "element" to align with Kumu software. See section 6.2.1. In this report, PRM elements are named in *red-brown italics*.
Relationship	A cause-and-effect link between two nodes (elements) in a causal model may be known as a relationship, connection, arrow, line, or edge (from graph theory terminology).
Connection	A relationship between two Elements in the Poverty Reduction Model. Depicted as an arrow in the PRM, which uses the term "connection" to align with Kumu software. See section 6.2.1.
Polarity	The behaviour of a relationship. Includes "Same" polarity (two connected factors move in the same direction) and "Opposite" polarity (factors move in opposite directions). See the PRM Connection Types defined in Table 9.
Loop	A series of Connections, where the last Element is connected to the first Element, with all arrows pointing in the same direction. See section 6.2.1.
Subject area	A societal system or domain that is a major topic covered by a system model. Examples: Housing, Employment, Criminal Justice. The PRM subject areas are listed in section 5.3.1. See also section 6.2.1.
Focus area	A subject area, or other theme, that is chosen as a priority area for exploring interventions. In the case study, YSM chose to focus on Housing and Employment.
Sub-topic	A narrower societal domain. Part of a subject area.

Term	Meaning
Chain	A chain, or path, of causality. A series of elements, all connected by arrows pointing in the same direction. A chain may be interpreted as an extended cause-and-effect relationship, perhaps between an intervention and the eventual goal it leads to.
Upstream	The chain of elements that are influencers on a particular element (arrows are pointing to the element). Looking upstream from an element means following the arrows backwards out of the element.
Downstream	The chain of elements that are influenced by a particular element (arrows are pointing away from the element). Looking downstream from an element means following the arrows in the direction they point.
Tag	In the PRM, an element may be assigned any number of tags. Each tag is a text string designating a related subject area, a sub-topic, a chain, or a temporary editing flag. Tags are used to filter and display subsets of the model. See section 6.2.1.
Grouping	The Summary Model is organized into four large groupings of subject areas. See section 6.5.2.
Goal	An Element Type (Table 8). A fundamental factor that we (society) want to increase or decrease, indirectly, by making Interventions. Most societal actors will agree upon the direction this factor should go.
Objective	An Element Type (Table 8). A factor that we (society) want to increase or decrease, because it will contribute to reaching a Goal. The objective is a changeable factor, meaning it can be influenced by making Interventions. Most societal actors will agree upon the direction this factor should go.
Intervention	Generically in systems thinking, an intervention is an action that can be taken in the system, to directly influence the level of a variable factor and indirectly influence the behaviour of related factors in the system. Interventions in social systems include making legislation, offering social programs, changing financial rates, communicating messages, etc., or advocating for any such change. In the PRM, an intervention is an Element Type (Table 8): A factor that can be changed directly by some societal actor, with the aim of increasing or decreasing a Goal or Objective. May indicate the quantity or quality of social program offerings. May indicate the existence or level of a policy, such as a funding rate.
Intermediate	An Element Type (Table 8). A factor that societal actors may want to increase or decrease, indirectly by making Interventions.

Term	Meaning
Focus element, Bloom, First order, Second order	Using the Kumu “focus” feature to display of part of the PRM involves selecting and focusing on one or more elements. The display may show a “first order bloom” of all the elements that are directly connected to the focus element, as in Figure 23. The “second order bloom” includes elements that are one or two connections away from the focus element, as in Figure 25.
Capacity	The time, knowledge, skill and other resources available to the experts, modellers, researchers and facilitators involved in a modelling process. See section 7.6.9 for further definition. Note the distinction from “Capabilities”, one of the groupings in the Summary Model.
Expert	Any person with knowledge about a system, including: community members with lived experience in the system, professionals (front-line staff, analysts, managers, executives, consultants, etc.), and academics.
Prioritization Criteria	Criteria, such as effectiveness and feasibility, for comparing and choosing objectives and interventions. The case study’s prioritization criteria are in section 5.1.
Breadth	The diversity of topics in the model. A dimension of scope (section 6.1.1).
Depth	The number of elements modelled about each topic. A dimension of scope (section 6.1.1).
Density	The average number of connections per element in a model. A dimension of scope (section 6.1.1).
Detail	The average amount of information captured about each element or connection in a model. A dimension of scope (section 6.1.1).
Evidence	The amount of model information that is justified by citing studies or recounting stories. A dimension of scope (section 6.1.1).
Quantification	The degree to which model elements and connections are measured by ratings or statistics. A dimension of scope (section 6.1.1).
Richness	The combination of depth, density, detail, evidence and quantification, i.e. all aspects of model scope other than breadth.
Comprehensive	A comprehensive model thoroughly represents the breadth of a system, and captures rich (deep, dense and detailed) information about it.

Photo 2

2 Context: Modelling complexity

The fine copper wire formed a tissue-like web of relationships. Interdependency is the essence of complexity in social systems, which abstract models attempt to describe. The uses of modelling are elucidated in chapter 3. The formats and challenges of modelling are applied in the case study methods, chapter 4.

2.1 Summary

Complex social systems are described as a large number of people and organizations interacting in multiple ways, with many indirect, non-linear, unknown and changeable effects. The case study is about the complex social system of Torontonians living in poverty, and the social services they use. Interventions can be made to improve upon problems in a complex social system, at the risk of unforeseen consequences from systemic side-effects.

System models are visual abstractions that may represent who and what interacts in a system, how, when, where, and why. These diagrams help to make sense of a system, especially if they have consistent structure. A model is a simplification, which risks misleading people to think the diagram represents all aspects of a system, which may lead to deterministic solution approaches.

Cause-and-effect models describe why things happen, and are the most useful system models for considering where and how to intervene in a complex system. There are various types of cause-effect models; the broadest consideration is offered by models that represent many causes of many effects. They can be used to identify multiple factors to intervene in, multiple interventions, and their multiple systemic effects.

The commonly known type of many-to-many cause-and-effect model, the Causal Loop Diagram, is useful for these purposes, but needs adaptation to contain more information in a more comprehensible format. This study's adapted model format will be called a causal model.

Modelling methods and formats are explored to tackle the following challenges:

> **Knowledge:** To reduce uncertainty about a system, knowledge can be gathered from experts, studies and other source documents. Knowledge may be captured as text, images, numerical ratings or statistics, using facilitated discussions, systematic questionnaires, or interpretation of documents. Quality concepts of are interpreted for assessing causal models.
>
> **Scope:** The scope of a model determines a model's size. Smaller models are easier to develop and comprehend, while larger models provide more information about a system. It is argued that a model of a complex system cannot be complete but it can be comprehensive enough for a purpose.
>
> **Comprehension:** The ease of understanding a model depends upon its structure, notation, and clarity of expression. Larger models need to be summarized, and stored in a database so small pieces of it can be displayed on demand.

This chapter provides explanation for the modelling methodology proposed in this study, by citing literature and referring to the researcher's career experience as a statistician and then as a modeller of business architecture and information structures.

2.2 Complex social systems

2.2.1 Systems

Systems have been defined by many authors, including Donella Meadows:

> *"So, what is a system? A system is a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time. The system may be buffeted, constricted, triggered, or driven by outside forces. But the system's response to these forces is characteristic of itself, and that response is seldom simple in the real world" (Meadows, 2008b).*

Systems include "any group of interacting, interrelated, or interdependent parts that form a complex and unified whole that has a specific purpose" (D. H. Kim, 1999), ranging from a toaster to a biosphere.

2.2.2 Systems thinking

Systems thinking provides terminology and techniques for communicating about these systems of interdependent behaviours. It "is a way of seeing and talking about reality that helps us better understand and work with systems to influence the quality of our lives" (D. H. Kim, 1999). Systems thinking is considered relevant to managing organizations, as "a language for talking about the complex, interdependent issues managers face every day" (Lannon, n.d.). For further introduction to systems thinking, see: Gharajedaghi (2011); D. H. Kim (1999); Monat & Gannon (2015).

2.2.3 Social systems

This study focuses on social systems, where most of the factors are under human control, as distinguished from other systems such as machines and ecologies (Ackoff & Gharajedaghi, 2003).

Social systems include established groups of people that do things together, such as a law firm, a library or a lacrosse team. Social systems may be more amorphous networks of activity, such as the labour movement, the logging industry, or the libertarian blogosphere. "Social systems are usually parts of larger social systems" (Ackoff & Gharajedaghi, 2003), such as a department within a corporation within an industry.

2.2.4 Complex systems

The concept of a complex system has been described by many authors, for example:

> *A complex system is any system featuring a large number of interacting components (agents, processes, etc.) whose aggregate activity is nonlinear (not derivable from the summations of the activity of individual components)…* (Rocha, 2003, section 1)

Complex systems include organisms such as a human body, ecologies such as a forest (Meadows, 2008b), and social systems as described above.

A complex system is a web of many interactions between the system's components and factors. "Interdependence is the essential source of complexity" according to Alex Ryan (2012). Ackoff & Gharajedaghi (2003) see degrees of complexity, measured by "the number of variables and their interactions required to explain the behavior of the system".

That web of interactions is not a linear series of effects that can be added up, nor is it a simple hierarchy. It is a non-linear network in which "the whole is the product of interactions of the parts" (Gharajedaghi, 2011). The many pathways of causation cause indirect effects and unforeseen consequences, including "circular loops of positive and negative feedback" (Ryan, 2012).

The Cynefin framework (Snowden, 2005; Snowden & Boone, 2007) distinguishes complexity from complication. They define complicated contexts as ordered, static and predictable, like machines. Complicated problems can be solved by bringing in a specialist (like a mechanic) to analyze the options, as "at least one right answer exists."

By contrast, in a complex situation, even an expert may not produce one best solution to the problem. Simplified, "reductionist thinking does not work for complex systems" (Monat & Gannon, 2015) where behaviours are not deterministic or machine-like. The behaviour of a complex system "is in constant flux" (Snowden & Boone, 2007), meaning that new patterns are continually emerging. The Cynefin framework guides managers to recognize complex situations and react to them appropriately.

People who make decisions within complex systems face a huge challenge: "How can managers and policy makers plan, make decisions, and formulate strategies in a complex world characterized by limited predictability, high levels of uncertainty, and future outcomes that they cannot even conceive?" (Makridakis, Hogarth, & Gaba, 2009).

2.2.5 Complexity of social systems

Based on the above, complex social systems consist of a large number of people and organizations interacting in multiple ways, including social and economic interdependence, political and legal interactions, and interactions between people and technology and the environment.

Problems are often perceived within complex social systems. Interventions can be made to improve upon them, at the risk of unforeseen consequences from systemic side-effects such as reinforcing causal loops, or from unpredicted change.

2.2.6 Poverty as complex social system

Poverty in Toronto was the subject of the case study. This subject includes residents of the City of Toronto living on a low income from government assistance, low-waged employment, or other sources. (An exact income cut-off level is not specified because each result from the case study may apply to a different set of lower-income people.)

A person living in poverty is enmeshed in a complex system. Their low income may be due to any combination of unemployment, immigration, disability, family difficulties, incarceration, or other causes, each of which has systemic causes and effects. When a person in poverty tries to improve one aspect of their life, they often run into barriers from other domains (for example, they can't afford childcare or transit fare to attend a training program). Government programs meant to alleviate poverty often trap people in poverty, because they might lose an important benefit if they earn too much employment income (Yonge Street Mission, 2017). Culture, discrimination and attitudinal barriers are just as much part of this complex system as government policies & financial constraints.

Selecting individual policy interventions, using mechanistic thinking, may not yield successful outcomes:

> *Poverty is a wicked issue - complex, multidimensional, unclear and changeable…. There are some common misunderstandings about anti-poverty policy. The first is the belief that we can prevent poverty by identifying and dealing with its causes, or the 'generative mechanisms' that lead to people being poor; this has led to a long series of bad policies. The second misconception is to suppose that if we know what causes the problems, we will know how to stop them; the way into a problem is not usually the way out of it.* (Spicker, 2016)

A food-bank executive sees hunger, an aspect of poverty, as complex:

> *[I]t hasn't worked to see hunger as a complicated problem that can be solved by having lots of smart people engineer a system that is centrally coordinated. … The system's parts cannot, or will not, be controlled and are constantly changing and adapting. Looking for solutions means collectively interpreting feedback, supporting communities of action, showing results, and tightening the observe/orient/decide/act loop so that we can react rapidly to what is working now, build upon that success, and emerge with our neighbors finding their way out of poverty.* (John Sayles, 2015)

The previous Toronto City Council approved a *Toronto Poverty Reduction Strategy* (City of Toronto, 2015) based on consultations that included people living in poverty. Major concerns reported in this municipal report include: "One in four children and one in five adults live in poverty in Toronto", a great increase since the 1970s. Income supports have eroded while the cost of living has increased, and education is no longer a guarantee of a good stable job. Poverty in Toronto is concentrated in particular neighbourhoods, and is higher amongst newcomers, racialized groups, people with disabilities and other marginalized groups (City of Toronto, 2015).

Many poverty reduction measures affecting Torontonians are under provincial jurisdiction: education, health care, social assistance, and more. The previous Ontario government set a poverty reduction strategy (Government of Ontario, 2014) and has been reporting its poverty reduction progress since 2009.

The case study views poverty in Toronto as one system that is very complex due to a high number of interdependencies between people, organizations, policies, programs, and other components and socioeconomic factors. This system of poverty shares components with other societal systems, such as the housing market and the health care system. The system of poverty in Toronto has fairly stable patterns, and policies and programs have been engineered to reduce its problems. So the complexity and uncertainty appears when making a change: what will be its systemic effects?

2.3 Modelling

2.3.1 Modelling a system's parts and relationships

A model is an abstract representation of a system that helps to make sense of it by conveying selected information about it in an organized fashion. Many types of models are displayed as diagrams, which may be supplemented by charts and text that define and describe pieces of the system. This study focuses on models that visualize concepts, rather than data, strategies or metaphors, as delineated by the *Periodic Table of Visualization Methods* (Lenger & Eppler, n.d.)

A model of a complex system visualizes and describes the system's parts and the relationships between them. Michel Godet articulates the importance of relationships: "Bajo un prisma de sistema, una variable existe únicamente por su tejido relacional con las otras variables" (Godet, Monti, Meunier, & Roubelat, 2000). A variable is not part of the system until it is part of the "relational tissue", connected to other variables. That tissue-like web is illustrated by wire in Photo 2.

2.3.2 Simplifying and exposing complexity

This definition of a "model" for information technology also applies to models of complex systems: "A model is a simplified representation of [a] certain reality. The 'system under study' (SUS): a software system, or whatever. Simplification (or abstraction): retaining only the relevant aspects" (Génova, 2009b, slide 6).

Modelling a complex system is a process of making sense of the "concrete, idiosyncratic, and personal" realities of individuals, by connecting them to "abstract and encyclopedic" knowledge, through aggregation and generalization (quotes from Paget, 1988 cited in Weick et al., 2005).

The value of a model comes from simplification and visualization: selecting which aspects of the complexity are important to the model user, and displaying them in a form simple enough to be understood.

Although a system model may expose some complexity to the user, it also hides other aspects of the complexity. "To think about anything requires a mental image or model of it. A mental model is a selective abstraction of reality and at best it is an oversimplification" (Gharajedaghi, 2011, p.110). This is diagrammed by Figure 4, which shows that real-world systems range from less to more complex. That complexity is abstracted by a model, which may range from very simple to a fully comprehensive depiction of that reality. (This study defined aspects of a model's scope that can describe how simple or comprehensive a model is, in section 6.1.)

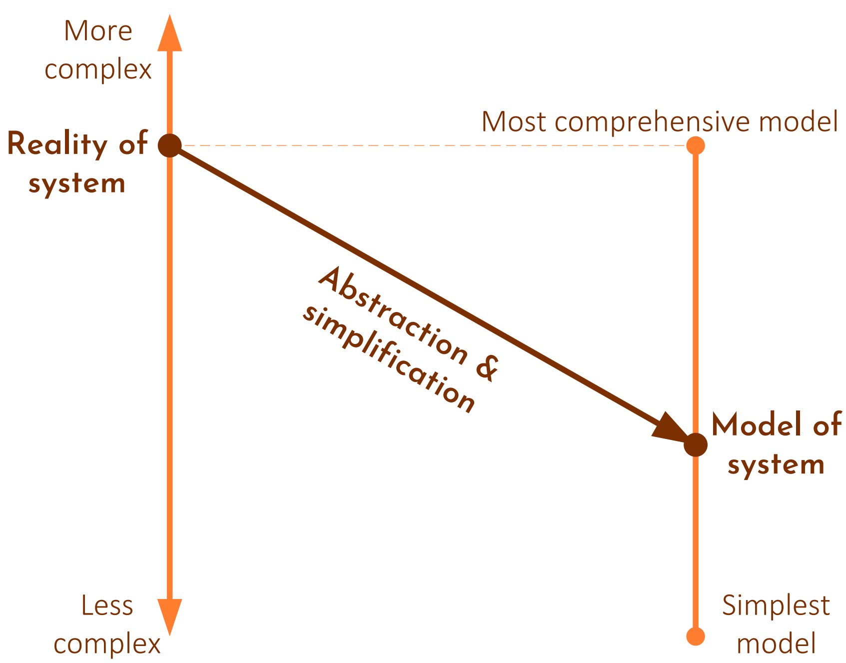

Figure 4: Models are simplifications of real systems

Writing about a book that recommends visualizing complexity for conflict resolution (Coleman, 2011), Sarah Lutman cautions against simplifying:

> *[I]ntractable conflicts are extremely complex in nature, so complex that it is difficult to sustain a mental map of factors that influence the conflict. The brain acts to simplify the conflict, and, in fact, the tendency is to over-simplify… A problem solving approach begins with complicating rather than simplifying the conflict description.* (Lutman, 2011)

In a radical guide to social justice strategy and facilitation, Adrienne Maree Brown urges the recognition of personal and interpersonal complexity in emergent social systems:

> *We have to embrace our complexity. We are complex. While many of us articulate a yearning for a more simple life, we continue practicing complexity as our evolutionary path. … I have grown an appreciation for simplicity, while also understanding that I enjoy it as a visitation – that being in a complex life is actually intriguing and delicious to my system. And that I have to understand that it isn't just my own complexity at work, but everyone I am in relationship with, creating an abundance of connections, desires, interactions and reactions.* (Brown, 2017)

Albert Einstein has often been quoted as saying "Everything should be made as simple as possible, but not simpler." Einstein's actual statement, traced by O'Toole (2011), was "It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience." This was a better articulation of the issue: how can complexity be expressed simply, without losing information that might be important?

Models need to strike a balance between their benefits and risks: abstracting complexity enough for comprehension, without misleading the audience into seeing the system's problems as simple and amenable to deterministic solutions.

2.3.3 Models and statistics about patterns in complexity

Models are generalizations of individual human experiences. The common and predictable patterns in a system can be estimated with statistics and visualized with model diagrams. The diagrammatic and statistical approaches can be combined in system dynamics, the quantitative practice of computer simulation of system behaviour (Sterman, 2000). Whether qualitative or quantitative, these modelling practices are good at capturing the known patterns.

Statistics provide probabilistic estimates to find the common patterns in uncertainty, while leaving some variation unexplained:

> *'Subway' uncertainty refers to what we can model and reasonably incorporate in probabilistic predictions that assume, for example, normally distributed forecasting errors. 'Coconut' uncertainty pertains to events that cannot be modeled, and also to rare and unique events that are simply hard to envision.* (Makridakis et al., 2009)

In a system, there are common events that recur in approximately-predictable patterns, similar to a subway journey that usually takes 16 to 19 minutes. For example, it is predictable that improving access to public transit will enable more unemployed people to commute to a job. There are also rare and difficult-to-predict events, such as a coconut falling on the subway tracks, derailing the train, causing severe injuries that disable those people from working.

A system with more coconut uncertainty is more complex, and more difficult to understand, predict, and manage, than one where most events are ordered in known, stable patterns.

> *[A] fundamental assumption of organizational theory and practice [is] that a certain level of predictability and order exists in the world. This assumption, grounded in the Newtonian science that underlies scientific management, encourages simplifications that are useful in ordered circumstances. Circumstances change, however, and as they become more complex, the simplifications can fail. (Snowden & Boone, 2007)*

If statistics show that people's problems are following a few predictable patterns, repeatable interventions can be designed to respond. For instance, governments set up social programs and services with regularized forms, rules and procedures, engineered to work efficiently within those patterns.

Sometimes governments and other service providers have an oversimplified understanding of a complex system. Having some detailed and precise information deceives people into believing the system is more predictable and manageable than it truly is. The complex system may be mistaken for an ordered situation (Snowden & Boone, 2007) where mechanical or procedural solutions are appropriate. People may attempt to control the coconuts.

Furthermore, statistical patterns might be interpreted as deterministic (universally true), rather than probabilistic (true for some percentage of people). When a person has a problem that does not match the patterns, and the government (or other service provider) is unwilling to make an exception to handle their situation individually, they "fall between the cracks".

In business, companies have a choice about how much complexity they will recognize in their marketplace. A company's "designed complexity" can offer "valuable wrinkles in their business model" (Birkinshaw & Heywood, 2010) to meet demand for many variations on their products and services. If they choose to simplify their offering to make the company more manageable and profitable, customers with more esoteric needs (exception cases, or less common patterns) can go to a competitor.

But for clients of social services, there may not be a competitor to go to. If government funding only supports the common patterns of need, people with exceptional circumstances will not be served effectively. Thus it is important for the social service sector to be able to understand and manage complexity, not erase its wrinkles.

Models and statistical evidence can be used to find the common patterns, and programs can be designed to address them with flexibility to accommodate the unique circumstances of each client. Ethnographic research (Government of Alberta CoLab, 2016; Kumar, 2013) should be employed to empathize with client experiences, rather than relying solely on the aggregate and abstract information.

A balance can be achieved: a model can provide useful simplification by showing the common patterns in a system, while capturing the holistic breadth and depth of the system's complexity. The model reader should be reminded that it might not include the rare and unknown patterns, and it does not express the emotions of individual people in the system. A model cannot be a complete, definitive depiction of a complex system full of change and unknowns.

2.3.4 Types of system models

Models may describe who and what interacts in a system, how, when, where, or why. Many different aspects of a system can be represented and connected in a model, including: organizational, individual and animal actors; physical objects and resources; money, information and other intangible things; geographic locations and areas; lifecycles of events; programs, services, functions, capabilities and products; activities, processes, projects and lifecycles of events; rules, policies, laws and governance; movements, flows and changes; and causes and effects.

Some common types of model include stakeholder maps, customer journey maps, data models and process workflows. At least 39 system modelling techniques have been indexed (Geofunders, n.d.) Various types of models and diagrams are also used in design research (Kumar, 2013). The researcher has created models of many types, in formats from systems thinking, business architecture, database design and other disciplines (Gharajedaghi, 2011; Ontario Ministry of Government Services, 2010b). Model types can be organized by the Zachman Framework (Zachman, 2008).

Each type of system model provides a different aid to understanding and considering action within a system. The purposes of modelling should determine the aspects of a system that needs to be modelled. Further research is suggested in section 8.5.3 to make a guide to choosing from the many available types of system model.

2.3.5 Structured modelling

Systems modelling can be very free-form, as in Rich Pictures (Checkland, 1981). Modelling can use a diagram format where the symbols have flexible meanings, as in Systemigrams (Blair, Boardman, & Sauser, 2007) or Concept Maps (Novak & Cañas, 2008). These are good tools to begin exploring a complex system with experts, to facilitate discussion of areas of concern. To understand the systemic patterns clearly, a more structured model is beneficial.

A structured model may be organized in many forms, such as a matrix, a Venn diagram, or linked nodes. In a structured model, a few constructs are used repeatedly and consistently, for example, a few types of nodes and a few types of links between the nodes. "A model is expressed in a modelling language" (Génova, 2009b, slide 6). The modelling language specifies how constructs are visualized with a notation, such as graphical symbols and colours to distinguish the types of nodes and links. For example, a (fictional) structured node-and-link modelling language might specify that every olive hexagon indicates a piece of legislation, every orange triangle is a population group, and the brown arrows between hexagons and triangles indicate which population is affected by which legislation. The modelling language defines the diagram's semantics, to answer "But what precisely do the arrows mean?" (Tufte, 2006, p.65).

Figure 5 may be read: the Projectile Coconut Regulation affects subway riders, subway mechanics, and lacrosse players. The Labour Act affects loggers and subway mechanics, who are also affected by the Blowtorch Bylaw and the Wire-Wrapping Regulation.

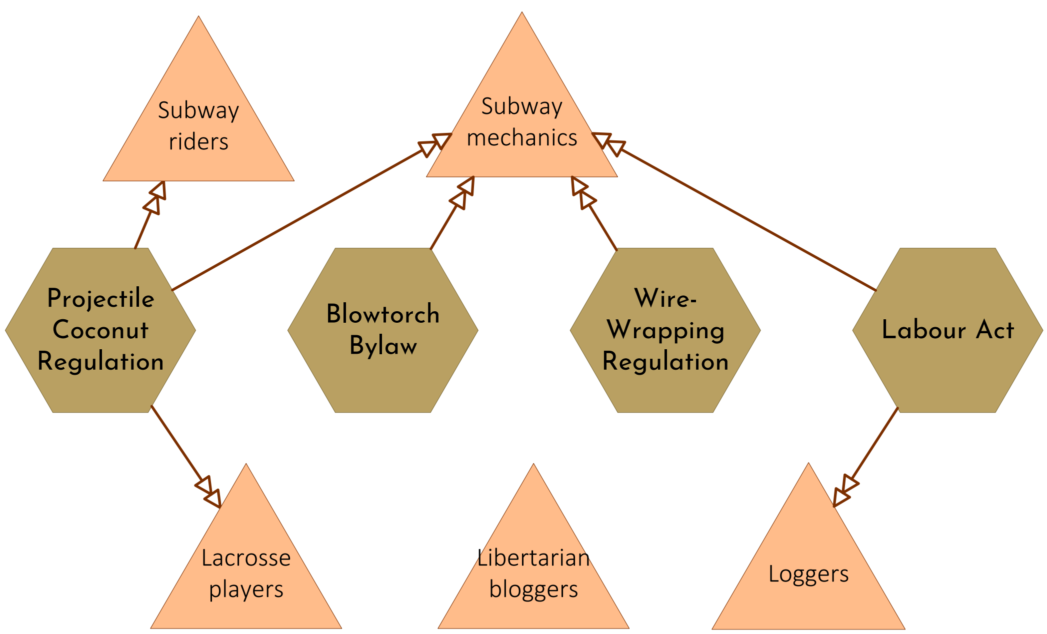

Figure 5: Fictional node-and-link model of legislation

The structured modelling language has "grammar" rules, for example, "every legislation hexagon node must be categorized as an Act, Regulation or Bylaw" or "every population must have at least one link to legislation". (When consulted in creating this model, the libertarian bloggers mistakenly claimed that none of the legislation applies to them, so they are not connected to any legislation in Figure 5.) The modelling language also specifies how constructs will be labelled and described with text, numbers, images or other data.   Detail may be captured about both nodes and links; Tufte recommends describing "when and how the link operates, its strength and persistence, credibility of evidence for the link" (Tufte, 2006, p.79). Perhaps the Projectile Coconut Regulation has different effects on subway riders, subway mechanics and lacrosse players.

Many structured modelling languages have been developed, such as causal loop diagrams (section 2.3.8). Modelling languages are sometimes standardized, such as the *Unified Modelling Language* (Object Management Group, 2017).

The researcher's consulting clients have often reported that developing models of a system "has changed their thinking". When people contribute to various structured business and information models (Ontario Ministry of Government Services, 2010a), they are pushed to clarify their thoughts. Modelling may bring order to mental chaos, by offering ways to organize multitudinous ideas about a complex system.

A structured model helps to identify patterns in the system, because they are indicated with matching symbols. The repetitive use of graphic multiples helps readers to "analyze, compare, differentiate, decide" (Tufte, 1997, p.105). There is obviously something similar about the olive hexagons in Figure 5. The system may be easier to comprehend once depicted in consistent symbols rather than textual narrative.

The modelling language rules will prompt the modelling team to fill gaps in knowledge by identifying more system elements and describing them fully. In the fictional example above, the modelling would discover who is affected by every law in scope. The diagram would show patterns such as one population that is affected by many laws.

Structured modelling can be challenging. When consulting to develop node-and-link models, the researcher has found that most subject-matter experts think about issues of concern, and conflate the concepts that might explain the issue (people, places, processes, events, rules, resources, etc.) People find it easier to say two concepts are related than to explain the nature of the relationship. The modeller needs to facilitate clarification of those concepts and relationships, and distinguish which type of model should be used to express each relationship of concepts.

The researcher's experience has shown that a structured model can record useful information about a system, even a complex system with emergent behaviour along non-linear pathways. Systems thinking should be *organized* thinking.

2.3.6 Modelling cause and effect

Understanding a complex system requires identifying patterns of cause and effect within it. "Systems thinking can help stakeholders better understand how complex interconnections of multi-level factors influence various phenomena in a plethora of disciplines" (Bureš, 2017).

An organization wanting to effect some change in a complex system needs to identify potential interventions, so they need a model of **causes and effects** in that system. Models of other aspects of the system do not answer the fundamental question of **why** does something happen, leading to imagine how that effect might be changed.

In root cause analysis, one issue or problem is identified, and the pattern of causes is traced backwards by repeatedly asking "Why does that happen?" The ladder of influence method, or "Keep Asking Why", surfaces symptoms, assumptions and root causes (Government of Alberta CoLab, 2016). This enables finding changeable points where taking action would improve on more fundamental issues than the surface symptom.

"Complex projects and situations require flexibility and generative thinking, including: … Rapid analysis of root causes and interactions, based on quality data, the wisdom of experience, and thoughtful insight" (Jones, 2008). That root cause analysis can be done using a cause-and-effect model that contains such data, wisdom and insight about a system.

An Ishikawa (fishbone) diagram is a common method for analyzing root causes of one manufacturing problem (Tague, 2005b).

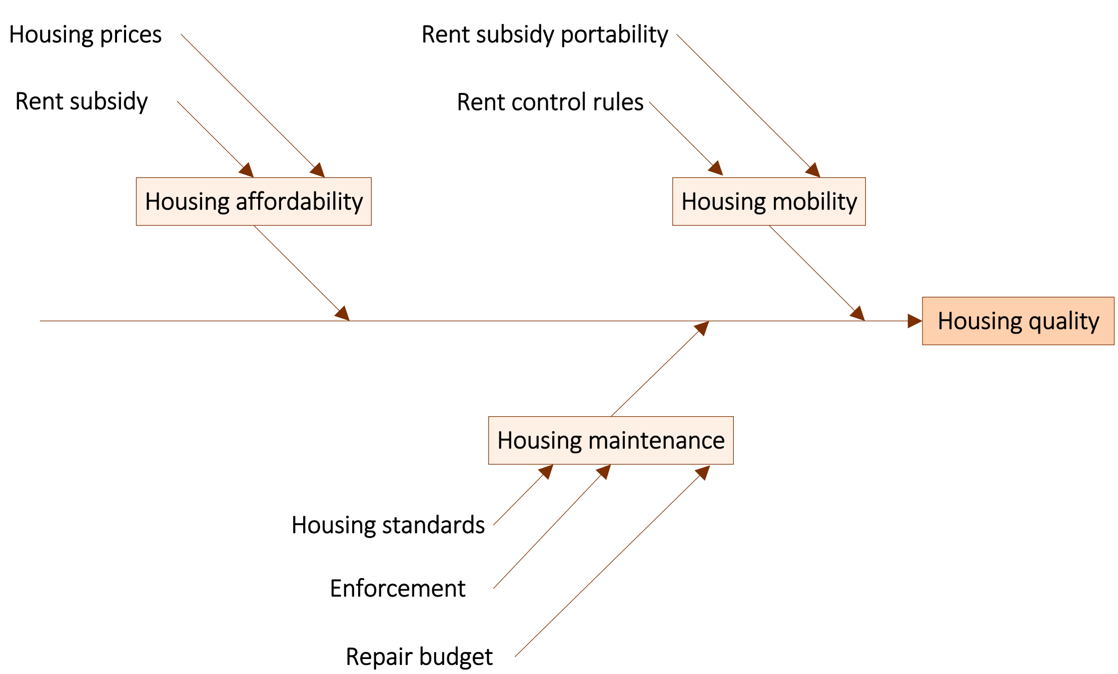

Figure 6: Root cause analysis of housing quality

This sample fishbone diagram, Figure 6, shows just a few of the housing issues identified in the Poverty Reduction Model, with arrows indicating cause or influence. In Toronto, high rents make good-quality housing unaffordable, and landlords have little motivation to maintain low-cost dwellings. Social assistance recipients may get a rent subsidy if they live in certain subsidized buildings, but it is not portable to other apartments. Further root cause analysis could be done of each issue, by asking more questions, such as: Why are housing prices high?

Cause-and-effect modelling also needs to look forward: if an intervention is made, what effects will it have, directly and indirectly?

A Logic Model (W.K. Kellogg Foundation, 2004) is a text chart describing the series of measurable outcomes that a social service program intends to achieve. This demonstrates that one intervention will have desirable results, looking forward in a linear fashion. There has been critique that logic models (also known as logframes) encourage linear, reductionist thinking that constrains social programming to a funder's requirements (Chambers & Pettit, 2004).

As an example, the "rent subsidy portability" issue in Figure 6 could be addressed by an intervention, the Portable Housing Benefit, which was selected on the Yonge Street Mission's short-list, section 5.2.1. This is its fictional logic model:

Table 2: Logic model for Portable Housing Benefit

Inputs	Activities	Outputs	Outcomes	Impact
Funding for higher usage of rent subsidy. Application form, eligibility rules, awareness materials.	Change rent subsidy policy to offer Portable Housing Benefit.	Households move, and receive rent subsidy in any new location. *Measured by:* Number of households that move and retain their rent subsidy	Increased housing quality and mobility. *Measured by:* Survey about housing quality after move, and benefits of housing mobility	Quality of life, in better housing.

The root-cause diagram, Figure 6, simplifies parts of a very complex system into a hierarchy of causes of one issue. The logic model, Table 2, also simplifies complexity, beginning from one intervention to the many outcomes it is expected to cause. Both of these might be called one-to-many cause-and-effect models.

This sample logic model does not show the likelihood of the intervention being effective, because it does not consider interference from other systemic effects (would rent controls still apply when tenants move?) The root cause analysis might have suggested alternative interventions to achieve similar outcomes, but the logic model does not compare which of them would be more effective.

The logic model does not show possible side-effects of the intervention: if low-income tenants moved more, how would housing prices and landlord behaviour change? Nor does it mention a chain of positive outcomes that was not in the root cause analysis: housing mobility may enable a tenant to move closer to a job, which they might retain because the commute is reasonable, which increases their employment income, financial stability, dignity and quality of life, and may enable them to transition off Social Assistance.

> *Systems thinking helps practitioners understand system complexity and bear it in mind, which is necessary to overcome natural human tendency to apply mechanistic approach built on cause-and-effect and linearization principles and thus miss "unintended" consequences of actions (e.g., intervention and policy change) that undermine the effort over time.* (Bureš, 2017)

Systemic thinking needs models that show more complexity than these one-to-many models. The non-linear systemic effects, including alternate pathways, side-effects and feedback loops, need to be considered when comparing options to intervene in the system. The more of these effects that can be modelled, the more a system can be understood holistically:

> *Complex systems are often referred to as 'wholes that are more than the sum of their parts,' wholes whose behaviour cannot be understood without looking at the individual components and how they interact…. Complex behaviour arises from the interplay, in densely interconnected systems, between multiplicative causation and positive and negative feedbacks.* (Waterloo Institute for Complexity & Innovation, n.d.)

A Theory of Change is a cause-and-effect diagram showing how one (or a few) social programs are intended to make an impact on society. A Theory of Change may be expressed in many different diagram formats (Center for Theory of Change, n.d.); there is no common modelling language. The Aspen Institute's guide (Anderson, 2009) shows a series of outcomes, interventions that lead from one outcome to the next, assumptions being made, and ways to measure each outcome. It has been recommended to model non-linear complexity of a system when developing a Theory of Change (Alford, 2017). A Theory of Change might be as simple as a logic model for one intervention, or might represent a few more interventions, outcomes and systemic effects than the one-to-many models, but are usually too small to cover all important aspects of a system.

2.3.7 Many-to-many models of cause and effect

When setting strategy to intervene in a complex system, there may not be a pre-set objective to achieve, so the one-to-many model formats above are not suitable. More knowledge can be captured by a many-to-many model, in which each item is "linked to an arbitrary number of other items" (Shneiderman, 1996) in the network of complexity.

A model of many causes and many effects is needed to explore a system, look backwards and forwards from many factors, and consider various objectives that could be tackled. Such a model might expose a causal factor with multiple downstream effects, which would not have been visible in a root-cause fishbone diagram. The model may make clear why some problems within that system are intractable. Reinforcing and balancing loops, and chains of positive and negative side-effects, may be considered when choosing where and how to intervene.

In a many-to-many model, much of the complexity of the system is preserved when causal relationships are allowed to form a non-linear network, rather than being forced into a single stream or hierarchy. This may be more difficult to comprehend than a one-to-many model that can be read in a linear sequence. Research has found that people have a preference for simpler chains of cause and effect, and typically reduce complexity to base their decisions on three to four causal factors (Klein, Moon, & Hoffman, 2006b). Model visualizations might help people avoid over-simplification.

Many-to-many models of cause and effect provide a framework to find multiple objectives (factors needing intervention), and to anticipate the outcomes, benefits and systemic side-effects of multiple potential interventions. If the effort is made to develop and think about many paths of causation, these models can be powerful tools with multiple uses in a complex system.

Node-and-link models can show multiple causes for any one effect, and multiple effects of any one cause, to understand the complexity of a system and compare interventions in it. In such a diagram, each variable factor is a node, linked to any number of other nodes by arrows indicating a direction of cause-and-effect.

2.3.8 Causal Loop Diagrams

A well-established technique for many-to-many modelling of cause and effect is the Causal Loop Diagram (CLD). Causal loops are a prominent tool in systems thinking (D. H. Kim, 1999; Sterman, 2000).

There are many guides to causal loop diagramming (Goodman, Kemeny, & Roberts, n.d.; D. H. Kim, 1992; Lannon, n.d.; Sterman, 2000; Zhou, 2012). The CLD shows cause-and-effect relationships between variable factors as arrows between text nodes. The causal relationships may form balancing or reinforcing loops.

The well-known advantage of a causal loop diagram is that it “shows not just how the system works, but where to intervene to transform the system’s dynamics” (Government of Alberta CoLab, 2016). That same guide to systems-dynamics facilitation cautions that CLDs are “not intuitive” and require pre-education of the facilitator and the participants.

Causal loop diagrams are qualitative descriptions of systems. The CLD can be the basis for using System Dynamics techniques for computer simulation of system behaviours over time, if considerably more effort is invested to gather quantitative information about stocks and flows (Van Zijderveld, 2007). That level of quantification was not feasible in this study.

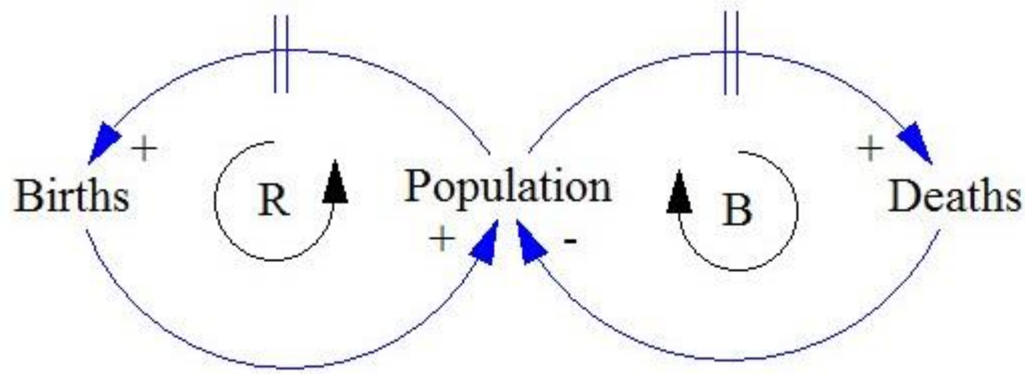

Figure 7: Causal loop diagram for births and deaths (Zhou, 2012, used with permission)

In this classic example of a small CLD, we see a reinforcing loop at left: a higher population leads to more births which further increases the population. This is balanced by the loop at right: in a higher population, there are more deaths, which reduces the population. The arrowheads are marked with a plus or minus sign to indicate the relationship polarity. The loop type is signaled by R or B within a circular arrow. The parallel lines crossing some of the arrows indicate delays: it takes many years between adding a newborn person to the population, and that person having births of their own, or that person dying.

This CLD notation is commonly used in the systems literature, so it has the advantages of familiarity, though there are many variations and no universal standards. (Notably, the relationship polarities are often defined as Same and Opposite.) The notation has some disadvantages, especially for readers new to systems modelling:

- The + and - symbols next to the arrowheads are small, thus difficult to notice.
- The reader must first learn the non-obvious meanings of R, B and the delay markers.
- The circular arrows around R and B might be confused with the relationship arrows.

The classic notation can be varied to show additional information. For example, in Figure 8, text colours are used to distinguish two sets of nodes (high-skill and lower-skill populations). The thickness of arrows is increased for higher-impact relationships. A box is placed around the dependent variable of interest (rental prices).

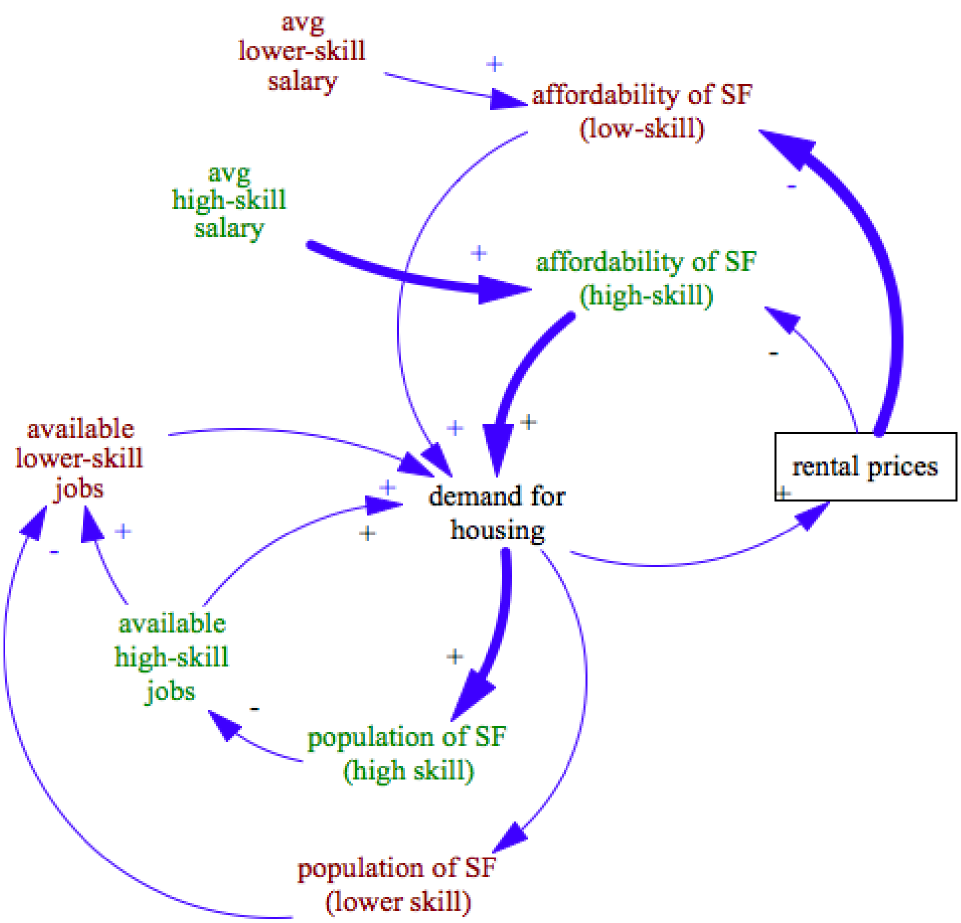

Figure 8: CLD for San Francisco housing (Zhou & Schwartzman, 2013, used with permission)

Other authors have experimented with adding more details to the CLD notation. For example, the CCTool software (Moschoyiannis, Elia, Penn, Lloyd, & Knight, 2016) also uses line widths to denote weak, medium and strong linkages. Nodes are coloured to indicate whether a factor is easy, medium or hard to control.

MARVEL (Van Zijderveld, 2007) is an adaptation of causal loop diagramming and system dynamics to analyze policy interventions where quantitative data is insufficient for computer simulation (see section 2.4.2). MARVEL uses a variety of small symbols to denote system-dynamics information, including using line widths and patterns to denote the strength of causal relationships on an ordinal scale. MARVEL notation also distinguishes "control variables" and "goal variables", showing that it may be useful to classify types of nodes.

Causal loop diagramming has been shown to be useful for making sense of complex social systems, but the method is ripe for adaptation to incorporate more information in a more readable format. Displaying the strength of causality, with line widths or other notation, is of particular interest for comparing intervention opportunities.

2.3.9 Causal models defined for this study

This study intended to adapt the format of causal loop diagramming. Like the CLD, the model format would be a node-and-link diagram, where nodes represent the variable factors in a system. Links would represent causal relationships, i.e. which factor causes or influences what other factor to change. The model would represent the multiplicity of non-linear patterns, with many causes of many effects. It would depict a system in qualitative language, but quantitative information might be stored about nodes and/or links.

A different name was needed for the type of system model to be designed, because it might not use the same notation as CLDs, and it might not emphasize the use of loops. The word "model" was preferred over "map" or "diagram", to encompass a database of model information that might be only partially displayed in any one diagram.

"System map" is the term used in Kumu software, which was chosen as the modelling tool. This is an accurate descriptive term, but it does not specify that cause and effect are being modelled, as opposed to other aspects of a system.

The term "influence model" would be suitable but is dominantly used for McKinsey's change management framework (Lawson & Price, 2003). The term "influence mapping" is widely used for stakeholder mapping (Mayers & Vermeulen, n.d.), sometimes expressed with node-and-link diagrams of the social network of people and organizations, rather than variable factors in a system.

The term "causation model" was used early in the study, but it was found that that name is commonly used in the risk management field for diagrams explaining how accidents and losses happen. These are notated in various formats other than node-and-link diagrams, and only sometimes recognize non-linear causation (Toft & Dell, 2012).

The term "causal model" was considered. A causal model has been defined, for educators, as "an abstract model of a system that uses cause-and-effect logic to describe its behaviour" (Federico & Quinn, 2017). These authors popularize the systems-thinking approach used in causal loop diagramming, with simple node-link diagrams and no technical or quantitative detail. Similarly, "causal mapping" is a facilitation method for qualitative diagramming of causality or influence (Bennett, n.d.)

By contrast, a "causal model" is often defined as a statistical artifact, tracing probabilistic relationships between variables (Asher, 1983; Little, 2016; Yudkowsky, 2012). An encyclopedic definition:

> *A causal model is an abstract quantitative representation of real-world dynamics. Hence, a causal model attempts to describe the causal and other relationships, among a set of variables.* ("Causal modelling," n.d.)

The variables and probabilities in these causal models may be depicted as node-and-link diagrams, as in the following modernized diagram of the data from a classic example (Blau & Duncan, 1967, fig. 5.1) :

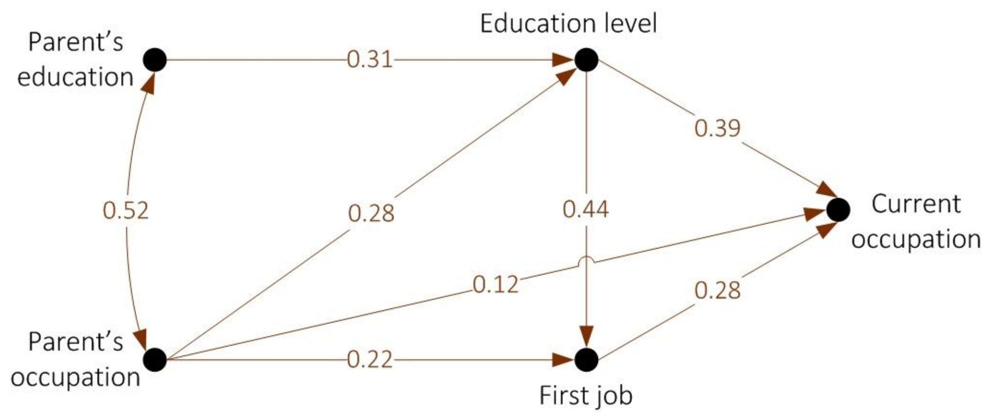

Figure 9: Example of statistical causal model

Figure 9 shows with numeric coefficients that a person's current occupation (perhaps as a lawyer, a logger or a blogger) depends more on their education level, somewhat on their first job, and a little bit on their parent's occupation. That first job depended strongly on their education level, and both of those factors depend upon their parent's occupation. Their parent's education influenced the parent's occupation and the person's education level.

The invocation of statistics might prompt the question "How do we know that a modelled relationship shows causation, not just correlation?" Although "correlation does not imply causation, it sure is a hint" (Yudkowsky, 2012). To establish causality, two variables need to be associated (correlated), the cause must logically happen before the effect, and alternative explanations need to be ruled out (Statistics Solutions, n.d.). To avoid spurious correlation, researchers are advised to first construct a causal model based on "theoretical expectations" (how one factor logically should affect another) and "experiential knowledge" before gathering "empirical evidence" to quantify the probabilities (Youngblut, 1994).

Whether or not probabilities are known, a causal model is a many-to-many model of cause and effect, expressed as a node-and-link diagram. The quantitative details may be hidden behind simple diagrams, as illustrated by Yudkowsky (2012). Larger sets of causal mechanisms need to be theorized and diagrammed before statistical validation of each causal path (Little, 2016).

This definition encompasses both qualitative and statistical versions of the causal model diagram:

> *A causal model is a formal device intended to represent a part of the causal structure of the world. It comprises several variables and specifies how (and if) these variables are causally connected to each other. Causal models are used in many disciplines (such as statistics, computer science, philosophy, econometrics, and epidemiology) to study cause-*

effect relationships, to formulate complex causal hypotheses, and to predict the effects of possible interventions. (Gebharter, n.d.)

Thus the term "causal model" will be used for this study's adaptation of causal loop diagramming. The case study will develop a qualitative causal model, which may be quantified as data becomes available.

Although a casual model is a powerful selection of information about complexity, it is still a simplification of the common patterns in a system (section 2.3.3). Models assert facts that are approximately true, according to research that has some chance of being incorrect. Causal models are not designed to show or predict change in systemic patterns over time. Nor can they convey the complexity of human experience that is expressed by stories from people involved in the system. Nevertheless, if interpreted with care, a causal model can be a useful abstract representation of a complex social system.

2.4 Modelling challenge: Knowledge

This study encountered three challenges of modelling a complex system: Knowledge, Scope (section 2.5) and Comprehension (section 2.6). The process of making and using a causal model presented the Capacity challenge (section 3.8).

Each stakeholder in a complex system has some incomplete knowledge about the system. A structured model can integrate the knowledge of multiple stakeholders. System modelling may be considered as a knowledge management tool that can share tacit (personal, experiential) knowledge as more explicit (documented) knowledge (Hajric, 2010b, 2010a; Nonaka, Takeuchi, & 竹内, 1995).

2.4.1 Knowledge sources and co-modelling

To develop a model, the knowledge of a system can be gathered from source documents (secondary research), and from various methods of primary research with experts – the people living or working within a social system. Tufte exhorts the use of multiple sources of facts and data in diagrams – "whatever evidence it takes to understand what is going on" (Tufte, 2006, p.78).

Researching a model from source documents has the advantage of lower time and costs: no consultation meeting needs to be arranged. The document author has already integrated the knowledge of multiple experts, provided some insights, and recorded details. There are disadvantages: the available source documents might not cover the scope required. The authors and experts are not available to help interpret the document, nor to expose the issues that were not written in the document. Reading an abstracted document may not provide an empathetic understanding of people's experiences within a complex social system.

Most modelling projects therefore need to learn more directly from experts in the social system. People with lived experience in a system are experts with deep personal knowledge of the aspects they encounter. Professionals delivering services (front-line staff) will have empathetic and detailed understanding of a few programs and rules. Managers, analysts and academics will have more abstract and generalized knowledge of more aspects of the system. Different methods may be appropriate to include these forms of expertise in a model.

This primary research may include individual consultation interviews, facilitated group workshops, or ethnographic research methods to observe or ask about phenomena in the system (Government of Alberta CoLab, 2016; Kumar, 2013). All these primary research methods can obtain rich, “thick” descriptions (Geertz, 1973) of the complex social system, some of which can be captured as words and symbols in the model. Modelling is an exploratory process in which survey questionnaires are less appropriate: “Surveys generally do not yield data rich enough to be useful in formulating a model” (Sterman, 2000, p.157).

During consultations, the experts might express their knowledge in their own way, and rely on the modeller to integrate the information into the model’s structure. If the modeller directly adds content to the model during a workshop, the experts can observe this, make comments and corrections, and build trust in the model. It may be more feasible to develop model content after the workshop, in which case, the draft model should later be validated with the experts to ensure their ideas were interpreted correctly.

Facilitation skill is needed in the modelling process, to help experts with articulating their specialized knowledge for a more general audience. Causal models also need to “state the obvious” to put all relevant factors on the diagram. According to Sterman, modelling cause and effect often requires adding factors and relationships that were not explicitly mentioned in expert interviews or secondary sources. The modeller’s additions might be logically required and obvious factors in the system, or they may require explanation and validation with experts (Sterman, 2000, p.158).

As the experts learn more about how to organize knowledge into the model’s structure, they can become co-modellers, either working together in facilitated workshops, or directly creating content in the modelling software. Co-modelling allows the experts to contribute to the model more directly and therefore with less chance of misinterpretation or omission. Co-modelling can yield richer model content if experts are articulate in the communication form chosen. Less rigid forms of system models, such as Rich Pictures and Concept Maps (Government of Alberta CoLab, 2016), are suited for active group participation: everybody has a marker in hand.

For system models with more regulated structures, such as causal models, co-modelling adds to the time required for expert participation. Various researchers have co-modelled a causal loop diagram with community stakeholders (Allender et al., 2015; Frerichs et al., 2016; Trani, Ballard, Bakhshi, & Hovmand, 2016). According to a guidebook (Hovmand, 2014), this practice of group model building, or community-based system dynamics, requires considerable planning, workshop time and multiple facilitators.

During co-modelling, the experts' cognitive load is increased: they need to think not only about how to articulate their knowledge of the system, but also how to organize that knowledge into the model's structure. In the researcher's experience with various rigidly structured model formats, it is usually more productive for the experts to concentrate on expressing their knowledge, and rely on the modeller to structure that knowledge in technically correct forms. Occasionally, an expert is keen to learn about the rigid model structure, which helps them to clarify their thinking about the system, so they become very active co-modellers.

2.4.2 Quantification

In a social system, there is a high volume of variable factors. Most of them involve human behaviour, and are thus difficult or costly to measure, compared to physical or natural phenomena. (For example, a survey about discrimination in a workplace would be less precise than a lab test of the nutrients in a coconut.) What statistics do exist will not be fully comparable, due to differences in definitions and measurement methods. Causality is difficult to trace; that discrimination may result from the combination of multiple contributors over many years. Therefore it is not usually realistic to do a fully quantitative simulation of the behaviour of a complex social system.

A system dynamics simulation can yield predictions of systemic effects, such as feedback loops, emerging in the long-run behaviour of a system's cause-and-effect relationships. It is possible to get some benefit from system dynamics even in complex social systems where complete quantitative measures are unavailable. Subject-matter experts "may not always be able to produce quantitative data at an acceptable effort but still often can agree on a somewhat holistic view on the 'strength' and 'speed' of causal relations in a Causal Loop Diagram" (Van Zijderveld, 2007). Van Zijderveld proposes a CLD notation modified to show an ordinal strength rating on every relationship arrow. That semi-quantitative information can be interpreted by a model diagram reader, or used in a computer simulation, to make conclusions about the indirect effectiveness and leverage of elements in the model.

2.4.3 Identifying and rating causal relationships

Similar strength ratings are proposed in the Structural Analysis method (Godet, 2010; Godet et al., 2000). This procedure systematically identifies the relationships in a causal loop diagram (or any causal model). A panel of subject-matter experts is engaged first to prepare the list of variable factors in the model. An automated survey tool is then used to ask each of the experts whether each of the N factors has a direct influence on another factor, and if so, they rate its strength on a scale of 1 to 4. The experts are asked the same questions about a relationship in the other direction between the same two factors.

Godet states that the expert panel spends two to three days answering these questions for a list of up to 80 factors. Assuming three 8-hour days to make 80 x 79 rating decisions, it apparently takes less than 14 seconds per pair. Godet claims that 80% of the structural analysis results are obvious and confirm intuitions, bringing value to the 20% of counter-intuitive results.

The results determine what relationships are drawn in the causal loop diagram. The results also form an NxN "cross-impact matrix" of numerical ratings of every possible relationship. About 80% of the matrix will be zeros (no relationship). The matrix can be analyzed for influence using the MICMAC algorithm (section 3.7.3).

Another systematic procedure for causal loop diagramming is Interpretive Structural Modelling. A group of experts identify variable factors and relationships in a system, then a computerized algorithm "identifies those elements that are most strongly dependent upon other elements, and also those elements that are the strongest influencers of other elements" (Monat & Gannon, 2015).

2.4.4 Quality

In quantitative research, accuracy is "the degree to which a measurement represents the true value of something", and bias is systematic deviation from accurate measurement (Roopesh, 2015). The nearly-synonymous concept of validity "is the extent to which a test measures what it is supposed to measure" (Purdue Statistics, 2004). Reliability means that repeating a test will produce the same results (Purdue Statistics, 2004), and precision is "the degree of resemblance among study results, were the study to be repeated under similar circumstances" (Roopesh, 2015).

Identifying the factors and relationships in a complex social system is a qualitative activity, not amenable to scientific rigour, even if quantitative measures are made of some information in the model. System modelling is subject to similar quality concerns as qualitative research, where human behaviour is not static or replicable, and "where the researcher's subjectivity can so readily cloud the interpretation of the data" (Cypress, 2017).

In qualitative research, validity can be interpreted as trustworthiness and confidence that leads to generalizable or transferable findings, and reliability can be interpreted as a need for consistency and dependability (Golafshani, 2003 citing Lincoln & Guba, 1985).

In a human system, there is no neutral source of information; all experts and source documents will have some kind of bias. Validity in qualitative research can be increased through "triangulation", meaning the search for convergence of multiple sources of information (Creswell & Miller, 2000, cited by Golafshani, 2003). To ensure full understanding of the impacts of a social system, "we must be sure that relevant voices of people directly affected are heard" (Brown, 2017).

This study proposes the following interpretations of these concepts for assessing the quality of a causal model:

Is the model a trustworthy representation of collective knowledge, which can be confidently used to learn about a system? Is bias reduced by combining multiple relevant sources of information, including documented evidence, lived experience of the system, and other knowledgeable experts with various perspectives? Where the model states facts (such as rules in a policy), are they correct, current and verifiable? Where the model includes quantitative evidence, is it accurate, reliable, and applicable to the system being modelled?

The next chapter (section 3.3.1) describes modelling as a process of "sensemaking", which increases the quality of knowledge about the system in scope:

> *Sensemaking is not about truth and getting it right. Instead, it is about continued redrafting of an emerging story so that it becomes more comprehensive, incorporates more of the observed data, and is more resilient in the face of criticism.* (Weick et al., 2005)

The challenge of developing a causal model is to integrate broad and rich perspectives to reveal what is known about the complexity of human experience.

2.5 Modelling challenge: Scope

The scope of a model is a boundary defined by what information is needed about the system. What topics should be covered? How much information is needed about each topic, for example, how many factors and relationships should be modelled? What kind of detail and evidence is needed? How richly will the complexity of the system be described?

A scope boundary is used to plan and limit the modelling efforts. The scope determines the model's size, meaning the number of elements and connections and the amount of information about them. (The aspects of scope, and the meaning of comprehensiveness, were further articulated by this study in section 6.1.)

When modelling a complex system, it is difficult to limit the scope because seemingly unrelated factors might turn out to be an important influence on the system. "Systems are always more complicated than they first appear" said Donella Meadows (2008). The model developers may include lots of detail about a topic, and many connections to other topics.

When modelling a complex social system, there may not be natural scope boundaries as when modelling within an organization, and setting artificial limits on the scope may exclude important information.

"There is no decision procedure that can tell us with certainty where to draw the boundary of a system" (Ryan, 2012).

Early in the exploration of the unknown unknowns, stakeholders might ask a wide variety of questions in attempts to find and frame the problem to be addressed. This can lead to gathering a wide variety of information, as observed by Ackoff (1967): "the less we understand a phenomenon, the more variables we require to explain it." Ackoff critiqued the irrelevancy of much of the data collected for management decision-support, but perhaps exploring that information was necessary to frame the problems.

Causal loop diagrams, and system models in general, become large because of the "natural tendency of users to develop more complex models in order to capture all relevant variables and explain more phenomena included in the problem situation" (Bureš, 2017). While Bureš is concerned about the comprehensibility of large models, small models are at risk of missing important factors in a simplistic explanation of complexity.

A smaller model might be created in less time than a large one. However, just as it takes a long time to write a short document, careful consideration should be put into choosing the elements of a smaller model. Expert knowledge is needed to make wise choices of those few elements that will cover the scope required. Therefore, it would actually take significant time with experts to create a high-quality yet small model.

That smaller model might be a summary of a broad scope, leaving out details that might influence a decision. Or the small model might focus on one problem that was framed while discussing many related issues. Either of these smaller models serves fewer purposes than a large model of the scope under discussion. The smaller model might also mislead the reader into thinking that the real-world system is an ordered situation, manageable by deterministic solutions (section 2.2.4).

An algorithm for simplification of a larger causal loop diagram is provided by Bureš (2017). This mechanical method makes assumptions, for example, that factors with only one connection are less central to the model's argument. The procedure also encapsulates longer chains of causation into one relationship between two factors. Bureš' simplification rules are designed to cover the breadth of a model's scope, but risk removing information that an expert would know to be important.

The difficulty of selecting a small model scope leads to consideration of large models of cause and effect.

2.6 Modelling challenge: Comprehension

2.6.1 Users of a causal model

The comprehension challenge should be tackled in light of who needs to comprehend a model, and what capacities those users have. A causal model may be used by a wide variety of people, for professional purposes, for education, or out of personal interest. The model users include the experts who learn while contributing to the model, and also people who read the completed model.

This study designs modelling methodology for model users who are professionals, who need to understand and make decisions about the complex social system they work within. The modelling methods were not designed or tested with other potential users, such as elected officials (who are more influential but busier than professionals) or community members (who have more lived experience but less influence in a system).

Causal models are usually depicted in a two-dimensional diagram (on paper or on screen) that contains text and symbols. Therefore, people with limited vision or literacy will need accommodation or assistance to read a causal model. With this context, we consider: how might a large causal model be made comprehensible by professionals and other stakeholders in a complex social system?

2.6.2 Afghan spaghetti: comprehension of large models

An infamous example of a large causal loop diagram will illustrate the advantages and disadvantages of a large system model, a key issue in this study.

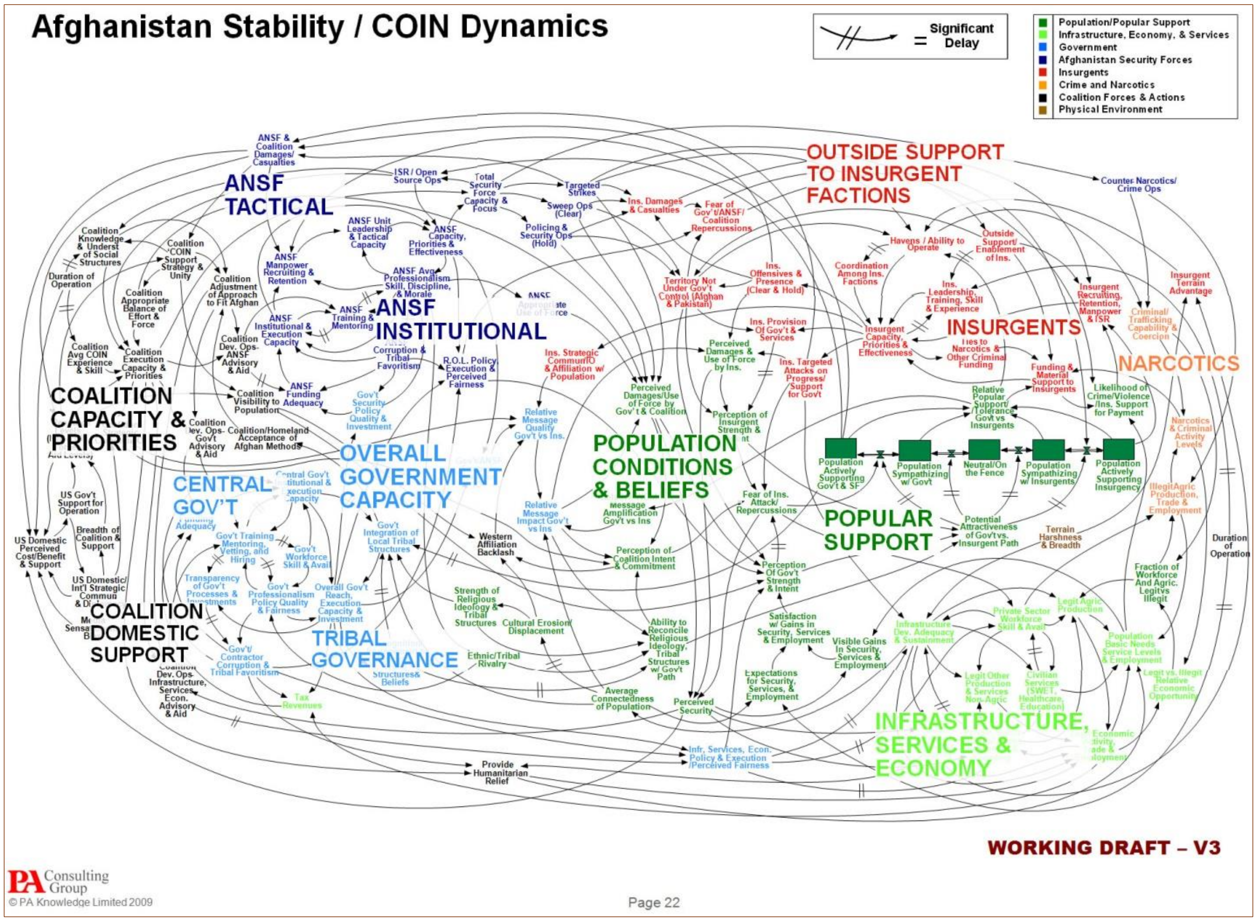

Figure 10: Afghanistan Stability example of large causal model

The Afghanistan Stability diagram (Figure 10) is a fairly large causal model, about the American counter-insurgency (COIN) strategy in Afghanistan, developed by PA Consulting Group for the U.S. military's Office of the Joint Chiefs of Staff. This model was originally published by the *NBC News World Blog* (Engel, 2009), who remarked "It sounds simple. But an attempt to visualize the strategy reveals how immensely complicated it is for U.S. forces to accomplish."

Engel then acknowledges the importance and the downside of such a complex system model: "The slide is undoubtedly overwhelming. For some military commanders, the slide is genius, an attempt to show how all things in war – from media bias to ethnic/tribal rivalries – are interconnected and must be taken into consideration." The model makes great effort to recognize the real complexity of Afghanistan, not oversimplify that social system. The large model provides more comprehensive coverage of the issues, and is thus a better decision support.

In a *New York Times* complaint about "rigid lists of bullet points" in military PowerPoint presentations (Bumiller, 2010), this diagram illustrated how generals actually wanted to understand interconnected political, economic and ethnic forces. But publishing this "Afghan spaghetti" diagram widely made it an infamous example of excess complexity, according to commentators desiring simple solutions: "I'm certain Napoleon and Alexander the Great didn't need garbage like that when planning campaigns: but there again, they were real Generals who could make decisions" (Daily Mail Foreign Service, 2010, comment by Doug, no surname).

The Afghanistan Stability diagram is overwhelming, both cognitively and emotionally. Because so many elements are shown on one diagram, it would have taken the generals lots of time to comprehend. "Making diagram[s] more complex has negative consequences ranging from time demands during the development process to reduced comprehensibility during diagram interpretation and analysis." (Bureš, 2017) There is a risk that the overwhelmed reader will give up on understanding a large model, thus wasting the effort of modelling. If a model becomes extremely large, even the modeller may have difficulty remembering the model content, which risks duplicating some factors and missing some relationships.

2.6.3 Multiple small views of a large model

If a small model would be insufficient to describe the complexity of a system, the challenge is to make the large model comprehensible. A system dynamics textbook (Sterman, 2000, p.155) advises: "How then do you communicate the rich feedback structure of a system without oversimplifying? Build up your model in stages, with a series of smaller causal loop diagrams." Each smaller diagram is accompanied by explanatory narrative, gradually building up to a larger diagram of the whole model. See an example of this method, for San Francisco housing, by Zhou & Schwartzman (2013). Figure 10 is labelled "Page 22", so the Afghan spaghetti diagram might have been preceded by a series of smaller diagrams for each topic.

Miller's Law states that most people can only hold seven (plus or minus two) items in short term memory (Miller, 1956). For design of any kind of information visualization, "Overview first, zoom and filter, then details-on-demand" is the mantra recommended by Shneiderman (1996). This sequence is opposite to Sterman's recommendation, but it still includes a recommendation to zoom into small diagrams.

The researcher's experience with presenting various kinds of information and business models to civil servants confirms Sterman's advice: that most readers appreciate a series of smaller diagrams with explanatory titles, captions or narrative.

Some readers also want to see the entire model in one large diagram, so they can gauge its overall complexity, explore the model at leisure, and see cross-cutting connections not apparent on the smaller diagrams.

Modellers and readers of that whole-model overview will contend with the difficulty of laying out dozens of relationship arrows in two dimensions, with minimal crossed lines. The Afghanistan Stability diagram is a bit like an airline flight map, in which the long parallel arrows are difficult to distinguish and trace to their destination. The overview of a large system model might need to summarize the content for readability.

2.6.4 Visualizing with flexible notation

The Afghanistan Stability modeller did make efforts to make the large model readable, by partitioning the diagram into colour-coded topics. This is just one way to adapt model notation for comprehension. Colours, shapes, sizes, fonts, layout and other graphic design choices can make a diagram more or less readable.

The cognitive load on a diagram reader can be reduced by simplifying notation. Adhering to a technical notation standard can result in displaying more information than the reader needs for a particular purpose. In the Afghanistan Stability diagram, only relevant causal-loop notation was used: relationships have delay markers, but not polarities, and loops are not marked.

An alternate approach is to load a model diagram with as much information as possible, for readers to explore patterns at leisure. The detail or quantification attributes of a causal model might be displayed with colour-coding, shape sizes, and annotations.

Another recent style of visualization (Lima, 2011) is the overview of massive complexity, using colours and shapes to show trends and categories, without any intention of readability at the detailed level. A very large causal model could be displayed in this fashion.

2.6.5 Database and software

The comprehension challenge of a large system model can be resolved by developing the model in software that generates visualizations from a database structure.

The database will enforce the model's structure by organizing all model content into data tables and fields representing the variable factors, relationships and other constructs. Those content items, and the links between them, are maintained by the database. That model data may be browsed, searched, sorted, reported, counted and exported. Model content items may be edited or manipulated, individually or en masse.

Modelling software can also display any selection, topic or category of that model content, with rules to transform data into diagram notation. Only one copy of the content is stored, for reproduction on many diagrams. Any item in the model database can easily be updated in one place, and all diagrams will immediately reflect that update. This avoidance of duplication is a capability of some system modelling software, similar to computer-aided software engineering (CASE tools), that graphic design tools do not support well.

Static small diagrams may be manually maintained by selecting the elements that tell one part of the system's story. Database-enabled modelling software can also generate diagrams on demand, from dynamic selections of elements, to view a "slice" of the model, zoom out to a wider perspective, or drill down to a specific detail.

In this report, the wire photos are a metaphor for the unreadable tangle of factors and relationships in a very large causal model. Displaying a slice of the model is rather like taking a two-dimensional photograph of a three-dimensional bundle of wire. The photograph, like the dynamic diagram, yields a perspective that can be comprehended and communicated. The diagram might reveal an insight, just as the camera sometimes reveals a surprise: Squirrel!

Photo 3

Photo 4

3 Context: Making sense of complexity

The copper wire is obscured in a shimmering haze, but the torched, blackened strands have distinct curvilinear trends. Continuing chapter 2's review of theory and literature: even amidst uncertainty, patterns can be found, understood and acted upon. Making sense of a system, with facilitation, causal models and option comparison, supports making decisions along the path to action. Chapter 4 describes how some of these methods were implemented for the case study.

3.1 Summary

A causal model can be combined with facilitated and computational methods for making sense of a complex system, and finding and comparing options to intervene in it. The concept of sensemaking is introduced to address the high level of unknowns and uncertainty in complex systems.

Causal models can be used for integrative sensemaking, in which a group of people develop their collective knowledge of a system while contributing to the model, or (to a lesser extent) by reading the finished model. That understanding of the system enables using a causal model for finding and comparing interventions, as part of processes such as strategic planning, policy analysis, grant-making, systemic design of programs and services, communications strategy, and program evaluation.

Those strategic decisions can also be supported by known practices to identify and prioritize interventions. These include facilitated workshop activities, and option-comparison methods ranging from rapid scoring to structured discussions of researched alternatives. Procedures for computational analysis can also compare factors in causal models.

Some of these methods were conducted in the case study. Choosing the methods for this study presented the challenge of **Capacity:** Understanding of complex social systems is needed by organizations with limited resources for hiring skilled professionals. Communities of experts have limited time to participate in model development a model and decision support activities.

3.2 Unknowns and uncertainty

> *The universe is both orderly and chaotic. We understand it to a point, and then there is mystery. And that is not linear or cumulative. There is no eventual elimination of mystery. There will always be mystery. And knowledge. Humans are both understandable and mysterious.* (Peter Hardie quoted in Brown, 2017)

The Cynefin framework (Snowden & Boone, 2007) describes the "constant flux" of complex systems as "the realm of unknown unknowns". Donald Rumsfeld famously described the difficulty of discovering these "things we don't know we don't know", such as terrorist threats (Rumsfeld, 2002). These unidentified risks are like the coconut uncertainty discussed in section 2.3.3 (S. D. Kim, 2012; Makridakis et al., 2009).

In a complex system, decision-makers are comparing options and making choices with inadequate information. Structured modelling and option-analysis can show clearly what is still uncertain after integrating the collective knowledge about a system. Once those gaps in knowledge become *known* unknowns, the questions about a system can be better articulated. Existing evidence and new studies can be researched. Debates can be reframed. Pilots and prototypes can test assumptions and alternatives, to allow solutions to emerge.

3.3 Sensemaking and decision-making

3.3.1 Making sense of a system

Sensemaking refers to how people make sense of their experiences. The notion of sensemaking has emerged as a subject for research into organizations and decision-making as well as information sciences such as human-centred computing (Klein, Moon, & Hoffman, 2006a). This study will interpret the development and use of system models as a sensemaking process.

Sensemaking involves creativity, curiosity and comprehension of complex things like events. Sensemaking is about the process of achieving situational awareness, and developing that knowledge into a mental model of concepts and principles that explain events. "Sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively" (Klein et al., 2006a). When people are making efforts to understand a complex system, they are sensemaking.

Sensemaking often involves communication between people. "To share understanding means to lift equivocal knowledge out of the tacit, private, complex, random, and past to make it explicit, public, simpler, ordered, and relevant to the situation at hand" (Obstfeld, 2004 cited in Weick, Sutcliffe, & Obstfeld, 2005). This process of sharing knowledge to make it more organized and usable is central to modelling systems. Collective and integrative sensemaking is further discussed in section 3.4.2.

3.3.2 Making sense of options for action

When groups and organizations are preparing to make a decision about what action to take, they need to make sense of their options within their environment (a social system).

> *Sensemaking involves turning circumstances into a situation that is comprehended explicitly in words and that serves as a springboard into action. …*
>
> *Sensemaking is about action. If the first question of sensemaking is 'what's going on here?' the second, equally important question is 'what do I do next?'"* (Weick et al., 2005)

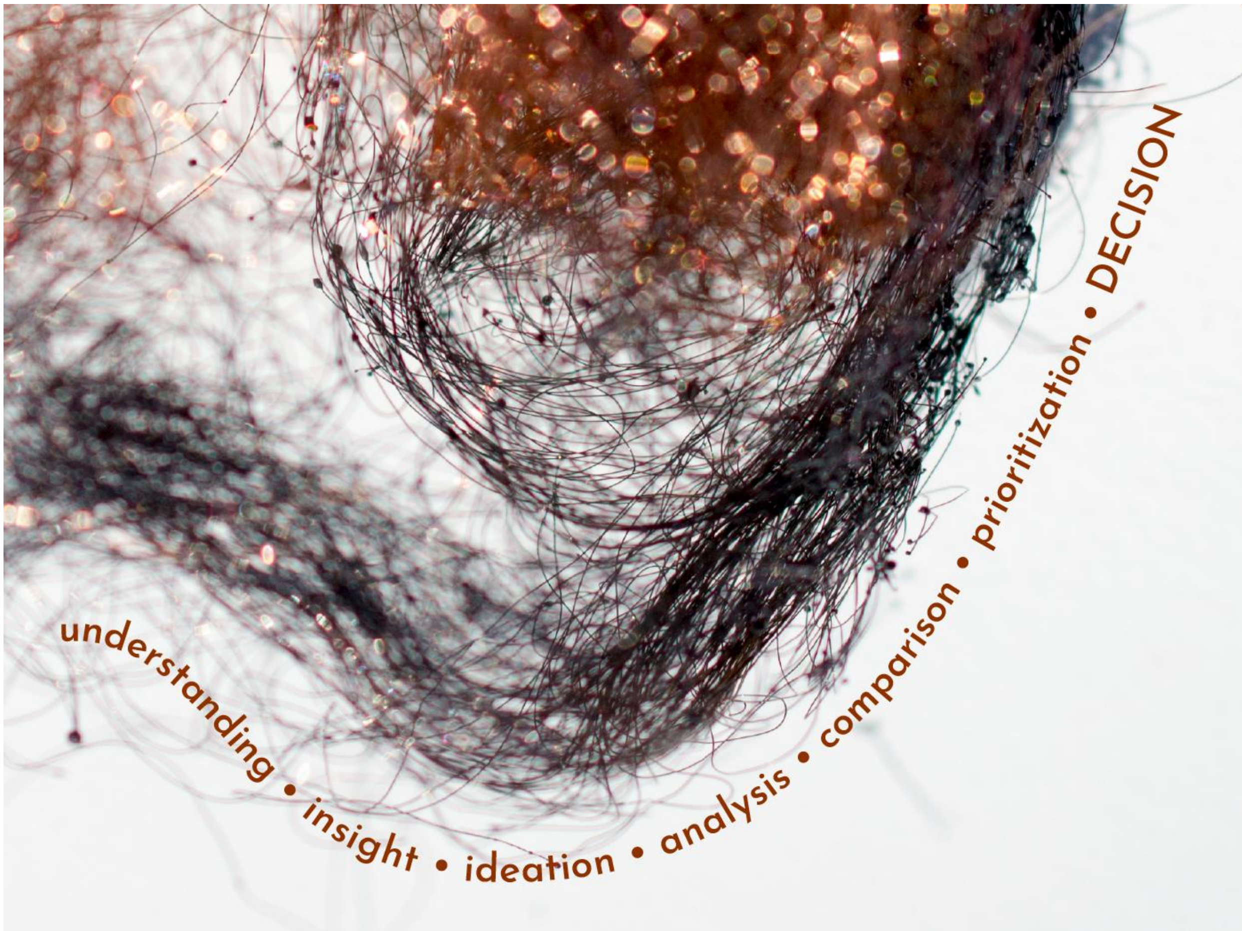

Figure 11: Spectrum of activities informed by sensemaking

Thus, we might consider a spectrum of activities that are informed by sensemaking, Figure 11. The journey towards action begins with passive understanding of what happens in the system. Thinking about that understanding, individually and in groups, may bring insight and generate new ideas (the activity known as ideation). These ideas may be options for a decision; the options may be analyzed, compared and prioritized. A decision to act is made based on the information enhanced by sensemaking activities. That action might be planning, designing, funding, delivering, evaluating or changing a policy, program or other activity that affects a social system.

Within organizations, decision-makers may make decisions in intuitive, arbitrary or self-interested fashions. They may instead make decisions in an informed, rational or analytical way, which enables the decision-making to be transparent to other people. The risks of taking action in a complex system can be reduced by sensemaking: increasing the decision-maker's knowledge to make informed comparisons of options. This study discusses tools to support more informed and transparent decision-making, including system models in section 2.3 and option comparison methods in section 3.5.2.

3.4 Modelling to make sense of complexity

3.4.1 Use of causal modelling in sensemaking and decision-making

Models of complex systems, including causal loop diagrams, have been described as useful for understanding the behaviour of a complex system:

> *Causal loop diagrams provide a language for articulating our understanding of the dynamic, interconnected nature of our world. … Creating causal loop diagrams is not an end unto itself, but part of a process of articulating and communicating deeper insights about complex issues.* (D. H. Kim, 1992)

> *[C]ausal loop diagrams can be thought of as sentences that are constructed by identifying the key variables in a system (the "nouns") and indicating the causal relationships between them via links (the "verbs"). By linking together several loops, you can create a concise story about a particular problem or issue. … By representing a problem or issue from a causal perspective, you can become more aware of the structural forces that produce puzzling behavior.* (Lannon, n.d.)

This study aims to show that causal models are useful not only for sensemaking and insight, but also as a support to decision-making. The model may be put into active use to help find intervention opportunities in a complex system (section 2.2.4) and during facilitated comparison of options for intervention (section 3.5.2). Causal models are useful all along the continuum pictured in Figure 11.

3.4.2 Integrative sensemaking

A causal model can share collective knowledge to make sense of the complex behaviours in a social system. "Causal loop mapping is especially powerful when done in a group—because by sharing our understanding of how a system might work, we can get a fuller picture of reality and therefore arrive at much more powerful action plans" (D. H. Kim, 1999).

Sensemaking (section 3.3.1) happens during model development, as the modelling team (experts, modellers and facilitators) figures out the system together. That group sensemaking process, a "collective induction of new meaning" (Weick et al., 2005), continues during use of the model, which may feed back further enhancements to the model.

Causal modelling can be considered as an integrative activity: The model condenses and organizes knowledge from multiple model contributors. During the group model development process, these experts learn from each other by hearing stories, discovering new ideas, and observing which topics are uncertain or debatable. The experts articulate their individual knowledge and gradually synthesize it with the knowledge from other experts and source documents, into a structured model (section 2.3.5).

Modelling, as sensemaking, is “often a social activity that promotes the achievement of common ground. It isn’t just an individual activity” (Klein et al., 2006a). Like any meeting, a workshop to develop a causal model is a convivial activity that can create or enhance social bonds, integrating the contributors into a group. The group modelling process can be considered distributed sensemaking, in which group members may “learn to work interdependently” even if some discrepancies persist in their understandings of the system (Weick et al., 2005). The group activity also affords higher trust and commitment (buy-in) to the project’s results.

Model contributors participate in an expansive learning cycle (Engeström & Sannino, 2010): questioning, analysis, modelling their breakthroughs, examining, testing and implementing the model, then reflecting on and consolidating the new practice they have learned. They integrate new thinking about the complex system into their daily activities and future work with each other.

People who read the model after it is developed will also gain an understanding of the system, making it an efficient tool to transfer collective knowledge, but without the intangible benefits of participating in model-building.

The modellers and facilitators also learn about the system they are modelling, gaining an integrated perspective that they might apply in future projects.

The phrase “integrative sensemaking” (S. Stein, personal communication, Nov. 7, 2018) therefore describes the power of causal modelling to synthesize and share collective knowledge.

3.4.3 Uses for knowledge exploration

Learning is sometimes an exploratory activity in which people seek out a wide swath of information without knowing in advance which pieces will become useful to them in future. Modelling may be used to discover unknowns, as discussed in section 3.2. Experts in some aspect of a system may believe they understand the system well, but they don’t know what they don’t know.

The model contributor or reader may integrate the model information with their own prior knowledge. Using the causal model, an individual may be better able to articulate and share their knowledge. This improved understanding of the system may influence their personal and professional actions within that system. They have new knowledge in memory for making everyday choices.

A causal model can also be useful when a person or group is not sure what problem to focus on solving. The discussions to choose a strategic focus, such as when adjusting the mission of an organization, can be supported by exploring the causes and effects in the relevant complex system.

3.5 Decision support

Steps for making a good decision are proposed by Thayer-Hart (2007, fig. 21): "identify root issues/challenges, list options, collect data, weigh the alternatives, choose one, do it, evaluate".

A causal model, combined with facilitated activities and analytical methods, may be a useful support for that decision-making process. The model may be used in finding opportunities to intervene in problems, and in comparing the systemic effects of interventions, as preparation for scoring and discussing options.

A causal model will not provide a single answer to a decision question. It is intended to be interpreted by decision-makers and those who influence them, in combination with other information about the system and potential interventions, in context of their mission and strategy.

3.5.1 Uses of causal modelling in management and governance

Causal modelling, in combination with facilitation and option comparison methods, may be useful in various governance and decision-making processes, including:

- Strategic planning, in which an organization decides what programs or change initiatives (interventions) to invest in, after identifying and comparing possible interventions
- Policy analysis, in which a government or other organization compares options for changes to laws and policies, to maximize desirable effects and mitigate negative side-effects
- Grant-making, in which a government or foundation decides what programs or projects to invest in, after comparing their anticipated effects.

Causal modelling may be used to ensure a systemic approach to program and service design. The cause-and-effect relationships may help an organization anticipate the positive and negative outcomes of various options for implementing an intervention as a service. Program evaluation may also benefit from using a causal model to identify outcomes that could be measured, and consequences that could be checked for.

3.5.2 Interpreting a causal model to find and compare interventions

A cause-and-effect model is suited to finding needs and opportunities for intervention in a complex system. The model can also inspire intervention ideas within a facilitated process. The systemic effects of intervention proposals may be mapped in a causal model.

The cause-and-effect relationships in a causal model may yield insights that would not be apparent from a simple list, hierarchy, or other type of system model. A causal model can be used to discover the fundamental causes of problems, and to identify factors that need to be increased or decreased to cause desired effects.

In a chain of cause-and-effect, some of the factors are more easily changed by interventions, while others are not easily controllable (by one organization or any societal actor). To find these needs and opportunities for intervention, trace the root causes of an undesirable factor until a changeable factor is found upstream. At that changeable point, systemic design and other facilitated practices (section 3.6) may inspire ideas for potential interventions.

The changeable points may be compared to find higher-leverage points: Which ones affect the more important downstream factors? Where is intervention needed more? Factors in the model may also be compared to determine where there is more potential for successful intervention.

Experts could be consulted about finding higher-leverage interventions in a system by using Meadows' 12 types of leverage point (Meadows, 1999), which argues that changes to the goals, rules or structure of a system are stronger interventions than adjusting rates and parameters.

Once some intervention proposals have been ideated, they may form a list of options to be compared and prioritized.

When comparing intervention options, the model should be reviewed for their causal effects: Which interventions would affect more downstream factors? Which ones would have stronger effect on the downstream factors? Are there systemic side-effects or feedback loops that would make an intervention stronger, or undesirable?

Feasibility criteria (not necessarily shown in the causal model) can also be applied to compare intervention proposals. Comparison and prioritization methods are outlined in section 3.7.

3.6 Practices for finding interventions

A causal model is just one tool for identifying intervention opportunities. Interventions in a complex system may be suggested by source documents and by experts, in facilitated workshops or through submitting written suggestions.

In facilitated workshops, experts may be prompted to formulate their latent thoughts about ways to intervene. Common methods such as brainstorming and the affinity process (theming) are useful (Thayer-Hart, 2007). However, experts may generate more intervention ideas if provided with tools to make sense of the system and its problems.

Systemic design practices (Government of Alberta CoLab, 2016) can encourage a group to find intervention ideas. Causal loop diagramming is one of the practices recommended for systemic design. Some of the human complexity will not be captured in the abstract model, so it is recommended to use complementary methods such as ethnographic research to empathize with the people involved in a system.

Analysis of other aspects of a system may also aid in generating intervention ideas: Using a journey map (Both, Baggereor, & Stanford d.school, n.d.), lifecycle diagram or process workflow model may prompt for ideas at all stages of something's lifecycle. Row 1 of the Zachman framework (Zachman, 2008), as used by the researcher in business architecture practice (Ontario Ministry of Government Services, 2010a), suggests making simple lists of the types of people, places, things, functions, events and rules in a system, which John Zachman calls "primitives". Discussing these lists and models may yield ideas for interventions throughout the scope of a system, which can then be related to the pattern of causes and effects.

3.7 Practices for comparing and prioritizing options

From many ideas generated, how do we choose a few to implement? How do we ensure those choices "have the maximum potential to achieve the desired change" (Laouris, 2012)? This study sought methods that could compare and prioritize a large number of interventions in a complex system. Rapid and resource-intensive methods exist, to use expert knowledge in facilitated, researched and algorithmic processes for option comparison.

3.7.1 Options analysis and options matrix

To analyze the options for a decision, research can be done to describe them and identify benefits, costs and risks. Continuing the fictional examples from chapter 2: If a transit authority needed to reduce subway delays caused by coconuts and other debris on the tracks, they might do an extended version of this options analysis:

1. Install **nets** beside and above the tracks.

   Analysis: Nets might catch some coconuts falling on open-air track, but cannot be installed on the platform edges where passengers need to enter and exit trains, and from which they throw debris. Squirrels and other rodents may damage the nets.

2. Install **platform barriers**, with doors that open when a train arrives in the station.

   Analysis: Platform doors serve as suicide barriers and safety measures as well as reducing track debris (Casey, 2018). They are costly and technically difficult to retrofit into an existing subway.

3. Use **vacuum trains** to clean the tracks regularly.

   Analysis: New York now prevents debris fires and delays by cleaning with vacuums designed for the subway system (Metcalfe, 2017). There are purchase costs and on-going labour costs.

4. Use **blowtorches** to burn the debris regularly.

Analysis: Subway mechanics are already equipped with blow-torches, but there would be ongoing labour costs. Controlled burning of debris may cause smoke and fume inhalation by passengers and staff, as well as increased fire risk.

Facilitation guides (Metz, 2016; Thayer-Hart, 2007) recommend first setting and ranking criteria, then making an **options matrix** to score how well each option meets each criterion. An options matrix might also be known as a decision matrix or grid, selection matrix or grid, problem matrix, solution matrix, criteria rating form, or originally a Pugh matrix (Tague, 2005a). Table 3 shows how the example options analysis might be scored:

Table 3: Options matrix example

	Effectiveness (5=best)	**Safety** (5=best)	**Cost** (5=lowest)	**Total score**
	Weight 3	Weight 2	Weight 5	
Nets	**1** x 3 = 3	**3** x 2 = 6	**5** x 5 = 25	3+6+25 = **34**
Platform barriers	**5** x 3 = 15	**5** x 2 = 10	**1** x 5 = 5	15+10+5 = **30**
Vacuum trains	**4** x 3 = 12	**3** x 2 = 6	**3** x 5 = 15	12+6+15 = **33**
Blowtorches	**5** x 3 = 15	**1** x 2 = 2	**4** x 5 = 20	15+2+20 = **37**

Each option forms a row, and each criterion a column, of the matrix. Each option is given a numerical rating on each criterion, a bold number between 1 and 5. The option-criterion scores are multiplied by the criterion weights, in brown numerals, to add up a total score (in bold) for each option. Decisions can be based on comparing and discussing the total scores. Weights and option-criterion scores might be adjusted once the results are known, as in this example where the inexpensive but dangerous Blowtorching option scored highest.

An options matrix breaks down a decision into smaller, better-articulated issues. The scores in each matrix cell are based on subjective judgement, but the process organizes thinking and ensures each criterion is systematically considered for each option (Enz & Thompson, 2013). The criteria may include systemic effects such as "potential negative consequences" (Tague, 2005a).

3.7.2 Simple methods for rating and voting

Dot-voting is a quick and easy way for a group to prioritize or select from a simple set of options. It is also known as dot-mocracy, multi-voting or stickers-and-dots, and is described in various guides (Diceman, n.d.; Seeds for Change, n.d.; Thayer-Hart, 2007). After developing the set of options and posting them on a board, every participant is given an equal number of dot stickers to attach to their preferred options. People can place more than one dot on options they particularly like. The criteria for selection might be discussed by the facilitator, or might be individual to each participant. Dot-mocracy results have higher validity if similar options are grouped before voting, and more reliable if more people vote.

In the **nominal prioritization** technique (Butler, 2014), each participant gives each option one numerical rating, on a scale such as 1=Low to 3=High. Ratings are totalled to compare the scores of items being prioritized.

For a group to rate many options along a numerical scale, a horizontal axis can be drawn on a large board or wall, and labelled with its meaning (the rating criterion). A sticky-note or card for each option can be attached and moved to the left or right, by participants discussing the relative rating of the options. The facilitator divides the axis (for example, from 1 to 10) and records where each option was placed.

This method can be extended into two dimensions. After placing options along the horizontal axis, a vertical axis can be drawn and labelled with a second criterion. Participants move the options up or down to form a **scatter-plot**. Working with one criterion at a time clarifies thinking. Options ranked high on both criteria will be in one quadrant of the board. This two-axis facilitation method was demonstrated successfully by the researcher (Boltwood, Bugeaud, & Selkin, 2017) in a classroom project to create a 2x2 matrix (Kumar, 2013, p.45).

Stormz.me is a **software** tool that can run online "workshops" in which the participants rate and vote for options on one or multiple scales. It can implement the rules for dot-voting, nominal prioritization, a scatter-plot or an options matrix with multiple weighted criteria. Participants can also sort and comment on options, according to steps customized by the facilitator. Total scores are calculated instantly and detailed results can be exported to a spreadsheet.

As we see from the above, guidance to facilitators for prioritizing options is focused on methods where each group participant expresses a rating of each option, and the ratings are aggregated arithmetically. The options matrix and the simpler prioritization practices above convert people's intuition and judgement into precise numerical ranks or scores. People "associate numbers with precision and confidence" (Zacarias, n.d.), at the risk of lending a false sense of objective certainty to an unknown future. Decisions can be made "automatically" from the numerical results, but it is more appropriate to use the new knowledge of the group's opinion to support further debate.

3.7.3 Analysis of ratings of causal relationships

Given a model of the network of causes and effects, it would be desirable to compute how much one factor influences or is influenced by the other factors (directly and indirectly). The more influential factors would be stronger causes of problems in a system, or stronger solutions to those problems, and thus would be priorities to work on.

The Structural Analysis procedure (section 2.4.3) produces expert ratings (on a scale of 1 to 4) of the strength of relationships in a causal loop diagram (Godet, 2010; Godet et al., 2000). The cross-impact matrix of all these ratings can be used in the MICMAC algorithm (available in Godet's software and in Kumu) to calculate the indirect influence of each factor on the system's behaviour.

The concerns about misleading precision would also apply to these quantitative results from expert ratings that are likely to be made rapidly on a high volume of relationships.

3.7.4 Research to compare options

Social Return on Investment (sROI) attempts to measure the value and impact of a social program in monetary terms. The U.K. government guide (Nicholls, Lawlor, Neitzert, & Goodspeed, 2009) shows that doing this quantitative method well requires identifying the inputs, outcomes and side-effects of a program, just as would be done in causal loop diagramming. With sufficient resources for estimating costs, multiple interventions could be thoroughly compared.

The Systematic Screening and Assessment Method (Leviton & Gutman, 2010) is "a way to identify the most promising innovations in preparation for rigorous evaluation" of programs. This resource-intensive process included:

1. Expert selection of areas with high potential leverage
2. Asking professionals to nominate hundreds of innovations in those priority areas
3. Expert screening of innovations against agreed criteria
4. Trained researchers write a full assessment of selected innovations, including describing a program with a logic model and theory of change
5. Expert review and prioritization of assessed innovations
6. Use of the information.

3.7.5 Multi-stage group discussion

Group discussion to compare options can be facilitated with various structured methods. These take more time but may yield higher-quality results than choosing based on a popular vote or rating score that may not "choose those ideas that have the maximum potential to achieve the desired change" (Laouris, 2012).

The **2-4-8 consensus** method (Seeds for Change, n.d.) asks pairs of participants to select their top three options, then two pairs join to discuss their top three, then two groups of 4 join to discuss their top three, etc., until the entire group has converged on three options, within a few hours.

Structured Dialogic Design is a multi-day facilitated group process for prioritizing issues within a complex system. The group discusses and researches obstacles to an ideal future state, then makes pair-wise comparisons that are entered into specialized software. The algorithm produces a diagram that traces the influence from one obstacle to another, and finds which obstacles are most fundamental (Laouris, 2012; National Coalition for Dialogue & Deliberation, 2008).

This study is also influenced by the **Syntegrity** process (Beer, 1994; Truss, Cullen, & Leonard, 2000) for facilitating large group discussions of complex problems (not prioritizing options). Syntegrity organizes a multi-day series of smaller meetings to discuss pieces of a big question, and then share problem refinements and potential answers with the larger group.

3.8 Challenge: Capacity

Decisions and actions in a complex social system are often made by government and non-profit organizations, where financial resources and staff time are limited. Relatively quick and low-cost decision-support tools are preferable.

This chapter has discussed many model development activities that take time: expert consultation, community involvement, secondary research, evidence gathering, systematic quantification, and of course model diagramming. Activities for finding, comparing and prioritizing interventions also take time. There is no universal formula for the duration and cost of a modelling project, because it depends on the model scope and quality required. A small causal model can be sketched out in one meeting, while a large model could be iterated through months of workshops and researched by a ten-person team.

Longer discussion time provides more insights from considering options in more depth, and iterating the expression of concepts in the model. Developing the system model throughout a decision-making process could yield more collective sensemaking benefit than rapidly producing a complete model to be read as a decision support. The benefits of longer discussion need to be balanced against their costs, in resource-constrained organizations.

This chapter has given theoretical justification for using those limited resources to use a causal model and deliberate methods to find and compare interventions. The remainder of this study tests the practicalities of doing this, for a very broad and complex social system.

Photo 5

4 Methods

The blast of the blowtorch brought a brief moment of colourful clarity in this tangle of wire. Modelling methods aim to bring that visual insight to an inscrutably complex system of poverty in Toronto. This chapter summarizes the methods used in the case study to develop a causal model and to use it to find and compare interventions that might reduce poverty. Chapter 5 provides the results of the case study. The findings about doing these methods are in chapters 6 and 7. Details are reported in the appendices.

4.1 Case study

4.1.1 Case study organization

The "organization" in the methodology research question (section 1.2) could be any government, non-profit or for-profit organization that wants to intervene, or advocate for intervention, in any complex social system.

The Yonge Street Mission (YSM) offered to serve as a sample organization in a case study. The YSM is a non-profit organization and registered charity established in 1896. YSM specializes in the challenges of poverty in downtown Toronto, providing a variety of supportive programs to three population groups: street youth, adults experiencing chronic poverty, and families in need (Yonge Street Mission, n.d.)

YSM has established a systemic and holistic approach to changing lives and building community. They recognize that in the case of chronic poverty, creating sustainable change requires positive action across all the intertwined issues in a client's life, so they use case-management software to track progress from surviving to thriving (Yonge Street Mission, 2018).

YSM's Director of Strategic Initiatives, Jeanie Son, is known in this report as the YSM Director. She liaised with the researcher and OCAD University, and coordinated a Working Group of YSM staff and partner organization representatives to participate in the case study. The researcher liaised with the YSM Director, held a planning meeting and agreed upon a Statement of Work.

The conclusions of this study are based on observing causal modelling with this one organization, which may not be representative of other situations.

4.1.2 YSM demonstration project requirements

The Yonge Street Mission wishes to extend their efforts to "Transform Toronto" by shaping social policy and research projects. Their "Policy Levers" project aims to identify what policy or program changes could have a high impact on poverty across the municipality of Toronto, and to conduct a demonstration project for one such policy or program (Yonge Street Mission, 2018).

This case study was designed to aid YSM in selecting a short-list of three interventions that would be highly effective in reducing poverty. Outside the scope of this study, YSM will research options on the short-list to choose a demonstration project. YSM set the following requirements for the short-list:

- Interventions that require changing policy (law, regulation or other rules) of any jurisdiction

- Innovations, meaning modifications of existing policies, and Toronto or Ontario implementation of policies that have been tried in other jurisdictions. (Completely new, untested interventions are less likely to succeed than incremental improvements.)
- Interventions that could be demonstrated and show measurable effectiveness within 3 years
- Include at least one intervention for each population that YSM serves: Street-involved youth, Families in need, and Adults in chronic poverty (Yonge Street Mission, n.d.)

The YSM set a very broad initial scope, encompassing poverty prevention, relief of its vicissitudes, and transitioning out of poverty. YSM has held "policy dialogue sessions" resulting in the internal Policy Dialogue report (Yonge Street Mission, 2017) about how Torontonians in poverty are affected by government policies & programs in the areas of social assistance (income support), housing, education, employment, immigration, childcare, child protection, mental health, and criminal justice. YSM needed to prioritize these many options for policy intervention.

4.1.3 Source documents

The Poverty Reduction Model was developed from expert knowledge, and three main source documents:

- YSM's internal Policy Dialogue report (Yonge Street Mission, 2017)
- Toronto's poverty reduction strategy (City of Toronto, 2015)
- Ontario's poverty reduction strategy (Government of Ontario, 2014).

All of these reports incorporate knowledge from many indirect sources, including the lived experience of people in poverty. Other source information about poverty was referenced by links in the descriptions of model elements.

4.1.4 Workshops

Facilitated group workshops afford a structured forum for professionals to exchange ideas and insight. In consultation with the YSM Director and academic supervisors, the researcher designed a series of five workshops to develop the Poverty Reduction Model and use it to prioritize interventions for the YSM demonstration project.

The YSM committed to provide a Working Group of about six people for five workshops of two hours each. The YSM Director invited staff of YSM (from front-line-staff to executives), the City of Toronto Poverty Reduction Office, and other partner organizations to participate in the workshops.

The workshops included informal education in systems thinking. In Workshop 1, the "systems thinking" approach was introduced with a slide that mentioned YSM is already taking a holistic approach to the complexity of poverty. Cause and effect in social and ecological systems were described to participants as complex, non-linear, changeable behaviours of many beings interacting, where unintended consequences are difficult to predict. Poverty was described as a problem where we seek interventions (not solutions) by mapping the interacting components and connections. Preparation for Workshop 3 included pre-reading about causal loop modelling and leverage points, listed in section B.6.1.1.

To iteratively improve the modelling methods, methodology feedback was requested at the end of each workshop. The researcher recorded observations after each workshop or other case-study meeting. Appendix section B.1 details the workshop schedule, materials, presentations and feedback questions.

4.1.5 Research ethics

Approval for this study was obtained from the OCAD University Research Ethics Board on June 5, 2018 (REB number 2018-40).

Two consent forms were devised, one for the Working Group participants and one for the additional liaison tasks of the YSM Director. Participants were informed that the study might benefit their own professional development, the YSM and other non-profit organizations, people in poverty (in Toronto and beyond), and society's ability to apply systems thinking for strategic planning in many fields of endeavour.

This study was expected to be a very low risk to the Working Group participants. Workshops to discuss poverty were similar to the participants' daily work, so they were likely familiar with emotional reflection on the difficult situations of people in poverty. Participants were not expected to discuss their personal or private matters in this study, though provisions were made for confidentiality if they decided to do so.

The following research ethics concerns were managed by the design and facilitation of the workshops:

- The burden on the time of participants
- Making participants aware that the researcher would make observations of their behaviour
- Power relationships between participants affecting what they say in workshops
- The social pressure of learning systems modelling in front of peers and superiors
- Ensuring Working Group members were voluntary participants, even though they were invited because of their professional role, and they were compensated by their regular salary.

The Research Ethics Board requested some revisions and clarifications to the original submission. Most notably, the participant time commitment was reduced from 8 to 5 two-hour workshops. The workshops were held during the work-day, so participants were compensated by their regular salaries, though they had the option to refuse or withdraw participation without consequences.

All participants signed an Invitation / Consent Form at the first workshop they attended. The first workshop included a discussion of research ethics and ground rules, and the ethics information was repeated briefly in subsequent workshops.

4.2 Methods summary

In the case study, the Poverty Reduction Model (PRM) was developed, used and analyzed to find and prioritize YSM's short-list of interventions to reduce poverty in Toronto. The following methods are described in this chapter and detailed in the appendices.

Model development began with the researcher interpreting three source documents (section 4.1.3) into a causal model, structured with elements, connections and loops. Kumu software was used, with a customized format adapted from causal loop diagramming. A one-page summary of the PRM was created.

The PRM was used in a process of **integrative sensemaking** (section 3.4.2) with the Working Group. During most of the **facilitated activities** in section 4.4, participants viewed the Summary Model or portions of the full PRM, to structure their mental maps of the system. Participants discussed the model content, building the group's collective knowledge as well as contributing comments to further development of the PRM. After all workshops, the PRM was delivered to YSM for further use in knowledge transfer.

Workshops 3 and 4 were designed to **find interventions** in housing, employment, and related issues. YSM sought policy innovations, but existing and programmatic interventions were also modelled to inspire related ideas, such as removing a policy barrier to a programmatic intervention. In these workshops, the researcher displayed portions of the PRM with housing and employment objectives, and then asked the Working Group what could be done to increase or decrease those factors, so as to ideate interventions.

The PRM was used as a decision support tool (section 3.5) to **compare interventions**. YSM needed a short-list of policy interventions for a demonstration project. The Working Group was facilitated to set prioritization criteria, which were interpreted for a series of activities to prioritize system elements for intervention. Semi-quantitative methods were used, such as dot-voting and expert ratings on ordinal scales (section 3.7.2). These activities, both paper-based and in Stormz.me software, were combined with discussion and expert judgement, to select the short-list. Two focus areas (Housing and Employment) were selected to narrow the range of topics under consideration, but other topics came up in discussions.

Some of these facilitated activities compared the **leverage** of interventions to find the ones with stronger influence on a larger number of more fundamental objectives, to push the system towards desirable goals. Various leverage calculation methods were tested or considered, but not used to select the short-list, mainly because the PRM connections did not have strength ratings.

Other **model analysis methods** were tested for applicability to the PRM, including Social Network Analysis metrics and a community detection algorithm. Statistics about the PRM elements, connections and loops were analyzed.

4.3 Model development

To develop the Poverty Reduction Model, the researcher integrated Working Group contributions and source documents into elements, connections and loops in Kumu software with customized structure and notation. The modelling process is illustrated with examples in Appendix A.

4.3.1 Setting the format and scope

4.3.1.1 Model scope

One of the challenges of this study was to address the very broad scope that YSM presented in their Policy Dialogue report (Yonge Street Mission, 2017): Social Assistance, housing, mental health, employment, education, criminal justice, child and family policy, and immigration. Narrowing to one topic was suggested in preliminary meetings, but YSM wanted a Working Group of multiple people involved in choosing the focus areas.

A strict scope boundary was likely to exclude important information about the complex system of poverty. The researcher did not have the expertise to select what was important enough to model. So the modelling effort expanded, by integrating all variable factors mentioned in two poverty reduction strategies (City of Toronto, 2015; Government of Ontario, 2014), and generating more model content in the workshops.

4.3.1.2 Model quality

The PRM's level of quality was intended for one organization to make a prioritization decision, and as a test of methodology innovations. Extensive research was not required about each element and connection.

4.3.1.3 Model structure

This study developed a structured model format based on Causal Loop Diagrams (section 2.3.8) to represent cause-and-effect relationships between variable factors in a complex system. The model format was evolved, using the features of Kumu software, to capture and display the large scope in a comprehensible way.

The model format evolved during the study; the final PRM structure is specified in section 6.2.1. It structures the model into elements, connections and loops, which can capture many-to-many, non-linear causal relationships. Elements must have at least one connection, but need not be part of a loop. The model elements are classified into goals, objectives and interventions, and multiple fields of data are stored about each element. Valid values were controlled for custom fields, to ensure data quality.

4.3.1.4 Model notation

The readability criteria, set in the original workshop guide, were: *"Quick to read; Pleasing to the eye; Comprehended, with intended meanings; Not too general, not too specific; Fonts, lines, colours, symmetry, layout, labelling"*.

PRM diagrams need to be readable on one screen, preferably showing a small number of elements, without crossed lines (Sterman, n.d.) or overlapping bubbles or text. The PRM elements are partitioned into meaningful sets (Subject Areas and topic Tags), so as to dynamically display arbitrary small pieces of the model.

The Kumu software was chosen for its customizable visualization and database of model content (section 4.3.5). Kumu was configured with flexible model notation (section 6.4.2) to optimize readability, without adhering to the traditional CLD notation. Model detail not needed for a sensemaking activity was hidden from view, to ease comprehension.

4.3.2 Model contributors and sources

The Poverty Reduction Model was developed from source documents and participant contributions. This integration process of analyzing and synthesizing multiple sources aimed to reduce unknowns and increase quality.

All poverty-reduction objectives and measures mentioned in the three source documents (section 4.1.3) were incorporated into the PRM before Workshop 1. These source documents each had many contributors, including low-income people as well as government experts and service-provider staff, and were relied upon as indirect sources of evidence about poverty in Toronto and Ontario.

The PRM was updated to incorporate knowledge that the Working Group offered during workshops, including the dozens of ideas from the sessions to develop Housing and Employment interventions.

Existing elements and connections were modified to coherently express the new knowledge. After each major update of the model, the Working Group was offered the opportunity to view, clarify and correct the model content. The PRM was edited whenever new information was obtained or an issue was discovered.

In this study, the Working Group members were not hands-on modellers, due to the time required for co-modelling methods, as described in section 2.4.1. For similar reasons, there was no attempt to crowd-source the Poverty Reduction Model content from dispersed contributors.

The YSM Working Group provided knowledge from multiple social-service professionals. The bias of their perspectives was known, accepted, and supplemented by the researcher adding economic and other factors to the model. For this methodology study, it was appropriate to work with professionals who would be typical modelling participants and users, rather than people in poverty.

To find interventions, this study did not do ethnographic research with people living in poverty. YSM's advice was that many previous studies had interviewed this population.

4.3.3 Modelling procedures

The solo modelling process began with a whiteboard drawing of elements and connections found in YSM's Policy Dialogue report (Yonge Street Mission, 2017). This and other examples from the Housing and Employment areas of the PRM illustrate the details of these modelling procedures in appendix sections A.1 and A.2.

This solo modelling process involved interpreting documents and workshop notes to identify factors in the social system, and to recognize how one factor might cause or influence another. The concepts in these texts were translated into an abstract structure of elements (nodes) linked by connection arrows which sometimes formed loops. The model content needed to be labelled, described, classified, and sometimes split apart or generalized together as knowledge sources were integrated.

4.3.3.1 *Interpretation of contributions*

Source documents and participant input were translated into the causal modelling language, by articulating and analyzing the variable factors and causal relationships embedded in a suggestion. A societal problem was interpreted as a goal or objective needing intervention. A proposal for a solution or action was interpreted as an intervention element. Cause and effect relationships were recorded as connections. Other information was recorded in element descriptions so that the PRM was entirely causal connections between variable factors.

Interpreting contributions to the model involved making inferences and analyses, based on subject matter knowledge and brief research. This included discerning the objective addressed by a suggested intervention, for example, find out that the *Housing First model* addresses *Homelessness.*

In the chains of cause and effect, elements were inferred that were not explicitly mentioned by sources, such as *Average rent per square foot.* Adding economic factors helped to consider counter-arguments to YSM's interest in increased funding to social programs, such as the cost of tax funding of the *Total housing subsidy budget.*

Concepts were generalized from multiple sources, to make the PRM applicable to more than current Toronto issues, and to reduce the number of elements and connections. Some elements and connections were split up to reflect more of the system's complexity (such as *Gross income* and *Net income*) and to better organize large clusters of connections (such as interventions in *Access to employment*).

The method of translating the source documents into model content is illustrated in section A.1.3.

4.3.3.2 Making elements

Each element was created in Kumu, and labelled immediately with a name, element type, source, subject area and topic tags. The other custom fields (Table 7) were filled in later by YSM through a spreadsheet import: policy status, innovation status, and ordinal ratings of impact and potential.

Element descriptions were written where necessary for clarity, sometimes with quotations from the source documents. Any secondary research done was linked to element descriptions.

Elements were named in terms understandable by Toronto social-service professionals. The phrasing of concepts by experts and source documents was modified to follow the PRM's modelling language, such as naming elements as variable factors in a positive direction, and not pluralizing elements. Text was checked for correct grammar and spelling.

4.3.3.3 Making connections

Whenever an element was added or modified, the PRM was reviewed for potential new connections to express its cause-and-effect relationships. Every element needed at least one connection.

Connections were identified using subject-matter knowledge and limited research, not systematic exhaustive procedures (such as Structural Analysis, section 2.4.3), due to the large size of the model and limited time.

To include a connection in the PRM, there needed to be some knowledge or expectation that one element may have some degree of causal influence on the connected element, under some circumstances. (There was no requirement to prove causation, but logic was applied to avoid including spurious correlations. See section 2.3.9.)

Each connection was created in Kumu, and assigned a connection type. Connections were not named or described.

4.3.3.4 Making loops

Loops were identified using subject-matter knowledge. In Kumu, a temporary tag was assigned to elements that were thought to be related to a reinforcing or balancing feedback pattern. The loop of connections was selected and named in Kumu, and assigned a loop type (reinforcing or balancing). In some cases, elements needed to be added or modified to form the loop.

4.3.4 Summarization methods

The Summary Model was developed to provide an overview of the (very large) PRM that would be easily comprehensible by the Working Group.

The researcher explored the major dependencies between subject areas, with two iterations on a whiteboard, followed by two iterations in a Visio diagram, to produce the original Summary Model (Figure 26). The diagram was expanded to a 36"x60" poster size, Figure 27. In the box for each subject area, the researcher wrote a text summary of the objectives and interventions in the PRM. This poster was the basis for discussion in the Workshop 1 prioritization exercise (section B.3). The Summary Model was revised after that workshop (Figure 3).

Other summarization methods were attempted to prepare facilitated activities and present views of the PRM. Mechanical methods were considered, as expert time was not available for selecting which elements were more important. Kumu could easily filter the PRM, to display only goals and objectives, or to hide elements with very few connections. Kumu could not maintain a hierarchy of summary elements to encapsulate detailed elements and connections. Kumu did not have all the features required for an iterative, mechanical method of summarizing a large causal loop diagram (Bureš, 2017).

4.3.5 Modelling software requirements

The Poverty Reduction Model had too many elements to be managed manually. Modelling software was required that could manage a database of all elements and connections (without duplication, and with custom fields), and display any subset of the elements, in two dimensions, with automatic layout to reduce overlaps. These requirements ruled out illustration software (such as Adobe Illustrator) and diagramming software (such as Microsoft Visio).

The modelling software also needed to allow iterative design of notation improvements by customizing the model format, and should permit multiple users to modify one model (stored in the cloud). These requirements ruled out the well-known system dynamics software such as Vensim.

The researcher had successfully used Kumu.io for previous causal loop diagrams. A search for Kumu competitors found online tools for diagramming and social networks, but none that would support causal-loop modelling with these requirements. Therefore Kumu was chosen for this study.

4.4 Facilitated activities

This section describes the methods used with the Working Group to make sense of the system of poverty, and find, compare and prioritize interventions in that system. These activities were facilitated by the researcher, in workshops and online. The following activities were conducted during and between workshops:

4.4.1 Visioning icebreaker

In Workshop 1, participants were asked to "Write or draw your vision: Poverty in Toronto could be reduced by…" on a sheet of paper, and explain their poverty reduction ideas. See details in section B.2.

4.4.2 Prioritization with Summary Model

Workshop 1 was an introduction to the Poverty Reduction Model. Participants annotated the Summary Model Poster (Figure 27) with questions, ideas, and notes about why subject areas were important. There was facilitated discussion about these annotations and about YSM's goals for preventing, alleviating and exiting poverty. Participants combined some subject areas before using dot-voting (section 3.7.2) to tentatively identify the ones most likely to help many people towards the goals. The high-ranking subject areas were discussed as potential focus areas, to be confirmed or reconsidered in Workshop 2. See details in section B.3.

4.4.3 Setting prioritization criteria

In prioritization processes, pre-establishing criteria is recommended by (Metz, 2016). In Workshop 2, the Working Group discussed and selected their criteria for prioritization. The proposed criteria (Table 17) were printed on slips of paper, which were defined, clarified, rearranged, combined, and added to. The group was asked how they would define the major criterion "Impact", and whether their priority was reaching a large population or having high impact on a smaller population. After discussion, dot-voting was used to rank the criteria, with results in Table 18. See details and photos of the method in section B.4.

4.4.4 Objective scatterplot

Workshop 2 continued on to select two focus areas, in an exercise that introduced participants to the fully detailed PRM for sensemaking as well as option-comparison. To prepare, the Working Group combined their criteria into Impact and Potential dimensions (section 5.1), which were drawn as horizontal and vertical axes on a whiteboard.

Each participant was given a stack of cards such as Figure 12, each showing an objective from the PRM with its "bloom" of direct causes and effects, colour-coded by subject area. Participants placed the objective cards along the Impact axis, and then moved the cards up or down the Potential axis, forming a scatterplot, as discussed in section 3.7.2. The placement of objectives on this board was captured in the Kumu database as ratings (Impact from 1 to 6, Potential from A to D).

The Working Group observed and counted which subject areas occurred in the higher-Impact, higher-Potential portions of the whiteboard. These were compared with the Workshop 1 votes to inform YSM's selection of focus areas for Workshops 3 and 4. See details and illustrations of the method in section B.5.

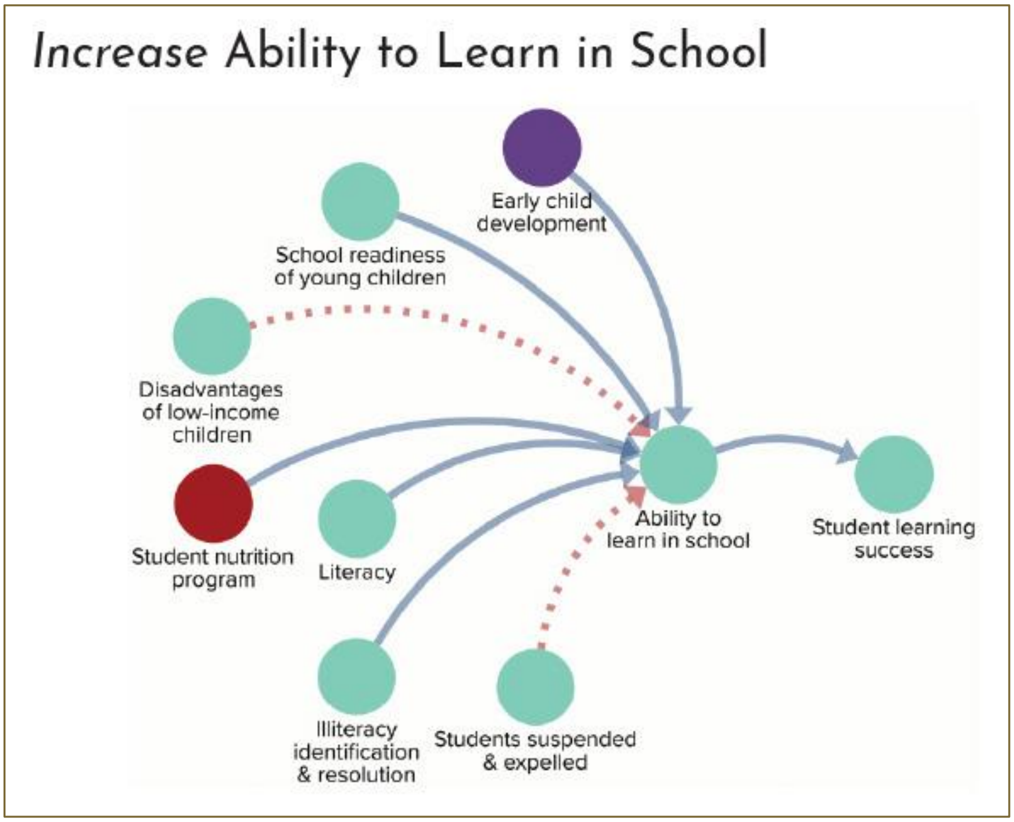

Figure 12: PRM: Sample objective card - *Increase ability to learn in school*

4.4.5 Developing Housing interventions

Workshop 3 was facilitated to find and develop high-leverage interventions in the Housing subject area. In advance, participants were invited to browse the Housing subject area of the PRM, and read some systems-thinking articles.

For a facilitated discussion of each Housing sub-topic, the researcher and participants browsed the PRM in Kumu to show its objectives, interventions and loops. The Working Group was asked for additional intervention ideas and modification suggestions, using dialogue prompts such as "How else could we reduce…" Each participant was assigned one of four roles, with tasks that included:

- Look for connections, loops, side-effects, multiple effects and synergies
- Suggest higher-leverage interventions using 12 types of intervention (Meadows, 1999).
- Use prompts for ideation: housing types, populations, geographic areas, lifecycles, policy levers and stakeholder motivations

- Test the intervention ideas against prioritization criteria
- Suggest modifications to overcome barriers
- Assign ratings in Kumu for element Impact and Potential, and connection strength.

See details of this divergent-thinking session in section B.6.

4.4.6 Employment agenda-setting

To prioritize the agenda for developing Employment interventions (Workshop 4), participants were invited to do online dot-voting for Employment objectives with high Impact and Potential. On the Stormz.me service, each objective was shown with its bloom of connected elements. Participants could familiarize themselves with the model and add intervention ideas as comments. See details in section B.7.

4.4.7 Developing Employment interventions

Workshop 4 was facilitated to generate new ideas for high-leverage interventions in the Employment subject area, with the sequence of sub-topics prioritized through online dot-voting. A more relaxed group discussion was held to generate many ideas, without the burden of assessing each one as was planned for Workshop 3.

Segments of the PRM were displayed in Kumu to understand systemic effects of the objectives. Questions such as "What are some barriers to job retention?" prompted intervention ideas and discussion. See details of this divergent-thinking session in section B.8.

4.4.8 Rating elements

Before Workshop 5, YSM staff were asked to help select a Promising List of interventions that would meet their criteria for a demonstration project. After ideas from the Housing and Employment workshops were integrated into the PRM, spreadsheets listing the elements were provided to YSM. They were asked to record Impact and Potential ratings for each intervention, as well as mark the policy proposals, innovation status, and applicability to YSM's three population groups. Impact was rated for all element types and all subject areas. See details and samples of the spreadsheets in section B.9.

4.4.9 Making the Promising List

Before Workshop 5, the completed element rating spreadsheet was filtered using YSM's criteria to select the Promising List of about 12 high-impact, high-potential interventions. Participants were invited to use the Stormz.me service to view each promising intervention, displayed with its first-order bloom and with a longer chain of downstream elements. They could comment on the intervention's fit to YSM, the jurisdiction and policies that would be affected, and variations on the idea. See details and illustrations in section B.10.

4.4.10 Selecting the Short-List

Workshop 5 selected the Short-List of 3 interventions. The Working Group reviewed the three scoring criteria (Feasibility; Reach, scalability; Leverage, synergy, side-effects) and their weighting. About five minutes was allotted to discuss each promising intervention, to ensure common interpretations and remove any that did not meet YSM's criteria. Kumu was used to view the chain of effects of each intervention, so the group could consider its leverage and check for unexpected consequences.

Each promising intervention was rated by each participant on the three scoring criteria, using Stormz on laptops. The weighted average scores were ranked, so the Working Group could consider the top three for the Short-List. The group discussed any adjustments necessary and confirmed whether they were comfortable with the choice of Short-List. See details of the method in section B.11 and results in section 5.2.

4.5 Model analysis methods

4.5.1 Computing model statistics

After all workshops, statistics were computed about the PRM content, to describe the model so it may be assessed for future use. This was done by exporting the model elements and connections from Kumu to a spreadsheet, then using the Pivot Table cross-tabulation feature of MS-Excel. Highlights of the results are interpreted in section 5.3.6. The detailed results in section C.1 include: counts of elements by type, subject area and source; counts of intervention elements by impact, potential, policy status and innovation status; counts of connections by type and subject area; and counts of loops by type and other characteristics.

4.5.2 Community detection

Kumu software provides the SLPA community detection algorithm. This feature was tested to see if computational analysis of connections in the PRM could yield meaningful combinations of PRM elements.

4.5.3 Social Network Analysis metrics

The PRM was analyzed with Social Network Analysis (SNA) metrics provided by the Kumu software, to test whether these metrics could identify the major goals & objectives or influential interventions in the PRM. The following SNA metrics were tested:

- **Degree** is the count of all direct connections to or from an element (Kumu, n.d.-b).
- **In-degree** is the count of direct connections incoming to an element (Kumu, n.d.-b).
- **Out-degree** is the count of direct connections outgoing from an element (Kumu, n.d.-b).
- **Size** is the count of elements directly connected to an element (Kumu, n.d.-b).
- **Reach** "measures the portion of the network within two steps of an element" (Kumu, n.d.-b).
- **Reach efficiency** is Reach divided by Size. "In general, elements with high reach efficiency are less connected but gain more exposure through each direct relationship" (Kumu, n.d.-b).
- **Closeness** is a measure of centrality, based on the number of connections needed to get from one element to all other elements in the model. Closeness is high for central elements with shorter paths to all other elements (Denny, 2014).
- **Betweenness** is a measure of centrality, measuring "how many times an element lies on the shortest path between two other elements" (Kumu, n.d.-b). High betweenness indicates an element that bridges less-connected parts of the model.
- **Eigenvector** is a measure of centrality, measuring "how well connected an element is to other well connected elements" (Kumu, n.d.-b).

With the exception of in-degree and out-degree, all of the SNA metrics include paths incoming to and outgoing from an element; the direction of connections is ignored in these computations. Kumu can compute these metrics with or without weighting the connections.

The results and interpretations of the SNA metrics for the PRM are in section C.2.

4.6 Methods for comparing leverage

A causal model may be used to compare the leverage of interventions. High leverage includes having stronger influence on a larger number of more fundamental objectives, to push the system towards desirable goals. Comparisons of leverage need to consider the cumulative strength of an intervention's effects, along the chain of causality: the direct and indirect connections from that intervention element out (downstream) to other elements. The leverage of objective elements can also be compared, to find objectives where an intervention would have stronger influence on goals.

This study used expert estimates and visual observation to compare the leverage of promising interventions, as part of selecting the short-list. Some analytical and computational methods were considered and tested to find high leverage in the PRM.

4.6.1 Methods implemented

The case study methods included activities where experts made estimates of leverage:

In **Rating elements** (section 4.4.8), Impact was originally defined as the effectiveness of an intervention on its own. However, the expert ratings may have incorporated knowledge about the downstream leverage of the intervention. These ratings were used to select the Promising List.

During the online activity of **Making the Promising List** (section 4.4.9), participants had the opportunity to view the chain of elements downstream from each promising element, such as Figure 29. The higher-Impact elements were also shown with larger bubbles, as in Figure 30.

That same display was used when **Selecting the Short-List** (section 4.4.10). Participants visually observed and discussed the chains of causality for each promising intervention. They applied their expert knowledge of these systemic effects to rate each promising intervention on three scales, one of which was "Leverage, synergy, side-effects". Expert estimates of leverage were therefore used to select the short-list.

4.6.2 Methods tested and considered

4.6.2.1 *Classifying by leverage levels*

To determine whether the PRM had high-leverage interventions that would cause or contribute to fundamental changes in a system, the researcher attempted categorizing PRM elements, using custom fields in Kumu, with two published classifications of interventions:

- Donella Meadows' 12 levels of leverage point (Meadows, 1999)
- Intervention Level Framework, an adaptation of Meadows' 12 levels into five levels for more reliable classification of leverage points (Malhi et al., 2009).

4.6.2.2 *Ranking direct connections by out-degree*

The **Social Network Analysis metrics** in Kumu were tested for applicability to the PRM (section 4.5.3). The Out-degree metric counts the number of direct outgoing connections from each element. Because it does not account for indirect connections, this metric is a simplified proxy for leverage. (Each direct connection might lead to multiple goals downstream, and multiple direct connections might lead to the same goal.)

4.6.2.3 *Estimating connection strength*

Multiple methods for comparing leverage rely on quantifying all connections in the causal model, to weight visual or computational analyses. Although the PRM contained a large network of causal relationships, it did not contain any knowledge about which of those connections had stronger effects. For example, if *Parental leave support* is provided, how much does that increase *Job retention*? Each PRM connection needed a measure of its strength, i.e. the magnitude of causality.

Ideally, those strength measures would have been based on statistical evidence. It was not feasible to seek out quantitative studies about each of the 1100+ connections in the PRM. Even if they had been found, the statistics from multiple studies would not have been comparable.

The alternative was to obtain expert estimates of connection strength. Experts would have absorbed some knowledge of causality, from reading statistical studies and observing real-world effects of actions (social programs).

The researcher made some test ratings of connections, which revealed that valid strength ratings would require much more subject-matter expertise than just knowing the connection exists. The YSM participants did not have time to provide numerical ratings of the many PRM connections, so analyses of connection strengths were tested but not used in the case study.

The study's original intent was to display the connection strength as the **line width** of arrows, so that leverage might be visually compared, when observing the chains of downstream elements. Kumu was customized to test line widths using the researcher's strength ratings.

4.6.2.4 Computation from strength estimates

Computational methods have the potential to compare leverage in a causal model, more so than human visual observation, if connection strengths are quantified. The study scope and timeline did not include researching and testing multiple software packages nor custom programming, but one available algorithm was tested.

Method tested: The MICMAC algorithm for cross-impact analysis (Godet, 2010) uses strength ratings on every connection in a causal loop diagram (or causal model), to calculate the indirect influence of each element on the system's behaviour. This matrix-multiplication algorithm is available in Godet's software and in Kumu.

Computational methods not tested: The Interpretive Structural Modelling algorithm for finding influential and dependent elements (section 2.4.3) was not tested.

System dynamics software might have run simulations of the causal effects, to compare leverage. System dynamics methods would need to be adapted for ordinal ratings of qualitative factors, as suggested by Van Zijderveld (2007).

4.7 Capacity for modelling and activities

The Capacity process challenge, section 3.8, was addressed by the methods as follows. (The other three challenges were addressed by model development methods, section 4.3.)

Expert capacity: The Working Group was composed of social service professionals, ranging from front-line staff to executives, from Yonge Street Mission and their partner organizations. Specialists in the Housing and Employment fields attended those workshops, to supplement the knowledge of ongoing participants.

Working Group members were expected to spend about 13 hours each on workshops and other contributions. To minimize burden on their time, the modelling process also used source documents in which lived experience and professional knowledge was already compiled. Working Group members were expected to be comfortable with computing so they could learn the Kumu and Stormz software and work with spreadsheets. No systems thinking or modelling skills were assumed at the outset.

Modelling capacity: To minimize expert time requirements, the researcher was the sole modeller of the Poverty Reduction Model. Working Group participants contributed review comments and new ideas during all five workshops, but they did not edit the model directly, nor discuss the translation of their ideas into the modelling language. No coordination or training was required as there was only one modeller. The researcher provided ample modelling time, previous experience with causal modelling, and extensive experience with other types of structured modelling. Kumu software was assessed as suitable for the case study (see section 4.3.5).

Research capacity: The large size of the model made it cost-prohibitive to do extensive secondary research or cost/benefit analysis about every element, but YSM plans to research the interventions chosen for their short-list.

Facilitation capacity: The researcher offered sufficient time for facilitating and recording the workshops. The researcher had extensive experience facilitating free-form consultations and capturing accurate notes, but less experience designing workshop activities such as the prioritization activities.

4.7.1 Methods not used

Some known methods for comparison and prioritization were not attempted in this study due to limited capacity. The following require extensive research and/or data: options analysis, section 3.7.1; the Systematic Screening and Assessment Method, and Social Return on Investment, section 3.7.4; gathering statistical evidence, and system dynamics simulation, section 2.4.2. The following require considerable time from experts: 2-4-8 consensus, and Structured Dialogic Design, section 3.7.5; and Structural Analysis, section 2.4.3.

This chapter has described a process of developing, using and analyzing the Poverty Reduction Model. The results of doing this case study are in the next chapter, followed by findings about the modelling methods (chapter 6) and about the facilitated activities and analysis methods (chapter 7).

Photo 6

5 Case study results

Developing a causal model is like untangling a system of wire, just enough to see a pathway through the complexity. This chapter provides the results of the case study (section 4.1): a Poverty Reduction Model that shows paths of causality, with its summary, subject areas and statistics; and a short-list of ways to intervene to reduce poverty in Toronto that meet the case study criteria. The case study methods are described in chapter 4. Appendix A includes more example diagrams from the model.

5.1 YSM criteria

The Yonge Street Mission's Working Group defined two general criteria for interventions and for objectives that are opportunities for intervention. These are based on the more detailed criteria that they discussed and voted on (section B.4.3):

- **Impact**, meaning measurable progress for an individual in poverty. This criterion incorporates measurability, evidence availability, whether the intervention has multiple effects (leverage), and potential synergy with other interventions.
- **Potential**, meaning the potential for finding feasible interventions, incorporating reach, scalability, total cost, cost per person, YSM expertise, and the potential to prevent poverty and exit poverty.

See also YSM's requirements for selecting a demonstration project in section 4.1.2.

5.2 Prioritization results

5.2.1 YSM short-list

The Yonge Street Mission has selected this short-list of interventions that meet their criteria:

Life skills education

Wraparound support for path to employment

Portable Housing Benefit

The first two interventions are aspects of YSM's position that to exit poverty, people need holistic long-term support for stabilizing many aspects of their lives, learning skills, obtaining jobs and staying employed. The policy issue is that funding for these supports is often separate and short-term.

The Portable Housing Benefit is discussed as an example in section 2.3.6. Currently, Ontario social assistance recipients may get a rent subsidy if they live in certain subsidized buildings. The proposal is to offer that rent subsidy for housing with any landlord.

5.2.2 Ratings of promising interventions

The facilitated prioritization activities developed a Promising List of interventions, which were scored during Workshop 5, following the procedure in section 4.4.10. Three top-scoring interventions formed the Short-List.

During the workshop, the initiative *Cost-benefit analysis to justify funding* was proposed. It scored highly, but does not require a demonstration project; participants declared "Just do it!" so it was not included in the Short-List.

YSM staff reported that the Short-List did reflect their prioritization criteria, and they were comfortable with the results.

Table 4: Short-List and Promising List ratings

	Intervention	Description	Feasibility	Reach, scalability	Leverage, synergy, side-effects	Sum of average scores
Short-list	Life skills education	Consider innovations to life-skills training, such as population-centred delivery, and providing awareness of existing services.	7.67	8	8.33	**24**
Short-list	Wraparound support for path to employment	Comprehensive supports to clients on a path towards employment, and continuing when they are employed. Ensure continuity of staffing.	4.67	7.83	8.17	**20.67**
Short-list	Portable Housing Benefit	Extend portable benefits across all eligible recipients. Ensure the pilot is long-lasting so people are willing to move.	6.4	6.6	7.2	**20.2**
Just Do It	Cost-benefit analysis to justify funding	Use the Halton methodology to calculate a societal cost-benefit analysis of various poverty-reduction programs, so as to convince business leaders, taxpayers and politicians to increase funding to those programs.	5.83	6.67	8.83	**21.33**
Promising List	Stackable Benefits	Design a package of benefits that doesn't dis-incentivize employment. Review the interaction of eligibility rules and clawbacks for all major transfer payments and subsidies: SA, CPP, EI, Childcare subsidy, Rent Geared to Income.	3.67	8.5	7.67	**19.84**
Promising List	Ease transition from SA[1] to employment	Two interventions: More gradual clawback of SA payment, and longer extension of health benefits	3.33	6.67	7.83	**17.83**

[1] SA = Social Assistance income support, including Ontario Works (welfare) and Ontario Disability Support Program.

Intervention	Description	Feasibility	Reach, scalability	Leverage, synergy, side-effects	Sum of average scores
Savings allowed on SA	Asset ceiling has just been increased in the last year. Part of provincial SA review.	5.33	6	6.33	**17.66**
Intervention to ease use of SA system	Rated multiple possibilities – personal case management, remove punitive aspects, ease navigation…	4	6.67	6.83	**17.5**
Wraparound supports in housing	Needs to be coupled with Portable Housing Benefit or some other assurance that people don't lose supports if they move. Design in conjunction with wrap-around supports for employment path.	5.2	3.8	7.6	**16.6**
Housing First model	Housing First must include wrap-around supports. There are differences between the youth and adult implementations of Housing First. High leverage for a narrower population.	4.2	5	7.2	**16.4**
Rent Trusteeship	Rent Trusteeship model interesting but needs risk mitigation. Explore other ways to reduce landlord risk and increase willingness to rent to low-income tenants.	2.17	5.83	6	**14**
Legal assistance for pardons	Make the process of applying for a pardon easier.	3.4	4.8	5.6	**13.8**

5.2.3 Reflections on the choices

Two major choices, made early in the project, affected the interventions that were found and prioritized:

The selection of Housing and Employment as the focus areas was a key decision that made interventions in other areas much less likely to be short-listed. Limited expert time was the motivation to select two focus areas, but the choice was not made until the end of the second workshop. YSM staff were later concerned that they had selected focus areas that aligned with YSM's current programs, rather than stretching into less familiar subject areas. Screening out areas that seemed infeasible (low Potential for intervention) may have prevented the Working Group from contemplating new approaches to intractable parts of the system of poverty.

A participant regretted that the study did not look for and measure the root causes of poverty, so as to develop preventative interventions. This may have been because the case study research question focused attention on finding interventions. Causal modelling can explore fundamental causes of social problems, but section 2.2.6 quotes Spicker (2016) about poverty policy: "the way into a problem is not usually the way out of it." The Working Group was interested in both preventing poverty (for which root causes would be relevant) and in helping people transition out of poverty, in which case the exit strategy might not address the root cause.

5.3 Poverty Reduction Model

This study has developed the Poverty Reduction Model (PRM), a causal model (section 2.3.9) about systems related to poverty reduction. Please contact the researcher for access to the full content of the PRM, or assistance with adapting or enhancing it.

5.3.1 Scope of PRM

The Poverty Reduction Model describes some policies and programs of the City of Toronto, the Province of Ontario, and the federal government of Canada, as well as non-governmental programs available to Torontonians. The PRM also contains insights about poverty that are applicable in other localities and government jurisdictions, especially large multicultural cities in developed nations.

The PRM contains over 550 elements (variable factors), which include goals, objectives, intermediate factors, and interventions (both existing and potential), as defined in Table 8. There are over 1100 connections, mostly indicating cause and effect relationships between elements.

The dimensions of scope, defined in section 6.1.1, are used to describe the PRM:

Breadth: Multiple societal systems affecting people in poverty, including the following subject areas:

- Physical health
- Mental health
- Social & Dignity (social support, discrimination, etc.)
- Housing
- Employment
- Financial
- Social Assistance
- Childcare
- Child welfare
- Education (kindergarten to high school graduation)
- Training (and post-secondary education)

- Newcomers (immigrant & refugee settlement)
- Criminal justice
- Transportation
- Other services (library, legal, etc.)
- Services (access, quality and coordination of any/all social services).

Depth: The PRM is a high-level model that identifies many objectives and some interventions, but may not recognize all of their benefits and consequences. The number of elements varies by subject area (Table 22), with the deepest coverage of Housing and Employment.

Density: The PRM is dense enough to recognize the complexity of poverty, but many more causes and effects could be found with further modelling effort. On average, each element has 4.29 connections. There are more connections in the subject areas with more elements (Table 26).

Detail: All elements are classified in a subject area, and tagged with various topics. 63% of elements have descriptions. All intervention elements indicate whether they would require policy changes, but the specifics are not usually documented. All intervention elements have an innovation status: existing, incremental changes, new to Toronto, or completely new. Connections are not described.

Evidence: The source of each element is recorded (a document, the YSM working group or the researcher). Some element descriptions have quotes or links to further information. The PRM does not cite evidence for the effectiveness of interventions or for other causal relationships. Personal stories about poverty issues are not recorded.

Quantification: Elements have been rated by YSM staff on a six-point Impact scale and a four-point Potential scale. Connections have not been quantified by experts or statistical studies.

5.3.2 Reading the PRM displays

The Poverty Reduction Model is very large, but Kumu can display smaller pieces of the model for easier reading: subject areas, tags (for topics and other groupings), a bloom of elements such as Figure 23, a loop, or elements filtered by the user's criteria.

As a non-linear structure, not organized in a line or a tree, the PRM does not have an origin or core element. A model user may start reading from any element, such as a goal or intervention of interest. The connection arrows may be followed upstream or downstream. Most elements have multiple connections, so the reader may need to go back to a starting point and follow another path outward. The PRM elements may be displayed with either of two colour schemes: the bubble colours could denote the 16 subject areas (Figure 13) or the element types defined in Table 8, on the legend in Figure 14. The connection types (Table 9) were displayed consistently with one colour scheme in both of the following legends. PRM diagrams in this report are shown in the subject-area colours unless otherwise noted.

Figure 13: Legend for the subject area view

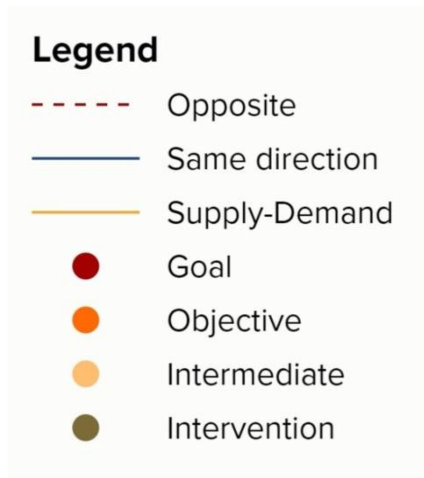

Figure 14: Legend for the element type view

5.3.3 Goals

The PRM's goal elements are shown in Figure 15, with connections to the other goals, in subject area colours:

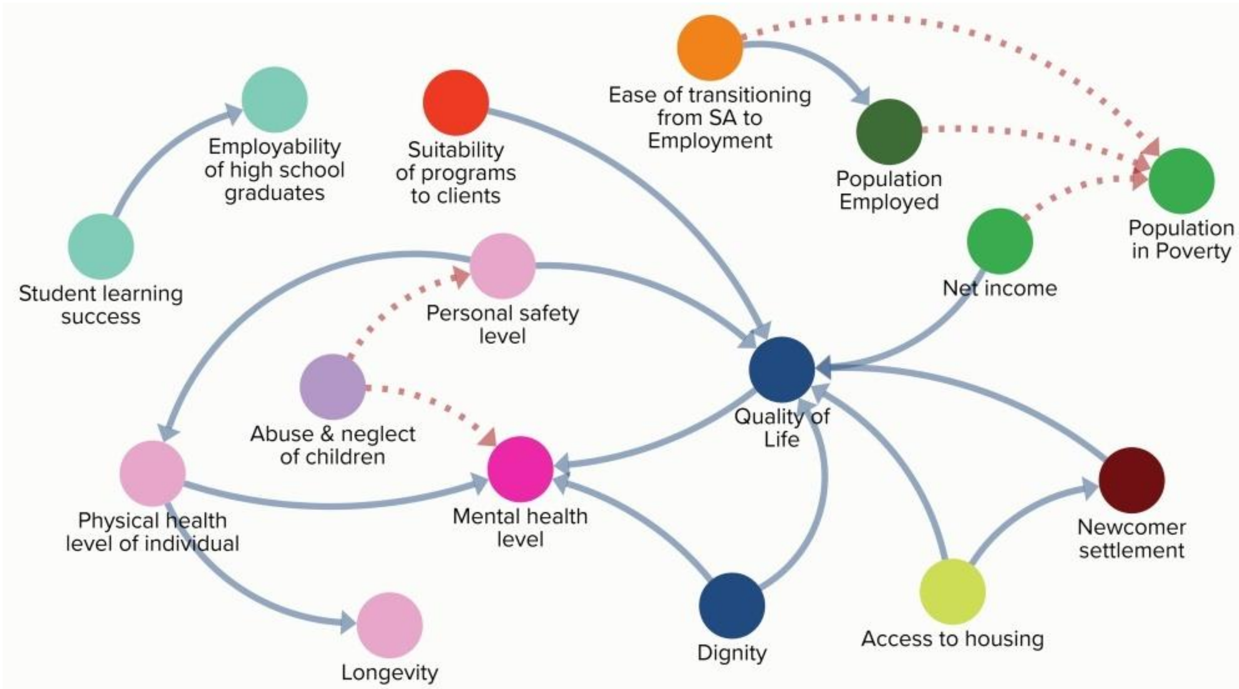

Figure 15: PRM goal elements

5.3.4 Central goals and objectives

The following goals and objectives seem to be central to reducing poverty, because they are strongly connected within the PRM, according to multiple Social Network Analysis metrics. They are grouped by subject area. See section C.2 for explanation, caveats about interpreting the SNA metrics, and the detailed results.

- Child Welfare: *Abuse & neglect of children*
- Employment: *Access to employment, Job retention, Population Employed*
- Financial: *Employment Income, Gross income, Net income, Population in Poverty*
- Housing: *Homelessness, Supply of low-cost housing*
- Mental Health: *Access to MH care, Addiction, Level of treatment of mental illness, Mental health level*
- Newcomers: *Language ability & cultural knowledge*
- Physical Health: *Physical health level of individual*
- Services: *Access to health & social services*
- Social & Dignity: *Appearance of poverty, Discrimination, Quality of Life, Social desirability*
- Social Assistance: *Ease of transitioning from SA to Employment, Social Assistance income*
- Training: *Access to training & postsecondary.*

5.3.5 List of goals and objectives

The following is a listing of all the goals and objectives in the PRM (after all workshops), organized by subject area. Interventions and intermediate elements are not listed. (Those element types are defined in Table 8.)

Table 5: Goals and objectives, by subject area

Housing	Housing continued
Demand for MH supportive housing	Safety in shelters & supportive housing
Total housing subsidy budget	Supply of shelters, transitional & supportive housing
Net cost of housing	Rent increases
Homelessness	Maintenance of housing
Ease of finding housing information	Likelihood of securing private housing
Landlords evicting for own use or renovations	Loss of housing
Vacancy rate	Supply of subsidized housing
Public investment in housing	Ability to pay rent
Density of low-income tenants	Concentration of hard-to-house people
Use of housing for AirBnB	Landlord discrimination
Likelihood of securing public housing	Supply of low-cost housing
Stability of housing	Access to housing
Tenant behaviour causing eviction	Quantity of housing affordable on SA
Landlord-tenant relations	Demand for shelter beds
Walk Score	Crowding of housing
Private investment in affordable housing	Ability to fight housing problems
Utility rates	Quality of Housing
Housing waiting list length	Housing mobility

Employment	Employment continued
Workplace difficulties	Job retention
Capacity to work long hours	Feasibility of taking a job
Unemployment Rate	Access to employment
Population Employed	Ability to find & apply for job openings
Costs to employer	Qualification for jobs
Job search supports	Necessity of job qualifications
Likelihood of being hired	Merit-based hiring
Workplace safety level	Emotionally healthy workplaces
Job openings	Wait time for job opportunities
Number of jobs (filled + open)	Unemployment spells
Advantages to employers	Quality of jobs offered to unemployed
Openness to hiring all eligible people	Job readiness
Youth NEET	Holding multiple part-time jobs
Benefits & paid leave	Duration of job
Motivation to work	

Social Assistance	Financial
Social Assistance income	Poverty of vulnerable populations
Total cost of SA payments	Access to affordable credit
SA services meet recipient needs	Money for unexpected expenses
Compassion of SA staff	Population in Poverty
SA system trust of recipients	Employment Income
Employed people deceiving to get SA	Business income
Accountability of SA system	EI income
Personalization of SA system	Cost of needs other than rent
SA recipient trust & respect of SA staff	Stability of income
Ease & speed to get ODSP	Gross income
Access to SA system	Illegal earnings & theft
Complexity of SA cases	Ability to manage money
Ease of transitioning from SA to Employment	Net income
Fair/Equal treatment by SA system	Pension & retirement income
Dependency on SA system	Financial stability
	Financial net worth
	Spending on addictive substances
	Desperation for income
	Youth poverty
	Access to affordable banking

Physical Health	Services
Longevity	Funding & existence of services
Cognitive ability	Comprehensive support & referral
Quality of medical care	Access to health & social services
Physical health level of individual	Eligibility for services
Reproductive freedom	Service location convenience
Access to health care & medication	Suitability of programs to clients
Personal safety level	Efficient use of funding
Birth weights	Access to service information
Population frequency of disability	Client - service provider relationship
Nutrition	Ease of getting funding for social programs

Mental Health	Social & Dignity
Addiction	Access to social activities
MH episodes (violent or misunderstood)	Social support network
Positive life events	Romantic partnership
Negative life events	Belonging
Resilience	Social desirability
Emotional self-regulation	Acceptance of students in poverty
Level of treatment of mental illness	Personal values
Demand for affordable MH care	Autonomy
Mental health level	Spiritual wellness
Self-confidence	Respect from others
MH issues addressed in childhood or adolescence	Appearance of poverty
Suicide rate	Quality of Life
Quality of affordable MH care	Social skills
Life stability	Dignity
Stability & consistency of MH counselling	Discrimination
Access to MH care	Self-respect
Accountability of MH system	
Supply of affordable MH care	
Population frequency of mental illness	
Willingness to get MH care	

Childcare	Child Welfare
Need for childcare	Quality of CAS care
Quality of childcare	Abuse of children by CAS care providers
Access to childcare	Systemic racism within CAS
Early child development	Unwanted children
	Support for 16+ youth with family issues
	Intact families
	Abuse & neglect of children
	Violent family member
	Parenting skills

Education	Criminal Justice
Employability of high school graduates	Actual crimes committed
Safety of students & teachers	False arrests for perceived crimes
Student learning success	Criminalization of poverty & neighbourhoods
Literacy	Violence in underground economy
Accountability of schools	Propensity to criminality
Systemic racism in schools	Recidivism
Disadvantages of low-income children	Police understanding of MH episodes
Students suspended & expelled	MH episodes on police records
Ability to learn in school	Incarceration
Individual attention to students	Intimate partner violence
School accommodation of differences	Post-incarceration poverty
High school graduation rate	
School readiness of young children	
Training	**Newcomers**
Cost of training	Newcomer settlement
Access to training & postsecondary	Language ability & cultural knowledge
Training & Post-secondary success rate	Ease of obtaining immigration status
Driver licensing	
Quantity of training available	
Women & minorities in trade schools	
Access to student funding	
Transportation	**Other Services**
Access to public transportation	Access to telecommunications & computing
Traffic collisions	Sufficiency of legal representation
Difficulty of commute	Access to culture & recreation
Traffic congestion	
Transit system quality	

5.3.6 Highlights of model statistics

According to the PRM statistics in section C.1, after all workshops, the model contained 554 elements, 1187 connections, and 13 loops.

The Housing subject area had 113 elements and Employment had 84, due to the focus in Workshops 3 and 4. Other subject areas ranged from 6 to 39 elements each.

There were 16 goals, 195 objectives, 307 interventions, and 36 intermediate elements. The interventions came from all sources in a fairly even distribution, with the most (28%) coming from the Working Group. The researcher provided more of the goals, objectives and intermediate elements (49%) as interpretations needed to show the causes and effects of interventions.

YSM staff tended to assign high Impact ratings to the interventions, meaning almost all of them would be effective in reducing poverty, and it was difficult to prioritize.

Most of the interventions were incremental changes (46%) or existing in Toronto (43%). Most interventions (74%) involved a policy change.

Of the connections, 35% were between elements in two different subject areas. Most of the connections (77%) were of the Same polarity. The Supply-Demand simplification was only used for 8 connections.

There were only 13 loops identified in this large model. Most (10 out of 13) were reinforcing loops, which reflects the barriers to exiting poverty.

The Poverty Reduction Model is a very large model of causes and effects, with mostly qualitative information about the system of poverty in Toronto. It was successfully used by the Yonge Street Mission to select a short-list of possible projects, and has the potential to be developed and used further by many organizations.

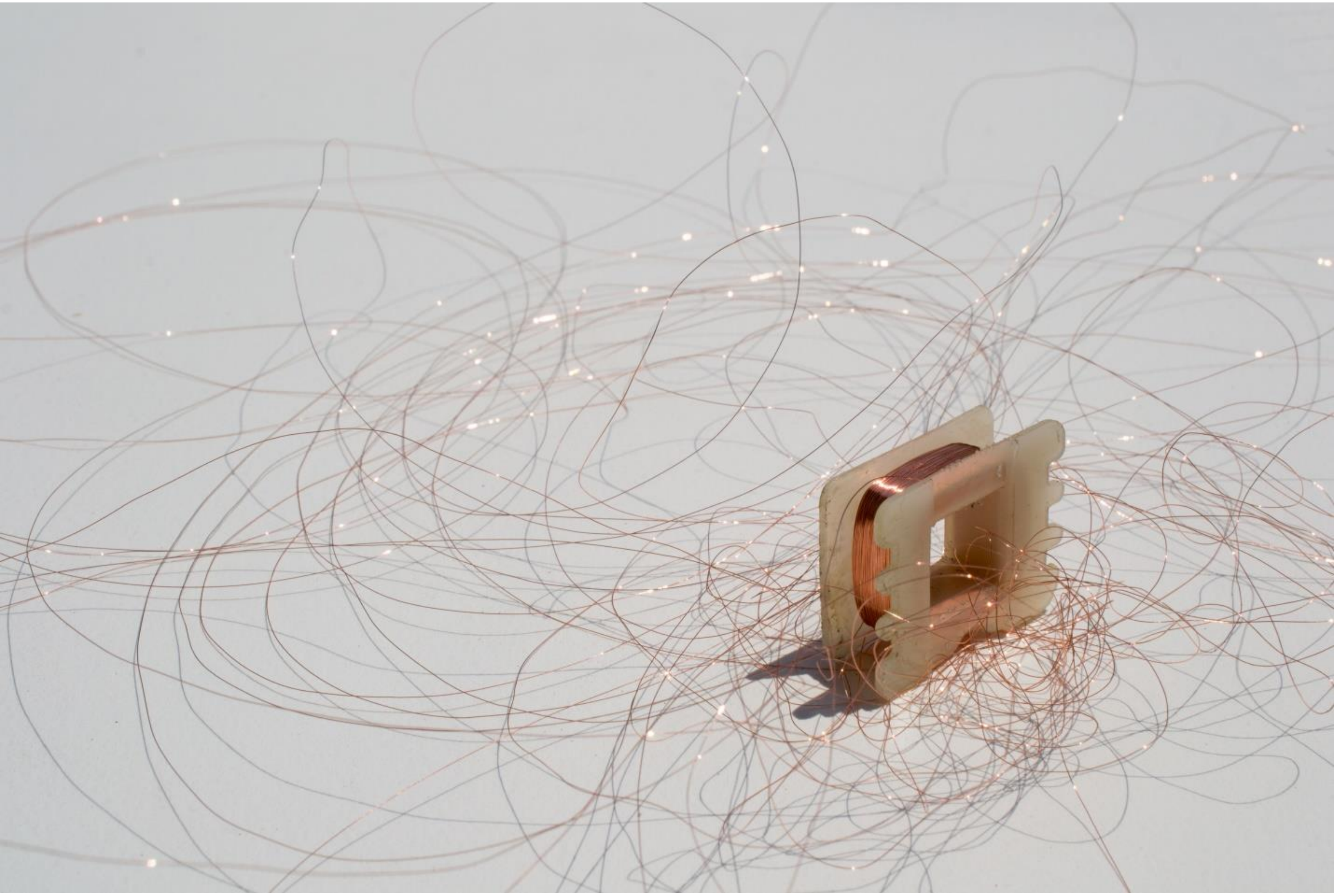

Photo 7

6 Findings about modelling

A structured model can organize knowledge about the interdependencies in a complex system, just as this plastic reel organizes the copper wire neatly. This chapter defines the model format that evolved for the Poverty Reduction Model (section 5.3), as well as the dimensions of scope that were observed. Findings are made about how the modelling process (section 4.3) addressed the challenges of knowledge, scope and comprehension, and how the model was summarized. The Kumu modelling software is assessed. Appendix A gives more detail about model development. Findings about using the PRM for decision support are in chapter 7.

6.1 Defining scope and comprehensiveness

6.1.1 Dimensions of scope

Scope refers to the information that is needed in a model, to capture, represent and work with knowledge. The scope specifies how much complexity of the real-world system will be expressed in the model's simplification, as explained in section 2.3.2. The scope determines the model's size, meaning the number of elements and connections and the amount of information about them.

Working with a large model in this study led to the identification of the following dimensions of scope for causal models:

Breadth: The diversity of topics to be covered, such as the PRM subject areas (societal systems ranging from transportation to criminal justice). If breadth is low, scope boundaries will be narrow. With a narrow scope, perhaps focused on one known problem area, connections to topics outside the scope boundary may be missed. A broader scope increases the model size (number of topics, therefore number of elements) and the variety of conclusions that can be drawn from discussing the model.

Depth: The quantity of elements (variable factors) identified about each topic. If depth is low (shallow), only the more important elements will be modelled within each topic, and elements may be very generalized. A deeper scope increases the model size (number of elements in each topic) and integrates more knowledge about each topic. For example, in the PRM, the Transportation topic was not covered in depth; the one element *Transit System Quality* generalized many transit issues that had a cumulative effect on people in poverty. A deeper model of factors in the transportation system would be needed to choose interventions in transit quality.

Density: The quantity of connections (relationships) between factors. If density is low, only a few connections will be modelled for each element, and expert judgement is needed to ensure that the more important connections are shown. A denser scope increases the model size (number of connections), and the knowledge available about systemic causes and effects

Detail: The amount of information captured about each element or connection. Are elements described and defined? Are connections explained: why does element A influence element B? Are attributes of the elements and connections recorded? More detail may be useful for decision support, but takes time to capture and read.

Quantification: The degree to which model elements and connections are measured by ratings or statistics. Are there quantitative measures of the elements (such as costs or benefits) or of the connections (such as strength of causality or length of delay)? Are there numerical ratings of the elements or connections?

Evidence: The amount of model information that is justified by citing studies or recounting stories. Are there studies or documentation showing that the information in the model is valid? Does the model include or link to personal narratives about experiences with the factors modelled, and effects of the system on people? Are there sources cited for facts stated about the elements and connections? How accurate and reliable is the evidence for the quantitative measures?

The term "**richness**" will be used to refer to the combination of depth, density, detail, evidence and quantification, i.e. all aspects of scope other than breadth.

6.1.2 Comprehensiveness

This study also evolved a definition of a **comprehensive** model: A comprehensive causal model thoroughly represents the **breadth** of a social system, and captures **rich** (deep, dense and detailed) information about its complexity.

If important aspects of a system are missing from a system model, it is not comprehensive. It may have uneven coverage of the topics, or it may be an over-simplification of complexity. However, it may suffice for the purposes of the model.

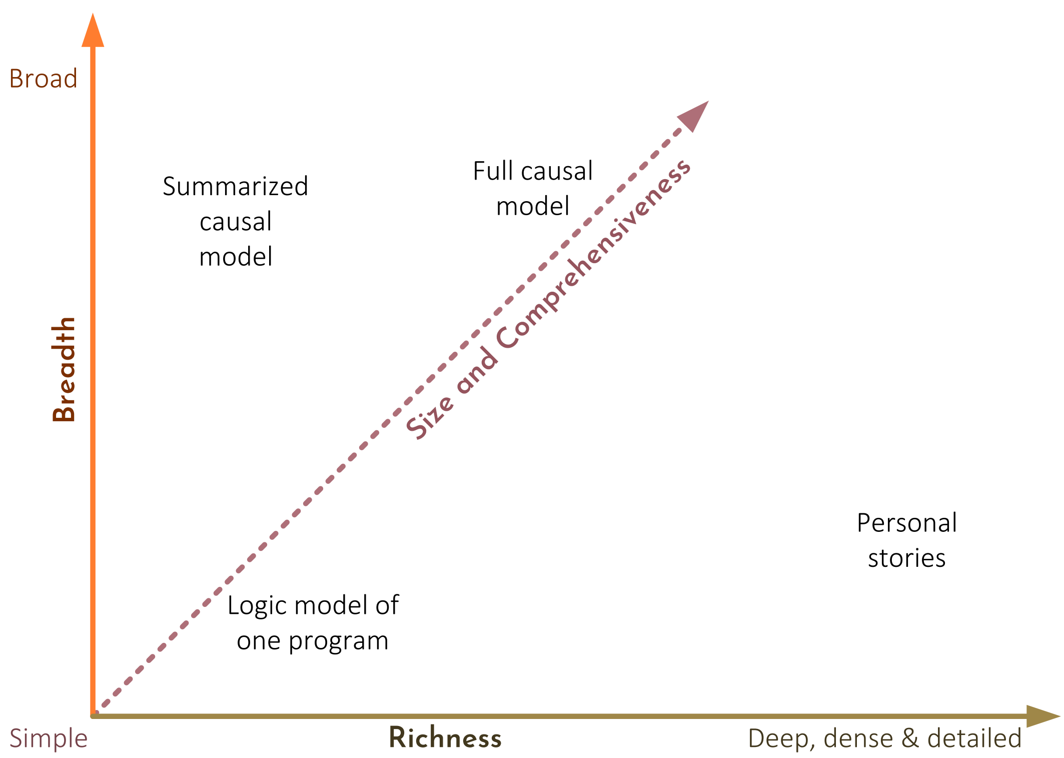

Figure 16: Aspects of comprehensiveness

The above graph, Figure 16, illustrates the comprehensiveness of different styles of model, using a vertical axis for breadth and a horizontal axis for richness. The diagonal arrow indicates that comprehensiveness, and model size, increases with both breadth and richness. Near the origin of the axes, the logic model in Table 2 is an example of a simple model; it is not comprehensive because it covers only one aspect of a broad system, with very little detail.

The upper-middle of Figure 16 mentions a "full causal model", similar to the PRM, which covers a broad system scope evenly, and provides moderate depth, density and detail about a system. If that fulsome model is summarized by removing detail, it may still cover the system fairly broadly, rather like the Summary Model in this study (high on the breadth axis but low richness).

This graph compares all of these models with personal stories and narratives, which may capture very rich "thick description" (Geertz, 1973) of people's experiences and emotions in a system, but may not thoroughly cover the breadth of systemic issues.

This study confirmed that a model of complexity cannot be complete because the factors in a complex system cannot be systematically, exhaustively enumerated. As a model becomes more comprehensive, it does seem to *approach* completeness.

Initial efforts to identify factors in the system are quick and easy: an expert can name top-of-mind issues. Involving multiple experts and source documents fills gaps in the knowledge of the first expert, gradually discovering the extent of the system under inquiry and covering the scope more thoroughly.

The more comprehensive the model becomes, the higher the effort required to find factors and relationships that have not already been modelled. Godet's structural analysis procedure (section 2.4.3) is an example of a resource-intensive method to systematically find all possible relationships between a set of factors. Attempting completeness reduces the risk of missing an important factor or relationship, but has diminishing returns.

6.2 Model format

6.2.1 PRM structure

This section defines the final structure of the PRM after all workshops were completed. Evolution of the model structure is illustrated in section 6.2.3.

This study designed a structure for a type of system model, which is documented in a "meta-model": a formal definition of the syntax, semantics, and notation for modelling information (Génova, 2009a). This diagram, Figure 17, shows what constructs are in the PRM, how they are related, and how they are expressed in visual notation. The PRM is implemented in Kumu software, so Kumu terminology is used wherever appropriate.

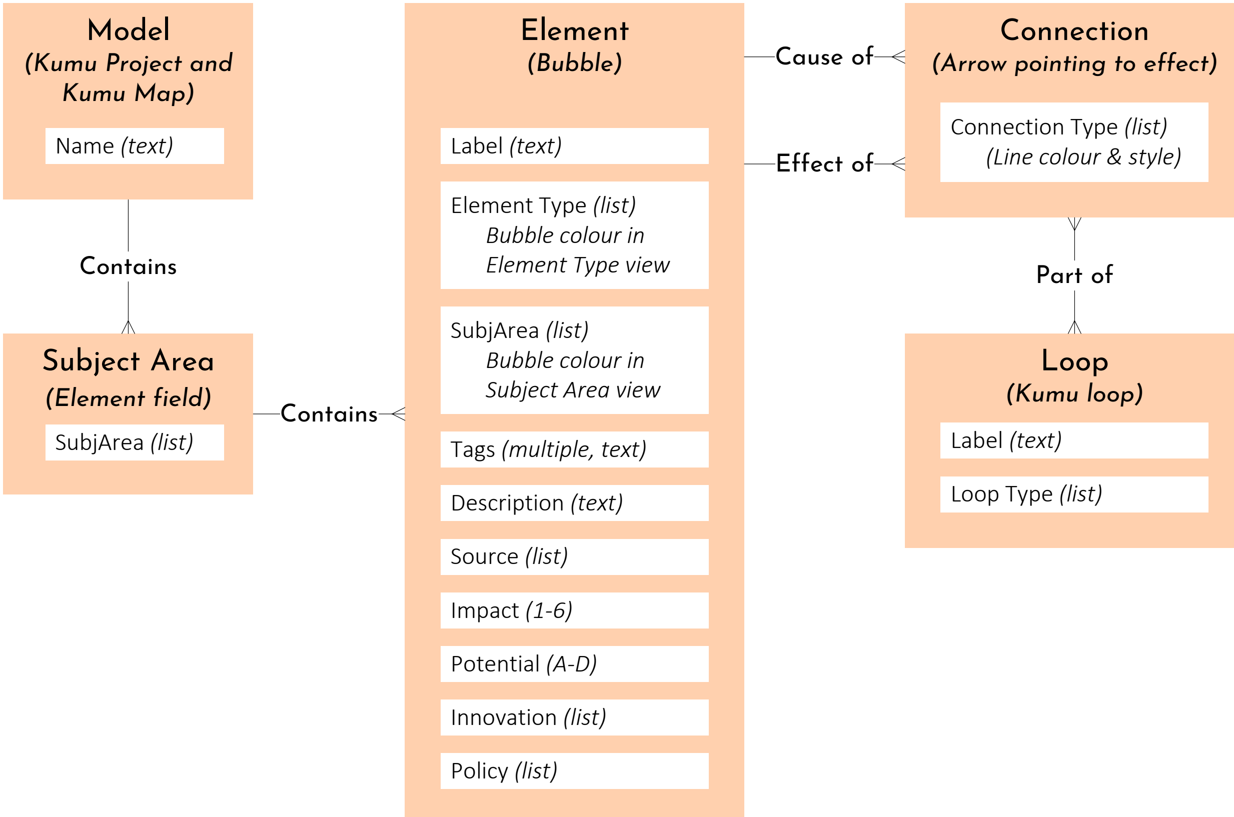

Figure 17: Structure of PRM

The diagram uses a crow's foot to indicate the "many" end of a one-to-many relationship. The structure diagram is read as follows:

- The Model is stored in one "project" in Kumu, which has one "map". The Model has a name.
- The Model contains many Subject Areas.
- One Subject Area contains many Elements. An Element belongs to one Subject Area.
- Each Subject Area is named, by the SubjArea field of each Element.
- Each Element is represented in Kumu as a bubble (a circle), and is described by various fields (Label, etc.).
- Each Element may be joined by many Connections.
- Two Elements may be joined by a Connection, represented by an arrow pointing to the Element that is affected. There are two relationships in Figure 17, which means: one Element is the cause end of the Connection, while another is the effect end of the Connection.
- A Connection has a Connection Type field, which determines the line colour & style.
- A Loop is formed from multiple Connections.
- A Connection may be part of zero, one or many Loops.
- A Loop has a Label (name) and a Type.

The following table explains and describes the constructs, with some guidelines followed to ensure model quality.

Table 6: PRM constructs

Construct	Description and Guidelines
Model	The entire official Poverty Reduction Model is stored in one Kumu Map within one Kumu Project. A Test copy of the PRM was created for experimenting with Kumu features. It is stored as one Map in a separate Kumu Project.
Subject Area	Every Element belongs to one Subject Area, for purposes of partitioning the model. This is implemented by assigning the SubjArea field of the Element.
Element	A variable factor that could increase or decrease in a complex system. Elements may combine various quantities and qualities, for example, *Landlord discrimination* could get more frequent (quantity) or more severe (quality). Intervention elements are also variable factors. For instance, Incentives *to repair* is a variable equal to zero if no incentives exist; if incentives are implemented, the incentive rates and eligibility rules could increase or decrease the total value of the intervention. Elements are notated as bubbles (circles). The bubbles are colour-coded either by Subject Area or by Element Type, depending on which Kumu view is used.
Connection	A cause-and-effect relationship between two Elements. (Other types of relationships are transformed into cause-and-effect, by redefining the elements as necessary.) Bi-directional relationships should be avoided, by adding or redefining Elements. Redundant paths should be eliminated.
Loop	A series of Connections, where the last Element is connected to the first Element, with all arrows pointing in the same direction. See section A.2.1 for loop examples.

Fields were either built into Kumu or implemented as custom fields. Some fields were considered mandatory when creating an element, but this is not enforced by Kumu. The descriptions below include other quality guidelines.

Table 7: PRM fields

Construct	Field	In Kumu	Description
Model	Name	Built-in, mandatory	The name of the Kumu Project and the Kumu Map.
Element	Label	Built-in, mandatory	The name of the element, displayed on the map visualization. Elements should have neutral or positive labels, such as *Likelihood of securing public housing* (not Difficulty of securing public housing). Use negative labels if they are much more recognizable (example: *Homelessness* not Being housed). Element labels do not contain "increase", "decrease" or other directional indicators. Element labels are as short as possible while still making the concept recognizable by experts without reference to a description.
Element	Element Type	Built-in, considered mandatory	Elements are categorized by their role in the system, as defined in Table 8. In the Element Type view, the bubble colour varies by Element Type.
Element	SubjArea	Custom, considered mandatory	Elements are categorized by societal domains of activity, such as Employment, Housing, or Social Assistance. See subject area list and counts in Table 22. In the Subject Area view, the bubble colour varies by this field.
Element	Description	Built-in	Text defining, explaining or providing more information about an element. Includes descriptions copied from the source documents.
Element	Tags	Built-in, considered mandatory	An element may be assigned any number of tags. Each tag is a text string designating some set of elements, which may be the element's subject area, a related subject area, a sub-topic, or a chain of downstream effects, as explained in section A.4. Tags are also used as temporary annotations, such as "Placeholder" (an element that needs more specific description from experts).
Element	Source	Custom, considered mandatory	The document or experts who provided information about the element. If there were multiple sources, the Source field records the first source used, other than the researcher's knowledge.

Construct	Field	In Kumu	Description
Element	Impact	Custom	YSM's rating of Impact (defined in section 5.1). 1 is low, 6 is high.
Element	Potential	Custom	YSM's rating of Potential (defined in section 5.1). A is high, D is low.
Element	Innovation	Custom	YSM's designation of an intervention element as "Exists in Toronto", "Incremental change", "New to Toronto" or "Completely new".
Element	Policy	Custom	YSM's designation of whether an intervention element is a policy change.
Connection	Connection Type	Built-in, considered mandatory	The kind of relationship, as defined in Table 9 .
Loop	Label	Built-in, mandatory	The name of the loop, displayed on the map visualization.
Loop	Loop Type	Built-in, considered mandatory	Indicates whether a loop is reinforcing or balancing.

In the following definitions of the final PRM Element Types, "societal actors" are governments, social service agencies, businesses, other organizations, and influential individuals. See Table 22 for counts of elements by type.

Table 8: PRM element types

Element Type	Definition
Goal	A fundamental factor that we (society) want to increase or decrease, indirectly, by making Interventions. Most societal actors will agree upon the direction this factor should go.
Objective	A factor that we (society) want to increase or decrease, because it will contribute to reaching a Goal. The factor can be influenced by making Interventions. Most societal actors will agree upon the direction this factor should go. (The desirable direction was not stored in the PRM but was indicated on the cards used for an activity, Figure 12.)

Element Type	Definition
Intervention	A factor that can be changed directly by some societal actor, with the aim of increasing or decreasing a Goal or Objective. May indicate the quantity or quality of social program offerings. May indicate the existence or level of a policy, such as a funding rate.
Intermediate	A factor that societal actors may want to increase or decrease, indirectly by making Interventions. It may be a factor that needs to be at an equilibrium level (not too high or too low), such as Supply of physicians. Societal actors may have different opinions about whether the factor should be increased or decreased, for example, *Immigration rate*. It may be a factor that benefits some individuals or companies, while bringing harm to society as a whole, such as *Car usage*.

The following table defines the kinds of relationships in the PRM. See Table 26 for counts of connection types.

Table 9: PRM connection types

Connection Type	Description	Notation
Same	A cause-and-effect relationship with same polarity: The two connected factors move in the same direction. Example: If *Population employed* goes up, then *Need for childcare* goes up. If *Population employed* goes down, then *Need for childcare* goes down.	Solid blue arrow
Opposite	A cause-and-effect relationship with opposite polarity: The two connected factors move in the opposite direction. Example: If *Summer programs for children* goes up, then *Need for childcare* goes down, and vice versa.	Dashed red arrow
Supply-Demand	An undirected connection that represents a supply-and-demand relationship between two elements. Example: *Need for childcare* is demand and the *Number of licensed childcare spaces* is supply. See section A.3.2 for more discussion.	Solid yellow line

6.2.2 Comparison of PRM and CLD notation

The following diagrams illustrate how the classic Causal Loop Diagram notation (Figure 18) was adapted for the PRM (Figure 19). Both these diagrams were created in Kumu; see section 2.3.8 for CLD examples created using other software, and more about causal loop diagramming.

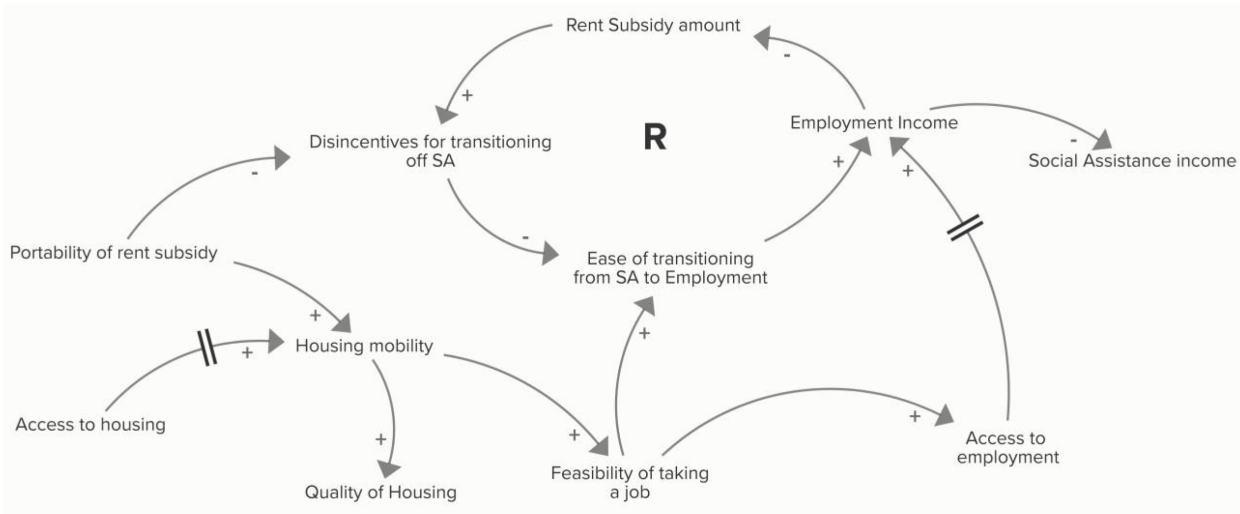

Figure 18: Rent subsidy model in CLD notation

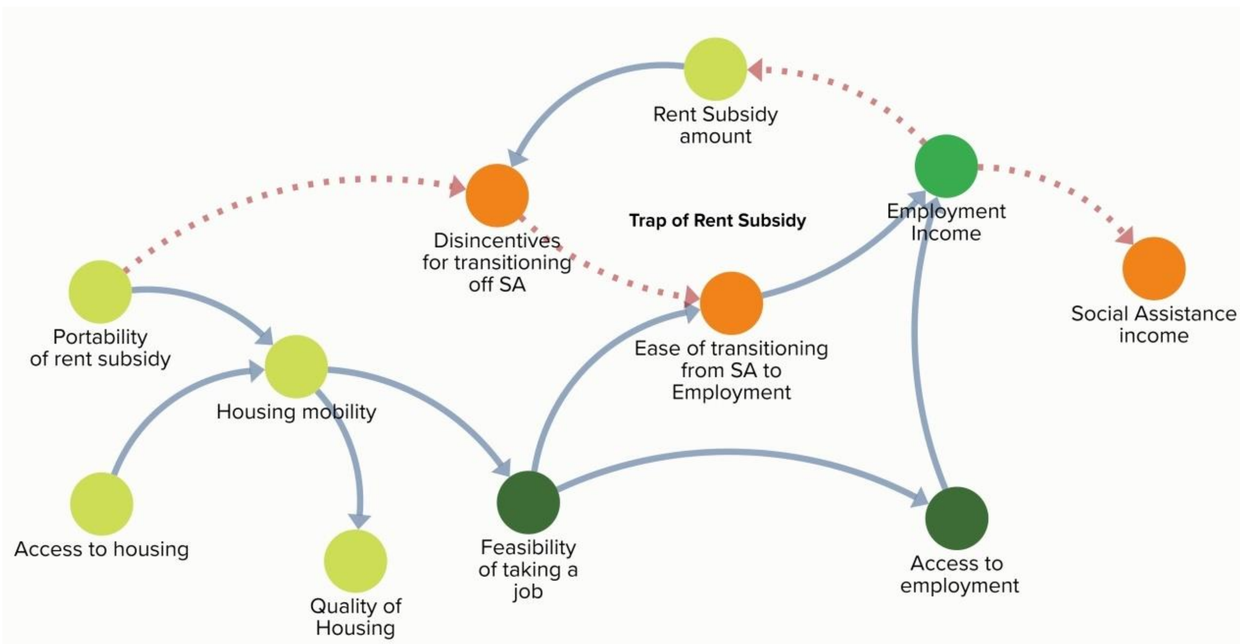

Figure 19: Rent subsidy model in PRM notation

The nodes of a CLD are equivalent to the elements in the PRM. CLD nodes are usually shown as a text string, not a geometric shape. Basic CLDs do not colour-code the nodes, but this has been done by some authors for larger diagrams, as in Figure 10. As the PRM grew large, it became necessary to classify and colour-code the nodes with subject areas (Figure 13) and element types (Figure 14).

CLDs depict cause-effect relationships with curved arrows, and the PRM continues this tradition. Classic CLDs do not use colour or dashed lines to distinguish the relationship type, as the PRM does. The polarity of relationship is classically shown next to the arrow by a letter S or O, or a plus or minus sign. The semantic difference between these notations (Richardson, 1997) was not significant in the PRM's broad and qualitative approach.

CLD relationships sometimes have delay markers (two parallel lines crossing the arrow). The speed of a causal effect was not documented in the PRM, but delay examples are shown in Figure 18.

The PRM uses an additional Supply-Demand connection type to simplify multiple economic cause-effect relationships that may be found in a CLD. See examples in section A.3.2.

In a CLD, most elements are expected to be part of at least one loop. The loops are usually marked with R for reinforcing or B for balancing. The PRM has few loops (section A.2.1) and marks them with a descriptive name, such as "Trap of rent subsidy" in Figure 19. The PRM loop type field stores the designation as reinforcing or balancing.

Guides to CLDs do not prescribe any structure for information that is not shown on the diagram, such as element descriptions. The PRM stores a database of multiple custom fields describing each element; Kumu can also store fields describing connections and loops.

6.2.3 Model format evolution

The following diagram, Figure 20, shows an early version of the PRM notation, which used Kumu to adapt the Causal Loop Diagram notation. Blue arrows are Same polarity connections and red arrows are Opposite connections. There were no loops identified yet.

Elements were shown as text boxes, not yet as the bubbles colour-coded by subject area. The orange elements were "key factors", and interventions were shown in teal-blue. The line widths varied, based on test data about the strength of connections (discussed in section 4.6.2.3).

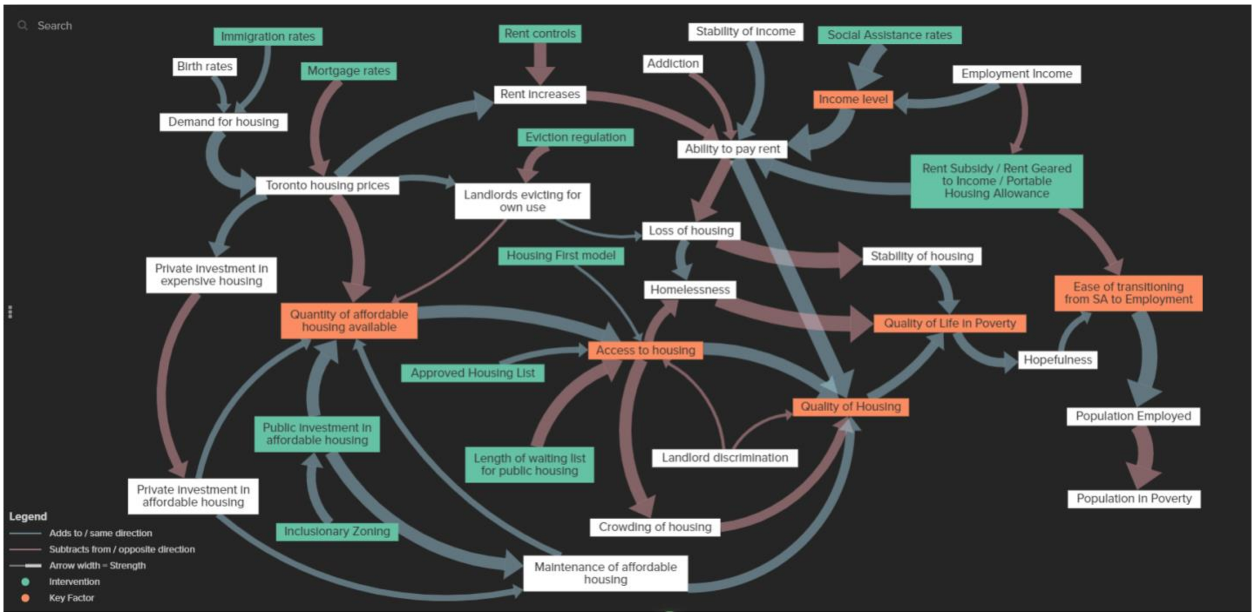

Figure 20: Early PRM: Housing subject area

This is a diagram of the structure for the early PRM shown above:

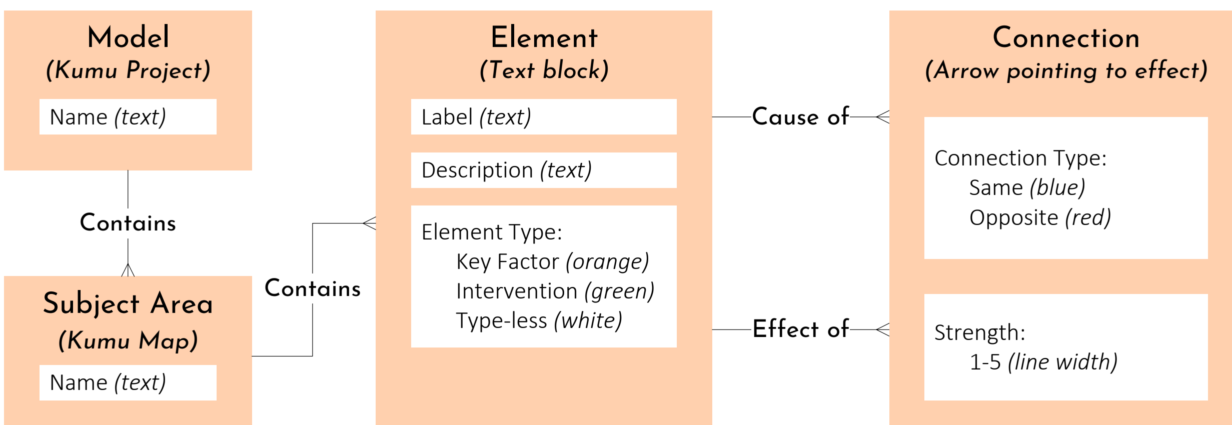

Figure 21: Structure of early PRM

This diagram can be read in similar fashion to the final PRM structure (Figure 17 described in section 6.2.1). Comparing the early PRM to the final PRM structure we see the following changes: Element fields were added. Loops were identified. The element types and connection types evolved (see section A.3). The subject areas were merged into one Kumu map so as to display connections across subject areas without duplication. Subject areas became classified with an Element field, and Tags were used for multiple purposes (see section A.4).

The notation (specified in section 6.2.1) was allowed to vary over the course of the study, using Kumu's flexible display features to improve readability and meet analysis needs. The notation evolved considerably from the early PRM (Figure 20) until Workshop 2. From then on, element and connection colours were kept stable to avoid participant confusion, unless there was a request for change. Because participants were satisfied with the notation in Workshop 2, it did not need to be iterated as much as expected in the original study design.

Element bubble sizes and bullseyes were often changed by the researcher for analytical or experimental purposes. These variations were also used in a few exercises with participants, such as displaying Impact as the bubble size when selecting the Short-List (section B.10.1). Only the relevant extra information was shown. Kumu's notation features were not maximized to display many custom fields on the same diagram.

6.3 Addressing modelling challenges

The three modelling challenges were to incorporate more knowledge of a complex system (section 2.4), to manage the scope of the resulting causal model (section 2.5), and to make it comprehensible (section 2.6). This section describes how the PRM and model development methods (section 4.3) addressed those challenges. The capacity challenge, to balance time and other resources with the needs for modelling and facilitated activities, is reported on in section 7.5.

6.3.1 Knowledge

Most of the modelling was done in a solo process of integrating participant suggestions with three source documents (section 4.1.3), which had appropriate scopes, but required policy and economics knowledge to interpret into causal model content. The interpretation methods, section 4.3.3.1, were effective.

Because of the Working Group's limited time, only a limited amount of knowledge could be captured from, and developed among, the YSM participants. Participation was low in online activities between workshops.

Classifying the elements by type (Table 8) distinguished which elements were influencing other elements, being influenced, or both. This enabled tracing the chain of causation from an intervention to fundamental goals. The objective elements were used to organize known interventions and to identify problems needing new interventions.

For the ideation and prioritization process, connection polarity (Same or Opposite) was not very important, and delays were not discussed; the mere fact that two elements had a causal relationship was often enough information.

There were not many meaningful loops found in the PRM, so many elements were not in a loop (contrary to guidance for causal loop diagramming). This may be due to taking a social-services perspective on people in poverty, with few economic factors modelled. The chains of causation were at least as relevant as loops to the analysis of systemic effects.

There was insufficient time to research or use detail and evidence about hundreds of elements and connections, but YSM plans to research the interventions on the Short-List. In the PRM, 63% of elements have descriptions. The Impact and Potential of the elements were rated rapidly by one YSM staff member using ordinal scales.

There was no attempt to explain why one element has a connection to another, or to find or cite evidence of the causation. Connection labels or descriptions would have been useful to share knowledge.

The experts did not have time to quantify the connections. It is also questionable whether valid ratings could be made to compare the magnitude of causal effects, in disparate policy areas, without specification of intervention design or budgets. Without rating the strength of connections, the PRM could not support computation of which interventions have more leverage. See section 7.3.5.

The Working Group found that the model content was of high enough quality to use it in meaningful discussions and prioritization activities. Participants made suggestions for changes during workshops, but they did not have enough time to fully validate the model content.

Working with social-service professionals enabled discussion of many abstract and generalized concepts at a rapid pace, without taking time to discuss individuals' struggles with particular programs and policies. Although most of the participants did not mention having lived experience of poverty, their bias was mitigated by their front-line experience delivering social services, and the community consultations that had informed the source documents. The model content may also have been biased by the researcher. The YSM Working Group came to consensus easily, indicating that involving outside organizations more would have diversified the perspectives.

If the PRM had been developed by different people using different information sources about the same scope, it would likely have covered similar issues in different words, with some different elements and connections. This could have resulted in a different short-list of interventions.

6.3.2 Scope

This study developed a large model with an unbounded scope, which allowed the PRM to include any issue that affects people in poverty. The PRM covered the topics required for YSM's need to prioritize interventions, with plenty of information about their potential effects. YSM staff liked having a "big big scope", because the breadth allowed them to see the entire system of poverty, before going deep in the later workshops.

YSM is using the overwhelming size of the PRM as a visual representation of the enormity and complexity of poverty in Toronto, which cannot be resolved by any one program or initiative. However, the broad scope leads YSM staff to wonder whether they can take action on the many problems and opportunities shown by the PRM. The large model also posed a high cognitive burden on model users.

Working on a large model had practical challenges. For example, making a new connection required the researcher to remember and search for an existing element. When a new element was created, it needed to be classified immediately (by element type and subject area) so that it would appear in filtered displays and not be "lost". It was necessary to use Kumu filters to occasionally check for inconsistencies such as mandatory fields left blank, and thus find the lost elements.

The number of elements and connections varied by subject area; the counts in Table 22 are highest for the two focus areas, Housing and Employment. Modelling of the other subject areas was needed to show connections to the focus areas. Modelling effort prioritized identifying the multiple effects of an intervention, so the average PRM element has 4.29 connections.

Intervention proposals in the source documents were sometimes generalized or combined. The objectives of those interventions were inferred, as were other significant economic and social factors in the system.

Workshop discussions showed that the expert participants could have suggested many more relevant elements and connections, if more time had been devoted to model development. However, it was not feasible to do an exhaustive Structural Analysis (section 2.4.3) to consider whether each of the 150,975 possible pairs of 550 elements might be connected.

6.3.3 Comprehension

The elements, connections and loops of the full PRM were an appropriate structure for the concepts being modelled, and were understood by the Working Group. A participant appreciated that the model's structure allowed the PRM to incorporate expert knowledge, qualitative evidence, and quantitative data. The fields used in the final model structure (section 6.2.1) were useful and worth filling in for about 550 elements. Other custom fields were created, tested and deprecated, mostly in attempts to compare the leverage of interventions (section 4.6).

The workshops did not allow enough time for participants to thoroughly absorb the information in the model. Participants found that doing some "pre-work really helped to understand the model", for example, by viewing the Promising List (section B.10.1) prior to the workshop. The Working Group did not ask many clarifying questions during the limited time they spent using the model.

For design of information visualizations, "Overview first, zoom and filter, then details-on-demand" is recommended by Shneiderman (1996). This was accomplished using the Summary Model as an overview, then filtering the PRM by subject area and tags, and using the search and focus features to look at blooms around one or two elements.

In Workshop 1, participants found the Summary Model provided a comprehensible overview of the subject areas of the Poverty Reduction Model. One said "This is fantastic", because it helped to digest complexity.

There is no natural starting point for reading the non-linear model. Facilitation guided participants by starting with known elements and browsing their connections. More guidance might have been useful when inviting people to read the model on their own, as it is overwhelming on first glance.

6.3.3.1 Readability and notation

The Working Group was asked at each workshop about the readability of materials, including various displays of the PRM. There were fairly few comments on the notation, and participants generally understood the model diagrams. YSM staff described the PRM notation as "very straightforward" to understand. One of them has coached a colleague, by phone, about how to look at the model.

It was important to have flexible notation to display additional information (such as subject area colour-coding) while hiding information that wasn't relevant to a workshop. With one exception, the stable aspects of the notation did not need iteration after Workshop 2.

The partitioning into subject areas was useful, and YSM appreciated the capability of Kumu to focus on small selections from the PRM (section 6.4.1). The Working Group found these diagrams to be readable and comprehensible. The large size of the model required spending significant time on categorizing, tagging and selecting small sets of elements for readable displays that were conceptually coherent.

The PRM can be assessed against the readability criteria set in the original workshop guide:

Table 10: Readability assessment

Readability criterion	Final PRM assessment
Quick to read	Participants were able to read the model as fast as can be expected for a diagram of non-linear, non-hierarchical connections.
Pleasing to the eye	Kumu offers a modern aesthetic. The element bubbles move during the auto-layout process, which brings a little joy to a meeting about poverty. The Subject Area view used 16 bright custom colours, making for attractive overview diagrams. The Element Type colour scheme was beige-orange-red-brown, based on the wire photos in this report. The Element Type colours were changed to be more distinct on the data projector.
Fonts	The default font in Kumu is readable, and the size was appropriate.
Lines	The connection lines were a readable width.

Readability criterion	Final PRM assessment
Colours	Bubble and line colours were selected to be distinguishable, and visible on the white background. The difficult-to-read notation traditions from black & white causal loop diagrams, such as a tiny "S" marking a Same relationship, were converted to simple colour-coding. (This took advantage of colour monitors, projectors and printers, and participants' vision abilities.)
Symmetry	Non-linear networks of many elements were not arranged symmetrically by Kumu's auto-layout. Focusing on one element produced a circular bloom. The objective cards (Figure 52) were manually laid out, using reflective symmetry to the extent possible.
Layout	The auto-layout features of Kumu made diagrams mostly but not entirely readable. Figure 23 demonstrates that readability is compromised when displaying just 13 elements, because label text overlaps the bubbles and arrows, and some arrows cross. Most diagrams presented to the Working Group, such as Figure 52, were manually adjusted to remove overlaps, so the layouts were of acceptable quality.
Labelling	All elements and loops were labelled. Participants seemed able to understand the element names, and raised no issues with spelling or grammar. Using some longer phrases meant that labels were usually understood without referring to the description.
Comprehended, with intended meanings	Workshop discussions indicated that most but not all of the elements were understood as intended. Connections sometimes needed explanation. Participants occasionally needed explanation of the connection polarities. Using solid and dashed lines of different colours made it obvious that Same and Opposite connections were different, so participants knew to ask what they meant. This polarity notation was also more visible than the small S, O, + or - markers in a classic causal loop diagram; see the comparison in section 6.2.2.
Not to general, not too specific	The PRM had some general elements such as *Quality of housing* and some specific elements such as *Incentives for energy-efficient retrofitting*. The Working Group needed specificity to compare interventions, such as two options for rent subsidy policy: *Base RGI on net income* versus *Base RGI on 25% of gross income*.

6.4 Findings about Kumu software

6.4.1 Displays of the PRM

The Working Group was shown the entire Poverty Reduction Model on one screen such as Figure 22, to show participants how much information was available. This colourful view, with bubbles moving around, succeeded in impressing and delighting the viewer, but was not intended as a readable, functional view of the model.

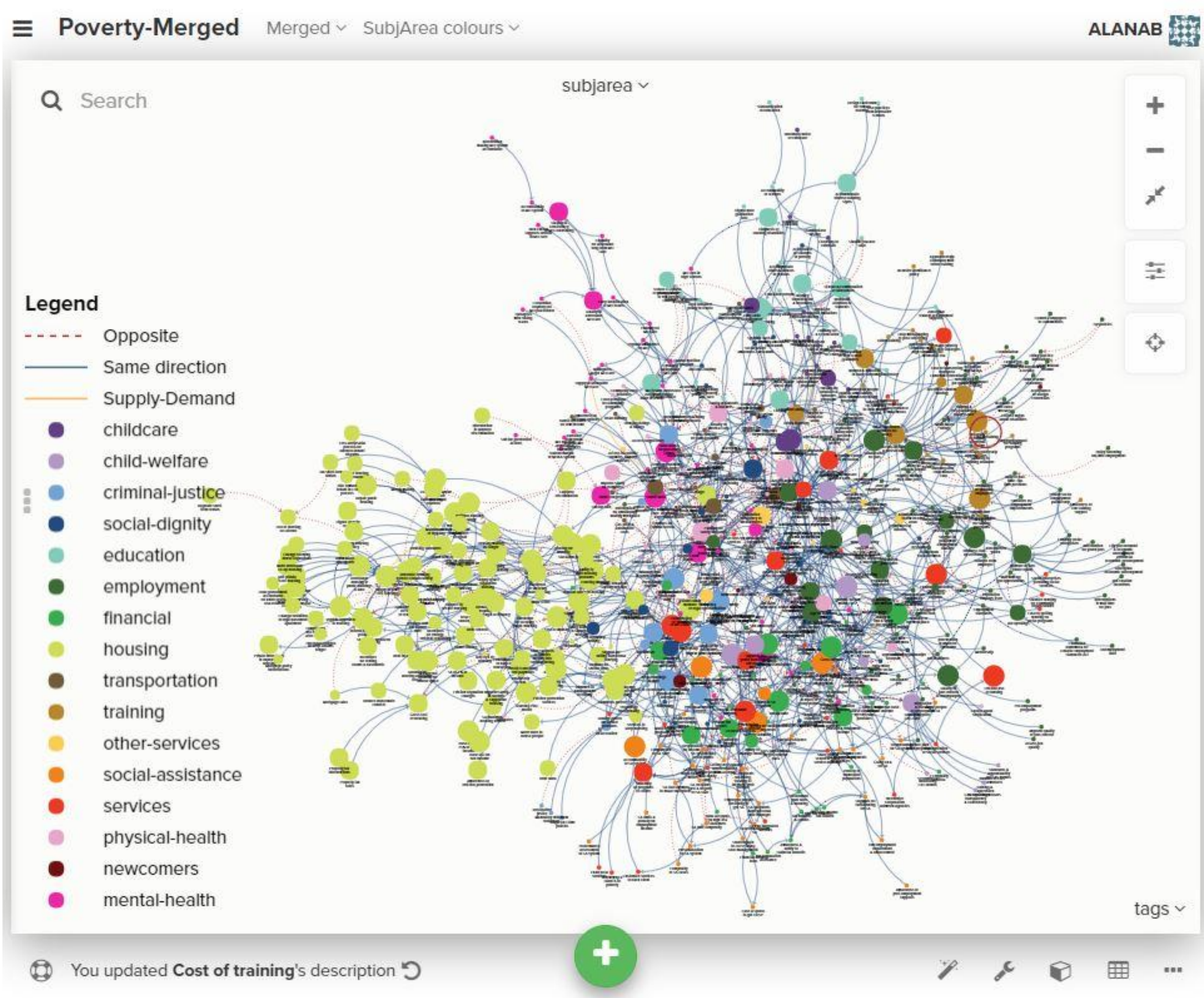

Figure 22: Kumu screen showing full PRM subject area colours

Custom Filters were set up in Kumu to provide drop-down lists where the user can select one or more Tags or Subject Areas to display. This partitioning of the model sometimes resulted in a readable display, depending on the number of elements in the tag or subject area.

To display readable subsets of the model on demand, the Kumu "focus" feature was used to show the elements directly connected to any element selected (the first-order bloom). Using the Focus feature with Subject Area colours could demonstrate the connections across social systems. For example, in Figure 23, an Employment issue (*Qualification for jobs*) is directly connected to education, training, health and newcomer settlement.

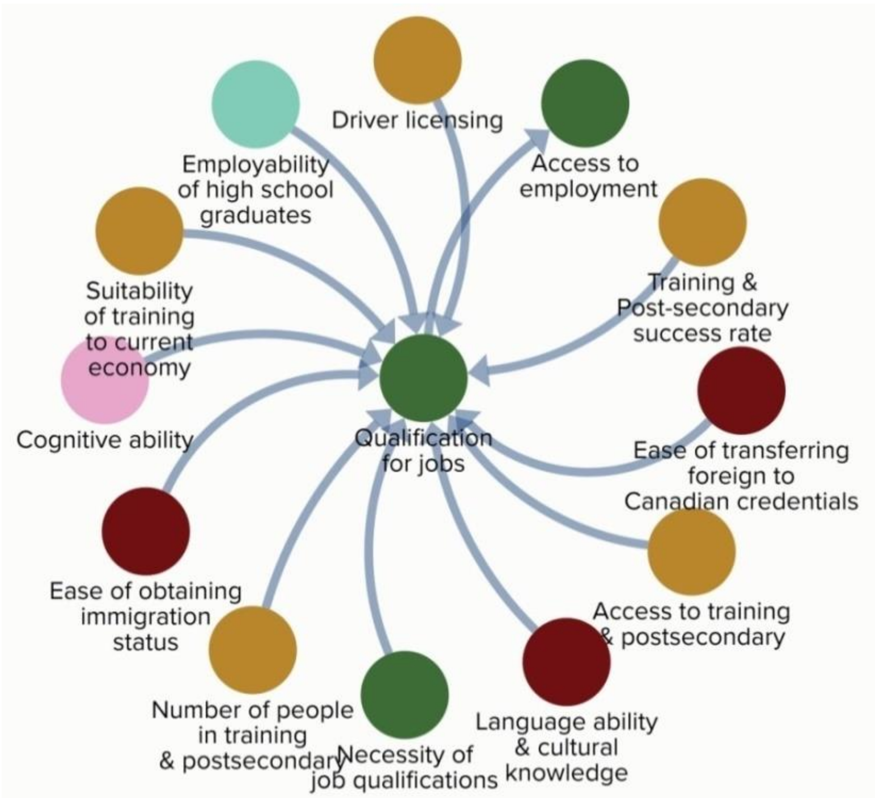

Figure 23: PRM: focus on one element, first-order bloom

Once the first-order bloom of one element is displayed, it is easy to expand the focus to a second element, to explore indirect effects. For example, expanding *Necessity of job qualifications* explains that *Credentialism* may lead to unnecessary qualifications, but writing *Explicit job qualifications* could re-focus employers on the necessary job requirements, which could lead to more *Merit-based hiring*:

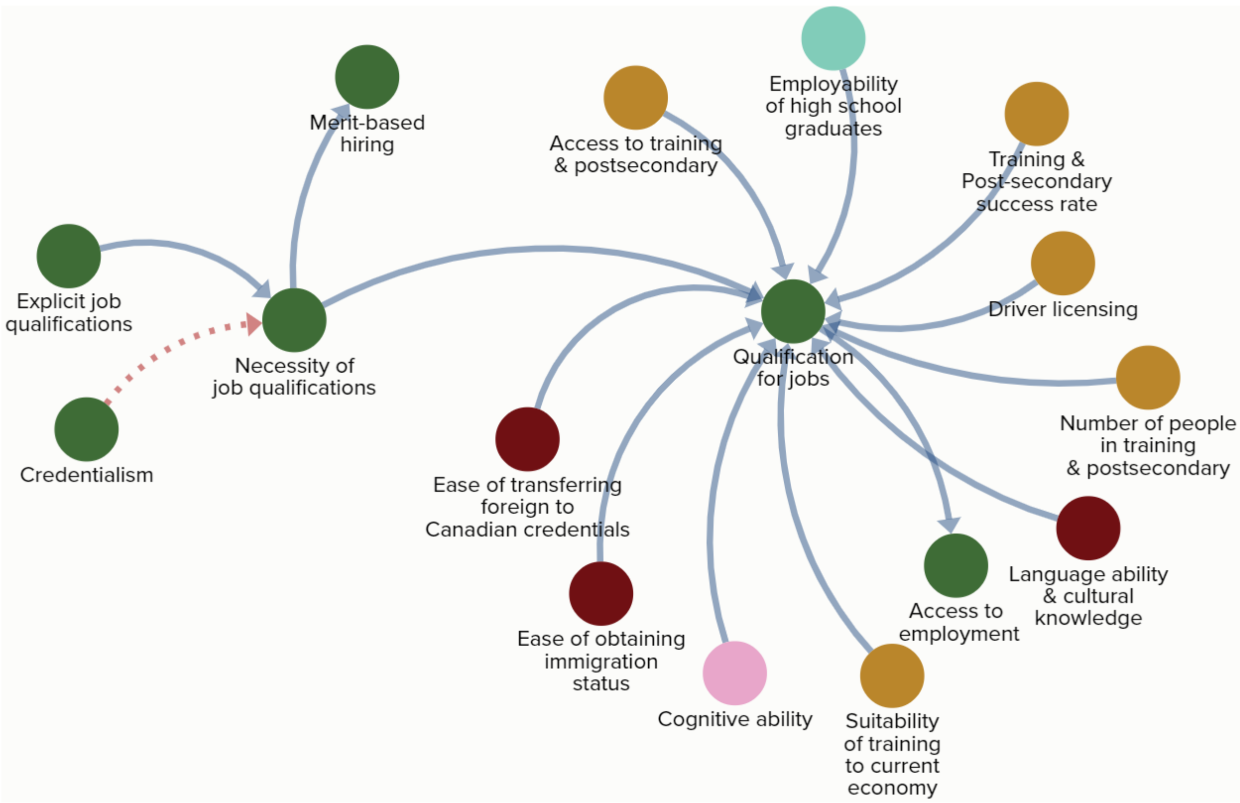

Figure 24: PRM: focus on two elements, first-order bloom

Kumu can also display two layers of connections to an element (the second-order bloom). Because of the high density of connections in the PRM, this usually results in too many elements to read on one screen:

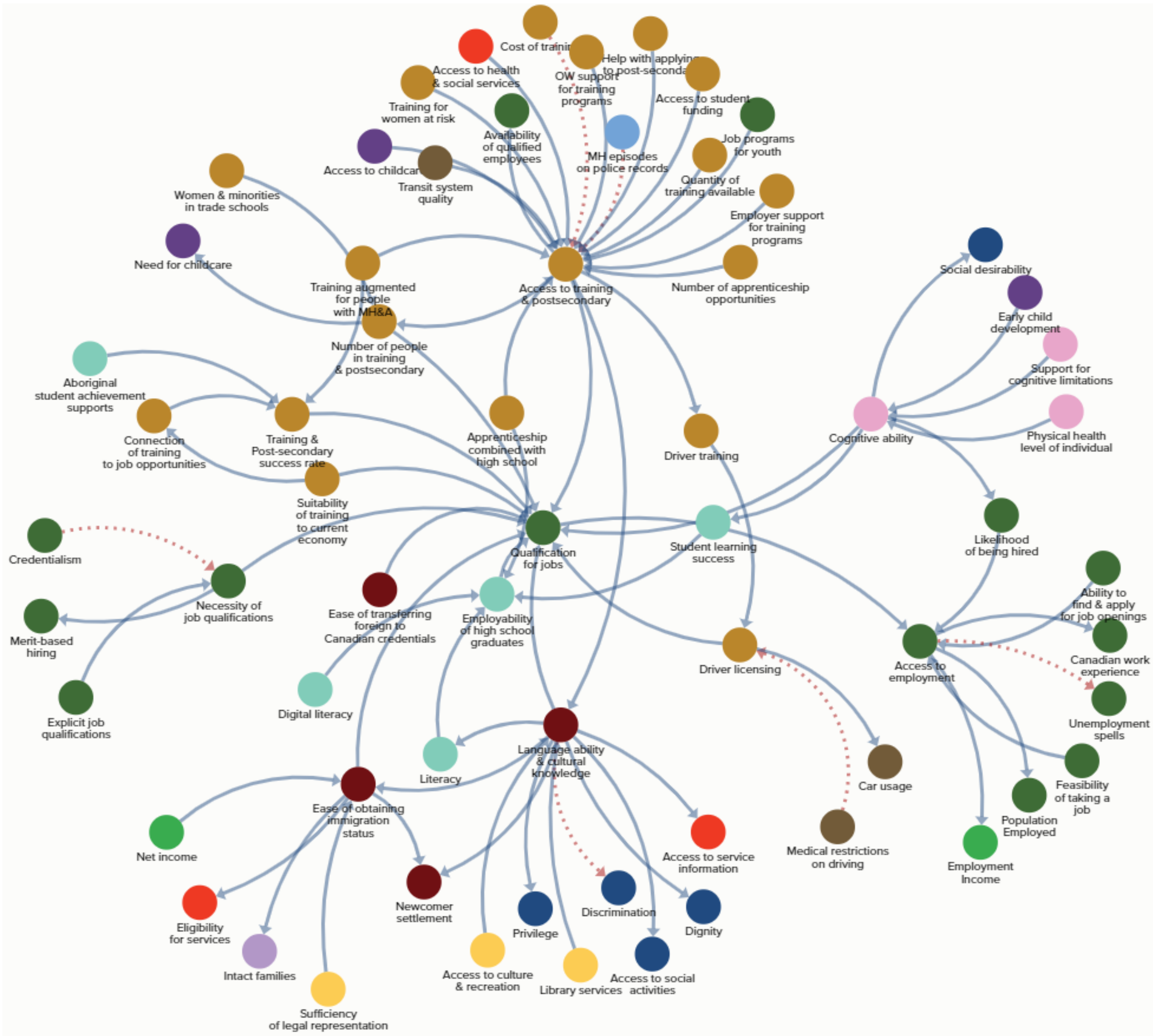

Figure 25: PRM: focus on one element, second-order bloom

6.4.2 Customizing notation in Kumu

The Kumu customization capabilities were used to design, prototype and test many possibilities for displaying the PRM. For the regular views for participants, the following Kumu properties were customized: Element bubble colour, font colour and size, arrow colour and pattern (solid/dashed). To add temporary information for participants, element bubble size and bullseye colour were also customized. Arrow curvatures were manually adjusted when laying out individual diagrams.

The researcher also tested or used other properties: element flags and arrow line widths. Many more properties were available for advanced customization, but the defaults were acceptable for this study. See section A.6 for the Kumu view settings used.

6.4.3 Tips for using Kumu for a large model

The following recommendations are based on this study's experience using Kumu for a system map of over 550 elements:

- Put all elements into one Kumu map so the elements can be linked and reused across subject areas.
- Use element types, tags, and custom fields (such as Subject Area) to distinguish the many kinds of elements that need to be connected in that one map.
- When creating an element, immediately assign its type, and any field used to filter displays (such as subject area). This ensures new elements will not be lost in the large model.
- When creating a connection, immediately assign its type. If the Same connections use the default notation, a new connection will look like the Same type even if it should be Opposite, and it will be difficult to find later.
- Set up custom Filter Controls to quickly isolate various smaller segments of the model.
- Use numeric fields, with the largest value indicating the highest rating, for any fields that might be used to scale the size of an element bubble, connection line width, or font size.
- Make a copy of the model for testing things, separate from the official (production) version of the model that is shared with other people.
- Make one or two views for collaborators to use, and keep their settings stable. The modeller should do filtering, testing, etc. on separate views.
- To share the model content with people who do not need to edit it, use the Kumu embedding, spreadsheet export, and screen-shot capabilities.
- Import model content from spreadsheets where available. Kumu can update existing elements with an imported spreadsheet, but first test the import on a copy of the model to make sure no duplicate elements will be created.
- For collaborative mass data entry, use Google Sheets. The participants' input can be imported as a spreadsheet. (Take note of the limitations on Kumu's integration with Google Sheets.)

6.4.4 Kumu software evaluation

The Kumu software was effective for developing and using this large system model. YSM staff enjoyed and appreciated Kumu. Its major advantages for causal modelling:

- Cloud software designed for collaborative modelling
- Free or low cost
- Highly customizable model format, especially for users comfortable with coding
- Modern, readable and customizable notation
- Good performance with a large model, even on high-quality view setting

- Manages elements and connections as a database, with custom fields and valid value lists
- Spreadsheet import, export and integration
- Active customer service and user community.

This study was affected by some weaknesses of Kumu that might be resolved by ongoing software development by Kumu or custom programming by the user:

- Inability to focus on only the incoming or outgoing connections of an element
- Auto-layout defaults leave some unreadable overlaps of arrows
- Slow performance prevented use of the Presentations feature
- Lack of features for finding, creating, managing and exporting loops
- Lack of features for summarizing the model (section 6.5.3)
- Lack of change-management features such as version history or batching changes into releases
- Lack of metrics designed for analyzing a system model (the Social Network Analysis metrics in Kumu were of limited relevance for causal modelling – see section C.2.)
- Inability to simulate system dynamics, which is a different category of software.

A participant wished that Kumu had offered the ability to write private comments on model elements, so they could recall their thoughts.

6.5 Summarization findings

6.5.1 Summary Model and Poster

The Poverty Reduction Model was summarized as a one-page (letter size) diagram of the subject areas, using Visio diagramming software. The first version of the Summary Model is Figure 26. The most recent version is Figure 3 in section 1.7.3, which provides a guide to reading the diagram.

For Workshop 1, it was important to present this one-page summary, but also necessary to inform participants what was included in each subject area.

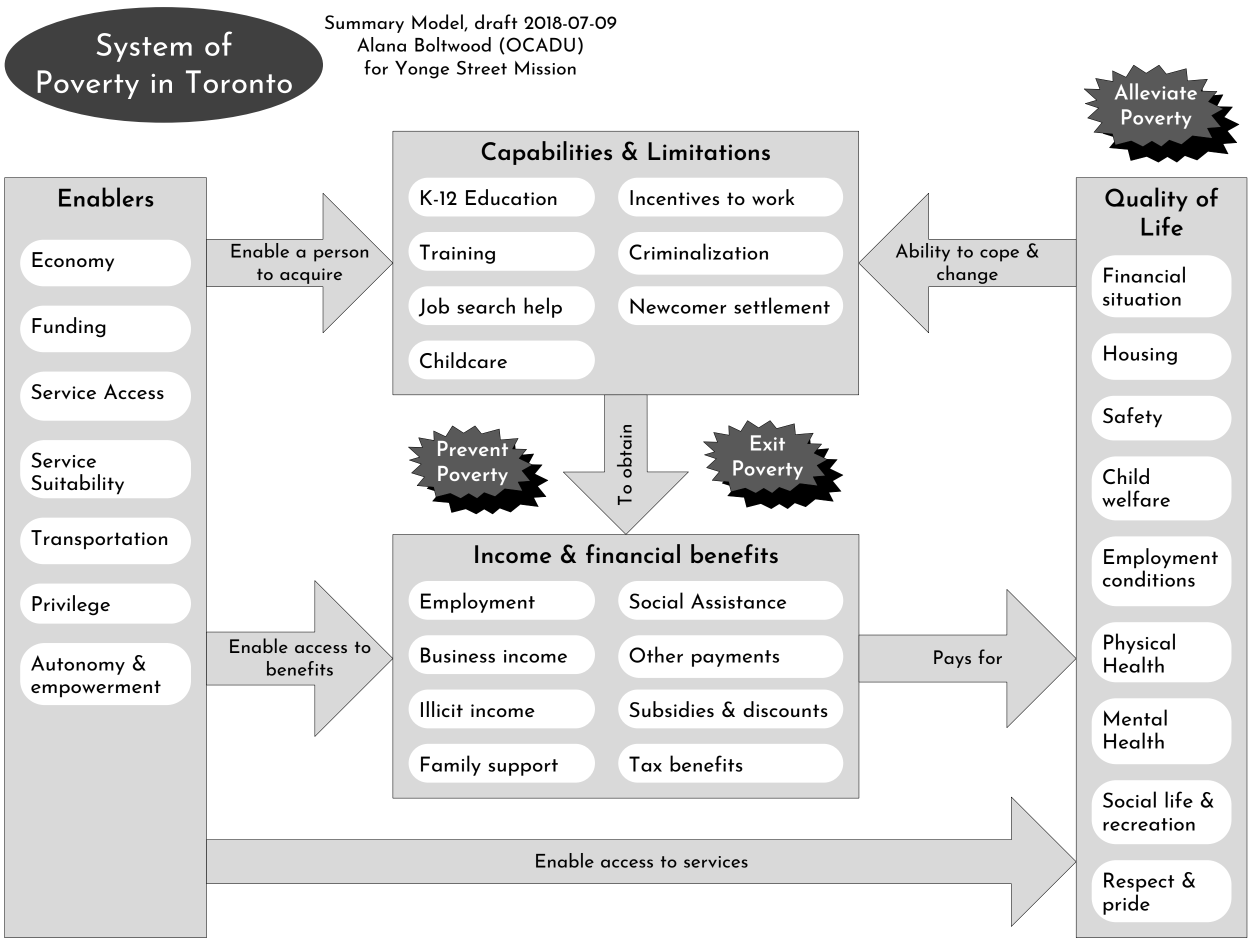

Figure 26: Summary model, prior to Workshop 1

The Summary Model was expanded to a 36”x60” poster with descriptions of the subject areas (Figure 27, which can be read by zooming in). These summaries have minor differences from the final subject areas, as they were not updated after the early workshops.

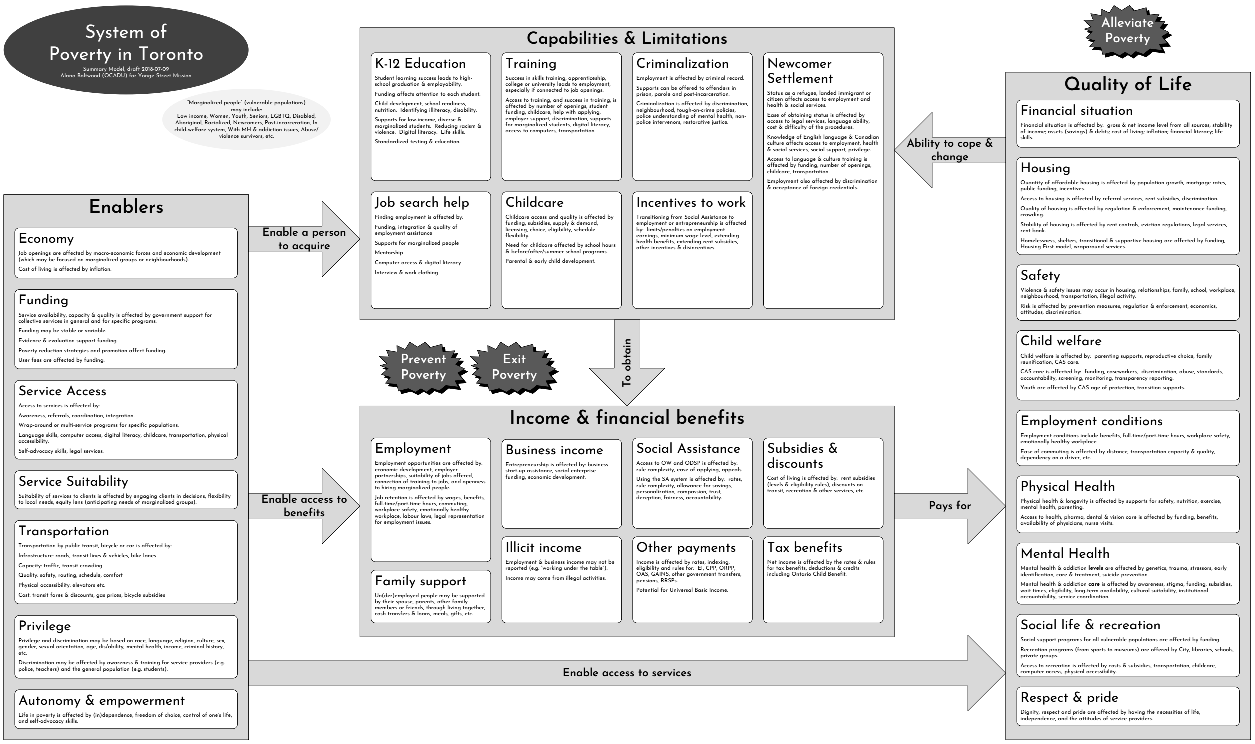

Figure 27: Summary Model poster, prior to Workshop 1

6.5.2 Summary Model structure

The Summary Model shows the Subject Areas within Groupings that summarize the systemic effects: Enablers, Capabilities & Limitations, Income & financial benefits, and Quality of Life. The Dependency arrows show a generalization of the many connections in the system. Starbursts indicate the Major Goals that can be achieved by the Groupings: preventing, alleviating or exiting poverty.

On the Summary Model Poster, each Subject Area is described with text summarizing the system objectives and interventions in that area.

Subject Areas are found in both the Summary Model and the fully detailed PRM. Other constructs differ, as shown by section 6.2.1.

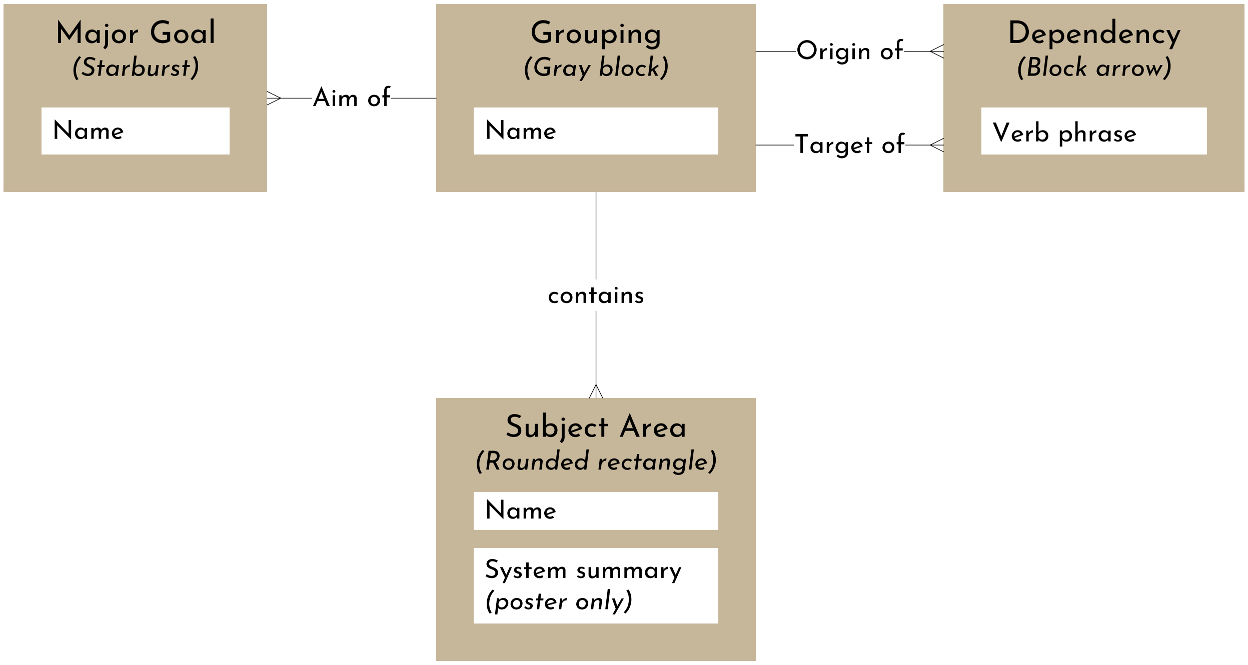

Figure 28: Structure of Summary Model

6.5.3 Findings about summarization methods

Various attempts were made to mechanically select a summary of PRM elements. Using Kumu to display only the goals and objectives did not reduce displays to a readable size, as there were so many objectives in the PRM, but it was a helpful way to look at one subject area.

Filtering for elements with more connections (using the Degree SNA metric) did not provide even coverage of the subject areas. This test showed that applying arbitrary summarization rules to a causal model might not reliably include all the elements that experts would deem important.

Using human judgement to summarize the model in Kumu was also considered. Kumu does not support a hierarchy of elements. If "encapsulated elements" were created to summarize a chain or bundle of elements and connections, Kumu would not help the modeller to keep both the detailed and encapsulated elements up-to-date in parallel.

The Summary Model diagram was created in Visio, after finding that a meaningful summary of the PRM could not be produced or stored in Kumu. The Summary Model information is not stored in Kumu, so it is not kept up-to-date as the PRM changes in Kumu. PRM subject area names and inclusions have changed since the Summary Model was created.

6.5.4 Findings about Summary Model

The process to develop the Summary Model in four iterations (of whiteboarding and Visio diagramming) was an effective use of time. It would have been preferable to involve at least one YSM participant in shaping the groupings and dependencies.

The structure of the summary model was effective. The subject areas were understood by participants, as were the three major goals (Prevent, Exit and Alleviate Poverty). The participants did not comment on the groupings (Enablers, Quality of Life, etc.) or on the dependency arrows between them.

Some PRM subject areas were split into multiple groupings. For example, "Job search help" was a subject area in the Capabilities grouping, because it helps to obtain "Employment" in the Income grouping. The Working Group decided to combine these two, plus three smaller areas, into a larger Employment area for voting. See the red loops in Figure 49 for this and other combinations of subject areas used during the Workshop 1 voting process.

The Summary Model Poster, at 36"x60", was just barely large enough for six participants to gather around; a longer rectangle would have been preferable. The poster was black and white because colour printing would have been much more expensive. This was a good choice because the poster needed to look less like a finished professional design, to encourage participants to write comments on it.

Participants did not remark on whether the descriptions on the poster were necessary, sufficient or excessive. Having descriptions printed avoided spending time explaining what was in a subject area, but also missed the opportunity to discuss what should be in a subject area. Shorter descriptions in a larger font might have been preferable.

Developing and summarizing the Poverty Reduction Model employed considerable subject-matter knowledge and technical capacity for modelling. The resulting model integrated a broad scope of knowledge about poverty in a comprehensible format.

Photo 8

7 Findings from model use

Like the shadow of this wire, many colours and shapes appeared when visualizing the system of poverty. This chapter summarizes what was learned from doing the case study methods (chapter 4): that the causal model was useful for finding and prioritizing interventions, but time and other capacities limit its use. This led to recommendations (section 7.6) about balancing scope and capacity in modelling projects. Detailed reports of facilitated activities are in Appendix B, and model analysis results are in Appendix C.

7.1 Findings from using the PRM

The case study showed that a causal model can be used for integrative sensemaking and decision support. The Poverty Reduction Model was developed in concert with experts, and combined with facilitated activities to find, compare and prioritize interventions in a complex social system. The YSM Working Group used their own criteria to make an informed choice of their short-list of interventions from options in the PRM. Computational analyses of this model were not as useful for comparing options.

The usefulness of the PRM and the model use process is also demonstrated by the City of Toronto arranging to use and enhance the model, and hold prioritization workshops, in developing their 2019 Poverty Reduction Strategy.

7.1.1 Integrative sensemaking

The Poverty Reduction Model has combined knowledge about poverty in Toronto that was previously dispersed, and organized it to highlight causes and effects. Although YSM participants already have a strong understanding of poverty in Toronto, the PRM organizes that knowledge: “All the things rolling around in my head are here on paper”, said a subject-matter expert in Workshop 3.

Feedback from participants indicated that YSM sees the usefulness of the Poverty Reduction Model. They reported that the PRM helps them see poverty as a system of interactions, leverage and feedback loops, rather than considering each social-service program individually. Seeing the PRM’s cause-and-effect connections helped YSM understand interactions between programs.

By discussing the model content in all five workshops, the Working Group developed collective knowledge with its attendant social benefits. YSM staff have access to update the PRM and are able to browse the model as a reference.

The PRM’s quality met the original expectations for use in the YSM workshops. Some participants wanted YSM to put more work into the systems modelling process. YSM would have benefited from spending more time developing, validating and using the model to understand the system, in addition to using it for finding & prioritizing interventions.

7.1.2 Finding interventions

The facilitated workshops to find interventions in the Housing and Employment areas were effective, though too short to fully the complexity of these policy issues. The objectives in the PRM were used to organize the search for policy innovation opportunities, making the model a useful framework for finding interventions. See sections 7.2.6 and 7.2.8 for more findings about these workshops.

7.1.3 Comparing and prioritizing interventions

This study combined the PRM with option-scoring techniques in a sequence of facilitated activities to successfully compare and prioritize a large number of interventions. The YSM used the PRM to select a short-list (section 7.2.11) of three very effective policy innovations for their demonstration project.

Although these rapid activities provided limited discussion time, YSM staff reported (at Workshop 5 and in the evaluation meeting) that the short-list did reflect their prioritization criteria, and they were comfortable with the results. (This assessment is limited because the YSM has not yet chosen one intervention from the short-list, designed their demonstration project, or measured its impacts.)

In these activities, the PRM was used to look for systemic effects of interventions. The PRM's high density of connections was useful for anticipating many positive effects, while few negative side-effects were found downstream from the Promising List interventions. YSM staff recognized (but were frustrated) that the model was too high-level to include the designs of specific policies and programs, so not all of their consequences can be anticipated.

YSM reports that the prioritization workshops "helped to narrow our focus in a more systematic way". If YSM had not used the PRM and this mass-prioritization process, they would have done research and consultation similar to their strategic planning process, and prioritized a simpler list of options.

Because the PRM did not have quantitative ratings of connection strength, there was little value in the computational analysis attempted of the PRM. With further quantification, and research into algorithms and software, the PRM might be more useful for comparing the indirect leverage of interventions. Social Network Analysis metrics did however identify the PRM's central goals and objectives. See section 7.3.

7.2 Findings about facilitated activities

The case study activities to use the PRM to find and prioritize interventions are assessed briefly in this section, with more detailed findings and results in Appendix B.

7.2.1 Workshop process

The sequence of facilitated activities was successful in narrowing a very wide field of options to a short-list of three interventions with very limited expert time commitment. YSM staff evaluated the facilitated activities as "great" – they "brought our thinking to another level", and were successful in reaching conclusions that participants felt comfortable with.

YSM has found this process useful as an introduction to systems thinking, which supports their mission to address systemic challenges (Yonge Street Mission, n.d.) Developing and using the PRM has "challenged and accelerated our thinking" according to YSM staff at the evaluation meeting (section B.12).

Participants felt that the workshops were low-risk, and they expressed no ethics concerns. Very few personal experiences were shared in the workshops. No pseudonyms were necessary for reporting stories.

In general, the simpler activities took less time to prepare, and were more successful because they did not overburden the participants. It was important to plan the facilitated activities in detail, and to test new approaches in advance. Making physical materials for testing was helpful, as illustrated in section A.5.

Effective techniques included the visioning icebreaker, discussing the Summary Model Poster, loosely facilitated idea-generation, and the option-scoring processes that included discussion time (including dot-voting, the scatterplot, and scoring in the Stormz online tool.)

The broad scope and the complexity of poverty did merit more discussion time than was available from the non-profit staff who have too many commitments to reliably participate in lengthy workshops. Having more time would have increased the quantity of knowledge integrated and the quality of comparisons. More systems-thinking techniques, such as the Workshop 3 roles, could have been applied with more workshop time. Section 7.6.5 recommends how to balance project scope with the time and other capacities available.

7.2.2 Visioning icebreaker

Workshop 1 engaged the Working Group in thinking about the whole system of poverty. Participants struggled to answer the "huge question" of how poverty in Toronto could be reduced, and they offered huge answers such as "Justice system revamp". Discussing the vision statements built the group's collective understanding, and contributed some ideas to the PRM. This activity was easy to prepare and a relevant use of introduction time. See details in section B.2.

7.2.3 Prioritization with Summary Model

Working with the Summary Model Poster in Workshop 1 was effective for integrative sense-making. Participants became familiar with the PRM, reconciled terminology with the researcher, modified the subject areas, and provided more ideas that were added to the PRM after the workshop. As in the icebreaker, the Working Group was more comfortable with discussion, and their written comments needed clarification.

Dot-voting was easy to prepare and learn. The subject areas with the most dot-votes were Transition to Employment, Mental Health, Criminal Justice, Housing, Funding, and Service Access. Further discussion of criteria and the model content was needed before two focus areas could confidently be prioritized. See detailed findings and results in section B.3.

7.2.4 Setting prioritization criteria

The discussion and voting activity in Workshop 2 set the prioritization criteria. It was important to hear the Working Group's interpretation of Impact and other criteria in this cognitively-demanding activity.

The dot-voting (by few participants, on a long list of proposed criteria) did not fully discern YSM's relative priorities and goals. The selected criteria did not include or prioritize all of YSM's demonstration project requirements. For some later activities, a shorter list of two or three criteria was needed, either Impact and Potential (as defined by the Working Group, section 5.1) or other interpretations by the researcher (such as the short-list scoring criteria, section B.11).

Having set criteria did provide clarity to avoid lengthy discussions about priorities. See details and results in section B.4.

7.2.5 Objective scatterplot

In Workshop 2, over one hundred objective elements from the PRM were sorted into a scatterplot, to find the subject areas with the most high-impact, high-potential opportunities for intervention. After discussion of the results, the Working Group selected Housing and Employment as their focus areas.

Participants placed objective cards on the board rapidly, but did not have much time to discuss which objectives were higher impact or potential. Most objectives were rated as higher impact. Placing cards in a Not Sure zone allowed participants to help each other work quickly.

Detailed planning of the logistics was necessary. Preparation for the activity was onerous because each objective card needed manual graphic layout of the bloom of elements. The element bubbles were too small, and in too many colours, to visually observe which subject areas were dominant in quadrants of the scatterplot. Thus, a tallying procedure was improvised, which did not use all the information available.

The objective scatterplot was a suitable, rapid and effective method for experts to comparatively rate many items. The results would have been more reliable with more participants, longer time to debate the placement of cards, and a digital scoring procedure. YSM staff appreciated using a ranking process, not just conversation, to winnow down the focus to high-impact areas that are feasible for YSM. See detailed findings and scoring results in section B.5.

7.2.6 Developing Housing interventions

Workshop 3 contributed greatly to the collective knowledge of housing issues, in spite of an overly ambitious agenda. Most participants did not have enough time to do the advance reading for Workshop 3, but those who browsed the PRM found it useful preparation.

During Workshop 3, participants were overburdened by the assigned systems-thinking roles, as well as by browsing or editing the PRM on their own laptops. The Working Group concentrated on expert discussion of interventions, and the researcher asked about systemic effects while limiting the time spent discussing details of each policy proposal.

Modifying the model "live" in Kumu was difficult, as the topic of discussion changed quickly, and the researcher did not know enough about local housing policies. Participants using Kumu were distracted from contributing to the group discussion.

YSM staff organized an extra session (Workshop 3A) to generate intervention ideas for the sub-topics that could not be covered during the original two-hour workshop. Based on the discussion in Workshops 3 and 3A, 27 interventions were added to the PRM, and most of the Housing subject area was modified in some way. See details in section B.6.

7.2.7 Employment agenda-setting

The Stormz online voting activity was a simple, successful way to prioritize the Employment sub-topics. Workshop 4 participants were comfortable with the agenda sequence even though few had voted on it. Working Group members did not make online comments about the Employment objectives, preferring in-person discussion.

The 25 online images of objective element blooms were too many to visually scan, and were burdensome to prepare, but a participant found them to be helpful preparation for the workshop. Related objectives were combined into sub-topics after voting, which could have been done before voting for higher efficiency.

The PRM was very useful in organizing for the Employment workshop. The agenda priorities were shown on a single diagram of related PRM objectives, Figure 58. This and other details are in section B.7.

7.2.8 Developing Employment interventions

Workshop 4 covered the three highest-priority Employment sub-topics, and other poverty reduction issues came up. With relaxed facilitation (and no systems-thinking tasks for the participants), the group discussion generated important insights such as employees being treated like machines. This conversation sometimes deviated from the ideation of interventions and modelling their systemic effects. The free-form notes and discussions were not easy to integrate into the PRM's structure, but 84 elements were added or significantly modified. See details in section B.8.

7.2.9 Rating elements

The element rating spreadsheets were a simple and successful way to gather a large volume of data. One YSM staff member rapidly filled in the impact, potential and other criteria columns. More participation would have increased the quality of data that was used in a key prioritization decision.

The Impact ratings estimated the effectiveness of each intervention, but the connections were not rated to show how much an intervention might influence each related objective. The intervention Potential ratings were preliminary feasibility assessments, which did not benefit from much discussion of how to overcome barriers to each intervention.

Logically, the overall effectiveness of an intervention element is a combination of its effects on its downstream connected elements. Therefore, quantifying the strength of the connections would have substituted for quantifying the element Impact, and would have had other uses in comparing leverage.

It was easy to export Kumu data to a spreadsheet; care must be taken to avoid duplication when importing a spreadsheet. See details in section B.9.

7.2.10 Making the Promising List

Using spreadsheet filtering was an easy way to create the Promising List before Workshop 5. Thirteen interventions met the criteria, including some from outside the focus areas. Tagging chains of elements in Kumu was not a quick or effective way to visualize the leverage of each intervention (see section A.4.3.)

Communicating the list in Stormz was effective, though the images were too large. Some Working Group members reviewed the interventions in advance, making a few comments online and suggesting variations that were considered in Workshop 5. See details in section B.10.

7.2.11 Selecting the Short-List

The activity in Workshop 5 was effective for quickly comparing the Promising List of interventions against multiple criteria to select a Short-List of interventions that the Working Group is comfortable with.

About four minutes were allotted to discuss each of the 13 interventions on the Promising List plus variations that were added before and during the workshop. Although YSM staff appreciated covering so many ideas in one workshop, the time was inadequate to clarify the meaning of an intervention idea and to fully review its systemic effects. Kumu was used to quickly browse the chain of elements downstream, but sometimes the first-order bloom was sufficient for experts to infer the systemic leverage of an intervention.

In this workshop, participants viewed the PRM with element bubbles sized by Impact. They did not mention the impact ratings in the Workshop 5 discussions, so it is unclear whether those ratings were useful in their scoring process.

Participants had difficulty understanding or agreeing with the criteria or weights until they had scored an intervention as an example. After the workshop, various weightings made no difference in which interventions scored highest.

The Stormz service allowed the options, criteria and weights to be modified easily during the workshop. All participants with laptops were able to score each intervention on three criteria and see results immediately.

Knowledge shared by Working Group members was integrated into the PRM after the workshop.

The Working Group of experts agreed that their numerical scoring had selected a good Short-List. Approaches were discussed to further research and design the three options before selecting one for YSM's demonstration project. See detailed findings in section B.11 and results in section 5.2.2.

7.3 Findings about model analysis procedures

The following sections report findings from analysis and computations attempted to describe the PRM and identify the most important and higher-leverage elements within it.

7.3.1 Computing model statistics

Computing statistics about the PRM was a simple method (section 4.5.1) with results in section C.1 that describe the content of this large model.

7.3.2 Community detection

The community detection algorithm (section 4.5.2) did not yield very meaningful results. Some commonalities could be perceived amongst the PRM elements in the detected communities, but the manual classification into subject areas and topic tags was of higher quality. Community detection did not suggest intervention opportunities. These results were not discussed with the Working Group and were not included in this report.

7.3.3 Social Network Analysis metrics

Social Network Analysis (SNA) metrics were indicative of which goals & objectives are central to the system, but not conclusive about where intervention might be most effective. The SNA metrics are intended to measure centrality in a network of undirected connections, so they merely indicate tendencies in a causal model of directed connections.

In early tests, the SNA metrics were obviously skewed by the variable depth and density of the early PRM, but the metrics became more meaningful after the model expanded. These computations were done without weights, since expert ratings of connection strength were not available. With those caveats, these are findings about applying SNA metrics to a causal model:

- The out-degree, reach, closeness, betweenness and eigenvector metrics were found to produce similar lists of important goals and objectives in the PRM.
- The in-degree metric was high for some goals and objectives, but its interpretation was ambiguous.
- Interventions with high out-degree are influential on multiple objectives, making the metric a simplified proxy for leverage. The computed ranking by out-degree was not strongly correlated with YSM's expert ratings of interventions.
- High out-degree might be a proxy for higher leverage
- The Size metric was not useful for the PRM. It was very similar to the Degree metric because very few pairs of elements in the PRM have more than one connection.
- The Reach-efficiency metric did not yield meaningful results for interpreting this type of model.

The results and interpretation of the SNA metrics are detailed in section C.2. The metric results were not discussed with the Working Group.

7.3.4 Classifying by leverage levels

The researcher attempted classifying PRM elements by Donella Meadows' 12 levels of leverage point (Meadows, 1999), and their adaptation into a five-level Intervention Level Framework (Malhi et al., 2009).

Most interventions in the PRM seemed to be at lower leverage levels. For example, the *Rent subsidy amount* is determined by rates and parameters, which are Meadow's lowest level of leverage. The *Supply of low-cost housing* is a stock that fits in Meadows' second-lowest level. Higher-leverage interventions could include changes to the mindset and goals of government housing programs.

Applying the classifications required considerable subject-matter knowledge. Judgement was required to interpret Meadows' explanations of the levels.

The Intervention Level Framework levels were abstractly defined and difficult to align with the PRM interventions. The Working Group was unlikely to benefit from the ILF classification.

The Working Group did not have enough discussion time available to interpret and apply the Meadows classification. Instead, it was used for ideating policy levers for intervention in housing, and became part of the "Donella" role instructions for Workshop 3 (section B.6.1.5).

7.3.5 Computation of leverage

The MICMAC algorithm for cross-impact analysis (Godet, 2010) uses strength ratings on every connection in a causal loop diagram (or causal model), to calculate the indirect influence of each element on the system's behaviour.

The Kumu MICMAC procedure was run without weighting by connection strength, and the results seemed meaningless. Elements with high MICMAC influence were not rated as high-impact by YSM. Errors were encountered when running MICMAC weighted by the test connection strengths.

Further research is suggested (section 8.5.5) to find a time-efficient method of gathering connection strength ratings from experts, then analyzing the model in MICMAC or another algorithm, to compare leverage of interventions.

7.4 Findings about comparing leverage

7.4.1 Visual observation of leverage

The process of selecting the Short-List (section 7.2.11) involved experts in rating the Impact of interventions, viewing the chains of their downstream effects, and scoring the leverage of each promising intervention. These facilitated methods were feasible given the limited expert time, but the PRM diagrams were too busy for easy visual comparison of leverage.

To visually observe the systemic effects of each element on the Promising List, the chain of elements downstream from the promising element was isolated in Kumu (see method in section A.4.3). The example in Figure 29 shows the promising element *Life skills education* with a black bullseye, and goal elements with red bullseyes, to help the reader seek paths from the intervention to the five connected goals.

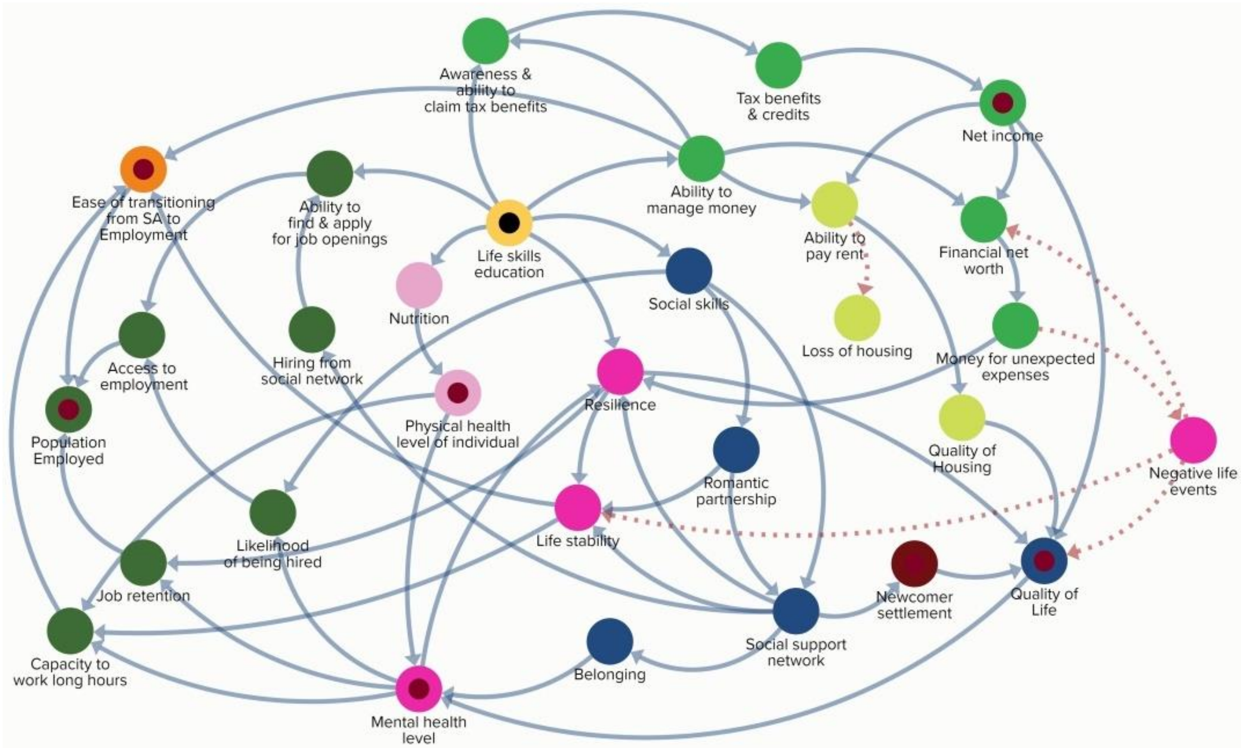

Figure 29: PRM chain downstream from *Life skills education*

The chains of causality made busy non-linear diagrams that were difficult to compare visually when reviewing the promising interventions, online and on a projected screen. As shown in Figure 29, each promising element had many downstream elements. Because there are so many connections in the PRM, the multiple paths leading out from any one promising intervention were not separate. The paths linked to each other, forming an intertwined network around the intervention, which required manual layout for readability.

Workshop 5 did not permit enough time to thoroughly view and discuss all chains of all the promising interventions in these diagrams, so the quality of the "Leverage, synergy, side-effects" scores is uncertain.

7.4.2 Rating connection strengths

The magnitude of causality of connections could be used for visual observation and computational analysis of the model. To test this, the researcher made some strength ratings of connections on a scale from 1 to 6 (to be comparable to the Impact ratings), using a Kumu custom field.

It was found that valid strength ratings would require much more subject-matter expertise than just knowing the connection exists. The YSM participants did not have time to provide numerical ratings of the 1100+ connections in the PRM, or even the 300+ connections that were downstream from the 13 interventions on the Promising List. Even with that expertise, would it be meaningful to make comparative ratings of connections without knowing how the interventions are implemented? For example, does a *Life skills education* program have a stronger effect on *Nutrition* or on *Ability to manage money*? The PRM does not specify the program's curriculum or other details.

7.4.3 Test of line widths in a chain

The researcher's strength ratings were used to test displaying line widths for visual comparison of leverage, and to test the MICMAC algorithm (section 3.7.3).

The following example, Figure 30, shows the downstream effects of intervening in *Portability of rent subsidy*, with arrow widths denoting connection strength. The bubble size reflects the element's Impact, but is very small for some elements with missing ratings. Adding this information to the subject area colours and connection type notation makes for a busy diagram with too much to focus on.

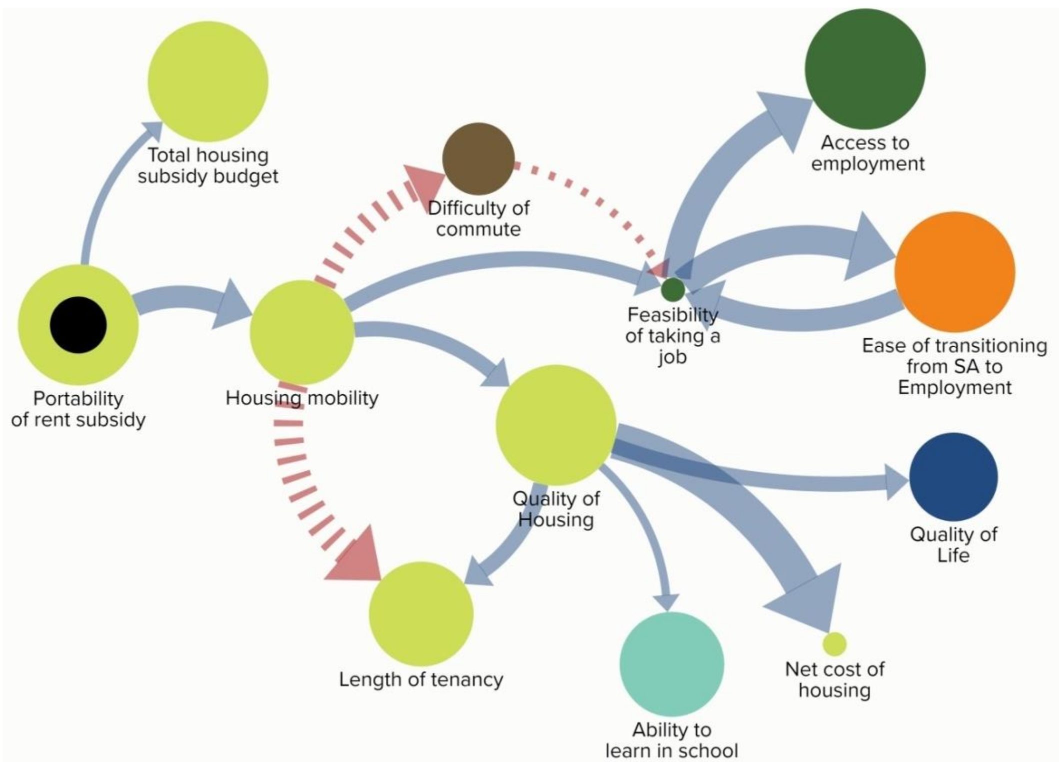

Figure 30: PRM chain with impact and strength ratings: *Portability of rent subsidy*

Because the downstream chains were intertwined as described above, the cumulative leverage of each intervention would not be obvious from visual inspection of the line widths. The line-width displays were not used with the Working Group.

Findings from other methods considered for comparing leverage included the SNA out-degree metric (section 7.3.3), classifications (section 7.3.4) and the MICMAC algorithm (section 7.3.5).

7.5 Capacity challenge

The following was found about this study's capacity for modelling and decision support. See the background about this challenge in section 3.8.

7.5.1 Expert time

There was insufficient time to involve the Working Group in extensive model development and validation, or to obtain quantitative ratings from multiple people. The prioritization process was designed to move rapidly, making most choices through scoring activities without much discussion. The time limitations forced an early choice to focus on two subject areas. The large size of the model led to spending workshop time on prioritization rather than model development.

The Working Group had 6 ongoing plus 9 occasional participants invited to various different workshops. Each participant spent from 2 to 12 hours in workshops (average 4.6 hours). There were many absences, late arrivals and early departures due to work commitments, etc. YSM staff evaluated the participation as "scattered"; the inclusion of many occasional participants brought more diversity of expertise, while requiring some extra facilitation effort to welcome new participants at each workshop.

Between four and eight people participated in each of the workshop activities, while between one and four people participated in each activity that occurred outside workshops.

Ongoing participants spent more time outside of workshops than they expected at the outset of this study. One estimated spending 3-4 hours outside workshops, which aligns with the consent form's estimate of 3 hours. The YSM Director who organized the case study spent about 16 hours on coordination and 6 hours on prioritization activities, which was more time than anticipated.

Before the model's large size was known, it was decided to reduce the time commitment from 8 three-hour workshops to 5 two-hour workshops. YSM staff described the two-hour workshops as a "massive time commitment" in their busy schedules. In retrospect they felt they needed to spend a lot more time on this process.

In the case study, having more time to discuss the model content with the YSM experts would have increased its quality and sensemaking benefits, and might have had different prioritization results. Substituting source documents and the researcher's knowledge for expert involvement was time-efficient but limited the social and learning benefits of group model development.

7.5.2 Expert knowledge and skill

YSM staff believe that the Working Group had sufficient knowledge and skill for the process. Participants brought extensive social-services knowledge, including front-line, professional and executive experience.

Housing and Employment specialists attended Workshops 3 and 4 respectively. YSM staff wished for more representation from partner organizations, who brought valuable outside perspectives, and from front-line staff. The researcher also provided a modicum of knowledge about government and social issues, enabling model development with relatively little expert input.

Workshops were designed to use the observed abilities of participants. Working Group participants seemed able to comprehend the model content quickly. Even in the fast-paced Workshop 3, new participants were able to keep up and contribute.

Participants needed facilitation and discussion to express and articulate their thoughts. Written exercises were difficult for participants, who preferred talking. Online exercises before workshops were not completed by many participants. Participants were tentative about marking their comments on finished-looking materials, whether printed (the Summary Model Poster) or online (the Stormz cards). Digital tools were nevertheless useful to manipulate large amounts of information, such as scoring the Promising List.

Participants did not compartmentalize their ideas to fit into the information structures provided. When asked for an intervention idea, the Working Group needed time to discuss the topic before recognizing where systemic intervention was needed. When asked for comments about one intervention, the response might discuss other interventions. This systemic thinking made it difficult to prioritize individual interventions. It was not realistic or necessary to expect participants to quickly learn and apply many systems-modelling techniques. These were handled by the researcher (as modeller), while the participants focused on explaining the subject matter.

7.5.3 Researcher time and skills

For this study, the researcher served as modeller, facilitator and note-taker. YSM staff appreciated that the researcher "did a ton of work" to develop the model. A rough estimate of time spent on the case study (including developing the model, preparing the facilitated activities and running the workshops) would be 55 days.

YSM staff complimented the researcher's facilitation skills. YSM staff appreciated the prioritization methods that captured more information than dot-voting, such as the objective scatterplot and scoring the Promising List. It was difficult to design facilitated activities that could prioritize the large amount of model content in very little time.

Note-taking and interpretation was of high enough quality that participants did not send corrections after seeing the updated PRM. Free-form note-taking was easier than capturing input in the Kumu model structure.

Aside from time, the study had sufficient other resources: software, computing devices, stationery, and meeting space. Kumu software was well-suited to developing a large, shared model with flexible notation. It did not support summarizing the model. See software evaluation in section 6.4.4.

7.6 Recommendations

This study found that a causal model can be a useful tool for understanding a complex social system and for supporting decision-making within it. The experience with the PRM led to the following recommendations for modelling, finding and comparing interventions, and planning projects.

7.6.1 Recommendations for integrative sensemaking

A causal model is a tidy abstract representation that can generalize some messy realities of a complex system. Causal loop diagrams have long been known to aid in understanding a complex system (section 2.3.8). This study showed that viewing a causal model (an adaptation of the CLD) is similarly valuable for people to make sense of complexity.

It is useful to integrate multiple information sources, including organizing evidence from source documents into the causal model format, as well as capturing input from multiple experts.

Expert contributors need to spend considerable time in group model development sessions to fully enjoy the learning and social benefits of collaboratively synthesizing their knowledge. It is possible to develop or browse a causal model on screen during workshops, using software such as Kumu. This is generally slower than free-form discussion and note-taking, but can involve experts in organizing their ideas into a consistently structured model. Live modelling should go slow enough for participants to understand and comment on the elements and connections.

The uses and benefits of a causal model gradually become apparent to contributors as they spend more time involved in the modelling process.

7.6.2 Recommendations for finding interventions

The case study demonstrated that a causal model is useful to inspire intervention ideas. Having a broad and deep causal model provides a frame to find a comprehensive list of interventions.

Problems in a social system can be seen as objectives, or changeable points, in a causal model. The existing programs and policies that intervene in that problem can be identified. Then new, modified or additional interventions can be ideated to improve upon the objectives. Facilitation prompts include "How could this existing intervention be improved?" or "What else could be done to increase …?"

The systems-thinking roles designed for Workshop 3 (section B.6.1) might have been effective in a longer workshop with a smaller scope. Preparing an analysis of the system's situations and lifecycles allows a more thorough search for intervention ideas, with prompts such as "What could be done at this stage?" An entire workshop could be devoted to using Meadows' 12 types of leverage point (Meadows, 1999) to seek more fundamental or higher leverage interventions.

Identifying the interventions requires subject-matter expertise and secondary research. A long list of interventions can be ideated quickly, but more time is needed to explore technicalities of each one, and to develop more feasible variations. Suggestions should not be constrained by feasibility or effectiveness, as further discussion may find creative ways to work around barriers to an intervention.

Causal modelling should be considered part of the suite of systemic design methods for developing interventions in systemic problems (section 3.5.2). Journey mapping would be a complementary method.

The ideated interventions, and other knowledge gleaned while discussing possibilities, can be added to the causal model for further sensemaking.

7.6.3 Recommendations for comparing and prioritizing interventions

To make informed and systematic choices of options for intervention in a complex system, a causal model needs to be combined with criteria, data, comparison methods such as option scoring, and discussion.

To compare or prioritize interventions, it is important to set criteria in advance. A long list of criteria is difficult to use in facilitated activities. Two major criteria should be defined for a project: effectiveness and feasibility. Effectiveness may include the direct impact of an intervention, the number of people it reaches, and the indirect leverage and systemic effects it might have.

Feasibility issues such as cost and capability, and the organization's other requirements, should not screen out ideas too early. Interventions and other options should be discussed to ensure a common understanding of their intent, and to find ways to overcome barriers to feasibility. Experts may be encouraged to creatively modify their ideas to better fit the criteria.

There are many methods available to compare and prioritize options, including automated algorithms, rapid sorting & scoring by experts, and more extensive group discussion that might be based on research of each option. Data may be recorded to compare the options against criteria.

After causal modelling, research, analysis and discussion, various rating, ranking, voting and scoring procedures can be used to prioritize a list of options according to pre-set criteria. An options analysis can recognize systemic effects and account for them in a scoring matrix. The numerical results should be considered by experts to discuss and make a final decision.

The causal relationships in a model diagram can be used to observe the direct and systemic effects of each intervention option. If the causal relationships are quantified, they can be used to compute the leverage of interventions, which are difficult to compare visually in a large model.

7.6.4 Recommendations for planning a facilitated process

Sensemaking and decision support within a broad and complex system is likely to require multiple meetings or workshops. The full process should be planned in advance, as each facilitated activity may depend upon results from previous activities.

The case study showed that model use activities should be designed with awareness of the model size and the expert time available. Longer workshops with consistent attendance are preferable. Balancing scope and capacity (7.6.5) is recommended when planning the use of the available resources. If a project's scope must be narrowed, avoid setting a restrictive boundary on a complex system. The area of focus should be selected before too much time is spent on topics that will be dropped. Consider various frames for selecting an area of focus, including societal systems, personas, lifecycles, journey maps, and other themes.

The challenge of prioritizing within a broad scope is that there may be too many options to give them all due consideration with research and discussion. The prioritization process needs to begin with some rapid methods that will winnow down the list of options, using criteria that will not eliminate too many of the options that just need some modification to be desirable.

Facilitated activities should be chosen with awareness of the participants' abilities and preferences. In-person discussion and physical activities yield many ideas through active interaction and collective sensemaking. Silent writing activities are meant to gather input from quieter participants, but some people express themselves more clearly by speaking than writing. If participants are comfortable with online interaction, software such as Stormz can be effective for discussing, comparing and rating options. With a larger model or longer list of items, digital tools may be much more efficient than physical activities, so facilitators need to ensure participants are comfortable expressing themselves digitally. The same is true if distance precludes gathering the participants in-person.

7.6.5 Balancing scope and capacity

Developing and using a causal model was a worthwhile use of very limited resources.

In modelling projects, scope and quality requirements should be determined in advance to plan the best use of available capacities, and to obtain appropriate software, tools and training. Figure 31 and these recommendations provide a framework for planning the modelling effort for causal models of complex social systems; it would be largely applicable to other modelling situations.

The scope and size of a model depends upon the amount and types of knowledge and complexity it needs to represent; refer to the six dimensions of scope in section 6.1.1. Modelling a larger scope requires higher capacities (time and other resources) for expertise, modelling, research and facilitation, which all lead to higher-quality model content. The modeller's skill and software determine the model's format and clarity, which influences comprehension, to counteract the difficulty of understanding a larger model. Scope and quality expectations can be balanced with the capacities available, to yield a useful (comprehensible, high-quality) model. Usage methods and facilitation effort, as well as a useful model, lead to high-quality results from using the model for various purposes (section 3.4.1).

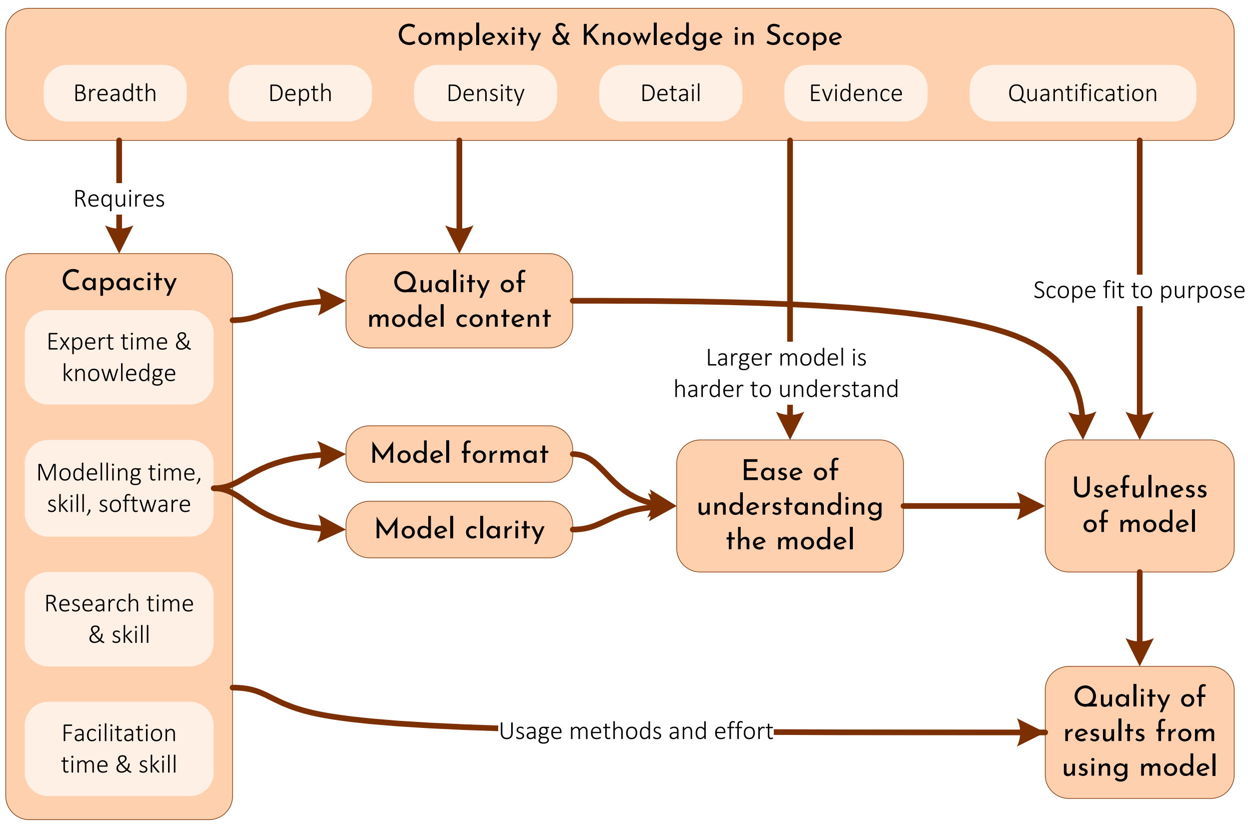

Figure 31: Balancing scope and capacity

7.6.6 Knowledge recommendations

A causal model can synthesize qualitative and quantitative knowledge and evidence about a system, and articulate multiple perspectives in a common language.

Validity and other aspects of quality are interpreted for causal modelling in section 2.4.4. Integrating multiple sources of knowledge, involving more people's perspectives, and spending time to discuss and debate ideas, increases the quality of content in a model. The perspectives and biases of experts, facilitators, modellers and source documents will be incorporated in the model, and thus will affect the validity of results from using the model. Sources should include knowledgeable experts with various perspectives, including lived experience of the system. Facts stated should be correct, current and verifiable. Quantitative evidence should be accurate, reliable, and applicable to the system being modelled.

Even if information is available from source documents, it is valuable for experts to provide their knowledge in a facilitated process of group model building. Discussion can shape the scope and expression of a model while building collective knowledge, a sense of ownership, and commitment (buy-in) to the results. Co-modelling (section 2.4.1) can increase the time and skills required from experts, so for a large and highly structured model, it may be more realistic for experts to comment on what a modeller is doing. Expert time should at least be devoted to reviewing the model for quality.

In a causal model, connections should be named or described to provide explanation, justification or evidence of causation. A causal model with qualitatively defined elements and connections can be useful for sensemaking, but valid quantification of the connection strength (preferably by multiple experts) is needed to compare leverage or to do system dynamics simulation.

7.6.7 Scope recommendations

The model's scope should be fit for purpose, meaning it aligns with the intended uses of the model. Careful planning and iteration is recommended to set the scope of a causal model to suit its purposes. The scope should not be strictly bounded, as seemingly unrelated issues may be significant causes of the problems under inquiry. The connection of multiple subject areas enables seeing the widespread effects of an intervention, and the potential for more interventions and partnerships across sectors.

A comprehensive model may be valuable. Consider all dimensions of scope (section 6.1.1) when setting a scope that can be accomplished within the modelling team's capacity. This may mean capturing a narrower breadth of topics, or less rich information about each topic.

It would be helpful to make a draft model, to make a size estimate, before planning group activities. Sketching out a very broad but shallow model of the major problems and objectives in many topic areas would enable discussion of which areas should be further developed by modelling interventions. When constraining the model size, experts should be involved in selecting which concepts are "important enough" to include.

During development of a causal model, all dimensions of the scope should be monitored and adjusted so that only necessary information is integrated into the model. This manages the time required for modelling, and also limits the size of model that needs to be displayed and maintained.

Gathering detail, evidence and quantification should wait until it is clear which parts of the model need what kind of rich information. Planning should determine whether the model's intended use merits spending expert time on wordsmithing text or discussing the arrangement of ideas into the consistent model structure.

In-depth modelling with subject-matter specialists may reveal unexpected side-effects and feedback loops. Given sufficient expert time, systematic searches can be conducted for possible connections and loops.

The scope and scale of a modelling project is likely to change as participants learn about the system under inquiry, and as they gradually discover the value of systems thinking. A small initial project may whet appetites for further system modelling, and lead to a more comprehensive model.

7.6.8 Comprehension recommendations

Comprehension of a complex system is enabled by visualization. Figure 31 shows that the ease of understanding a model depends upon the size of the model, its format, and its clarity. A large causal model can be understandable, if it has a summary, is structured, is written clearly, and can be viewed in small pieces.

A causal model needs a flexible format to capture all the information needed, and a flexible notation to display only the information needed at one time. Notation should be adjusted for readability, without the constraint of diagramming traditions. Software with flexible notation produces model diagrams that are easier to read and potentially more informative than causal loop diagrams.

A large causal model needs a summary (high-level overview), and it should be partitioned into meaningful categories such as subject areas. Software is needed that can dynamically display any portion of the model, automatically laid out for readability.

Figure 31 states that model format and model clarity enable comprehension. Aspects of model format include:

- Structure: organization of information into elements, connections, loops, other constructs
- Fields: data elements captured about elements, connections and other constructs
- Categorization: element types, connection types, and valid values of data elements
- Partitioning of information into meaningful parts, for displays of comprehensibly small size
- Notation: colours, shapes, sizes, fonts, legend
- Layout on the screen/page, and other graphic design issues
- Language patterns: parts of speech, pluralization, capitalization, punctuation
- Software ability to discover and display the model: browse, search, sort, export.

Model clarity issues include:

- How well the concepts and relationships are explained by the text and diagrams

- Abstraction and generalization of patterns in the system
- Summarization: overviews that encapsulate detailed model content
- Language simplicity and suitability to the reading abilities of model users & contributors
- Language correctness: grammar, spelling, capitalization, etc.
- Language consistency (following the language patterns of the format).

7.6.9 Capacities that may be needed

Figure 31 shows that the modelling team will need experts, and people who are skilled at modelling, facilitating, note-taking and researching. A larger scope requires higher capacities. The amount of time available from experts and the modelling team is a major determinant of the usefulness of a model: Did they provide and gather enough information to cover the scope? Did their efforts yield a high quality model and meaningful results?

Members of a modelling team may play multiple roles from the following list, such as experts being trained to do modelling, or one person being the modeller, facilitator, note-taker and researcher.

Expert time and knowledge is required to develop high-quality and detailed model content, to cover the scope required, and to make informed use of a model. Higher variety of experts leads to more dependable model content and usage results.

Experts include people who know about the topic of modelling: people with lived experience in the system (community members), professionals (front-line staff, analysts, managers, executives, consultants, etc.), and academics. The level of their capacity and contribution includes:

- Time available from individual experts
- Time available for group activities
- Subject-matter knowledge of experts
- Communication and cognitive abilities of experts

Modelling time, skill and software includes:

- Amount of time available from modeller(s)
- Skill level of modeller(s)
- Modeller(s)' ability to capture expert input correctly or with valid interpretation
- Standardization and coordination, if there are multiple modellers
- Capabilities of modelling software

The modeller's working time and speed enables or limits the model size and coverage of the scope. The modeller influences the quality and detail of model content captured from the experts. The modeller's skills, and the software features, determine the appropriateness of the model format.

Facilitation time and skill: The quality, quantity and detail level of model content are affected by the facilitator's ability to elicit information from experts, and the note-taker's ability to capture it fully and correctly, and the time available from these team members. Using the model effectively depends upon the facilitator's time, skill, and selection of usage methods.

Research time and skill: The amount and quality of evidence and other information in the model depend upon the modelling team's capacity for research. A researcher's time is required to gather and cite evidence from secondary sources. Unknowns might need to be answered by conducting original research, which requires time and a budget.

Other resources: A modelling project may require a meeting space with whiteboards and data projector, computers for the modelling team, various software, printing services, and stationery (markers, sticky notes, etc.)

7.6.10 Quality of results from using the model

The quality of results and conclusions from using model, in Figure 31, can be assessed with concepts discussed in section 2.4.4, including validity (trustworthiness and confidence) and reliability (consistency and dependability).

When assessing the comparison or prioritization of options, these quality questions may be asked: Do the results reflect the prioritization criteria? If more experts were involved in comparing options, would the results differ?

The quality of results from using the model depends upon the capacities and effort put in, especially expert time and facilitator skill. The results also depend upon the quality and suitability of methods for using the model, such as facilitated activities to find interventions, or computational procedures to analyze the model. Issues include: ease of doing the method, ability of the method to yield the results needed, and quality of tools used in the method, such as clarity of some criteria, or correctness of an algorithm.

All of the above recommendations lead to a well-planned process for developing a causal model, and using it with a group to make sense of a complex system, find opportunities for intervention, and compare them to support prioritization decisions.

Photo 9

8 Conclusions

With the completed causal model, the system can be seen as a whole, like the blowtorched bundle of wire above. This chapter answers the research question, recounts the study's journey, states how it has contributed to methodology and poverty research, and suggests future research projects.

8.1 Answers to the research questions

Methodology research question	What modelling format and process would an organization find useful for making sense of a complex social system, and for finding & comparing potential interventions in it?
Answer	A large causal model was shown to be useful as part of a facilitated process for making sense of a complex social system, and finding interventions in it. A causal model can be combined with option-scoring methods to compare and prioritize those interventions.
Case study research question	What might be the most effective system interventions (potential policies or programs) to reduce poverty in Toronto?
Answer	The Yonge Street Mission has selected this short-list of interventions that meet their effectiveness and other criteria: • *Life skills education* • *Wraparound support for path to employment* • *Portable Housing Benefit* See section 5.2 for more about this selection.

8.2 Review of the study

8.2.1 Review of argument

A tangle of copper wire was photographed as a metaphor for the web of connections in a **complex social system**, where the ever-changing interdependencies of people, organizations, policies and programs lead to problems whose causes and effects are difficult to trace (section 2.2).

System **models** (section 2.3) are visual abstractions that represent some of these interdependencies. Models, especially with consistent **structure**, help to make sense of the tangled web. A model is necessarily a simplification and generalization, so it must be interpreted with caution to avoid over-simplifying the real-world complexity.

To consider how to intervene in the system's problems, a model of cause and effect is the most useful type of model, especially if it represents the non-linear reality of many causes of many effects. A **causal model** is defined in section 2.3.9 as an adaptation of the classic Causal Loop Diagram, with more qualitative and perhaps quantitative information, stored in a database and visualized in more readable diagrams.

Like causal loop diagrams, causal models are shown to be useful for **integrative sensemaking**, in which a group of people develop their collective knowledge of a system while contributing to the model (section 3.4). Qualitative and quantitative **knowledge** is synthesized from multiple experts and source documents in the process of developing a high-quality model. A causal model can inspire experts when **finding interventions** in the system's problems (section 3.5.2). Readers of a finished model also gain some understanding of the system.

Models of more comprehensive **scope** provide broader and richer information about a system's complexity (sections 2.5 and 6.1), but large models need to be viewed in small pieces to be understandable. The **comprehension** of a model (section 2.6) is also aided by structure, summarization, readable notation and clear writing.

The **capacity** of the modelling team (including the time of experts, modellers, facilitators and researchers, section 3.8) may constrain the size and quality of a causal model. Those resources also limit how much the model is used for **comparing interventions**. If many interventions or opportunities need to be prioritized, rapid processes such as sorting, rating or voting are needed before spending time to discuss the higher-ranked proposals (section 3.7). To support informed decision-making, the causal model information can be used to analyze, score and discuss options.

The study's findings supported the argument that a causal model can be a **useful** abstract representation of a complex social system, in combination with facilitated activities for sensemaking and decision support. This is achievable if capacities are sufficient to develop a comprehensible model of comprehensive scope that integrates enough knowledge about the complexity of the system, and sufficient to make use of that large-enough model.

8.2.2 Review of methods

The researcher was excited by the opportunity to use causal modelling for the important work of reducing poverty in Toronto. The case study with the Yonge Street Mission (section 4.1) intended to use systems modelling to choose a short-list of interventions that might be effective policy changes, one of which would be selected for a demonstration project.

A causal model was drafted in Kumu software (section 4.3.5), based on the policy issues that YSM staff had identified in previous meetings, and on the poverty reduction strategies of the provincial and municipal governments. This solo modelling process (section 4.3.3) involved interpreting documents to identify factors in the social system, and recognize how one factor might cause or influence another. The concepts in these texts were translated into an abstract structure of elements (variable factors, nodes) linked by connection arrows which sometimes formed loops. The model content needed to be labelled, described, classified, and sometimes split apart or generalized together as knowledge sources were integrated.

Five workshops (section 4.1.4) were planned with a working group of YSM staff and partners, to develop the model further and prioritize the opportunities found within it. This study was intended to adapt the causal loop diagram format, so each workshop ended with feedback questions, so as to iteratively improve the readability and information content of the model diagrams. Kumu software was customized to store and visualize this adapted model format.

The first workshop introduced systems thinking and the causal model that became known as the Poverty Reduction Model (PRM, section 5.3). Participants discussed their vision for poverty reduction, and goals of preventing, alleviating and exiting poverty (section 4.4.1). The workshop used a poster-sized summary of the PRM (Figure 27) to identify the working group's interests by commenting on and dot-voting for topics including employment, income support, housing, child care, education, health, criminal justice, service access, and dignity.

The second workshop defined and ranked the YSM's prioritization criteria using discussion and dot-voting (section 4.4.3). Objectives (problems and opportunities) from the PRM were sorted according to their impact, then according to their potential for intervention, using cards that showed each objective in context with related system elements (section 4.4.4). The subject areas with high impact, high potential and high interest in the first workshop were considered, and the group chose the focus areas for subsequent workshops: Housing and Employment.

The third workshop (section 4.4.5) generated ideas for intervention in Housing objectives, by browsing the PRM and gathering the group's expert suggestions. In this workshop, participants were too busy providing new ideas to use the various systems-thinking tools provided to assess and improve upon the interventions. A supplementary meeting was needed to complete the agenda of Housing sub-topics.

Employment interventions were ideated in the fourth workshop, section 4.4.7. To avoid over-burdening participants, the working group voted in advance for a prioritized agenda, and this workshop was conducted with free-form facilitation. All these activities showed objectives and interventions in context of the PRM so that systemic effects might be considered.

The dozens of intervention ideas generated were integrated into the Poverty Reduction Model, through further efforts of interpretation, abstraction, generalization, description, classification and linking the model elements with connections and loops (section 4.3.3). All of the intervention possibilities, from the documents and workshops, were then rated by YSM staff according to impact, potential and other screening criteria (section 4.4.8).

The top-rated interventions were reviewed online and in the fifth workshop (section 4.4.10) to form YSM's short-list. Participants viewed chains of connections in the model to observe and rate the systemic effects (leverage, synergy and side effects) of each promising intervention. The working group also discussed each option and rated its feasibility for YSM and its reach (size of population affected). This "options matrix" of ratings on multiple criteria was implemented with Stormz software that instantly summed up the participants' ratings to score and rank the interventions. The short-list of three was adjusted and confirmed by the expert working group.

After the workshops, the researcher met with YSM staff to listen to their evaluation of the process and to hand off the PRM and other deliverables (section B.12).

Computational analysis of the PRM was done (section 4.5), including statistics, community detection, Social Network Analysis metrics, and the MICMAC analysis of indirect influence. Connection strength ratings were tested for computation, and were displayed as line widths for visual observation. These and other methods were considered for finding higher-leverage interventions by analyzing systemic effects in the PRM (section 4.6).

8.2.3 Review of findings

As the case study progressed, the challenges of developing and using a causal model (especially of a broadly-scoped complex social system) became apparent.

It was originally expected that diagram notation would need to evolve through multiple workshops. Causal loop diagrams were adapted with colour-coding of important information (subject areas, connection types) and removal of less relevant symbols (section 6.2.2). Feedback from participants indicated that the customized notation was easy to understand (section 6.3.3.1). The Kumu software made it fairly easy to extract smaller diagrams on any topic (section 6.4), so the **comprehension challenge** was the easiest to tackle (section 6.3.3). Kumu did not support summarizing the model but Visio software was appropriate for making a summary diagram (section 6.5).

The **knowledge challenge** was approached (section 6.3.1) by choosing some professional experts and high-quality source documents (section 4.1.3), and accepting that they could provide only limited perspectives on the vast problem of reducing poverty. The difficulty of integrating multiple sources of information into a rigorous model structure was mitigated by the researcher's extensive experience with modelling systems.

The scope and size of the Poverty Reduction Model was much larger than expected. This **scope challenge** made this study time-consuming but instructive about how to manage and use a large causal model (section 6.3.2). Although small models are more convenient to work with, a comprehensive model (section 6.1.2) can capture more complexity of a social system, making it more useful for decision support. Although only two subject areas of the PRM were extensively used in the case study, the connections to other subject areas were important information. The model's breadth may make the PRM valuable to additional organizations for a variety of purposes.

The large size of the PRM, and the limited time of YSM experts, led to identifying the **capacity challenge**. Although this study gradually evolved methods to work with limited resources, future modelling projects could benefit from the recommendations for balancing scope and capacity when planning for an understandable, high-quality model, and for using it in facilitated activities (section 7.6.1).

The resource limitations (section 7.5) had greatest effect in workshops 3 and 4, where time was insufficient to discuss the many opportunities for intervening in the system. Nevertheless, the process of **finding interventions** was successful in adding dozens of ideas to the model for prioritization. It was found that a free-form discussion was needed to generate possibilities (section 7.2.8), before applying systems thinking to adjust the intervention proposals to better meet criteria.

Those possibilities were assessed with a multi-stage process to **compare and prioritize interventions** (section 7.2). The design of these facilitated activities evolved after each workshop, as it gradually became clear that there were too many opportunities to discuss in the time available. Choices were made by small numbers of participants using rapid activities, always showing intervention opportunities in context with the system. These rating, voting and scoring activities were used to make quick comparisons and winnow down the list, acknowledging the risk of dismissing a proposal that might have been very effective if discussed and revised. Nevertheless, the choice of focus areas, promising interventions and short-list were aligned with expert intuition. The final workshop (section 7.2.11) showed that a causal model of systemic effects, an option-scoring matrix, and facilitated expert discussion are a trust-worthy combination of tools for supporting experts in making decisions. YSM staff found the causal model and the workshop process to be **useful** systemic thinking.

Computational model analysis (section 7.3.1) found that the Social Network Analysis metrics could indicate which goals and objectives are of central importance in the system, but were not suitable for identifying effective interventions. The community detection algorithm did not provide useful information, but cross-tabulation statistics were useful to describe the large model. See results in Appendix C.

For comparing leverage (section 7.4), the PRM diagrams were too dense for visual observation, and the unweighted MICMAC results were not meaningful. Quantifying connection strengths, such as with expert ratings, would be needed to do computational comparisons of leverage in a large causal model.

The Poverty Reduction Model has gone through a first phase of development, but is not a “completed” artifact; future projects may develop the PRM further.

8.2.4 What was not studied or achieved

The case study only tested causal modelling with a small number of experts at one organization. It was not feasible to compare how causal modelling might be done and used within multiple organizations.

This study took a rapid approach to modelling a broad and deep scope, which precluded a systematic search for possible connections and loops, or collecting evidence and quantification of connection strength. Expert time was too limited to do extensive modelling in a group setting, or to discuss many intervention options at length.

The original plan to use line widths to display strength of causality was infeasible. With very limited time, the YSM experts could not rate the strength of hundreds of connections in the PRM. Thus line widths were not used for the visual comparison of leverage in Workshop 5. Other computational comparisons of leverage were not attempted or were not successful. See sections 4.6 and 7.4.

This study was not an in-depth inquiry into the process of decision-making in the social services sector. Although there was executive participation in the case study Working Group, there was no observation of how executives might use a causal model when making a final decision. The funding and grant-making process was not researched for opportunities to use causal modelling.

These and other topics are suggested for future research in section 8.5.

8.3 Contributions

This study developed a large causal model, the Poverty Reduction Model (section 5.3), which is available for enhancement to support understanding and decision-making by organizations in Toronto and elsewhere. The case study enabled the Yonge Street Mission to make an informed selection of a short-list of interventions (section 5.2.1) which might reduce and alleviate poverty in Toronto.

Choosing a type of system model may be aided by the articulation in section 2.3 of why structured, many-many, models of cause and effect are the most useful type of system model for choosing interventions in a complex system, and are more informative than a Logic Model or Theory of Change.

This study has found ways to develop and use a large causal model of a complex social system. The following methodological contributions respond to the challenges of knowledge, scope, comprehension and capacity:

This study defines a causal model structure suited for complex systems, section 6.2.1, including fields useful for describing and comparing model elements. The method of interpreting sources and contributions into a causal model format is described in section 4.3.3.

The choice of scope and size for a system model may be informed by section 2.5's arguments for large models. Scoping decisions may be clarified by the definition of comprehensiveness and dimensions of scope, section 6.1.

A framework (section 7.6.5) is presented for planning modelling projects to meet quality expectations with limited resources. Defining those quality expectations may be aided by the interpretation of validity and other quality concepts for causal models of complex social systems (section 2.4.4).

Methods are developed for displaying a large causal model in understandable small pieces (section 6.4.1). It is demonstrated that causal loop diagram notation can be adjusted to improve readability and convey additional relevant information (section 6.2.2). This was accomplished with customization of Kumu modelling software (section 6.4.2), which is evaluated in section 6.4.4.

People needing decision support tools within complex social systems may benefit from this study's combination of causal modelling with option-scoring techniques. Facilitated methods to rapidly find and prioritize many interventions were researched (section 3.7), developed (section 4.4) and assessed (section 7.2). The prioritization criteria defined for the case study (section 5.1, detailed in section B.4)) could elucidate effectiveness and feasibility criteria for future projects. Qualitative and computational methods to compare leverage of interventions were explored, section 7.4.

8.4 Potential uses of the PRM

The Poverty Reduction Model could be further used and developed with organizations interested in reducing poverty. Model development activities could include:

- Reviewing and revising the PRM with more experts with more time, including people with lived experience, specialists in each subject area, and an economist
- Enhancing the PRM by researching more depth, density, detail and evidence in areas of interest
- Further quantifying the PRM by asking multiple experts to rate the strength of connections (potentially with online survey tools), then calculating the (indirect) effectiveness of objectives & interventions, using the MICMAC algorithm in Kumu, or custom programming
- Finding alternative ways to display the chains of downstream effects for easier visual comparison
- Melding the cause-and-effect model with other types of elements and connections, such as stakeholders involved, statistical indicators, or applicable legislation, using Kumu's customizable element and connection types
- Updating the Summary Model through discussion with experts.

It may be feasible to crowd-source PRM content, by making the Kumu model public, setting quality guidelines, and then holding workshops to train experts to contribute to the model and to extract the content they need from it.

The PRM and the Summary Model can be used to explore the system of poverty for educational and strategic discussions. It could enable a review of the social service sector's activities and gaps. The model may help an organization see which aspects of the system are within their mandate, and which PRM objectives are addressed by their programs. The model could help an organization see the downstream effects of their programs, and consider related opportunities for reducing poverty. Individual professionals could use the PRM to see how their work contributes to reducing poverty.

The PRM may also be useful for planning, designing and evaluating a social program. The model could help to assess whether a particular program would be an effective intervention in a problem, and what systemic side-effects it might have. A chain of PRM elements and connections might be a framework for a Logic Model, a Theory of Change, or cost/benefit analysis, to justify or evaluate a program.

It would also be enlightening to find out how people in poverty would use, react to and contribute to the PRM.

8.4.1 Next steps for YSM using the PRM

Now that the YSM has a short-list of potential demonstration projects, they plan to do a literature review, internal and external consultations, and senior leadership discussions, to make their final choice. YSM staff plan to use the PRM and prioritization results to justify their choice of demonstration project.

The PRM was demonstrated to YSM senior management, who saw that it could be a decision-support tool. YSM plans to apply the systems thinking approach in further analysis and decision-making, so they are learning to use Kumu software for system modelling.

The model suggests many potential interventions that YSM could act upon or advocate for, so it could be valuable in future facilitated discussions. YSM could return to develop the PRM further, by enhancing the quality, or detailing selected topics.

8.5 Further research

8.5.1 Collective causal modelling

Large or small causal models could be developed about many different topics, for collective sensemaking and decision support. Just as for continuing development of the PRM (section 8.4), practices and tools could be evolved for groups to contribute to or maintain a system model at a high level of quality. These might be facilitated sessions where experts have high involvement in a modeller's expression of the group's knowledge. Or the experts might receive training to use online modelling tools to collaborate. Developing a high-quality, internally-consistent system model would be a challenge for a group or crowd-sourced project.

Existing methods (section 3.7) might be adapted for gathering expert input to a large causal model: Interpretive Structural Modelling, Structured Dialogic Design, and Structural Analysis. It might also be possible to combine causal modelling with facilitation processes such as 2-4-8 consensus or Syntegrity.

Combinations of model types might be tested in facilitated group modelling of complex systems:

- Beginning with a less structured modelling language that is easy to learn (such as Systemigrams, section 2.3.5), and moving towards a more rigorous and informative structure such as causal modelling
- Combining causal modelling with systemic design methods such as journey mapping to find, compare and design interventions
- Making a system model that combines causal connections with other information about the system, such as stocks & flows, stakeholders, statistical indicators, resources, cycles of events, capabilities, functions, processes, or value chains.

This study's processes for using a causal model are open to many improvements, including adaptation for senior decision-makers (executives, elected officials, etc.), and for community members who are involved in a system but have little power to change it.

8.5.2 Using causal models in the social sector

Potential uses of a comprehensive causal model in the non-profit and government sector could be tested: not just finding and comparing interventions, but also designing, justifying and evaluating those interventions (such as social programs and policies). Research questions include:

- What facilitation process and tools would yield higher-leverage interventions? For example, applying the 12 types of leverage points (Meadows, 1999).
- If intervention options were prioritized both with and without a system model, how would the results differ?
- What is the method for using a causal model to derive a Logic Model? A Theory of Change? Performance indicators?
- Is it useful and feasible to ask grant applicants to situate their proposal within a causal model?
- Would a decision about funding social services be different if it were supported by a causal model instead of a Logic Model or a Theory of Change?

- How might a causal model be used in evaluating a social program, or reviewing an organization's strategy and programs?
- Explore other uses for a causal model, such as conflict resolution (Coleman, 2011).

To enable such a project, motivation would need to be found for a government, foundation or other institution to fund and sponsor the development of a comprehensive causal model, for use by many actors in a complex social system.

8.5.3 Planning modelling projects

There are many modelling languages and techniques for making sense of complex systems (see section 2.3.4). It would be helpful to create a guide to choosing an appropriate type of system model. Meta-modeling (section 6.2.1) could be used to compare model structures.

Developing and using a causal model may be labour-intensive, depending on its scope and quality. When planning and budgeting for a modelling project, a manager could use guidance about questions such as:

- When modelling a very complex system, how might the scope be restrained to the needed breadth and depth? For example, in developing a broad but not deep summary model, what criteria are appropriate for selecting the important concepts to model?
- For each purpose of a causal model, what would be sufficient quality?
- How much effort needs to be put into gathering expertise and evidence for a causal model? Where is the point of diminishing returns?
- How many experts need to spend how much time to make valid comparisons of a large number of interventions or objectives?
- How much time does it take a researcher to find evidence for one causal connection, at an acceptable level of quality?
- What is a feasible way to gather evidence or quantification for all connections in a large causal model?

To make evidence-based decision-making more economically accessible, perhaps future technology could speed the process of researching evidence about a large number of variable factors and causal relationships.

Managers of modelling projects might also consider: How might a system be monitored for changes in behaviours, so as to keep a causal model up to date?

8.5.4 Comprehension, creation and display

The format of the causal model, visualized in Kumu software, is relatively easy to develop and understand. But could it be improved upon? Is it easy and fast enough for busy executives to use?

Kumu elements can be represented with images or icons, as well as coloured shapes, on the two-dimensional screen. But how about presenting the model in three dimensions via virtual reality technology?

Kumu co-founder Jeff Mohr writes that their company is considering "overhauling Kumu's interface to make systems mapping as easy as drawing on paper" (mass email, Dec. 14, 2018).

That physicality is important in the process of creation. Could playful materials be used to represent causal connections, such as wire and beads?

When working on a large model, it becomes inefficient to capture input from paper and markers, or other analog tools. How can facilitators encourage participants to make their mark on digital drafts that look too perfect to change?

Could the patterns of narrative be used to reliably interpret storytelling into a structured model? Perhaps a storytelling method could help people comprehend a large, non-linear system model. This may play a part in accommodation to make causal models accessible to people with little or no vision.

8.5.5 Analyzing causal connections

When a developing a large causal model, it's quite possible to miss making an important connection. To systematically search for possible connections, what method would be more feasible than making thousands of pairwise comparisons (section 2.4.3)?

An arrow cannot convey everything there is to say about a cause-and-effect relationship. How can a causal model depict variations of the causes and effects, by demographic groups or situations? If one connection has different strengths under various circumstances, how could that variation be depicted in a diagram and stored in a model?

Once the causal connections are mapped, what is the best procedure to use them for comparing systemic effects? What algorithm, metric or software can best identify the most fundamental causes in a large causal model, or identify the elements with the most leverage (cumulative indirect effects)?

What more can be concluded if the strength of causal connections is quantified? Are expert ratings of connection strength likely to be valid, or is statistical evidence required? What guidelines would help a group of experts compare the effectiveness of interventions that have not been designed or budgeted? How can system dynamics software be adapted to work with a large causal model with ordinal ratings of connections, rather than full quantitative data?

Is it feasible to gather statistical evidence about causal connections? Is it valid to compare statistics from multiple studies, to quantify the strength of connections in a causal model? How might the methods for statistical causal modelling (section 2.3.9) and meta-analysis (blending data from multiple studies) be blended with causal loop diagramming and system dynamics? Is it feasible to apply such methods to large models of complex social systems?

8.5.6 Defining complexity

Some more theoretical questions came up in writing section 2.2 of this study. The systems thinking literature has many definitions and descriptions of a "complex system", which were not consistent and specific enough for a technically-minded reader.

What exactly makes a system "complex"? If a high level of interdependence is the most fundamental property (as stated by Ryan, 2012), can we show how that leads to non-linearity, high uncertainty and other properties claimed about complex systems? Is "the whole is more than the sum of its parts" a metaphorical or mathematical statement, and what is happening beyond summation?

Is complexity a binary property, or do systems have variable levels of complexity? Are there multiple properties of complexity, which might be present in different degrees in any one system? Could the Cynefin framework be seen as a continuous (multi-dimensional) spectrum rather than bounded quadrants?

This study observed a very complex social system, poverty in Toronto, which many governments and organizations have intervened in. They have measured needs with statistics, and engineered solutions with rules, forms and procedures. Patterns can be observed in how people in poverty adapt to those policies. That engineering seems to reduce the complexity of the social system towards ordered complication.

In general, Canadian society is heavily regulated, and stabilized into predictable behaviours. How can we be free to self-organize our social systems, and allow positive change to emerge?

Photo 10

9 Bibliography

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Photo 11

Appendix A Model development

A model can make a complex system more scrutable, like the twists of wire in Photo 11. This appendix provides explanatory details about the methods for model development, which were summarized in section 4.3. It is illustrated with examples from the Housing and Employment focus areas of the PRM. The Kumu customization settings are also documented.

A.1 Integrating and generalizing model content

A.1.1 Initial modelling

Before the workshops, the PRM was developed by integrating ideas from the three source documents (section 4.1.3). To test the possibility of extracting a causal model from the YSM Policy Dialogue report

(Yonge Street Mission, 2017), the model was first drawn on a whiteboard. This sample, Figure 32, shows the Housing area in blue, with other topics in black. Potential elements are name and encircled. They are joined by potential connection arrows, with solid lines for Same polarity and dashed for Opposite. The drafted model content was then input to Kumu; see an early version of the Housing subject area in Figure 20.

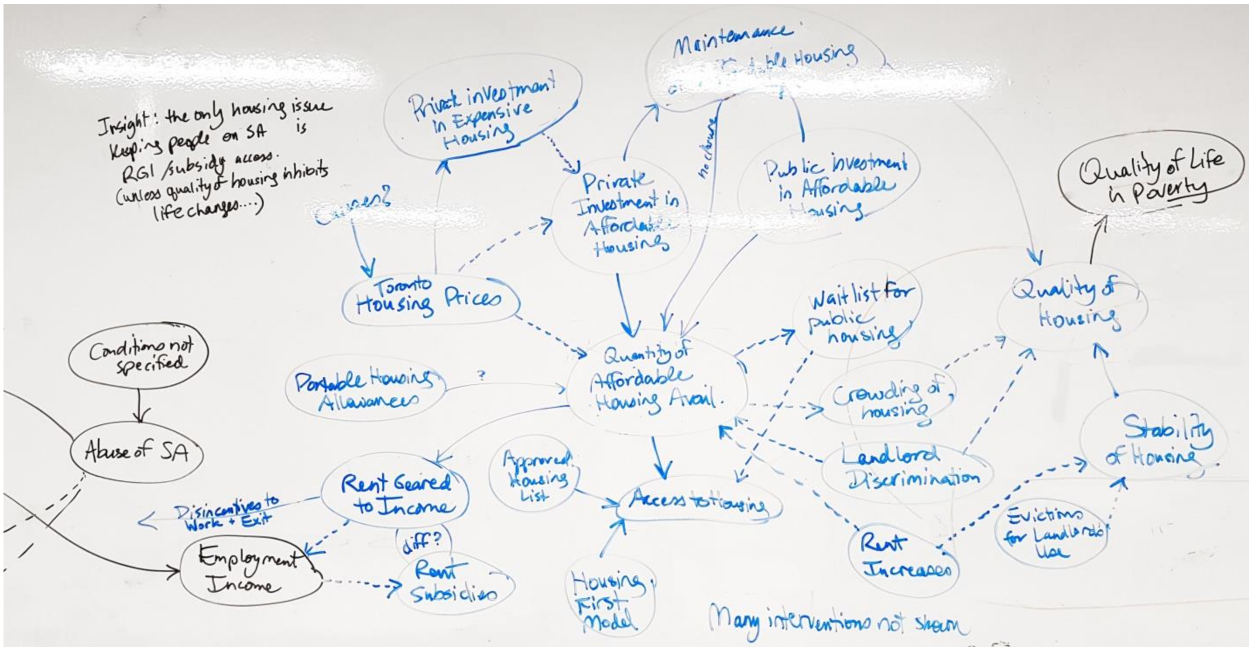

Figure 32: First model of Housing subject area, on whiteboard

A.1.2 Integrating sources and editing the model

The Poverty Reduction Model was developed from source documents and participant contributions. It was also edited during preparation for workshop activities.

When new ideas were suggested in workshops or found in source documents, they were integrated into the PRM by doing the following analysis and synthesis actions. Examples are from Table 11.

- Articulate and analyze the variable factors and causal relationships embedded in a suggestion
- Generalize the concept to cover similar situations (see section A.1.5)
- Conduct brief research to understand and describe concepts
- Discern the objectives addressed by interventions, for example, find out that the *Housing First model* addresses *Homelessness*
- Name the new elements as variable factors, consistent with other elements, in neutral or positive terms where possible
- Make connections to express the causal relationships
- Set the connection type

- Infer some elements in the chain of cause and effect that were not explicitly mentioned, such as *Average rent per square foot* and other economic factors
- Consider counter-arguments to YSM's interest in increased funding to social programs, such as tax funding of the *Total housing subsidy budget*
- Find related existing elements (which requires remembering, browsing or searching the large model)
- Modify existing elements and connections to coherently express the new concepts
- Assign a temporary tag to elements being added or edited
- Ensure every element has at least one connection
- Look for new loops that could be formed
- Classify the element by element type and subject area
- Fill in other mandatory fields such as source
- Check spelling, pluralization, capitalization and grammar.

A.1.3 Translation from source document

The following table demonstrates how the text of the YSM Policy Dialogue report (Yonge Street Mission, 2017, Housing policy section) was analyzed to develop PRM model content. Elements were created for each concept in the text that could be expressed as a variable factor, as explained in Table 6's definition of an element. The translation process involved the modelling tasks listed in section A.1.2.

Table 11: Translation from source document to PRM: Housing

Text from YSM Policy Dialogue	PRM elements, connections and loops
"Access to safe, secure, and stable affordable housing affects all population groups. "	Objective: Safety in housing became an aspect of *Quality of housing* Objective: *Stability of housing* Objective: Affordable housing became *Supply of low-cost housing*
"Toronto's increasingly unaffordable housing market also creates barriers that "price out" low-income families and limit investments in affordable housing stock."	Connections: *Toronto housing prices* increases *Average rent per square foot* increases *Net cost of housing* decreases *Ability to pay rent* Objective: *Private investment in affordable housing*
"Housing policies intended to assist low-income families often contain barriers that limit access to housing for YSM's community members."	Further research is needed to model the negative side-effects from specific housing policies.

Text from YSM Policy Dialogue	PRM elements, connections and loops
"YSM staff identified systemic barriers of housing policy, including:"	No element from this introductory phrase.
"Extremely long TCHC[2] wait lists"	Objective: *Housing waiting list length*
"Absence of portable housing allowances"	Intervention: *Portability of rent subsidy*
"Lack of approved housing lists"	Intervention: *Units on Approved Housing List* based on further explanation by participants
"Funding levels too low to pay for repairs, resulting in deteriorating social housing (and closures)"	Connections: *Funding for housing* increases *Public investment in housing* increases *Maintenance of housing*
"RGI[3] may create disincentives to earn more"	Loop: "Trap of Rent Subsidy"
"Landlord discrimination"	Objective: *Landlord discrimination*
"Increase in family income (including children) impacts rent subsidies"	Connection: *Employment income* reduces *Rent subsidy amount*
"Insufficient affordable and subsidized rental units available"	Objective: *Supply of low-cost housing*
"YSM staff suggested policy changes to overcome systemic barriers of housing insecurity and access. All three sessions included discussions of expanding affordable housing stock."	Goal: *Access to housing* Objective: *Supply of low-cost housing*
"Ideas for policy improvement included a portable housing allowance and housing first models."	Intervention: *Portability of rent subsidy* Intervention: *Housing First model*
"YSM staff emphasized the need for enforcement and implementation of anti-discrimination policies that protect community members from landlord discrimination."	Intervention: *Intervention in landlord discrimination*
"YSM staff also focused on possible changes to RGI housing policies, including the need for transitional grace periods."	Intervention: *RGI transitional grace period*
"Rent controls, inclusionary zoning, and support for a national housing strategy were also discussed."	Interventions: *Rent control*, *Inclusionary zoning*, *National housing strategy*

[2] Toronto Community Housing Corporation provides subsidized and low-rent publicly-owned housing.
[3] Rent Geared to Income, the rent subsidy for recipients of Ontario social assistance.

Text from YSM Policy Dialogue	PRM elements, connections and loops
"YSM staff frequently mentioned the need for Toronto Community Housing Improvements to increase funding for repairs and maintenance."	Intervention: *Repair public housing*
"Some staff members suggested that TCHC housing should not be maintained for life/generations."	Intervention: *Time limit on use of public housing*

A.1.4 Interpreting workshop discussions

The Working Group provided many ideas that were integrated into the model, especially during the workshops to find Housing and Employment interventions. The workshop conversations were not confined to those two subject areas, so input about other systemically-connected topics was also integrated.

Participants made suggestions that might be phrased as a problem or solution. For example, a participant stated "There is nowhere to go" when an individual leaves transitional housing. This was interpreted as a need for intervention: *Support for exiting transitional housing*.

Some free-form discussions did not seem to be about interventions. Creativity was required to translate the Working Group's insights into model elements. For example, *Humanity of the workplace* was identified as an intervention, and was described to explain how it is a variable factor: "Higher if the employer is people-friendly and family-friendly, seeing workers as humans who have needs and responsibilities outside the workplace. Lower if workers are seen as machines, expected to work continuously, and are easily replaced." (The PRM does not specify how such amorphous variables would be measured.)

Based on the discussion in Workshops 3 and 3A, 27 interventions were added to the PRM, and most of the Housing subject area was modified in some way. Workshop 4 was a 2.5 hour discussion that required 2.5 days of modelling to add or significantly modify 84 elements.

A.1.5 Generalizing

Similar, repetitive or localized ideas from experts and source documents were sometimes generalized so the PRM would be a smaller model, applicable beyond Toronto.

For example, the intervention *Affordable housing in public buildings & land* represents these action items from the Toronto poverty reduction strategy, captured in its description:

3.4 Seek opportunities to provide affordable housing in existing or proposed public buildings

3.5 Provide surplus government land for new affordable housing development, incorporate affordable housing in developments on government lands, or dedicate a percentage of the net proceeds from the land sales to affordable housing (City of Toronto, 2015)

In some cases, two or three of the source documents all contributed to the description of a more general element. For example, *Public investment in housing* was suggested in the YSM Policy Dialogue, the Toronto strategy included "Increase investments in repairs to existing social housing", and the Ontario strategy discussed the Investment in Affordable Housing for Ontario program (Government of Ontario, 2014).

To enable wide use and adaptation of the Poverty Reduction Model, generic concepts and phrasing were used wherever possible. For example, a Working Group suggestion of "Twenty-four-hour subways" became "Overnight transit service", with the Toronto specifics mentioned in the element Description. Most goals, objectives and intermediate factors were phrased generically so as to apply in many jurisdictions. Some of the interventions are specific to laws and programs in Toronto and Ontario.

Before Workshop 3, the PRM contained generalized existing interventions such as *Rent Geared to Income* (RGI, a form of rent subsidy). During the workshop, participants suggested interventions with policy details, such as *Base RGI on net income* or an alternate proposal to *Base RGI on 25% of gross income*. Participants felt this concreteness was useful, as there were important issues in the details of Ontario and Toronto policies.

To reflect the Working Group's interest in funding of social services, the PRM contains elements such as *Funding for housing* and *Government funding for employment supports*. It is useful for the model to include funding elements, so this basic enabler can be included in loops, metrics, political and economic analysis. However, because most interventions in the Poverty Reduction Model depend upon public or charitable funding, there is a risk of overwhelming the model with connections to funding elements, or of inconsistently modelling some but not all of those connections. The number of connections to funding elements was minimized by linking them all to a generic *Government support for collective services* element, and by linking each funding element to a few core elements in its subject area.

There are other generic factors that enable or present barriers to intervention in a social system. Any government policy change would need to overcome the barriers of political risk aversion, bureaucratic slowness, and cultural resistance to change. These factors were not modelled in the PRM, to avoid repetitive clutter. One exception was made for *HR policies*, to recognize a Working Group discussion about how traditions of the Human Resources profession would inhibit *Hiring practice innovations*.

A.2 Clarifying complexity

Developing the Poverty Reduction Model was a process of bringing clarity to complexity. Causal loops were identified. Some general concepts were unpacked as the model developed, by splitting up relationships or elements.

A.2.1 Identifying loops

Loops were identified by the researcher during the solo modelling process, using a combination of broad subject-matter knowledge, systems thinking ability, familiarity with the model elements, and time for analysis. In some cases, elements were added so that an economic or social phenomenon could be expressed in a loop. A systematic search for loops was desirable but not feasible due to the large size of the PRM. During workshops, a few loops were demonstrated to participants, but no further loops were found during discussion with participants.

A long single loop is shown in Figure 33. This example is a reinforcing loop: a person with a better *Quality of Life* will have the *Mental health level* and *Self-confidence* to apply for jobs, giving them access to *Employment income*. This increases their gross and net income and their *Ability to pay rent*. When they can afford a better *Quality of housing*, it improves their *Quality of life*.

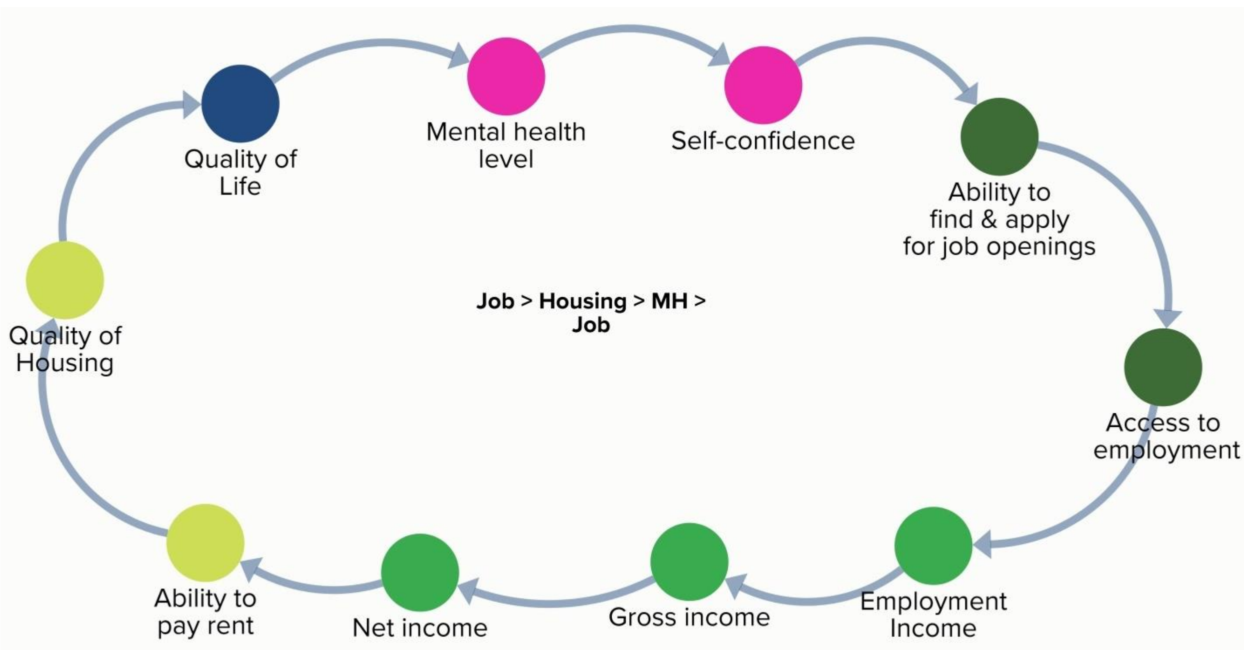

Figure 33: PRM reinforcing loop: mental health, employment and housing

In some cases, a loop name was assigned to multiple related pathways. The following example, Figure 34, again shows that *Ability to find & apply for job openings* leads to increased income, which can affect a person's *Social desirability*. That income also leads to higher *Quality of life* and *Mental health*, which also increase *Social desirability*. This may lead to a *Romantic partnership* and can strengthen their *Social support network*. Those supporters may suggest job openings and boost a person's *Self-confidence*, encouraging their ability to apply for jobs, making this a reinforcing loop.

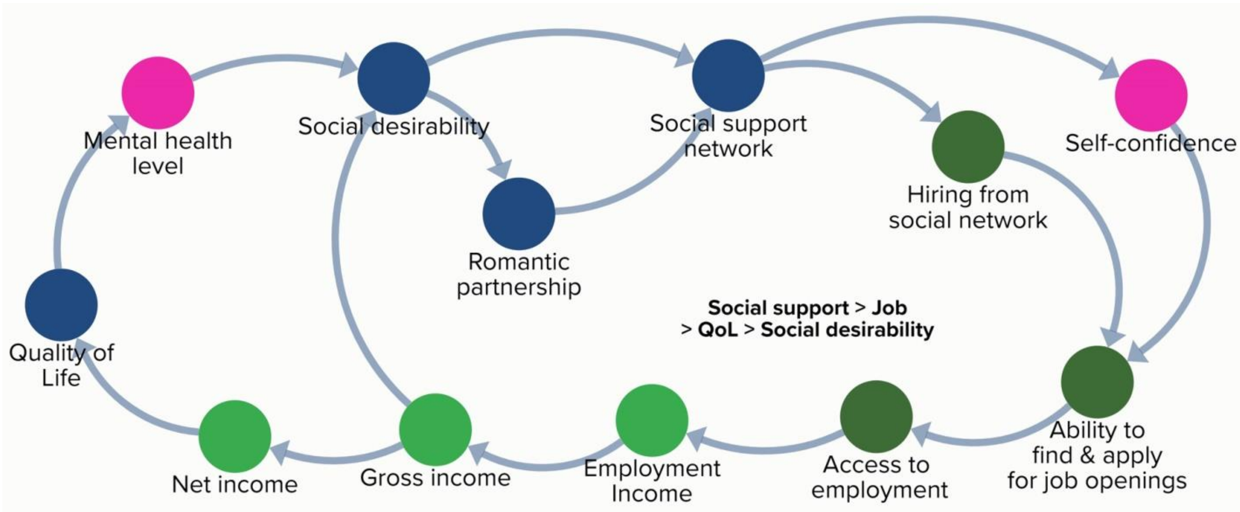

Figure 34: PRM loop: Social support leads to employment, mental health, social desirability

A.2.2 Splitting a relationship into components

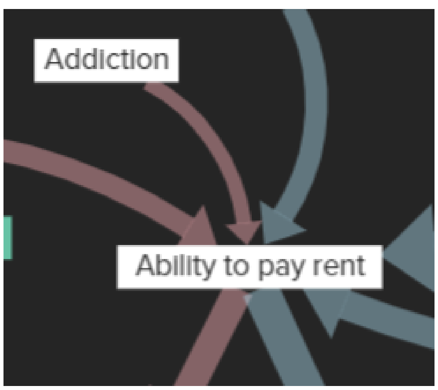

Figure 35: Early PRM: Addiction and rent

This excerpt, Figure 35, from an early version of the PRM (Figure 20), includes a single connection saying that *Addiction* reduces *Ability to pay rent.* This is a leap of logic that assumes the model reader knows why an addicted person might have difficulty paying rent. There is a hazard of jumping to incorrect conclusions about stigmatized conditions such as addiction.

Sterman (n.d.) recommends clarifying causal relationships by "making links explicit". The single connection from *Addiction* to *Ability to pay rent* was split into two connections with a new element between them, in later versions of the PRM, Figure 36. This allows model readers to understand and validate the reasons for the causal relationship, and ideate interventions at multiple points along the path. Further connections were found from the new element *Spending on addictive substances*, which increases *Cost of needs other than rent*, which might influence *Financial stability*, and lead to *Desperation for income*.

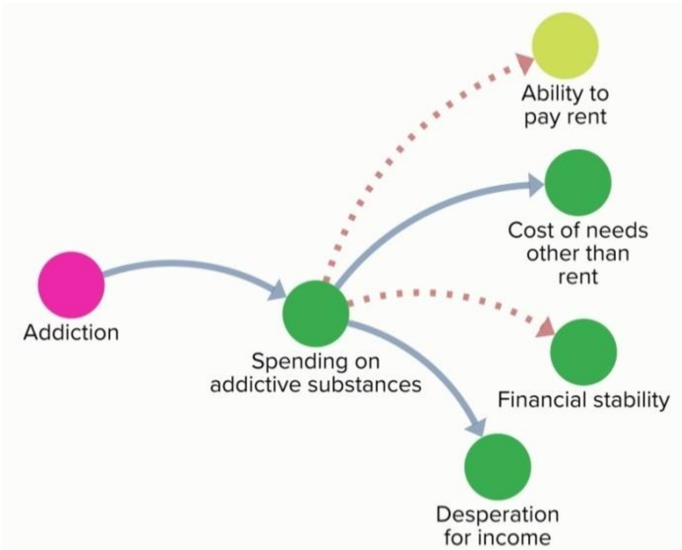

Figure 36: PRM: Addiction and rent

A.2.3 Splitting an element into components

Figure 37: Early PRM: Income and rent

The simple element *Income level* was used in early versions of the PRM (Figure 20). The excerpt in Figure 37 connects *Employment income* to *Income level* to *Ability to pay rent*, which also depends upon rent subsidies.

When analyzing Housing factors prior to Workshop 2, it was observed that it might be important to distinguish a person's *Gross income* and *Net income*. Figure 38 shows some of the PRM elements related to these economic factors. More sources of gross income were enumerated: employment, business and informal income, government benefits (Social Assistance and Employment Insurance), and pension & retirement income. Taxes and *Tax Benefits & Credits* affect net income, which is what determines a person's *Financial net worth*, *Ability to pay rent* and pay for everything else that determines *Quality of Life*, a meaningful way of measuring the *Population in poverty*.

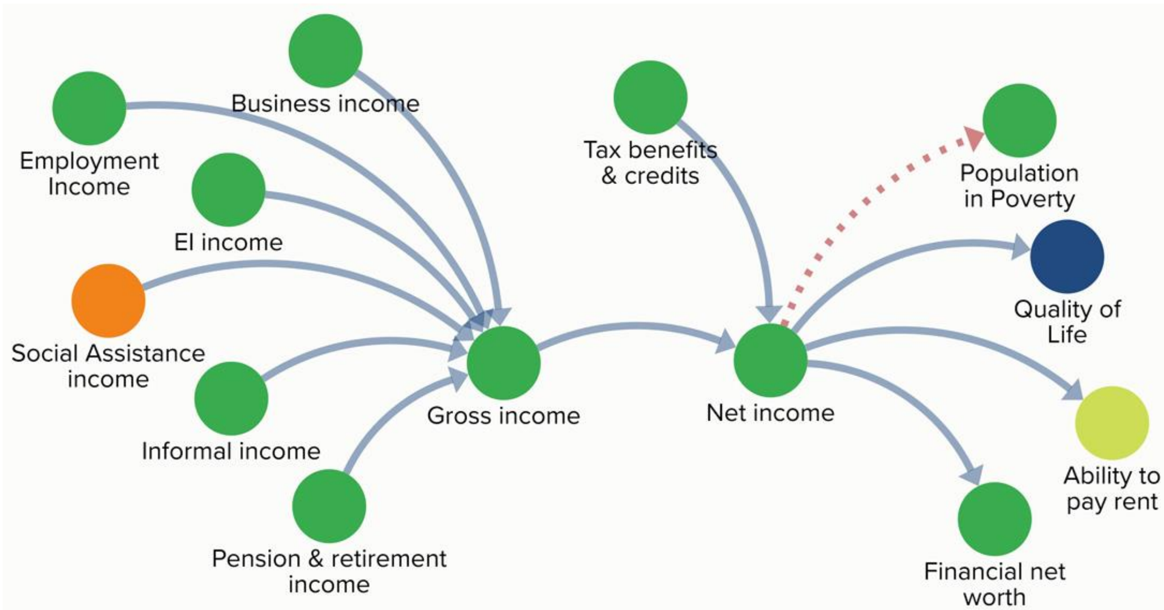

Figure 38: PRM blooms for gross and net income

Similarly, the *Gross cost of housing* and *Net cost of housing* were added to the model, to expose how they each relate to other elements in Figure 39. The gross cost of a given *Quality of housing* depends upon local *Average rent per square foot, Utility rates, Mortgage rates* and *Property tax rates* paid by the landlord or resident. A person's *Ability to pay rent* and the *Quantity of housing affordable on Social Assistance* depend upon the *Net cost of housing*, after deducting the *Rent subsidy amount* and other benefits such as potential *Incentives for energy-efficient retrofitting*. *Home sharing* can also reduce a person's net cost of housing.

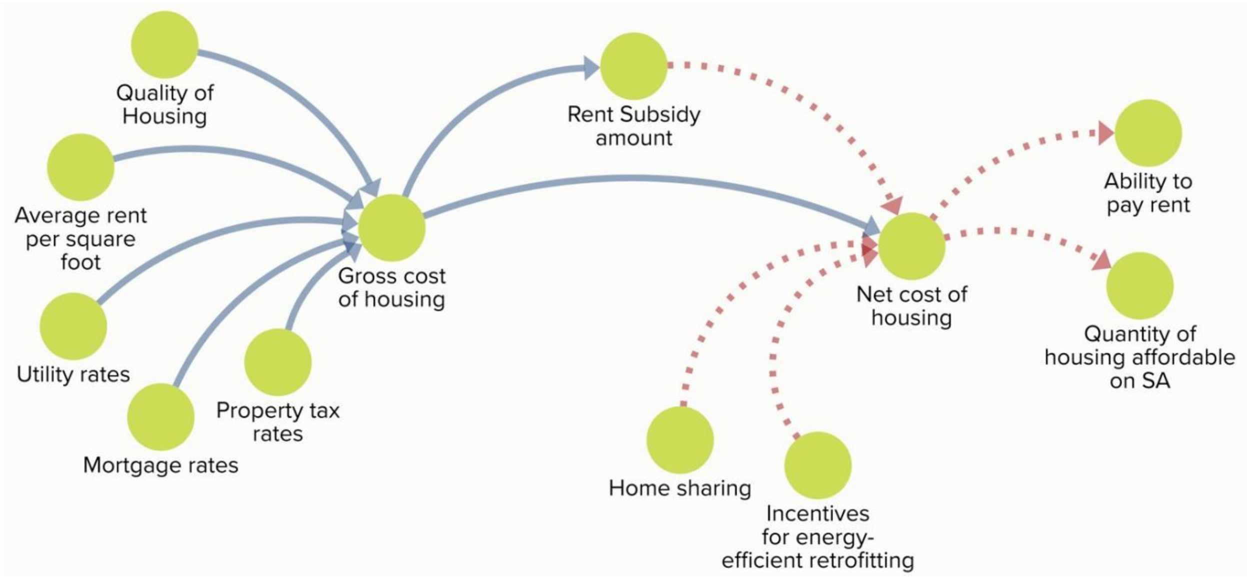

Figure 39: PRM blooms for gross and net cost of housing

There is a disadvantage to splitting up an element, such as separating *Gross income* and *Net income*: Some paths and loops became longer, thus harder to manage and comprehend. See an example in Figure 33.

A.2.4 Splitting up major elements

Some PRM elements had so many related elements that it became difficult to display, read and comprehend even one layer of connections. This was also a sign that the concept named by the element deserved to be unpacked for greater insight. This was a variation on the need to split up elements, as described above. Prior to the workshops, it was noted that *Access to employment* was in this situation (an early version of the element type colours appears in this diagram, Figure 40):

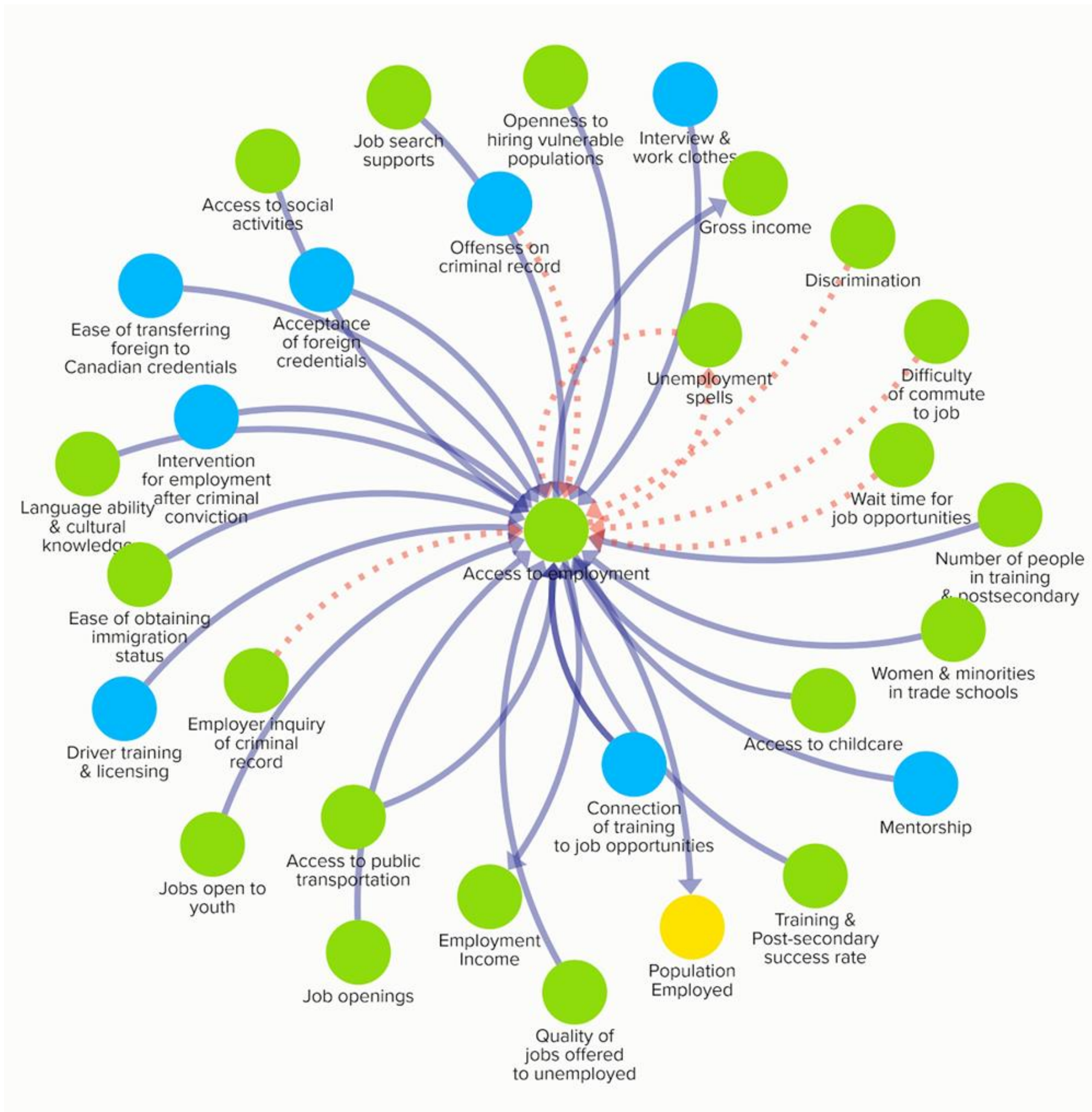

Figure 40: PRM before workshops: *Access to employment*

The stages of becoming employed were analyzed to find four meaningful combinations of factors: *Qualification for jobs, Ability to find & apply for job openings, Likelihood of being hired* (if an applicant qualifies), and *Feasibility of taking a job.* This organized connections into two layers, Figure 41. Focusing on each of the four new objectives made it easier to generate even more interventions during workshops.

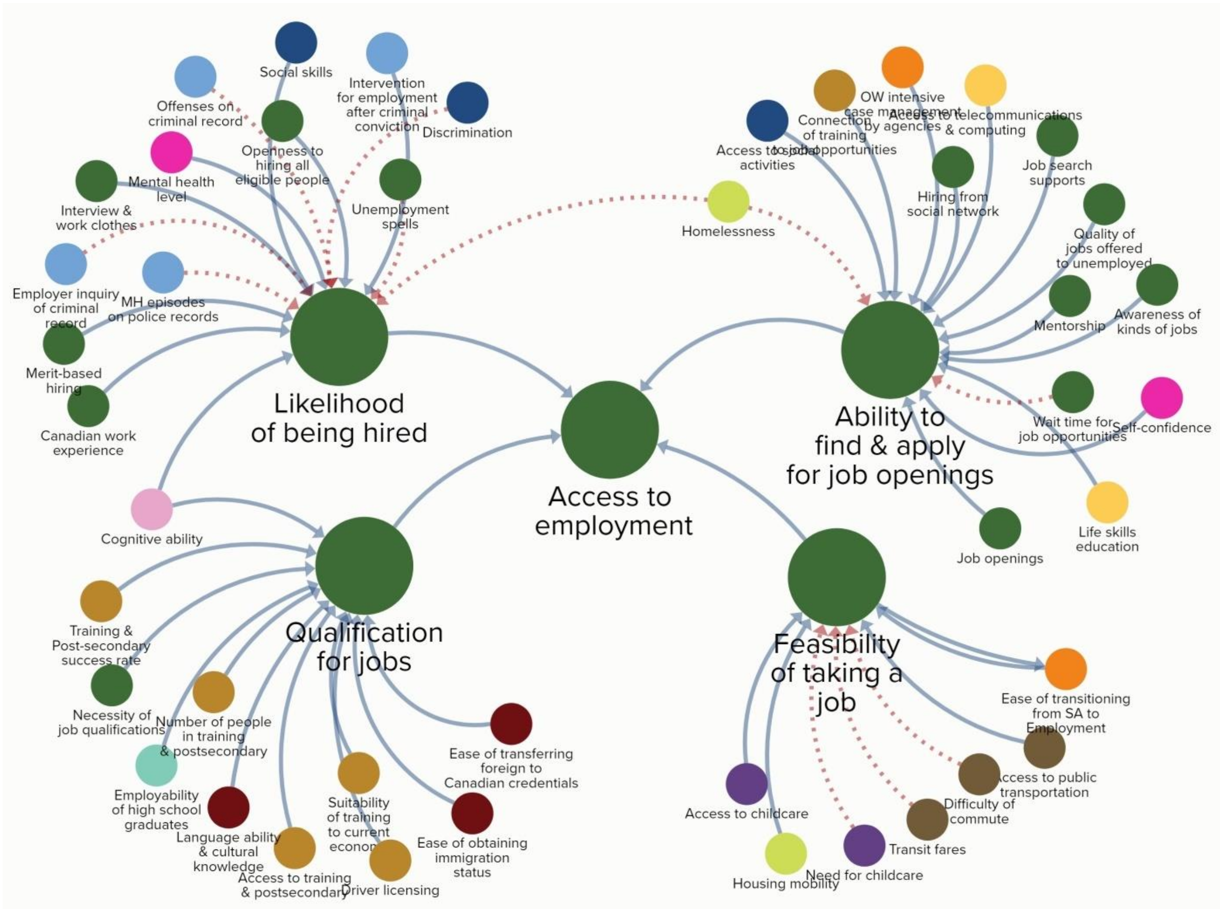

Figure 41: PRM after workshops: *Access to employment*

A.3 Evolution of element and connection types

A.3.1 Evolution of element types

The need to categorize PRM elements emerged gradually as the model grew in size. There was evolution in the element types from the early to final model structure, as shown by the graph in Figure 42. Causal loop diagrams usually show small sample models. In the literature reviewed, the only suggestion for classifying the elements was as goals or control variables (Van Zijderveld, 2007).

Many existing interventions were identified in the early PRM (Figure 20), such as *Rent controls* and *Social assistance rates*. The “Intervention” element type remained in use in the final model.

That early model also identified some “Key Factors”, as an attempt to summarize the model. There were no clear rules for selecting a Key Factor.

Many other elements did not have a type in the early model. Most of them were factors that most societal actors would want to increase (such as *Population employed*) or decrease (such as *Homelessness*) by making interventions. It was decided to call the most fundamental aims "goals" and the secondary aims "objectives".

A few type-less elements remained, such as *Birth rates*, *Walk score* and *Urban density*. The "Intermediate" element type was assigned to these elements, including economic factors and elements that YSM did not have an interest in changing. Later in the modelling process, the element type definition was clarified and generalized beyond YSM's interests. Some Intermediate elements, such as *Walk score*, were re-classed as Objectives, if most societal actors would agree on the desirable direction. Other Intermediate elements, such as *Birth rates* and *Urban density*, remained as Intermediate because some actors benefit from increases while others hope for stability or decreases.

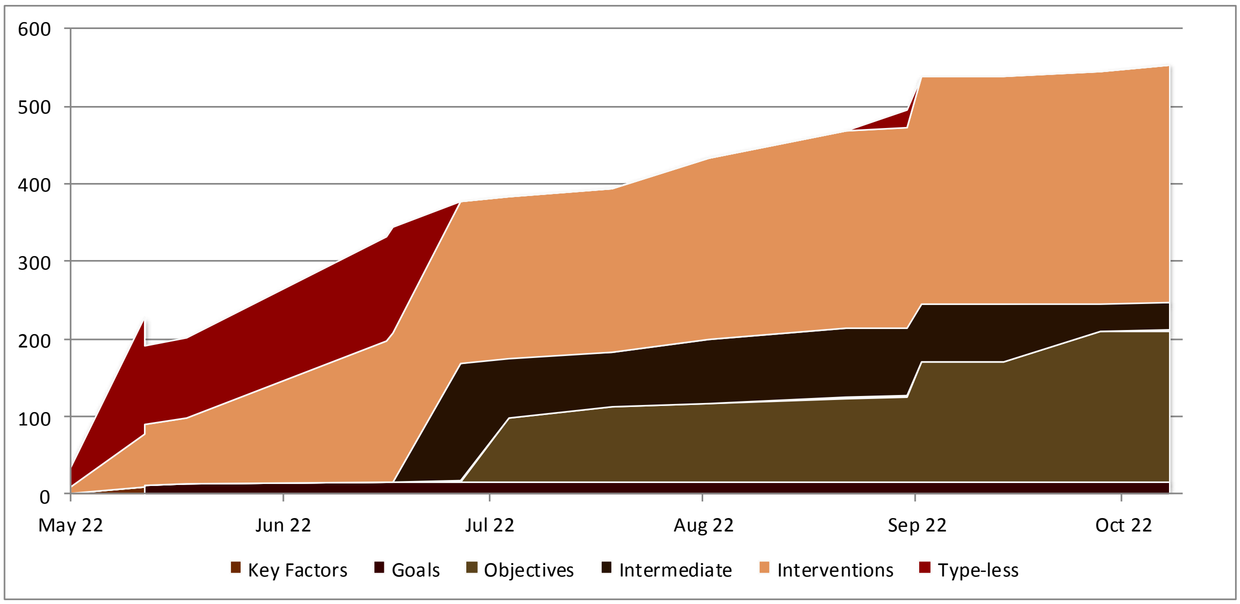

Figure 42: Element counts by type, during model development

A.3.2 Evolution of connection types: supply and demand

Most connections in the PRM are of the Same and Opposite types, classic in causal loop diagrams. These connection types stayed stable throughout the study.

During model development, the supply-demand connection type (an undirected light-orange line) was created to simplify modelling of some economic relationships. Figure 43 is an example diagram of the supply and demand for mental-health-supportive housing:

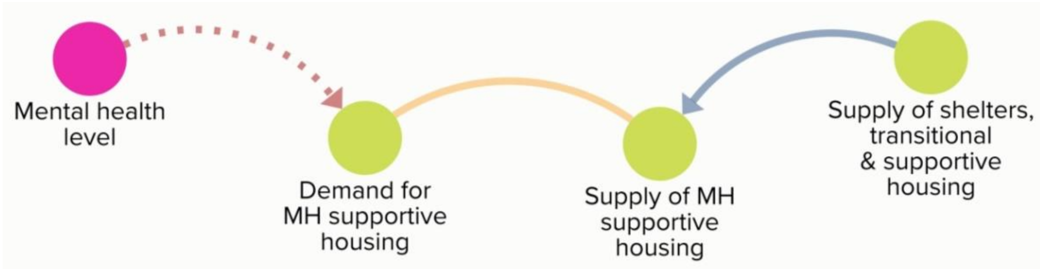

Figure 43: PRM: Supply and demand for mental-health-supportive housing

A supply-demand relationship is short-hand for multiple economic effects:

- If demand goes up, supply may go up to meet demand
- If demand goes up but supply stays stable, prices go up
- If supply goes up but demand stays stable, prices go down
- If supply goes up, hidden demand may appear
- All of these effects are also true if "up" is replaced by "down".

In some cases, in-depth understanding of supply-demand relationships was desirable. This required breaking out the multiple causal connections and additional elements that can explain supply, demand and pricing in the presence of subsidies, regulations, monopolies and government-funded services.

Figure 44 is an example, showing just some of the elements and connections involved in the supply, demand and cost of housing. There are three small loops in this diagram (loop names are hidden). The diagram is read: When *Demand for housing* increases, the *Average rent per square foot* is expected to go up, which can decrease demand, forming a balancing loop. Increases in average rent are an incentive to increase the *Supply of low-cost housing,* which should decrease the average rent (another balancing loop). The average rent is also affected by *Toronto housing prices* and *Urban density*. Average rent is the main component of *Gross cost of housing*, which in turn affects the *Net cost of housing,* and the *Rent subsidy amount* for tenants on Social Assistance.

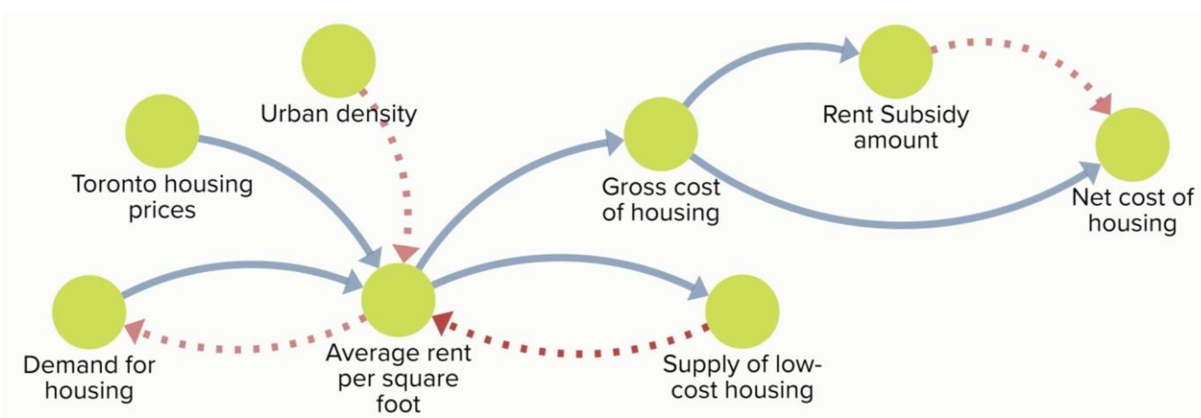

Figure 44: PRM: Supply and demand for low-cost housing

A.4 Tagging and subject areas

This section elucidates the difference between subject areas and tags, how they evolved, and the uses of tags for sub-topics and chains of downstream effects.

A.4.1 Tagging topics and sub-topics

To partition the PRM into readable displays, the Kumu tagging feature was used to label each element with one or more tags for the topics it related to. The original tags were the subject area names, meaning that connections across subject areas were visible by filtering for a tag. Tagging was a judgement call; not every connection across subject areas was tagged for display in both.

As the model grew, each topic tag contained too many elements to display without overlapping lines. A few topics were divided into two tags, such as employment-access and employment-conditions, but they still became unreadable.

For Workshops 3 and 4, elements were tagged with multiple sub-topics, designed for readable display of a conceptually meaningful group of elements. Figure 45 is an example of the elements from five subject areas that were relevant to employment qualification. It was labour-intensive to set up the sub-topic tags, because policy knowledge and judgement was required to make a conceptually coherent selection of few enough elements to be readable on one screen.

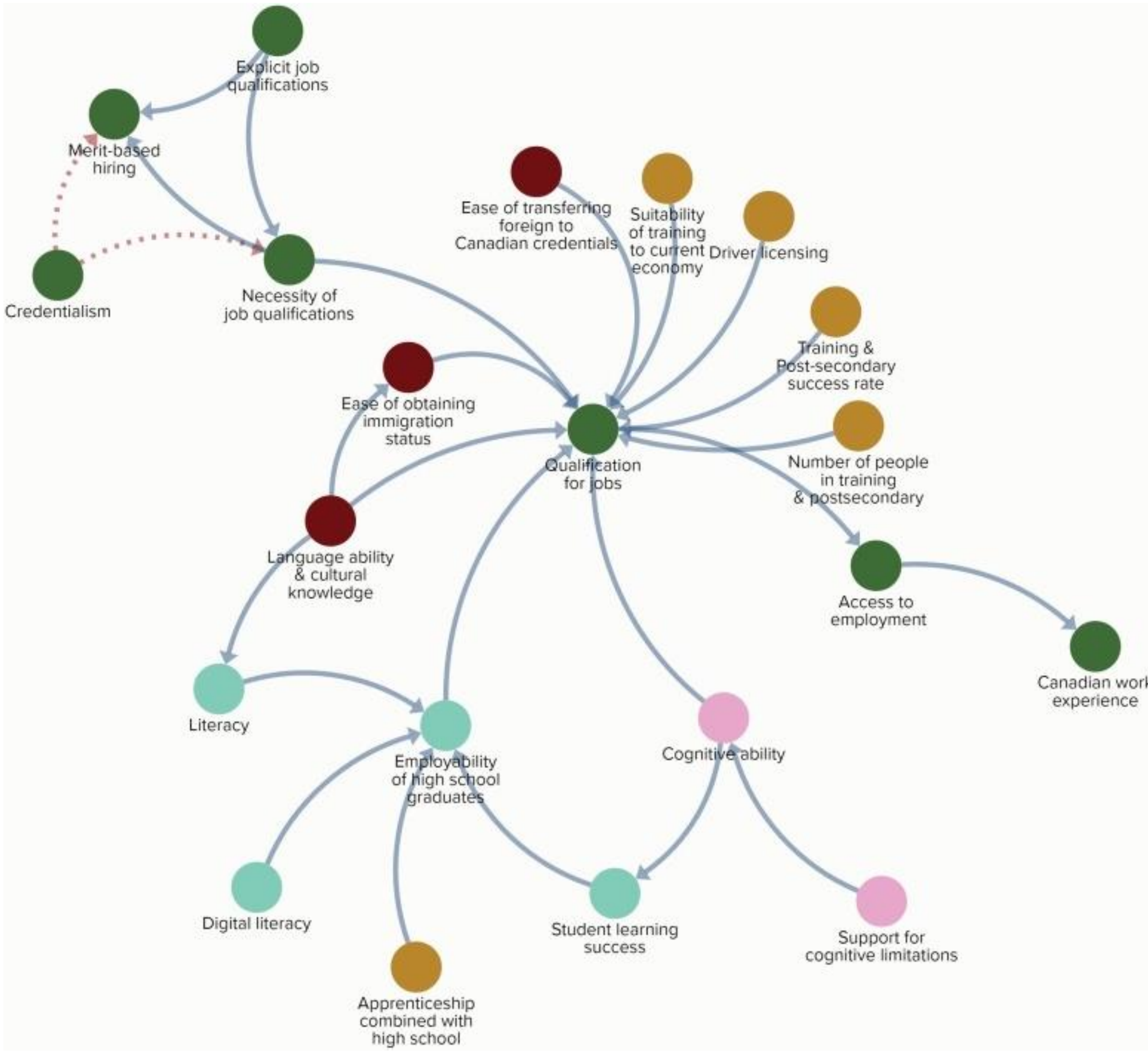

Figure 45: PRM employment qualification sub-topic

A.4.2 Subject areas and tags

The SubjArea custom field was created after the Tags, to classify each element into exactly one subject area. The SubjArea classification allowed thorough and systematic processing of the model (for reviews, graphic design work, etc.) A display of all elements in a SubjArea was sometimes more readable than the Tag display, since fewer elements were selected. If an element could have fit in two different SubjAreas, an arbitrary choice was made, and that element was assigned Tags for both topics.

As elements were added to the model, the researcher used policy knowledge to occasionally redefine the subject area boundaries. (Participants did not mention being confused by these changes.) As the subject areas evolved, an upper limit of 16 subject areas was imposed to keep the colour codes distinguishable.

After all the workshops, 156 elements were tagged with Employment. Of those, 84 were in the Employment subject area, shown in dark green in Figure 46 below:

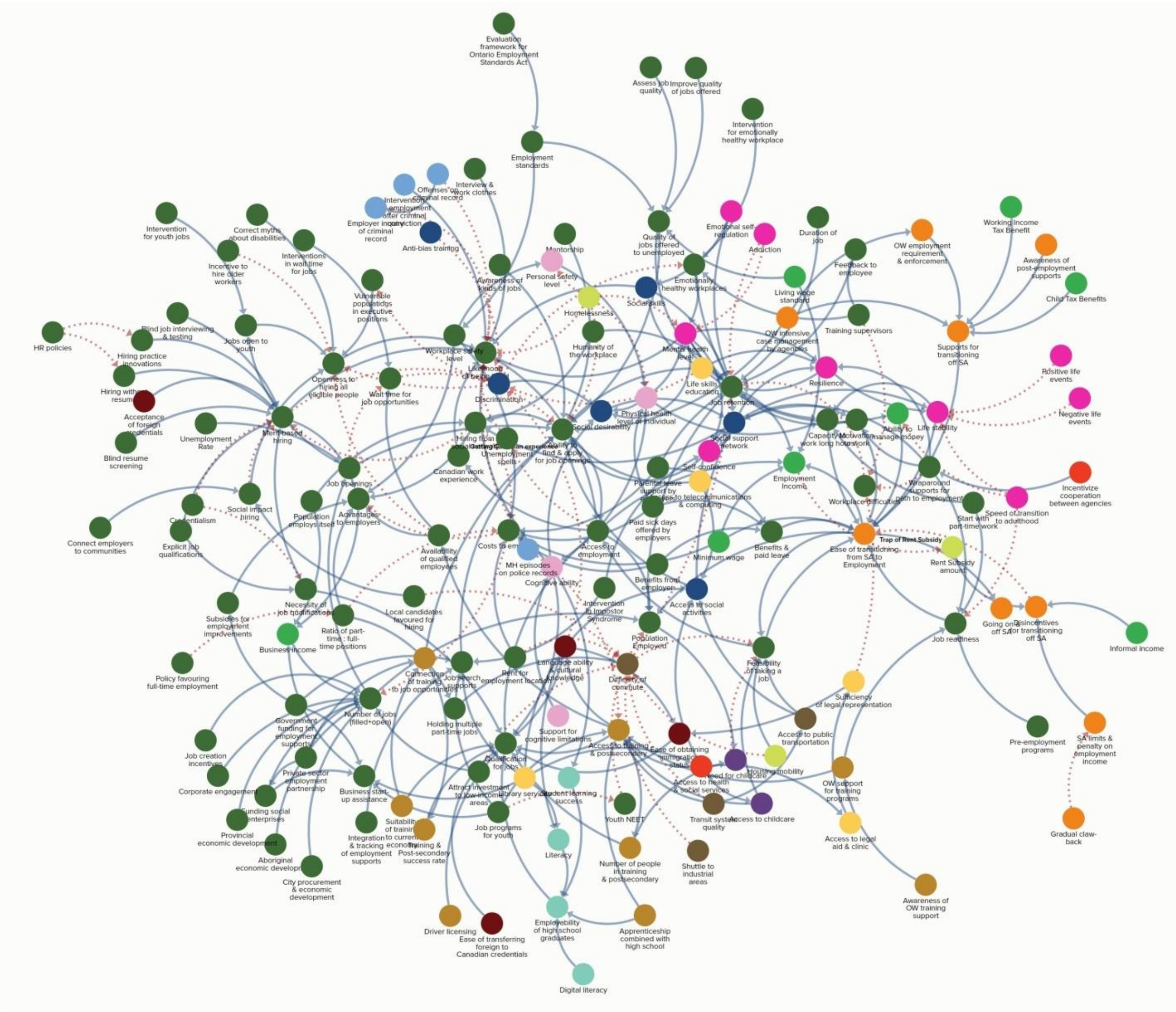

Figure 46: PRM Employment tag, after all workshops

A.4.3 Tagging chains of downstream effects

To prepare for selecting the Short-List (section B.10), a tag was assigned to the chain of elements downstream from each intervention on the Promising List. The use of these chains is explained in section 7.4.1.

Manual selection was required to include only the outgoing connections to downstream elements, because Kumu did not have a feature to focus only on outgoing connections. Some paths to goal elements were very long, so it was decided to cut off the chain display at some elements with obvious consequences. It was not effective to set an arbitrary limit, such as “up to 3 hops from the intervention”.

Figure 29 illustrates that these tags selected fairly dense networks of connections, not cleanly isolated strings of elements.

A.5 Physicalizing the model

Manipulating physical objects on a large surface (a table or whiteboard) helped to clarify strategies for modelling and facilitated activities. With the very large number of elements in the PRM, some analysis results are difficult to see on a computer screen.

For example, in preparation for Workshop 2, the researcher produced a paper slip for every model element (about 200 interventions and 150 other elements, at that time). The slips were easily made by exporting all elements from Kumu to a spreadsheet, then using that data for a "mail merge" in MS-Word, and cutting the pages with a guillotine. A sampling is shown in Figure 47. Each slip shows the element type, subject area, element label, and its tags. The paper slips were used to test a classification (Figure 48) and to test the prioritization method for Workshop 2 (as described in section B.5.1.1). Both these tests were unsuccessful, which prevented further failures.

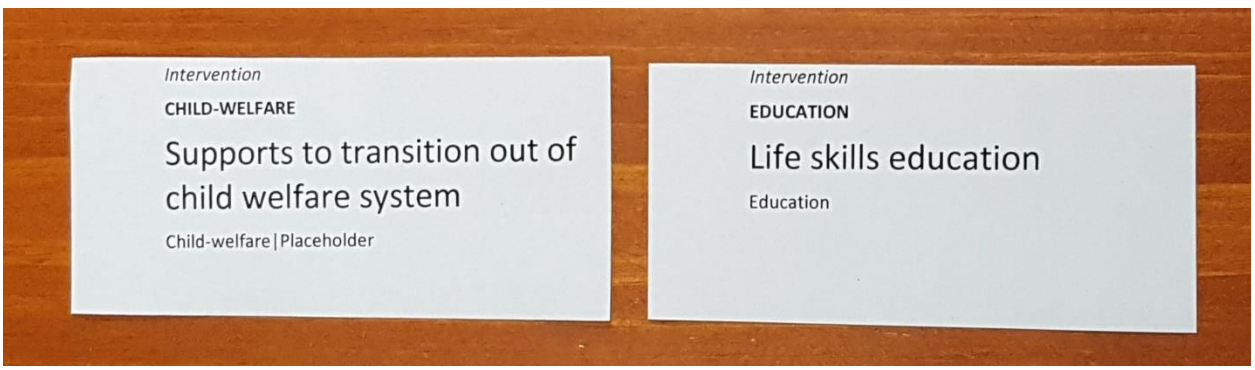

Figure 47: Sample of interventions on paper slips

The intervention paper slips were physically sorted into piles on a table (Figure 48) to develop a new classification of the elements. It was noted that some elements were specific to a sub-population (such as youth, job-seekers, or newcomers), but it turned out that many elements were general to any person in poverty. The sub-populations were mentioned in Workshop 2's discussion of Reach, but the Working Group did not find this to be an important analysis. This classification was abandoned, and not entered into a Kumu custom field.

Figure 48: Sample of elements on paper slips, sorted by sub-population

A.6 Kumu view settings

The following Kumu code was used for the PRM. The same code was used for both the subject area view (Figure 22) and element type view except where noted. Refer to the Kumu documentation (Kumu, n.d.-a) for more information.

Table 12: Kumu view settings

<table>
<tr><th>Code in Advanced Editor</th><th>Purpose</th></tr>
<tr><td><pre><code>@controls {
  bottom {
    filter {
      target: element;
      by: "element type";
      as: buttons;
      multiple: true;
      default: show-all;
    }
  }</code></pre></td><td>Creates a Custom Filter, with buttons to quickly show only the element type selected by the user.</td></tr>
<tr><td><pre><code> top {
    filter {
      target: element;
      by: "subjarea";
      as: dropdown;
      multiple: true;
      default: show-all;
    }
  }</code></pre></td><td>Creates a Custom Filter, with a drop-down list where the user can select one or more subject areas to display. The “subjarea” command is visible near the top of Figure 22.</td></tr>
</table>

Code in Advanced Editor	Purpose

`bottom-right {`
`  filter {`
`    target: element;`
`    by: "tags";`
`    as: dropdown;`
`    multiple: true;`
`    default: show-all;`
`  }`
`}`
`}`
	Creates a Custom Filter, with a drop-down list where the user can select one or more Tags to display. The "tags" command is visible near the bottom-right of Figure 22.

`@settings {`	Begins the Settings section.
`template: systems;`	Kumu offers templates for multiple styles of modelling. The PRM is based on the Systems template.
`layout: force;`	By default, elements will be automatically laid out using a force-directed algorithm. (Any "pinned" elements will stay in a fixed position.)
`layout-preset: dense;`	The "dense" and "auto" presets resulted in more readable layouts than the "hairball" preset, which expanded the space between elements but made the font size too small.
`theme: light;`	The model is displayed on a near-white background. The only other option is the "dark" theme, a near-black background.
`connection-color: #204a80;`	The default colour of a connection is set to blue, to match the colour of the Same connection type. Thus, connections created quickly look like Same connections, which were most common in the PRM.
`opposite-color: #A20000;`	Sets opposite connections to a red line colour.
`opposite-style: dashed;`	Uses dashed lines for the opposite connections.

Code in Advanced Editor	Purpose
`element-size: 30;`	Sets all elements to the same size of bubble.
`element-size: scale("Impact", 10,50);`	Sets the size of each bubble according to the Impact custom field. Bubbles will range from size 10 to 50. (Note that this setting is used instead of element-scale, which enlarges the label font along with the bubble size.)
`element-text-align: bottom;`	Places element labels below the bubbles, not in the middle of the bubbles. This is preferred for longer element labels.
`element-color: categorize("Element Type", #a20000 "Goal", #ff6802 "Objective", #ffbe6f "Intermediate", #669e2f "Intervention");`	The custom colour scheme for the element type view.
`element-color: categorize("SubjArea", #634086 "childcare", #B297C7 "child-welfare", #72A3D7 "criminal-justice", #204A80 "social-dignity", #81CCB9 "education", #3E6C36 "employment", #39AC4F "financial", #CDDD55 "housing", #725B39 "transportation", #BA862B "training", #FCCC53 "other-services", #f2821a "social-assistance", #EE3923 "services", #E8A6CA "physical-health", #701013 "newcomers", #ed28a8 "mental-health");`	The custom colour scheme for the subject area view. (The built-in Kumu colour schemes did not have enough colours to display all of the PRM's subject areas.)
`font-size: 25;`	Sets all element labels to the same font size.
`font-color: #000000;`	Sets label font to black.

Code in Advanced Editor	Purpose
`include: element, connection, loop;` `}`	Displays all elements, connections and loops. (This code changes whenever a filter or focus is applied.)

`/* Supply-Demand */`
`connection["connection type"="Supply-Demand"] {`
`  color: #FAA52D;`
`}`
	Sets supply-demand connections to a yellow line colour. Places "Supply-Demand" in the legend.

`/* Same direction */`
`connection["connection type"="Same"] {`
`  color: #204A80;`
`}`
	Sets same-polarity connections to a blue line colour. Places "Same direction" in the legend.

Photo 12

Appendix B Facilitated activities

This process photo shows how a piece of electronic waste was wrenched apart to extract the thick red wire that was torched in Photo 5 and a plastic reel of fine copper wire tucked underneath it (Photo 7). Like the process photo, this appendix serves as a record of how the case study was done, for those assessing the study or considering doing similar activities. This section describes how the YSM Working Group was involved in finding and prioritizing interventions while making sense of the system of poverty. It details the workshops and other facilitated activities that were outlined as methods (section 4.4) and findings (section 7.2).

B.1 Workshops

B.1.1 Workshop schedule

Table 13: Workshops held

Session	Date	Duration	Agenda
Workshop 1	July 11, 2018	2 hours	Set goals and rank important subject areas with Summary Model
Workshop 2	August 7, 2018	2 hours	Select 2 focus areas with effective interventions
Workshop 3	August 22, 2018	2 hours	Develop high-leverage interventions in Housing focus area
Workshop 3A	August 27, 2018	1.5 hours	(Extra meeting to cover sub-topics not completed in Workshop 3)
Workshop 4	Sept. 20, 2018	2.5 hours	Develop high-leverage interventions in Employment focus area
Workshop 5	Oct. 24, 2018	2 hours	Select a short-list of 3 interventions

B.1.2 Common workshop materials

In addition to the modelling and prioritization activities, the following methodology procedures and materials were used for all five workshops:

Table 14: Common workshop procedures and materials

Material	Procedure and content description
Workshop Guide	An indicative agenda for a typical workshop, as submitted for REB approval.
Facilitation plan	The YSM Director contributed to this early version of the planned agendas for the five workshops.
Preparation emails	Participants were emailed before each workshop to build enthusiasm, remind them of the date and time, ask them to do various advance preparation, and ask them to bring a laptop computer for certain activities.
Invitation/Consent Forms	Informed consent was obtained from all participants. See section 4.1.4.
Workshop slides	PowerPoint slides shown at each workshop are listed in Table 15.

Material	Procedure and content description
Feedback questions	Ten minutes at the end of each workshop was reserved for the researcher to ask participants for methodology feedback, using the semi-structured interview questions in Table 16.
Observation Guide	The researcher wrote observations after each workshop or other case-study meeting, to improve the methods and materials for the next workshop.
Follow-up emails	Participants were emailed after workshops to thank them for enthusiastic participation, with results from the workshop's prioritization process. Participants were also provided with a link to browse the updated PRM, and the opportunity to send comments and corrections to the researcher.

B.1.3 Workshop presentations

The following table summarizes the slide presentations given at the workshops, W1 to W5:

Table 15: Slides presented in workshops

Slide	W1	W2	W3	W4	W5
Workshop agenda	✓	✓	✓	✓	✓
Informed consent & ground rules	✓	✓	✓	✓	✓
YSM requirements for demonstration project	✓	✓	✓	✓	✓
Case study research question	✓	✓	✓	✓	✓
List of 5 workshops	✓	✓	✓	✓	✓
Methodology research question	✓				
Introduction of the researcher	✓				
YSM systemic approach	✓				
Systems Thinking concepts	✓				
Views of PRM (3 slides)	✓				
Sources for PRM	✓				
Summary model	✓	✓			
Instructions & info for processes in workshop	✓	✓	✓	✓	✓

Slide	W1	W2	W3	W4	W5
Results from previous process		✓	✓		✓
Next steps			✓	✓	
Your Top Criteria			✓	✓	✓
Feedback questions	✓	✓	✓	✓	✓

B.1.4 Methodology feedback questions

The methodology feedback questions varied somewhat in each workshop:

Table 16: Workshop feedback questions

Question	W1	W2	W3	W4	W5
Did you find (today's materials) understandable? What could be improved?	✓	✓	✓	✓	✓
Was your previous input captured accurately?		✓	✓		
How do you feel about the activities we did today? What could be improved?	✓	✓	✓	✓	✓
Were you comfortable doing your role?			✓		
What did you think about the pre-reading articles?			✓		
The plan for our next workshop is (aims). Do you have any suggestions for the process we will use, or the information & materials that I'll bring?	✓	✓	✓	✓	
Do you feel comfortable with the short-list we selected?					✓

B.2 Visioning icebreaker

As an icebreaker in Workshop 1, each Working Group participant was given a letter-size sheet with space to write their Name and Job at YSM, then: "Write or draw your vision: Poverty in Toronto could be reduced by…"

After writing their visions, the sheets were posted on a board. Participants were asked to explain their poverty reduction ideas to the group. The researcher annotated the vision sheets with explanatory comments.

B.2.1 Findings: Visioning icebreaker

The visioning activity was a suitable challenge to the Working Group that engaged them in thinking about the whole system of poverty, beyond their daily work. It was also successful in introducing participants to the researcher, while using the icebreaker time to gather relevant information. The activity did not directly compare or prioritize options, but it did inform the choice of focus area in Workshop 2.

Participants needed encouragement to begin answering a "huge question": their vision of how poverty in Toronto could be reduced. Some examples of their vision statements:

- "Seeing & knowing people and why they are in poverty"
- "Justice system revamp"
- "More affordable housing options"
- "Linked specializations (e.g. mental health workers in community-based organizations)"

Setting up this activity took little time, with just one simple form to create and print.

Participants struggled to begin this exercise. They weren't sure what to highlight from the many poverty issues they knew about. They were assured that writing multiple things was acceptable. After writing, discussing the participants' visions was valuable for understanding what they wrote and building the group's common understanding.

The researcher used a distinguishable colour (hot pink) to write explanatory comments on the vision sheets. These notes enabled the researcher to incorporate the vision statements into the "themes of interest" reported back to Workshop 1 participants. A few statements were specific enough to become elements in the Poverty Reduction Model, for example, "Linked specializations (e.g. mental health workers in community-based organizations)".

B.3 Prioritization with Summary Model

Workshop 1 aimed to tentatively identify the subject areas or themes that would be the focus of later workshops, using the Summary Model Poster (Figure 27). Participants were invited to stand up to read the large-format summary model, posted on a whiteboard. For reference, participants were also given a personal letter-size copy of the Summary Model (Figure 26).

Participants used markers to annotate the poster, given the prompt "I think this area is important because…" They were also asked to write clarifying questions, notes and ideas.

After this writing exercise, the researcher facilitated a group discussion about YSM's goals for preventing, alleviating and exiting poverty. Participants clarified what their annotations meant, and the researcher added yellow sticky-notes accordingly (Figure 49). Participants had the opportunity to modify the subject areas before prioritization, so they combined some subject areas, as shown by red loops on Figure 49.

Then the Working Group did their first prioritization exercise, using dot voting (Diceman, n.d.): Each participant was given 8 sticker-dots to vote for the subject areas they considered most likely to help many people towards the goals. Participants were allowed to place any number of dots on an area. The high-ranking subject areas were discussed as potential focus areas, to be confirmed or reconsidered in Workshop 2. The annotated poster is Figure 49, which may be zoomed in. Results are compiled in Figure 50.

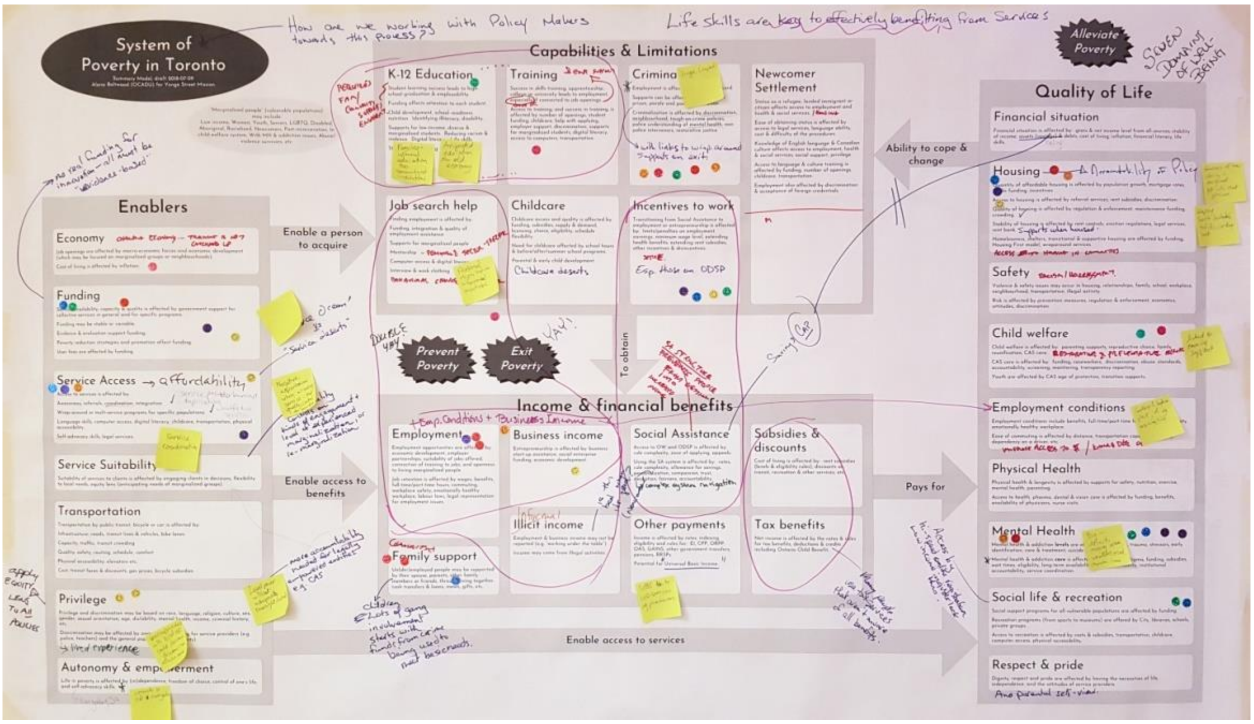

Figure 49: Summary model annotated in Workshop 1

B.3.1 Findings: Prioritization with Summary Model

B.3.1.1 Evaluation of activity

The summary model exercise in Workshop 1 was effective in getting participants familiar with the content of the Poverty Reduction Model, and sharing their knowledge with the researcher. The Summary Model Poster provided enough information about subject areas for participants to discern their relative priorities.

The voting part of the exercise informed the selection of two focus areas, which was finalized in Workshop 2. The votes for subject areas were not sufficient to confidently select two focus areas, because participants had not yet learned about and discussed the many PRM elements within the subject areas.

During this exercise, participants were able to annotate the poster with comments about various subject areas, though one said they were “not sure of the value of” writing on the poster. The facilitated discussion was important to clarify what those written comments meant. Recording the clarifications helped the researcher report back the themes of discussion.

Giving participants the opportunity to modify subject areas was important, both to use more sensitive wording (“informal income” instead of illicit income) and to combine the multiple employment-related areas, as shown by red loops on Figure 49. The discussion helped the researcher re-define various subject areas in subsequent versions of the system model.

Participants learned the dot-voting procedure quickly. Eight dot stickers sufficed for prioritizing the 24 (combined or original) areas.

This activity was simple to plan and facilitate, though it took significant time to develop the Summary Model Poster. See also findings about the structure and content of the Summary Model as used in this activity, section 6.5.

B.3.1.2 Results: summary model prioritization

Participants ranked the subject areas they considered most likely to help many people towards the goals. Results are shown in Figure 50. At this initial assessment, the most important subject areas were: Transition to Employment, Mental Health, Criminal Justice, Housing, Funding, and Service Access.

The following themes and comments from the Workshop 1 discussions were incorporated into the system model:

- Transition from Social Assistance to Employment (sometimes through Training)
- Criminalization (informal income, family issues, gangs, policing, post-incarceration support)
- Mental health
- Housing
- Universal Basic Income
- Funding & resource coordination
- Service access & quality (policy design, lived experience, equity lens, innovation, modernization, duplication, accountability, discrimination, staff burnout, awareness, affordability, deserts, coordination, co-location, navigation, customization, self-advocacy, life skills, recovery from negative experiences).

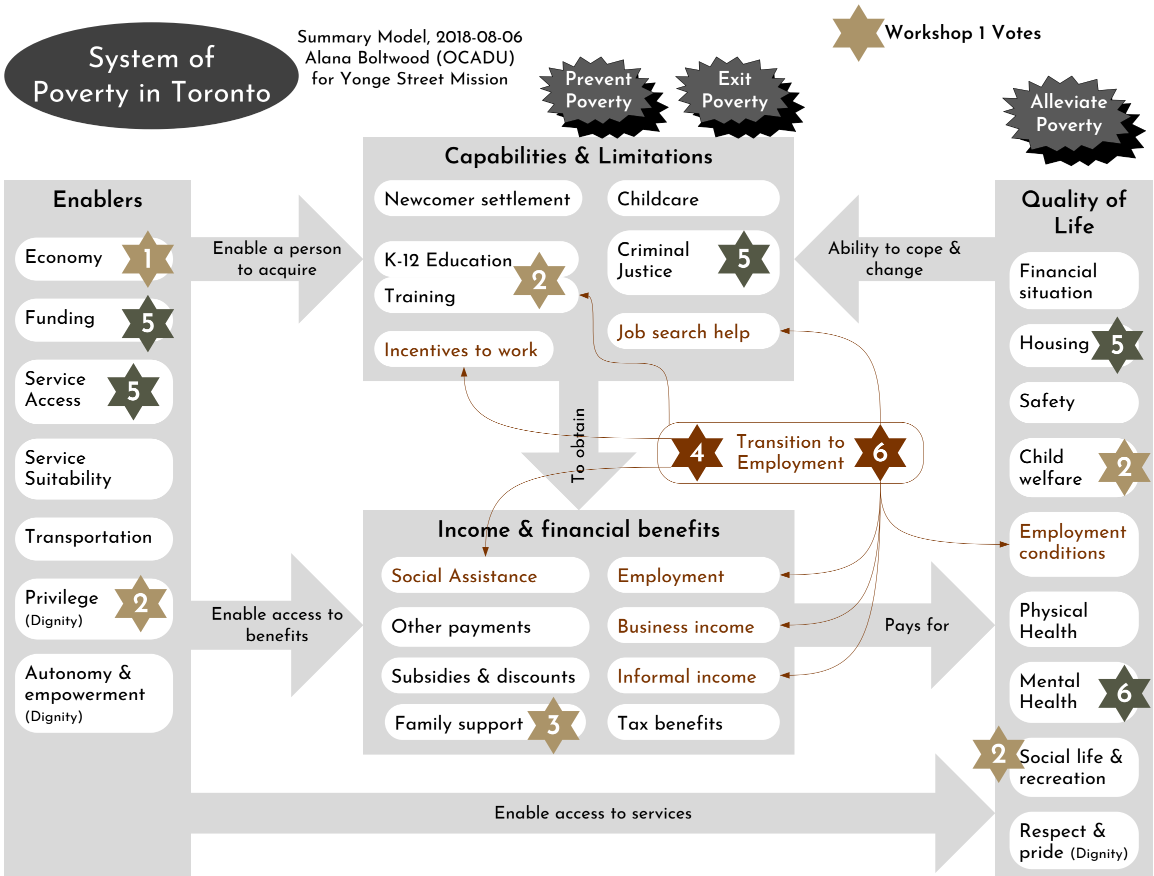

Figure 50: Summary model updated with Workshop 1 votes

B.4 Setting prioritization criteria

In prioritization processes, pre-establishing criteria is recommended by (Metz, 2016). Workshop 2 used discussion then dot-voting to set YSM's criteria for prioritizing interventions and selecting a Short-List.

B.4.1 Discussion of Reach and Impact

The Working Group was asked whether they wanted to prioritize interventions that reach a larger population, or whether they were interested in interventions with high impact on a smaller population. A list of potential populations was displayed, based on the researcher's sorting of model elements (Figure 48).

The Working Group was asked how they would define "Impact". This would be an important criterion for comparing the effectiveness of objectives and interventions in reducing poverty. The researcher suggested some possible definitions:

- How much an objective improves one person's life

- If you invest $1 million in each objective, which ones yield more results?

The Working Group was also alerted to the difference between:

- Reach, the number of people who could be affected by an intervention
- Likelihood of the intervention succeeding with each person
- Impact: if an intervention is successful, how much effect it has on one person's life.

B.4.1.1 Results of discussing Impact and Reach

The Working Group defined Impact as "forward moves" on the YSM's TIMES framework, or other measurable progress for an individual in poverty. Participants also considered the costs of poverty to society, such as trauma and early mortality. The concept of social return on investment (sROI) was of interest: if $1 million is invested in two interventions, which one returns greater benefits?

On the question of Reach: The Working Group wanted to focus on YSM's three populations. They saw advantages to choosing a niche within one of these populations, where they had the capacity to specialize, if the demonstration project could later be scaled up. Working with a very broad population would go beyond YSM's capacity for leadership and funding.

B.4.2 Criteria-setting activity

A list of proposed criteria was prepared (Table 17). Small papers were prepared for each proposed criterion, with its name in large font, and a short description. The cards were adhered to the whiteboard with sticky-tack.

The Working Group was facilitated to discuss the proposed criteria, which led to rearranging and combining criteria, writing clarifications on the papers, and writing additional criteria on blank papers. See examples in Figure 51.

After discussion, dot-voting was used to rank the cards, with each participant allotted 8 voting stickers. The prioritization criteria as defined and ranked by the Working Group are shown in Table 18.

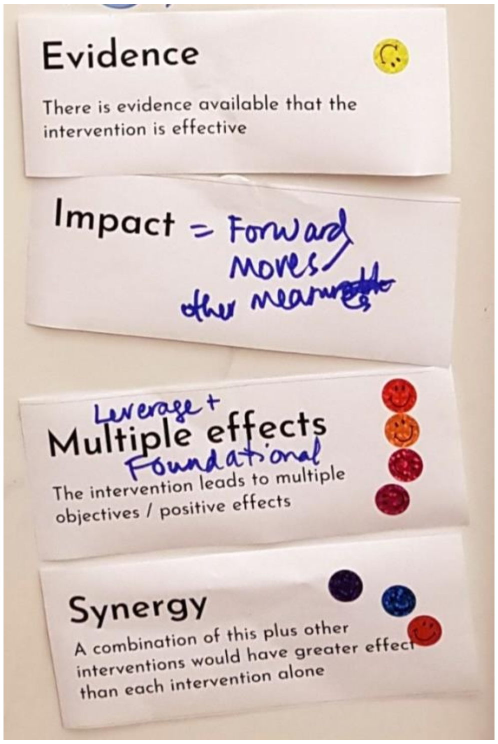

Figure 51: Sample of criteria cards, discussed and ranked in Workshop 2

The list of proposed criteria was developed in seven iterations before presenting it to the Working Group. The list grew from simply "effectiveness, feasibility, desirability, viability" to a whiteboard filled with 42 sticky-notes, based on reviewing systems-thinking literature. The list was reduced to 26 proposed criteria (Table 17). Criteria were excluded if applying them would require significant training in systems thinking, with no guarantee of valuable results.

The list iterations included multiple ways of classifying interventions to find higher leverage (see section 7.3.4). None of these were included as practical criteria for the Working Group to apply during the limited workshop time.

Table 17: Prioritization criteria proposed to the Working Group

Proposed criterion	Short description
Impact	*Blank, for group to define*
Likelihood	How likely is the intervention to succeed? What % of people get the intended effect?
Reach	Number of people who could be affected
Multiple effects	The intervention leads to multiple objectives / positive effects

Proposed criterion	Short description
Synergy	A combination of this plus other interventions would have greater effect than each intervention alone
Negatives	This intervention is likely to have downside risks or unwanted side-effects
Immediacy	Years until the intervention has a measurable effect
Evidence	There is evidence available that the intervention is effective
Measurability	The results of the intervention will be easy to measure.
Prevent Poverty	Intervention keeps people from ending up in poverty
Exit Poverty	Intervention helps people raise their income above poverty level
Alleviate Poverty	Intervention improves the quality of life of people in poverty
Is Policy Change	Intervention requires a change to legislation, regulation or other policy
Cost per person	Direct & indirect costs of the intervention, per person affected
Total Cost	Direct & indirect costs of the intervention, for everyone in the population affected
Feasibility	Assuming costs are covered, how easy is this intervention to implement?
Innovation	The intervention is new to the world, new to Toronto, or a new improvement to something existing
Jurisdiction	Which government or other authority controls the policy to be changed?
Perception	Will stakeholders (including people in poverty) be in favour of this intervention?
Directness	People in poverty will notice this intervention directly affecting them
Simplicity	The intervention is simple to explain, understand and implement
YSM Expertise	Yonge Street Mission staff have a lot of knowledge related to this intervention
YSM Goal Fit	The intervention aims To end chronic poverty in Toronto in one generation.
YSM Mission Fit	Yonge Street Mission exists so that all the poor and vulnerable in Toronto that we encounter will experience God's love, peace, and justice at a level that represents the highest stewardship of the resources invested.
YSM Population Fit	Intervention is particularly suited for Street-involved youth, Adults in chronic poverty, and/or Families in need.

B.4.3 Prioritization criteria results

The YSM Working Group defined two general criteria in Workshop 2, based on the more detailed criteria ranked below:

- **Impact**, meaning measurable progress for an individual in poverty, incorporating measurability, evidence availability, multiple effects and synergy
- **Potential**, meaning the potential for finding feasible interventions, incorporating reach, scalability, total cost, cost per person, YSM expertise, and the potential to prevent poverty and exit poverty.

The following table shows YSM's more detailed prioritization criteria, after discussion and ranking by the Working Group. This chart includes some lower-ranked criteria near the high-ranked criteria that they might be combined with. Notably, the Working Group considered each intervention's fit and feasibility for YSM, which means that another organization might have prioritized different interventions.

Table 18: Criteria defined and ranked by Working Group

Votes	Criterion	Description *and Notes*
5	Impact	Working Group defined Impact as "forward moves" on the YSM's TIMES framework, or other measurable progress for an individual in poverty. *Working Group combined Measurability into Impact. Measurability means:* The results of the intervention will be easy to measure.
1	Likelihood	How likely is the intervention to succeed? What proportion of people gets the intended effect? *Was not discussed. May be naturally combined into Impact.*
0	Yield Independence	*Working Group discussed this during Workshop 2; it seems to be an aspect of Impact.* The intervention leads clients to independence from social service agencies and to interdependence with their communities.
4	Multiple Effects	The intervention leads to multiple objectives / positive effects. It is foundational. It has leverage.
3	Synergy	A combination of this plus other interventions would have greater effect than each intervention alone.

Votes	Criterion	Description *and Notes*
4	Reach + Scalability	*Combined by the Working Group.* Reach = Number of people who could be affected. Working Group is interested in interventions that affect a larger or a smaller (niche) population, so long as it's a population that YSM specializes in. Scalability: The intervention should be applicable beyond the demonstration project in Toronto (i.e. can be adapted to elsewhere in Ontario or the world). Interventions affecting the wider society (not just people in poverty) are not particularly of interest.
3	YSM Fit	Intervention is suited to the Yonge Street Mission's goal, mission, populations and expertise. Expertise: YSM staff have a lot of knowledge related to this intervention. Goal: To end chronic poverty in Toronto in one generation. Mission: Yonge Street Mission exists so that all the poor and vulnerable in Toronto that we encounter will experience God's love, peace, and justice at a level that represents the highest stewardship of the resources invested. Populations: Street-involved youth, Adults in chronic poverty, and/or Families in need. (Not focusing on seniors, disabled or Aboriginal populations.)
0	Geographic scope	*Working Group discussed this during Workshop 2 but did not vote for it.* The intervention is applicable to the downtown-Toronto scope of YSM (see YSM Fit), but could be adapted/adopted elsewhere (see Scalability).
3	Prevent Poverty	Intervention keeps people from ending up in poverty
3	Exit Poverty	Intervention helps people raise their income above poverty level.
0	Alleviate Poverty	Intervention improves the quality of life of people in poverty. (Note that YSM's programs are not focused on seniors and disabled people who will remain on government assistance rather than becoming employed.)
1	Cost per person	Direct & indirect costs of the intervention, per person affected.
1	Total cost	Direct & indirect costs of the intervention, for everyone in the population affected.
0	Funding can be ongoing	*Added by Working Group at Workshop 2*
1	Directness	People in poverty will notice this intervention directly affecting them.
1	Evidence	There is evidence available that the intervention is effective.

Votes	Criterion	Description *and Notes*
1	Innovation	The intervention is an incremental innovation: new to Toronto (borrowed from elsewhere) or a new improvement to something existing. (Completely new interventions are not favourable.)
1	Journey Length	(Working Group added this during Workshop 2. Not clear whether long or short journeys are favourable.) Some interventions are suited for people who need just a little bit more help to exit poverty. Others are for people with a long way to go (a long journey).
0	Feasibility	*Probably replaced by YSM Fit.* Assuming costs are covered, how easy is this intervention to implement?
0	Simplicity	The intervention is simple to explain, understand and implement.
0	Perception	Will stakeholders (including people in poverty) be in favour of this intervention? *Workshop 2 discussed describing proposals so that politicians can say Yes to them.*
0	Immediacy	Years until the intervention has a measurable effect. *No votes, but 3 years is one of YSM's criteria for the demonstration project.*
0	Is Policy Change	Intervention requires a change to legislation, regulation or other policy. *No votes, but one of the criteria for selecting the demonstration project is that it be a policy change, not a program.*
0	Jurisdiction	Which government or other authority controls the policy to be changed? *Not a big concern because the demonstration project is likely longer than the 4-year election cycle.*
0	Negatives	This intervention is likely to have downside risks or unwanted side-effects
0	Culturally acceptable	*Researcher added this during Workshop 2*
0	Environmentally Sustainable	*Researcher added this during Workshop 2*
0	Socially Sustainable	*Researcher added this during Workshop 2*
0	Financially sustainable	*After the above sustainability criteria were mentioned, the Working Group suggested "Financially sustainable" but they meant it as a goal, not a criterion: individuals in poverty need financial sustenance. Not included in voting.*

B.4.4 Findings: Setting prioritization criteria

Interpreting the above criteria for use in later activities provided the Working Group with clear justification for their choices, and prevented lengthy discussions about priorities.

Asking the group to define Impact was important, as was listening to comments about adding, combining or clarifying criteria. Participants interpreted some criteria in unexpected ways. Understanding the various interpretations of criteria was cognitively demanding for the facilitator and participants. The discussions seemed conclusive, but in retrospect, the list should have been reduced further before voting.

B.4.4.1 Assessment of dot-voting

After defining and modifying the proposed criteria, the Working Group ranked the criteria using dot voting (section 3.7.2). Each of 4 participants had 8 dot-votes, perhaps not enough to identify all the important criteria on the list of 29 being ranked. There were zero or few votes for some requirements for choosing the demonstration project, such as Innovation, and some other criteria that the group had discussed with interest, such as Geographic Scope. Therefore the dot-voting was not a fully effective way to discern the relative priorities and align the criteria with the demonstration project requirements.

The major goals of Prevent Poverty, Exit Poverty and Alleviate Poverty were included as potential criteria, because the Workshop 1 discussion had not sufficiently clarified which of these YSM was most interested in addressing. This major decision was not appropriate for dot-voting. Votes were higher for preventing and exiting than for alleviating poverty, which is indicative but not conclusive about YSM's goals.

B.4.4.2 Uses and interpretation of prioritization criteria

Having criteria defined and ranked was valuable for subsequent prioritization activities. Because the results of dot-voting were suspect, the criteria actually used in these exercises were interpretations of the ranked list combined with YSM's demonstration project requirements. It was also found that the ranked list had too many criteria for exercises where only one, two or three criteria could realistically be used.

In setting up the objective scatterplot, participants decided which criteria to amalgamate into Impact and Potential dimensions (section B.5.2.2). These same two dimensions were used in rating elements (section B.9.1) to select the Promising List, in combination with the demonstration project requirements (being an innovative policy change affecting at least one YSM population). The Short-Listing needed additional criteria to further distinguish the high-impact, high-potential interventions, as discussed in section B.11.1.

Impact and Potential were combined in the one voting scale used in the Employment agenda-setting (section B.7.1). Using only one scale made that exercise simple, but its criteria were not clear to a participant.

B.5 Objective scatterplot

Narrowing to two focus areas was critical, because the PRM was too large to digest or discuss in the workshop time available. Workshop 1 had tentatively ranked the importance of subject areas. To make this important scoping decision, the participants needed to apply clear criteria to more granular pieces of the model.

This scatterplot exercise was planned to rank the PRM objectives along the Impact and Potential dimensions, and then observe which subject areas had both high Impact and high Potential.

B.5.1 Methods: Objective scatterplot

First, the facilitator led the Working Group to combine their newly selected prioritization criteria (Table 18) into an Impact dimension (Figure 53) and a Potential dimension (Figure 54).

Participants were each given a stack of objective cards, each showing an objective from the PRM, the interventions that lead to it, and the consequential effects of the objective. The elements were coloured by subject area. See sample objective cards in Figure 52. Participants were instructed to place the objective cards along the horizontal Impact axis, and then move the cards up or down the Potential axis.

The Working Group used the element colours on objective cards to observe and count which subject areas occurred in the higher-Impact, higher-Potential portions of the whiteboard. The subject areas with the higher-ranked objectives were compared with the Workshop 1 votes for important subject areas (Figure 50). The two rankings, and YSM's practical experience, informed a group discussion that selected two subject areas as the focus of Workshops 3 and 4.

This activity had the side benefits of increasing the Working Group's familiarity with the subject areas and elements of the PRM, and capturing their numeric ratings of objectives in the Kumu database.

B.5.1.1 Evolution from intervention to objective scatterplot

The original plan for Workshop 2 was to make a scatterplot of interventions rather than objectives. The researcher prototyped the intervention cards (see samples in Figure 47), and tested whether they could be arranged along a spectrum from lower to higher impact. It quickly became apparent that these interventions could not be compared without knowing more details: What kind of supports would be offered to how many Aboriginal students? How much funding, for what aspect of the transportation system?

And so, Workshop 2 was redesigned to compare objectives instead of interventions. The Working Group would focus on the needs of people in poverty, not the design of policies and programs. Because there were fewer objectives than interventions, the scatterplot process would take less time in the workshop.

B.5.1.2 *Preparing for objective scatterplot*

The following advance preparation was done for the objective scatterplot exercise:

- Find a large vertical surface in the workshop room that cards can be attached to, and that participants can reach. (Sticky-tac was used on whiteboards.)
- Measure the size of the surface, number of objectives, and number of participants, to calculate the size of cards and amount of sticky-tac needed. To fit many cards on the board, with readable fonts, cards were 4.25" x 3.5", eight to a legal-size page.
- For each objective in the model, capture a screenshot of the first-order bloom, with manual layout.
- Design and lay out the objective cards, with titles indicating the desirable direction (increase or decrease), print in colour, and cut with guillotine.
- Design and print subject area legend, connection type legend, Impact & Potential axis labels and Not Sure zone label.
- Shuffle and divide the objective cards into one stack for each participant who is expected to attend.
- Prepare a package of materials for each participant and materials to be posted.

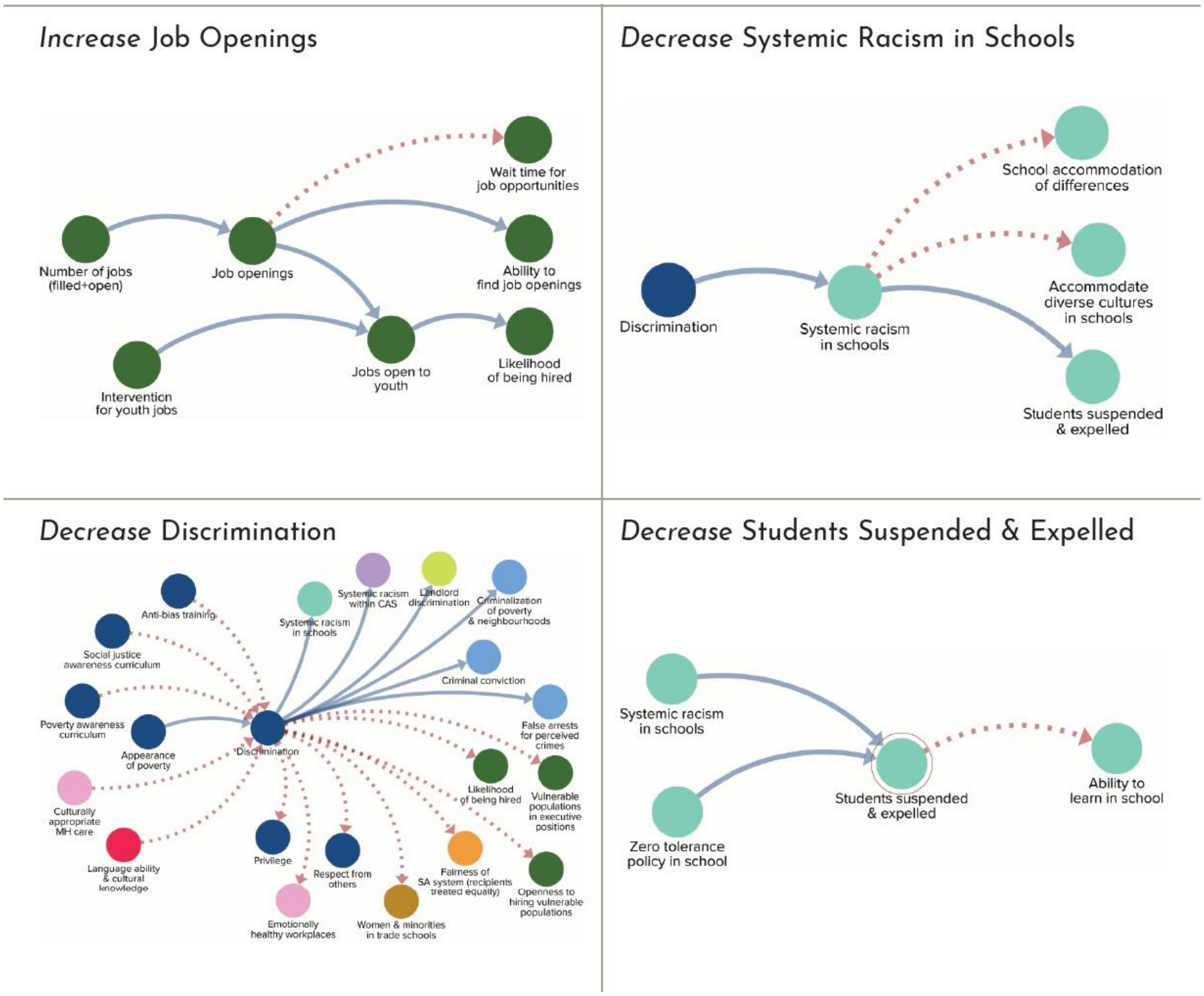

Figure 52: PRM: Sample of objective cards

B.5.1.3 *Scatterplot procedure*

During the workshop, the objective scatterplot exercise followed this procedure:

- Explain the activity, and how to read the objective cards, using the subject area and connection legends.
- Mark the whiteboard with a horizontal axis. Place the Impact label on one end of it. Place the Potential label at the top-middle of the whiteboard.
- Move all criteria cards next to the Impact or Potential axis labels, to combine those criteria into two generalized dimensions for rating. See results in Figure 53 and Figure 54.
- Mark a section of the whiteboard as “Not Sure” and instruct participants: “If you can’t quickly decide an objective’s Impact, put it in the Not Sure zone. When you are finished with your stack, try placing the cards in the Not Sure zone.”

- Instruct participants to place objectives along the horizontal axis, from least to greatest Impact. Vertical placement does not matter at this stage. Participants may review the objectives, discuss their Impact and move them horizontally.
- Draw the vertical axis for Potential. Prompt participants "Are we likely to find multiple interventions that contribute to this Objective, and meet many of the high-ranked criteria?" Instruct participants to move objectives up if they have high Potential, or down if low Potential. (This was only done for objectives rated Impact = 4, 5 or 6.) Participants may review the objectives, discuss their Potential and move them vertically.

B.5.1.4 Scoring and choosing subject areas

After all cards were placed, the following steps were followed to capture Impact and Potential rating data for each objective:

- Mark the whiteboard with vertical lines to split the objective cards into 6 levels of Impact (1, 2, 3, 4, 5, and 6). (This was an arbitrary scale based on the size of whiteboard in use.)
- Mark the whiteboard with horizontal lines to split the objective cards into 4 levels of Potential (A, B, C, D).
- Ask participants to adjust the placement of any cards that straddle two levels of Impact or Potential.
- Photograph the whiteboard. Label each objective card with its Impact and Potential levels (from 6A down to 1D). Pull objective cards off the whiteboard and retain them.
- After the workshop, enter data into the Impact and Potential custom fields in Kumu.

Three participants used subject area legends to count, record and total the number of objectives in each subject area with Impact=4, 5, or 6, high Potential = A or B, and low Potential = C or D.

The top-scoring subject areas were discussed, in tandem with the votes from Workshop 1, to decide on the focus areas for the remaining workshops.

B.5.2 Findings: Objective scatterplot

The Working Group selected Housing and Employment as their focus areas for Workshops 3 and 4. This was largely based on the objective scatterplot activity, which rated 131 objective elements to find the subject areas with the most high-impact, high-potential opportunities for intervention.

The objective scatterplot was a suitable, rapid and effective method for experts to comparatively rate many items. Preparation for the activity was onerous and the scoring procedure was imperfect. As expected, the scores, and results from Workshop 1, were discussed to decide on the final choice of focus areas.

B.5.2.1 Needs for selecting focus areas

The Working Group needed to assess the opportunities for intervention in all the subject areas before deciding which two to focus on. It was successful to consider all of the PRM objectives as these opportunities, in a more detailed and quantitative approach than Workshop 1.

YSM staff appreciated that they needed a ranking process, not just conversation, to choose their focus areas. They saw "weeding out" (prioritization) as a positive. The Potential dimension was important for the Working Group to select objectives where YSM has a higher chance of intervening effectively.

B.5.2.2 Combining criteria into axes for scatterplot

The Working Group decided that for the scatterplot activity, the Impact axis would incorporate some other criteria: Measurability, Evidence, Multiple Effects, and Synergy. The Potential axis would incorporate Reach, Scalability, Total cost, Cost per person, YSM expertise, and the potential to Prevent Poverty and Exit Poverty. Those prioritization criteria are defined in Table 18. The axis combinations are illustrated below:

Figure 53: Criteria used for the Impact axis

Figure 54: Criteria used for the Potential axis

B.5.2.3 *Process observations*

The scatterplot placement took about 25 minutes for 4 participants to complete. This included rating 108 cards on the Impact axis, then rating the Potential of only the cards rated Impact = 4, 5 or 6.

The Working Group did not spend much time discussing the placement of cards. During the Potential vertical rating, a few cards were also moved horizontally, because a participant disagreed with the card's Impact rating by another participant.

During Workshop 2, the scatterplot began on just one 4'x6' whiteboard, but it became too crowded. Participants then spread the cards out over two whiteboards. This confirmed prior calculations that two boards would be needed.

Placing the objectives along continuous scales was unnecessary, as only the 6 levels of Impact and 4 levels of Potential were used. Participants might have had an easier time placing objectives into 6 and 4 delineated levels, without concern for finer gradations.

Figure 55 shows some of the objective cards, placed in the high-impact, high-potential area of the board. The counts of subject areas are visible in this post-workshop photo.

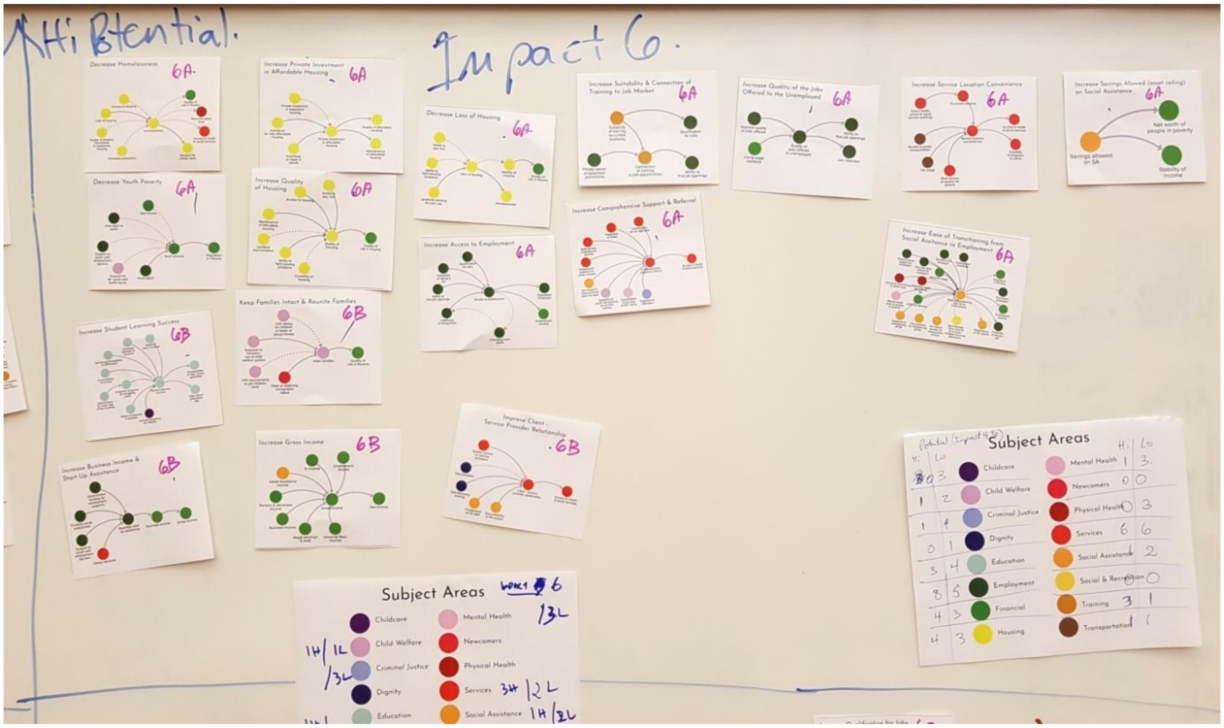

Figure 55: Objectives in the top quadrant of the scatterplot

The Not Sure zone, Figure 56, was effective in preventing participants from contemplating any one Objective for too long, and thus ensured the process was rapid. This photo also shows the legends for subject area colours and connection types, posted on the board as well as provided to each participant.

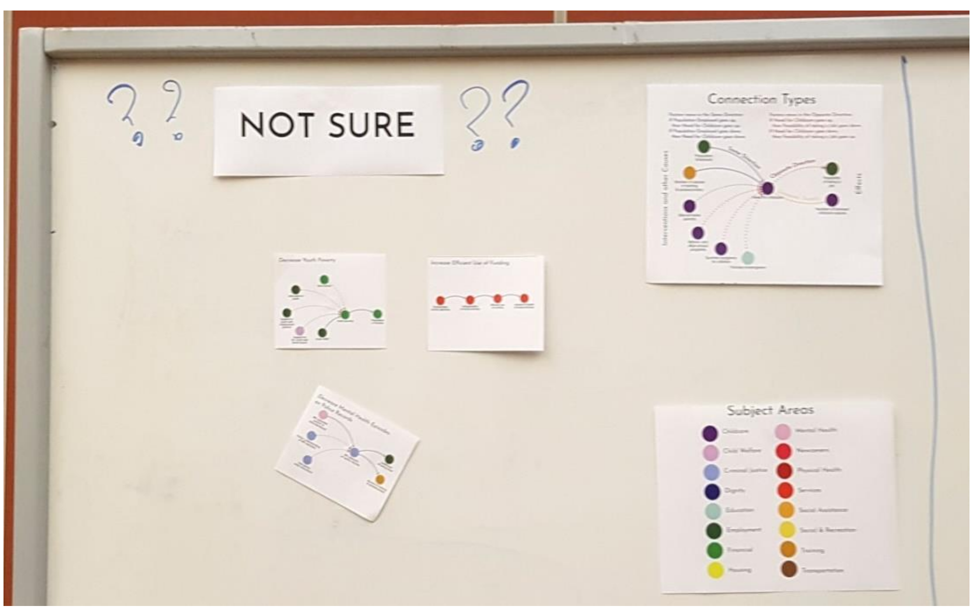

Figure 56: Legends, and the Not Sure zone, for the objective scatterplot

B.5.2.4 *Results of ranking subject areas*

In Workshop 1, Employment was ranked highest (Figure 50), so Workshop 2 did not change that conclusion. Housing was among the subject areas ranked highly in Workshop 1, but Workshop 2 winnowed out some other high-Impact subject areas that would present practical difficulties.

Table 19 compares the Working Group's rankings of subject areas in Workshops 1 and 2. The Working Group considered the scores for both Impact = 6 and Impact = 4, 5 or 6. High-potential objectives were considered more valuable but low-potential objectives also contributed to the choice.

Employment was a top-ranked subject area through both workshops. The transition to employment was a broader theme that relates to other subject areas with moderate to high rankings, such as Social Assistance.

The second focus area was a less obvious choice.

- Mental Health was of great importance in Workshop 1, but the Working Group sees barriers to intervening in that system, so it was a low-potential subject area.
- Services received high ratings across the board. There was concern that this subject area contains generalized objectives and interventions applicable to any social service, so it might be difficult to find direct, actionable and understandable intervention proposals.
- Housing emerged as a strong contender in Workshop 1. It had the most objectives with Impact = 6. YSM has strong knowledge of housing issues and saw great potential for intervention, so it was preferred over Services.

Table 19: Ranking of subject areas in Workshops 1 and 2

Subject area	Votes in Workshop 1	Impact=4, 5 or 6 in Workshop 2		Impact=6 in Workshop 2	
		High potential	Low potential	High potential	Low potential
Childcare	0	0	3	0	0
Child Welfare	2	1	2	1	1
Criminal Justice	5	1	4	0	3
Dignity	0	0	1	0	0
Education	2 with Training	3	4	1	0
Employment	6	8	5	3	1
Financial	3 (Family support)	4	3	2	1
Housing	5	4	3	4	3

Subject area	Votes in Workshop 1	Impact=4, 5 or 6 in Workshop 2		Impact=6 in Workshop 2	
		High potential	Low potential	High potential	Low potential
Mental Health	6	1	3	0	0
Newcomers	0	0	0	0	0
Physical Health	0	0	3	0	0
Services	5	6	6	3	2
Social Assistance	4	1	2	1	2
Social & Recreation	2	0	0	0	0
Training	2 with Education	3	1	1	0
Transportation	0	1	1	0	0

There was a tendency to rate objectives as higher Impact, because "everything is important"; these are all poverty reduction objectives thought to be effective. 66% of the objectives were rated Impact = 5 or 6.

Table 20: Impact and potential ratings from Workshop 2

	Impact					
Potential	**1**	**2**	**3**	**4**	**5**	**6**
A				0	10	12
B				0	5	5
C				2	8	9
D				6	10	9
Not rated	7	11	9			
Total	7	11	9	8	33	35

B.5.2.5 *Assessment of preparation*

The objectives scatterplot was the facilitated exercise that required the most careful planning because of the large size of the model and the limited time available. Design considerations ranged from the element type to be used (intervention vs objective, section B.5.1.1) to the method of attaching cards to the various vertical surfaces available. Calculations included the number of objective cards, layout of template for printing cards, square footage of whiteboard space, and even the quantity of sticky-tack. More pre-planning was needed for the counting and scoring procedure.

Creating the objective cards (Figure 52) was an onerous manual procedure, taking about four days of work for 131 cards. It was thought that showing the inputs and outputs of an objective would be more informative than just naming the objective on the card. This led to manually optimizing the layout of the bloom around each objective, capturing screen-shots, and laying them out in an Adobe Illustrator template. Creating the objective cards manually caused a detailed review and editing of the model, which led to inconsistencies between cards.

The objective card size (4.25" x 3.5") was successful, large enough to read the element labels, but small enough to place many cards on the whiteboard.

B.5.2.6 Assessment of scoring

The 131 objective cards were divided into eight packets of about 16 cards, for the eight expected participants. At Workshop 2, only four participants arrived. The packets of objective cards were gradually reallocated, so each participant rated about 27 cards. Due to an error in reallocating the packets, 23 cards never got rated. Five cards were duplicates, such as different names for the same objective, and were rated twice. After un-duplication, 103 objective ratings were recorded in Kumu. (It is not thought that the missing or duplicate cards made a significant difference in the choice of focus area, which was made by expert discussion informed by the objective scatterplot and the Summary Model.)

Showing the subject areas by colour of element bubble was not effective for determining which subject areas should be the focuses. Sixteen colours are too many to visually distinguish and remember. The bubbles were small in relation to the amount of surrounding white space, so it was not feasible to visually observe the dominance of any subject area colours in the high-Impact, high-Potential portion of the whiteboard.

Because the Working Group could not visually determine which subject areas they had rated highly, it was necessary to count the objectives by subject area, Impact and Potential ratings. This counting procedure was not pre-planned or tested, so some choices were made very quickly during the workshop.

The participants were helpful in improvising a reasonable procedure and implementing it. It took time to resolve confusion amongst participants about what to count and how to notate the tallies.

The results of the objective scatterplot should be interpreted with the following caveats:

- Only the objective (the central bubble on each card) was counted. There was not enough time to tally up the many related elements by subject area, so they did not influence the scores.
- There was no pre-determined rule for how to combine Impact and Potential ratings for a final score. Impact had a greater influence than Potential on the choice of subject areas.

- The tallies were based on six relatively large divisions of the Impact axis, and two divisions of the Potential axis, rather than a more fine-grained rating. Information was lost about the relative sequencing of cards along those axes.
- The scoring method was biased towards subject areas with more objectives.
- A few objective cards contained a chain of two middle elements. When these two elements were in different subject areas, they were assigned arbitrarily to one subject area for scoring.

The Potential ratings were collected as letter values from A to D, which helped to distinguish them from the numeric Impact ratings. Later use of the Potential field in Kumu was limited because it was not numeric.

Any similar scatterplot exercise should be planned with more attention to how ratings would be captured and scores calculated. Online voting software such as Stormz should be considered for easier tallying. More time should be allowed for participants to review each other's ratings and come to consensus.

B.6 Developing housing interventions

B.6.1 Methods: Developing housing interventions

Workshop 3 was planned to develop high-leverage interventions in the Housing subject area. This was a divergent-thinking session to generate new intervention ideas, map their systemic effects and improve their feasibility, using systems-thinking techniques.

B.6.1.1 Preparing for Workshop 3

Housing-related elements of the PRM were tagged with sub-topics (section A.4) to ensure readable small displays. Then participants were invited to browse the Housing subject area of the PRM in advance, and to bring their laptops to view the model during the workshop.

Participants were asked to do some advance reading:

- Slides introducing systems thinking and causal loop diagramming, with an example about housing the homeless (Bergman, n.d.)
- A community-developed causal loop diagram of San Francisco housing affordability (Zhou & Schwartzman, 2013)
- A classic article about making 12 levels of higher-leverage changes in systems (Meadows, 1999).

B.6.1.2 Roles for developing interventions

Participants would be learning about the many considerations in developing a system model. To divide up the cognitive labour, each participant was assigned to one of four roles, with mandates for different tasks. Table 21 summarizes the role instructions (shown in full in section B.6.1.5):

Table 21: Roles for Workshop 3 tasks

Role name	Mandate
Donella	Develop the system model by suggesting cause-and-effect relationships, loops, side-effects and higher-leverage interventions (using Meadows' 12 levels). Consider stakeholder motivations.
Wonky	Analyze and suggest policy interventions, by considering housing types, populations, geographic areas, lifecycles and policy levers.
Popeye	Ensure that the interventions have a strong purpose, a big impact and a lot of leverage. Assign element Impact and connection Strength ratings in Kumu. Look for multiple effects and synergies.
Tillie	Review whether the interventions are practical choices for the YSM demonstration project, and suggest modifications to overcome barriers. Assign Potential rating in Kumu based on prioritization criteria: innovation, cost, YSM knowledge, directness and immediacy.

The role instructions incorporated YSM's prioritization criteria (section B.4.3) and the researcher's analysis of the housing system using Zachman primitives (section 3.6): stakeholder types, housing types, geographic areas, lifecycles, and policy levers.

The roles were designed to introduce playfulness into hard work about a serious topic. Board games such as *Battlestar Galactica* (Konieczka, 2008) and *Pandemic* (Leacock, 2008) inspired the use of "character sheets" to give instructions for these roles. The role names made cultural references to help participants understand their tasks, and to introduce participants to the systems thinking of Donella Meadows.

Each role could be played by one or two participants, depending on how many people attended the workshop. The researcher assigned each role to the participants with the most appropriate systems-thinking skills. Participants were informed of their roles in advance. Popeye and Tillie were asked to register for Kumu accounts so they could modify the PRM during the workshop.

B.6.1.3 Workshop 3 activities

At the workshop, the researcher demonstrated a section of the PRM to explain the model notation. The model was described as an extended Theory of Change, since participants were familiar with that type of cause-and-effect model.

After introducing the roles, the researcher facilitated a discussion of each Housing sub-topic, by showing the objectives, interventions and loops that were already in the model, then asking for modifications and additional intervention ideas.

The researcher displayed the PRM to participants using a data projector, and edited the model "live" so that participants could make comments and corrections as the model developed. Kumu filter and focus features were used to display the elements under discussion. Elements and connections were created, and notes were taken in the element Description field.

B.6.1.4 Process evolution before workshop

Originally Workshop 3 was planned to generate intervention ideas (divergent thinking) and then select the most promising ones (convergent thinking). This was not feasible within two hours, so the selection of promising interventions for short-listing was done by YSM staff between workshops (see section B.7.1).

One option considered for Workshop 3 was the use of "intervention sheets": paper forms that participants would use to rate each Housing intervention on various prioritization criteria. Another option was for all participants to use Kumu to directly fill in custom fields about each intervention. These approaches would have yielded more thorough review of a smaller number of interventions. It was decided to not document the assessment of every criterion for each intervention, but rather to provide a "mental checklist" in the role instructions, so participants would speak up about any interventions that needed revision to meet criteria.

In hopes of finding higher-leverage interventions than already in the model, the researcher tested Meadows' 12 levels of leverage point (Meadows, 1999) by ideating Housing interventions at each of the 12 levels. This generated 30 intervention ideas, which were transformed into facilitation questions for the Working Group, and items in the Donella role instructions. The workshop discussion was not organized around these 12 levels because there were many other criteria to consider.

B.6.1.5 Role instructions

The following instructions were provided on four "character sheets" as described in section B.6.1.2.

B.6.1.5.1 Donella

"A small shift in one thing can produce big changes in everything" – Donella Meadows

What would happen next? Your job is to look for:

- Cause-and-effect relationships
- Loops (balancing & reinforcing)
- Side-effects (positive & negative)
- Higher-leverage interventions

Examine the system model. Add interventions, other factors, and connections.

Higher-leverage interventions, adapted from (Meadows, 1999)

12. Change rates & parameters.

11. Change the size of buffers (stocks that stabilize flows).

10. Change the structure of stocks & flows.

9. Reduce delays.

8. Weaken negative loops.

7. Go faster around positive loops.

6. Change who has access to information.

5. Change the rules, constraints, dis/incentives.

4. Empower someone to change the system structure.

3. Change the goals of the system.

2. Change the mindset out of which the system arises.

1. Transcend the paradigm.

What would they do? Consider motivations & behaviour of stakeholders:

- Homeless
- Tenants
- Landlords
- Public housing providers
- Neighbours
- Governments
- Businesses (construction, realty, mortgages, etc.)

B.6.1.5.2 Wonky

Thinking things through: You are a policy wonk. Your job is to analyze policy interventions, and suggest more.

Analyze Interventions: Is it a policy change? Which law or policy would change? Which jurisdiction? Is it a good fit for YSM?

What would happen if we changed these policy levers?:

- Funding for housing
- Loans & capital for housing
- Housing density, zoning, planning rules
- Housing standards & enforcement
- Rent subsidy rates or rules
- Property tax rates or rules
- Mortgage rates or rules
- Grants & tax benefits
- Taxes, fines & disincentives
- Information provision
- Services connected to housing
- Power balances
- Reactions to behaviours

Which type of housing?

- ❑ Sleeping outdoors
- ❑ Shelter
- ❑ Couch-surfing
- ❑ Transitional
- ❑ Supportive
- ❑ Public
- ❑ Co-op
- ❑ Private rental
- ❑ Condo
- ❑ Freehold

Who does it serve? A small niche or broad population?

- ❑ Street youth
- ❑ Adults in chronic poverty
- ❑ Families in need

- ❑ Other populations

Where would it work?

- ❑ Downtown
- ❑ Suburbs
- ❑ Big city
- ❑ Small town
- ❑ Ontario
- ❑ Canada
- ❑ Other countries

When could we intervene in these lifecycles?

- **Building:** Plan, Build, Move in, Maintain, Renovate, Demolish
- **Ownership:** Purchase, Find tenants, Collect rent, Pay costs, Manage, Sell building
- **Tenancy:** Search, Move in, Pay rent, Make requests, Terminate, Move out
- **Transition:** Leave a place, Homeless, Shelter, Services, Seek housing, Move in

B.6.1.5.3 Popeye

Making stronger interventions: Your job is to ensure that the interventions have a strong purpose, a big impact and a lot of leverage.

Impact: In Kumu, assign the Impact (bubble size 1-6) of each intervention on one person (forward moves in TIMES, or other measurable impact on poverty).

Purpose of Intervention

- ❑ Prevent poverty
- ❑ Exit poverty
- ❑ Alleviate poverty

Objectives: Suggest more interventions to meet the objectives.

Path of Causality: Make sure the system model has a chain of connections to show how the intervention reduces poverty.

Strength: In Kumu, assign the Strength (arrow width 1-6) of each connection. How much does one element affect the next element? How likely is the effect to happen?

Multiple Effects: How many objectives does this intervention contribute to? Could this intervention contribute to another objective?

Synergy: If we combined this intervention with another, would they have a greater effect together than alone?

B.6.1.5.4 Tillie, the Little Engine that Could

Addressing practical objections: Your job is to review whether the interventions are practical choices for the YSM demonstration project. Suggest modifications to overcome barriers!

Scoring Potential: In Kumu, assign the Potential rating (A-B-C-D) to summarize whether the intervention has potential to meet these criteria:

Innovation

- ❑ New to Toronto
- ❑ New to Ontario
- ❑ Modifies something existing
- ❑ Evidence available

Cost per client: (circle order of magnitude) $10, $100, $1000, $10,000, $100,000, $1M +

Annual total cost: Total direct & indirect costs for full-scale implementation: $100K, $1M, $10M, $100M, $1B+

YSM Knowledge: Low, Medium, High

Directness: Low, Medium, High

Immediacy: Low, Medium, High

Other issues

B.6.2 Findings from developing housing interventions

This section provides findings about the facilitated activity to develop Housing interventions. See also section A.1 about integrating this participant input into the model.

B.6.2.1 Participant preparation

Participants were asked to do a large amount of preparation for Workshop 3 (section B.6.1.1). More time was needed; participants asked for materials to be sent at least 1 week in advance. Browsing the model in advance was useful to some participants, and was probably the more valuable part of preparation. Some participants appreciated the pre-readings as grounding in systems thinking. Others did not have enough time to read the articles, or did not apply them much during the workshop.

B.6.2.2 Workshop activity and roles

It took 30 minutes to gather and welcome the participants, assign the roles and tasks (section B.6.1.2), and set up participants' computers to view or edit the PRM in Kumu.

In Workshop 3, the four participants assigned to the Donella and Wonky roles did not perform those systems-thinking tasks. They were mostly new participants, and they were busy speaking about housing issues. Their verbal contributions of expertise were valuable, so the researcher substituted for their roles, by asking systems-thinking questions during the workshop, and editing the model after the workshop. There was not enough time to test the applicability of the 12 levels of leverage (Meadows, 1999).

Active facilitation was needed to limit the workshop time spent on discussing details of policy interventions. Facilitating would have been easier if the researcher had studied local housing policies in advance. Modifying the model "live" in Kumu was difficult, as the topic of discussion changed quickly. The note-taking challenge distracted the researcher from understanding some discussion.

The two participants playing the Tillie and Popeye roles were able to make a small number of ratings in Kumu as instructed. This activity distracted them from contributing to the verbal discussion. Because the PRM was being updated during the workshop, they could not have completely rated the full set of elements under discussion.

It was clear that assigning the four roles imposed too much cognitive burden on an already challenging task: to articulate dozens of policy issues in two hours. The workshop was so busy that nobody had time to open the bags of snacks, even though the crackers contained spinach (to support the Popeye character role).

B.6.2.3 Evolution of the activity for Workshops 3A and 4

Twelve Housing sub-topics had been prepared for Workshop 3. Two sub-topics were thoroughly covered during the allotted time, and five more were discussed but not completely covered. There was not enough time to discuss the remaining five sub-topics, or to review or develop any loops.

The YSM staff decided to hold an extra session to cover the remaining material. At this Workshop 3A, lasting about 90 minutes, the researcher reviewed the 10 under-covered sub-topics with three participants, and gathered additional intervention ideas. No roles were assigned, no ratings were made, and no methodology questions were asked during Workshop 3A.

After experiencing the volume of work required in Workshop 3, participants agreed that the next workshop could be up to three hours long. They also asked to prioritize sub-topics for the Employment workshop in advance.

B.7 Employment agenda-setting

To prioritize the agenda for Workshop 4 (developing Employment interventions, section B.8), the researcher set up an online equivalent of dot-voting using the Stormz.me service. Participants were presented with "cards" showing the first-order blooms around all the objectives tagged "Employment" in the PRM. See the example in Figure 57, which has green bullseyes on objectives and peach bullseyes on goals.

Participants were emailed with instructions to "Vote for the objectives where you think we will find high-impact policy interventions with high potential for the YSM demonstration project. You have 8 votes; you can put more than one vote on an objective." Participants were also encouraged to add intervention ideas as comments on the cards. Participants were given 10 days to do this, with a reminder email the day before the deadline.

The researcher used the voting results to set up sub-topics for Workshop 4, as described in the findings, section B.7.1.

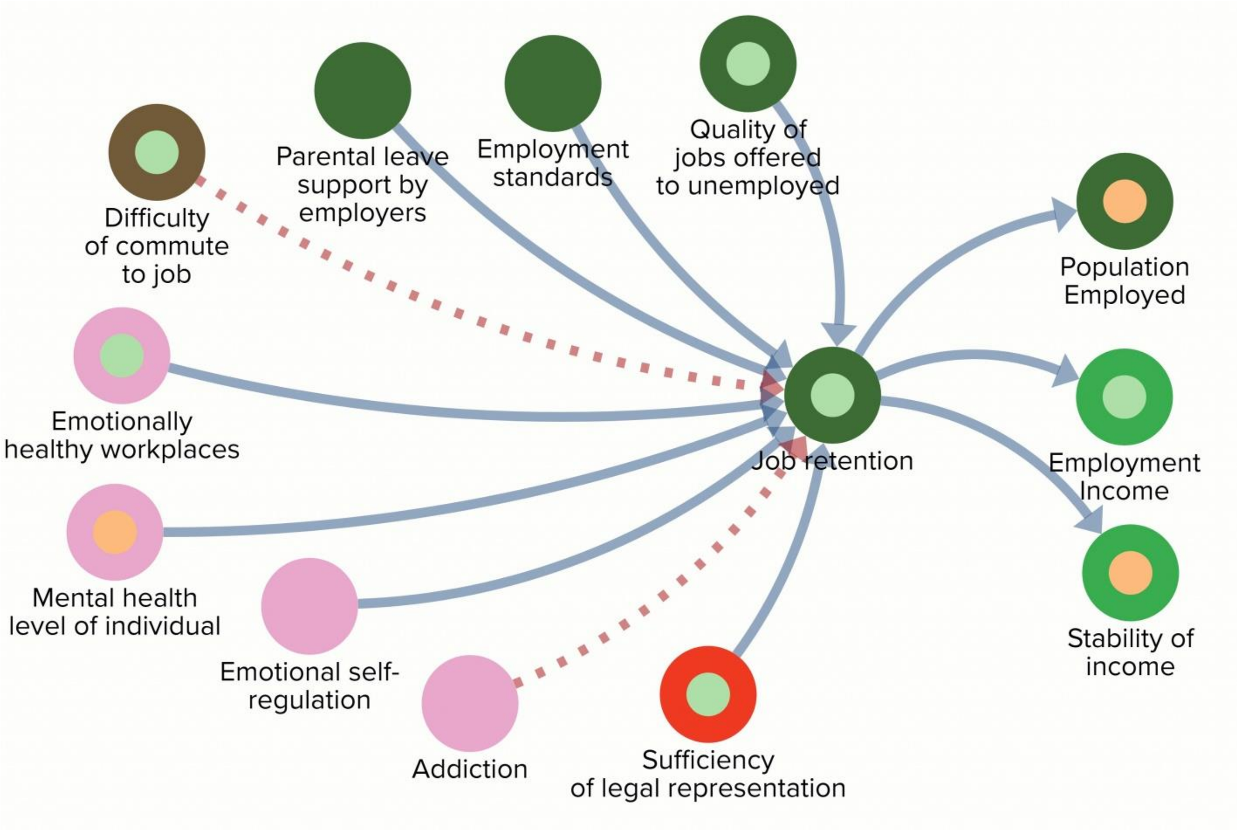

Figure 57: PRM: Employment objective card for *Job retention*

B.7.1 Findings: employment agenda-setting

The Stormz online voting activity was successful in prioritizing the agenda for Workshop 4. It was a suitable method for discerning the relative importance of topics. Workshop 4 participants were comfortable with the agenda sequence.

In this activity, there was a Stormz card (Figure 57) for each of the 25 objectives tagged with Employment in the PRM. The high number of cards, and the amount of information on each, made it difficult to visually scan the options, and took significant time to prepare. Showing only the objective names, not the diagrams for each, would have made the Stormz display easier to prepare and read but less informative. One participant commented that it was helpful to look at the Employment objective cards in advance of the workshop.

Four participants (out of 10 Working Group members invited to Workshop 4) voted for employment objectives. This level of participation was low, calling the voting results into doubt. When the priorities were presented at the workshop (with 7 attendees), there were no requests to change the sequence.

None of the participants made online comments to suggest additional interventions. When asked why they had not, a participant indicated that they preferred in-person interaction to the digital tool, and another said they were “lazy”. One participant said they “don’t want to mess it up” (perhaps not understanding that their comment would not erase any other information on the card).

After the deadline for voting, the votes for objectives were combined into sub-topics (small groups of related objectives) for Workshop 4. The *Job retention* objective received the most votes (6), and there were also 2 votes for the related objective *Quality of jobs offered to unemployed*, and 1 vote for *Difficulty of commute*, so the “employment-retention” tag was applied to elements related to those three objectives. Six sub-topic tags were applied in that fashion.

The Working Group’s votes for Employment-related objectives are shown as bubble sizes in Figure 58. (Bubble colours indicate subject areas, because two related objectives were in other subject areas.) PRM elements were tagged with the six tags (in red), showing the order of the agenda for Workshop 4.

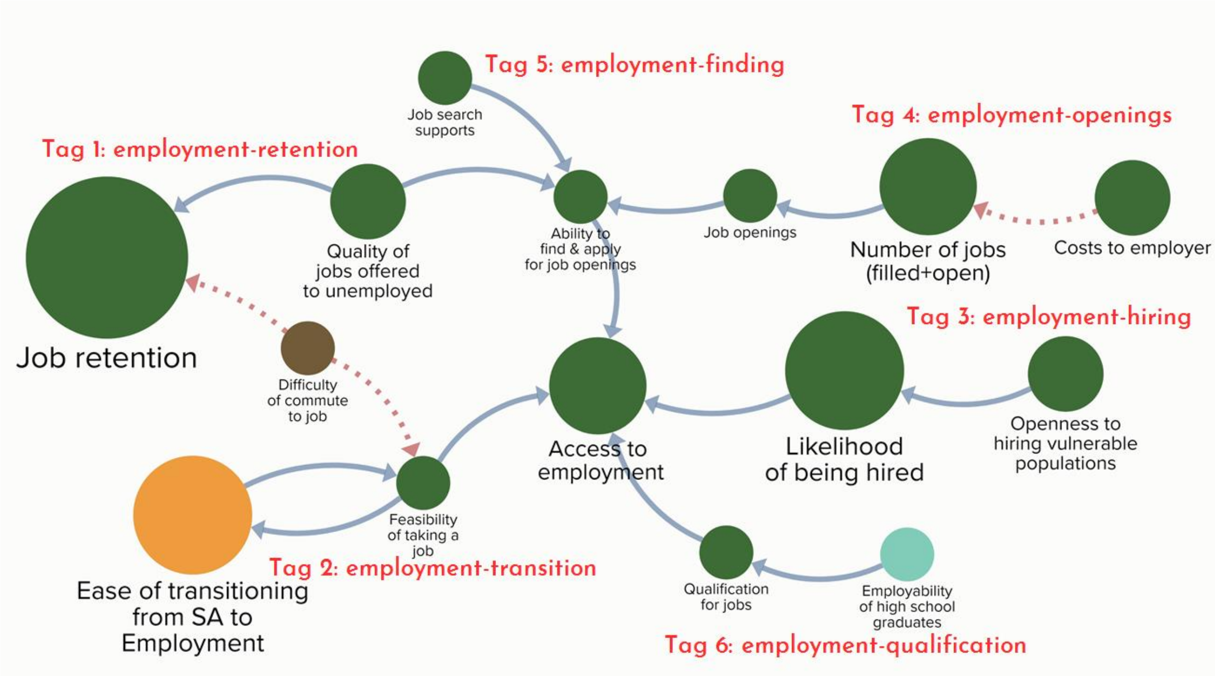

Figure 58: PRM: Employment workshop agenda priorities

B.8 Developing employment interventions

Workshop 4 was planned to develop high-leverage interventions in the Employment subject area. This was a divergent-thinking session to generate new intervention ideas and understand their systemic effects.

Originally Workshops 3 and 4 were to follow the same facilitation method, with different content (Housing then Employment). Because Workshop 3 was overburdened, both with too much Housing content and too many tasks for participants, the method was changed considerably for Workshop 4. The four roles (Table 21) were dropped, so that all participants could focus on a more relaxed group discussion.

Workshop 4 was scheduled for 3 hours, with the hope of ending early. The Employment sub-topics were discussed in the order determined by voting in advance (Figure 58) until participants were fatigued after 2.5 hours.

The researcher facilitated a discussion of each Employment sub-topic, by showing the objectives and interventions that were already in the model. Segments of the PRM were displayed to participants using a data projector, but most of the note-taking was done on a whiteboard.

The Working Group was asked general questions, such as “What are some barriers to job retention”, and was then asked to suggest related interventions. The focus was on generating many intervention ideas, rather than discussing details of each one.

B.8.1 Findings from developing employment interventions

Workshop 4 covered the three highest-priority Employment sub-topics, out of the six prepared (section B.7.1). There was also some discussion of sub-topics that had not been prioritized, for example, the *Credentialism* issue in *Qualification for jobs*.

The more relaxed facilitation style in Workshop 4 was effective, as was free-form notetaking on the whiteboard. Participants generated important insights, such as employees being treated like machines. The Working Group’s conversation roamed freely, and a participant stood up to draw the extended path to employment. Continuous support to people on that path ended up on the Short-List (section 5.2).

Adding the Working Group’s input to the PRM is discussed in section A.1.

B.9 Rating elements

YSM staff were asked to help select a Promising List of about 12 interventions, before Workshop 5. This was done in two stages:

After Workshop 3A, YSM staff were provided with a spreadsheet (Figure 59) of the elements tagged Housing, exported from Kumu, to record their ratings on multiple criteria: Impact, Potential, policy status, innovation status, and relevance to YSM’s three populations. The spreadsheet also had columns for the subject area; the element type, label (name), description, source and tags. It included previous Impact and Potential ratings from the objective scatterplot. The spreadsheet had filters and it controlled the valid values in the criteria columns.

YSM staff were encouraged to browse the PRM in Kumu for information about the elements. It was up to YSM which staff members to include in the rating task. The data included previous Impact and Potential ratings from the objective scatterplot.

Subj Area	Type	Label	Policy?	Innovation ?	Street Youth?	Adults Chronic	Families Need?	Impact (6=hi)	Potential (A=hi)	Description	Source	Tags
housing	Intermediate	Ability to fight housing problems									Alana	Housing|MH-hc
housing	Intervention	Mortgage rates									Alana	Housing|housir
criminal-ju	Objective	Intimate partner violence									Alana	Criminal-Justice
housing	Intermediate	Urban density								- Population pe	Alana	Housing|housir
housing	Intervention	Homeless prevention								A long-term sc	Ontario-stra	Placeholder|ho
housing	Intervention	Tax short-term rentals								AirBnB rentals	YSM-workir	Housing|housir
housing	Intervention	Stackable Benefits								Align the rates	YSM-workir	housing-subsid
housing	Objective	Quality of Housing						6	A	All aspects of	Alana	Housing|MH-hc
housing	Intervention	Laneway housing policy								Allow housing	YSM-workir	Housing|housir
Housing	Objective	Ease of finding housing information								At a given leve	Alana	Housing|housir
housing	Intervention	Base RGI on Net Income						6	C	Base rent sub:	YSM-workir	Housing|housir
housing	Intervention	Rethink approach to housing						6	A	Brent suggest	YSM-workir	Housing|Placeh
housing	Intervention	Base RGI on 25% of gross income						6	C	Calculate rent-	YSM-workir	Housing|housir

Figure 59: Rating spreadsheet 1 (housing)

After Workshop 4, a second spreadsheet (Figure 60) was provided to YSM staff, to rate the remaining elements. The criteria columns were updated based on feedback from rating the first spreadsheet: all interventions were relevant to all three YSM populations. “Rating priorities” were provided so that the Employment-related interventions would definitely be rated, and other elements might also be rated to gather Impact data for all elements.

SubjArea	Type	Rating Priority	Label	Impact (6=hi)	Potential (A=hi)	Policy	Innovation	Source	Tags	Description
employment	Intervention	1	Evaluation framework					YSM-Policy-I	Employment	YSM staff say some ch
mental-health	Intermediate	2	Speed of transition to		NA	NA	NA	YSM-working	edit|Child-welfa	Youth without family su
child-welfare	Intervention		Supports for youth tra	5	A	Yes	Incremental chang	Ontario-strat	Child-welfare|S	Wrap-around support n
transportation	Intervention	1	Shuttle to industrial ar					YSM-working	edit|Employmer	Workplaces on the indu
childcare	Intervention	4	Access to parental de					YSM-Policy-I	Childcare|Child-	Why is this a barrier re
criminal-justice	Intervention	4	Prevention of crime					Alana	Criminal-Justice	Which crime prevention
social-assista	Intervention	1	Awareness of post-er					YSM-working	edit|employmer	When a Social Assistar
housing	Intervention		Offer supports to tena	5	B	No	Exists in Toronto	YSM-working	housing-suppor	When a new tenant is r
housing	Intervention		Eviction regulation cha	5	B	Yes	Incremental chang	Alana	Housing|housin	What other changes ar
child-welfare	Intervention	4	Supports to transition					YSM-Policy-I	Child-welfare|P	What kind of supports?
employment	Intervention	1	Intervention for emotic					Alana	Employment|Pl:	What emotional issues
child-welfare	Objective		Systemic racism withi	6	D	NA	NA	YSM-Policy-I	Child-welfare|D	what does this cause?
mental-health	Objective	2	Life stability		NA	NA	NA	YSM-working	edit|employmer	What does "life stabiliz

Figure 60: Rating spreadsheet 2 (all elements)

After receiving each set of the ratings from YSM staff, the element spreadsheet was imported into Kumu, to update custom fields in the PRM.

Expert time was insufficient for gathering the connection strength ratings, so alternate measures of leverage were attempted, as reported in section 4.6. The final plan was to rely on expert estimations of leverage, via visual observation of the downstream chains in Workshop 5.

B.9.1 Findings: Rating elements

The element rating spreadsheets were a simple, quick, and successful way to gather a large volume of data, but more participation would have increased the quality of data that was used in a key prioritization decision.

During the element rating, YSM staff found that almost every intervention in the PRM would benefit all three populations that YSM serves: Street-involved youth, Families in need, and Adults in chronic poverty.

It was easy to export Kumu data to a spreadsheet, select and add the relevant columns, and set up data validation to check valid values. Sharing the spreadsheets and requesting ratings by a deadline was successful.

YSM staff chose to have only one person fill in the spreadsheets to rate interventions. They were able to fill in the ratings quite rapidly: a total of 6 hours for about 550 elements in the two spreadsheets. This was similar to the decision-making speed observed in the objective scatterplot activity.

Speed may have compromised the quality of these ratings. For example, the intervention *Assess job quality* was top-rated and added to the Promising List. During Workshop 5, it became apparent that the rater had misread this as "Access to job quality", which would be very important given the low quality of jobs available to many people in poverty. The assessment of jobs was not thought as important, and excluded from the short-list scoring.

YSM staff did not filter the spreadsheet to select a Promising List, as suggested. This was left to the researcher.

Once the ratings were made, the spreadsheets were imported to Kumu to update the custom fields of the elements. Kumu imports will update existing elements, where the element label and element type match. Therefore the import procedure was first tested on a copy of the model. There were a few duplicate elements created, where the element name or type had changed between the date of export and date of import. The spreadsheet was manually updated to match the more recent element names and types, and then successfully imported to the production version of the model.

B.10Making the Promising List

The completed element rating spreadsheet 2 was filtered using the following criteria to select the Promising List:

- Interventions, not other element types
- Impact = 6 (highest)
- Potential = A (highest)
- Policy = Yes, a policy change would be required
- Innovation = Incremental change, or New to Toronto (not Exists in Toronto)
- All subject areas were eligible for inclusion.

Intervention elements that were too general would be excluded, pending confirmation with the YSM Director.

Prior to Workshop 5, the Stormz.me online service was set up with a card for each intervention on the Promising List; see example in Figure 61 and Figure 62. In the top half of the screen, the promising intervention was displayed with a black bullseye and its first-order bloom, with elements sized by the Impact ratings. A longer chain of downstream elements was shown in a diagram attached to the card. (See example in Figure 29.) During Workshop 5, this screen also showed three sliders for rating the intervention, from 1 to 10, on the three scoring criteria: Feasibility; Reach, scalability; Leverage, synergy, side-effects.

Six days before the workshop, participants were invited by email to sign into Stormz, review the diagrams, and contribute descriptive text in the fields shown in Figure 62: Jurisdiction, existing policy, proposed policy; Fit to YSM and three populations; Variations on this intervention; and other comments.

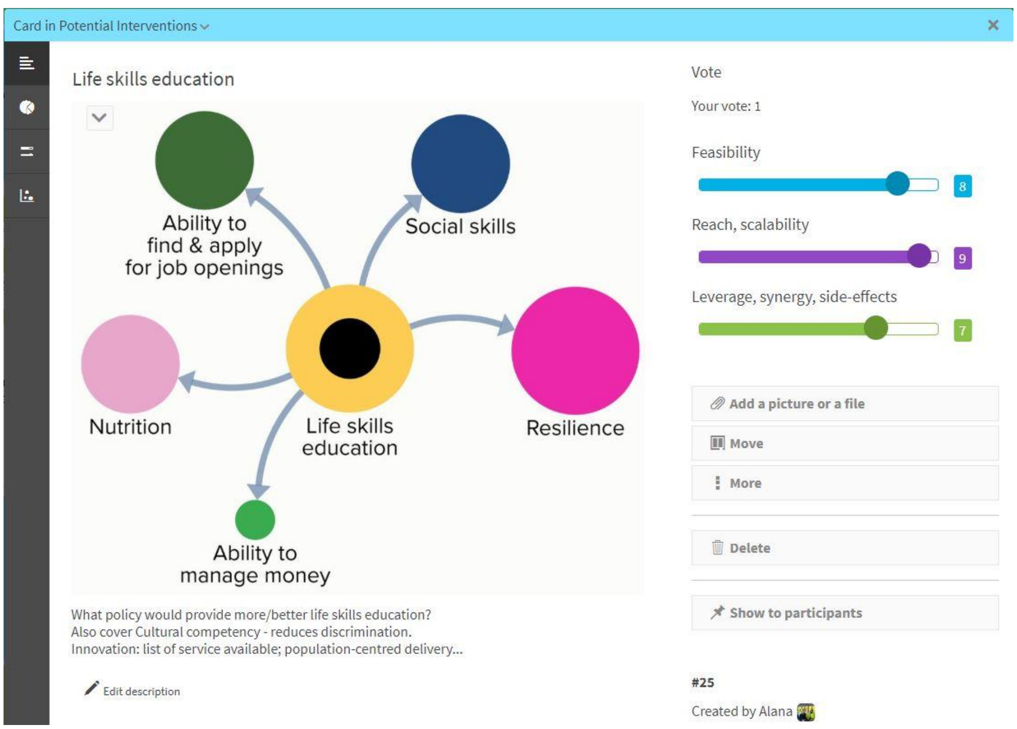

Figure 61: Promising List card for Life skills education, top half in Stormz

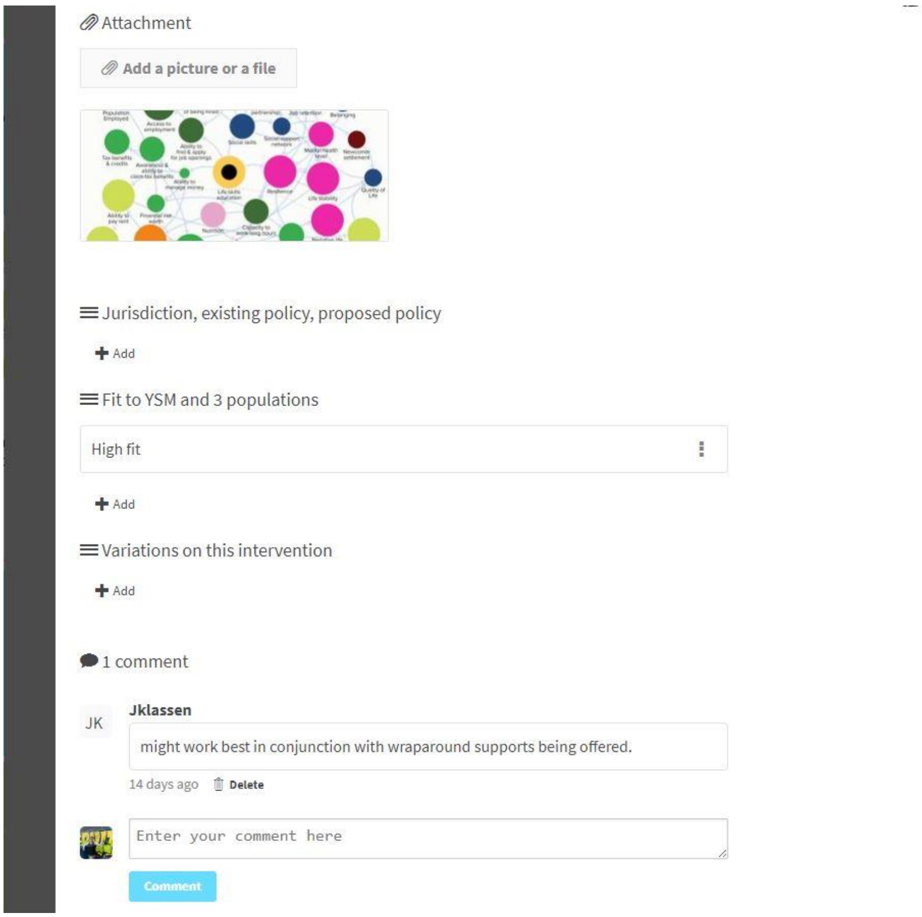

Figure 62: Promising List card for Life skills education, bottom half in Stormz

B.10.1 Findings from making the Promising List

Using spreadsheet filtering to create Stormz cards was an easy and effective way to create and communicate the Promising List. Tagging chains of elements in Kumu was not an ideal way to visualize leverage of each intervention, as discussed in section A.4.3.

It was simple to filter the element rating spreadsheet to select the Promising List according to pre-established criteria. The Promising List was intended to be about 12 interventions, and luckily only 13 met the criteria. Including all subject areas allowed the list to include some interventions that had been discussed but were not classed in the Housing or Employment subject areas.

Displaying the promising interventions in Stormz was effective, though the cards (Figure 61 and Figure 62) became too big to display on-screen due to the amount of information displayed and sought. It took time to carefully set up the steps of the Stormz activity with different displays and permissions for each stage of the prioritization process. As with the Employment agenda-setting (section B.7.1), Stormz cards without images would have been easier to prepare and read but less informative.

Four Working Group members participated in advance to review the interventions. They entered some comments but descriptions were not as fulsome as hoped; some questions would remain for discussion in Workshop 5. Variations on the promising interventions were suggested, so more cards were created.

B.11 Selecting the Short-List

During Workshop 5, the Working Group participated in the following steps to select the Short-List from the Promising List:

1. Review the following scoring criteria (which were amalgams of the prioritization criteria, Table 18) and adjust the weighting:
    a. Feasibility (weight 2)
    b. Reach, scalability (weight 1)
    c. Leverage, synergy, side-effects (weight 3)
2. About 5 minutes was allotted to review each intervention on the Promising List:
    a. Discuss to ensure participants have a common interpretation of the intervention.
    b. Remove interventions that need more clarification or do not qualify for the Short-List.
    c. View the chain of downstream effects, displayed in Kumu by the researcher, to estimate leverage by observation, and to check for unexpected consequences of interventions.
    d. Use Stormz on laptops to rate each intervention on the scoring criteria, using the sliders shown in Figure 61.
3. Review the list of interventions in order by weighted average score. Consider the top 3 for the Short-List, and discuss any adjustments necessary.
4. Confirm that the group is comfortable with the choice of Short-List.

A physical dot-voting method was prepared, with the promising interventions on sticky-notes, as a back-up in case the digital method ran into difficulties.

B.11.1 Findings from selecting the Short-List

The activity in Workshop 5 was effective for quickly comparing the Promising List of interventions against multiple criteria to select a Short-List of interventions that the Working Group is comfortable with.

Participants were invited to discuss the scoring criteria and weighting that had been set up in Stormz. There were questions about how the Working Group's prioritization criteria had been collapsed into the three scales. The following criteria had already been rated or considered in rating elements (section B.7.1) and selecting the Promising List, so were not used in the short-listing activity: Impact, Potential, Innovation, Policy, and YSM population.

The weighting discussion was not well-understood, so it was decided to equalize the weighting, and do some actual scoring as an example. The equal weights remained throughout and produced acceptable results. After scoring the interventions, participants were able to agree on weights: Leverage x3, Feasibility x2, and Reach x1. After the workshop, various weightings were tried in a spreadsheet, with no change in which interventions scored highest.

The two-hour workshop was a very limited time to discuss the 13 interventions on the Promising List, plus variations that were added before and during the workshop. The discussion of criteria was longer than planned, leaving only 4 minutes to discuss each intervention. Participants said afterwards that it was good to have a timer to constrain discussion, although sometimes the busy facilitator forgot to restart the timer.

Those four minutes were sometimes spent clarifying the meaning of a new intervention idea. In other cases, Kumu was used to browse the PRM starting from the intervention and following the downstream chains to estimate leverage. This browsing "moved pretty fast" for participants to follow. Often the browsing was stopped at an element with well-known consequences, to save time. In fact, in most cases it sufficed simply to view the first-order bloom (captured in the Stormz cards). The element bubbles were sized by Impact but this information was not discussed, perhaps because most of the elements in these chains were higher-impact, levels 4-5-6, which were not easily distinguishable sizes in Kumu scaling.

The Stormz service worked well for scoring each intervention on three criteria (below). Electronic input was equalized between outspoken and quiet participants. Participants were excited to immediately view the weighted average scores for each intervention they rated (Figure 63), which took time. YSM staff preferred the online scoring to physical dot-voting, which does not rate multiple criteria.

There were multiple additions and modifications to the Promising List of interventions before and during the workshop. Participants agreed to remove some interventions that were unclear or incorrectly rated (such as *Assess job quality*). One of the highest-rated interventions, *Cost-benefit analysis to justify funding*, was removed from the Short-List because YSM could do it separately from the policy demonstration project.

YSM was encouraged to hold more lengthy discussions about the short-listed interventions, to identify which legislation or policy needs to be changed to enable these interventions, how to improve upon existing versions of these interventions, and how to design a variation of each intervention for each population.

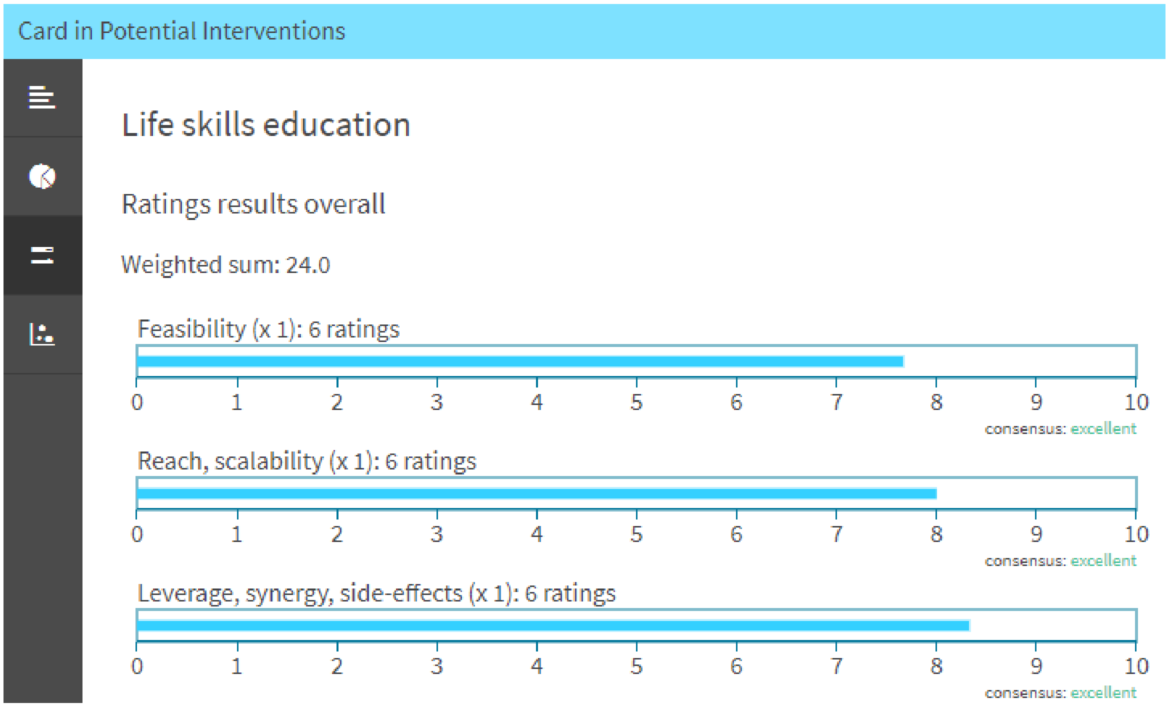

Figure 63: Stormz screen with scores of *Life skills education*

B.12 Hand-off and evaluation meeting

On October 29, 2018, a Hand-Off Meeting was held to complete the case study, and evaluate the usefulness of the PRM. The researcher met for 1.5 hours with the YSM Director and two Working Group participants (also YSM staff), to ask the following questions:

1. Did the prioritization and short-list reflect YSM's **criteria**?
2. Were the **prioritization processes** helpful to compare options?
3. Could you have prioritized well, with a **list** of interventions (no causal connections)?
4. Was the model **useful** to you?
5. How will you **use the model** in future?
6. Does the model's **scope** meet your needs? Why/not?
7. How easy or hard is it to **understand** the model? Why?
8. Does the model content **accurately** reflect reality and best practices?
9. Does the model have the needed level of **description and evidence**?
10. Would the model be more useful to you if it contained more **quantitative** data?
11. Did we (the Working Group, Jeanie, Alana) have sufficient **skills and knowledge** for this process?
12. Are you concerned that our **biases** affected the model and prioritization results?

13. How much **time** did YSM staff spend on this process? Should you have spent more or less time?
14. Based on this process, what would you **recommend** to other organizations?

These questions were revised to reflect the challenges emerging in the study. The original Hand-Off Meeting Guide had these more general questions:

1. Did we achieve the goal of the workshop process?
2. Were the deliverables of sufficient quality? What could have been better?
3. Were the deliverables easy to read and understand? How could the format be improved?
4. How useful were the draft materials in accomplishing the workshops' goal?
5. What have the deliverables been used for? What might they be used for in future?
6. Other than the deliverables, what benefits have or will come from doing the workshop process?
7. How much resources did this process require?
8. What were the down-sides, if any, of doing this process?
9. How well did we handle changes and problems during the process?
10. If an organization had a similar goal, would you recommend this process?
11. Do you have any further feedback to share?

Instruction for updating the deliverables was no longer required in the Hand-Off meeting, as YSM staff were learning the Kumu software independently. Case study results documents were delivered to YSM prior to the Hand-Off Meeting.

YSM's responses to the evaluation questions are incorporated in the findings (chapters 6 and 7).

Photo 13

Appendix C Model analysis

The human eye might detect a rabbit in the wire above. Similarly, computer algorithms might detect patterns in data about complexity. This appendix provides the results of computing model statistics and the Social Network Analysis metrics for the Poverty Reduction Model. These methods were summarized in section 4.5, with methodological findings in section 7.3.

C.1 PRM statistics

C.1.1 Element counts by type, subject area and source

The following tables provide statistics about the contents of the Poverty Reduction Model after all workshops were complete.

Table 22: Element counts by element type and subject area

Subject area	Goal	Objective	Intermediate	Intervention	All elements
Housing	1	35	10	67	113
Employment	1	28	7	48	84
Mental health	1	19	1	18	39
Financial	2	18	2	15	37
Social Assistance	1	14	4	16	35
Services	1	9	0	22	32
Physical health	3	7	3	18	31
Education	2	11	0	18	31
Social & Dignity	2	14	1	11	28
Criminal justice	0	11	4	13	28
Child welfare	1	8	2	14	25
Training	0	7	1	15	23
Transportation	0	5	1	10	16
Childcare	0	4	0	12	16
Other services	0	3	0	7	10
Newcomers	1	2	0	3	6
All elements	**16**	**195**	**36**	**307**	**554**

Table 23: Element counts by source and element type

Source	Goal	Objective	Intermediate	Intervention	All elements
YSM Working Group	0	39	11	85	135
YSM Policy Dialogue (Yonge Street Mission, 2017)	2	41	3	65	111
Toronto Strategy (City of Toronto, 2015)	1	10	1	42	54
Ontario Strategy (Government of Ontario, 2014)	2	15	0	49	66
Income Security Roadmap [4]	0	0	0	1	1
Researcher	11	90	21	65	187
All elements	**16**	**195**	**36**	**307**	**554**

C.1.2 Ratings of elements

The following tables show YSM's ratings of the interventions, after Workshop 4. (Eleven interventions added after Workshop 5 were not rated.)

Table 24: Interventions rated by impact and potential

	Potential					
Impact	A	B	C	D	Blank	Total Interventions
6	29	20	9	9		67
5	25	56	31	8		120
4	4	29	31	14		78
3	1	7	12	4		24
2		1	1	3		5
1				2		2
Blank					11	11
Interventions	**59**	**113**	**84**	**40**	**11**	**307**

[4] Citation: (Income Security Reform Working Group, First Nations Income Security Reform Working Group, & Urban Indigenous Table on Income Security Reform, 2017)

Table 25: Interventions by policy and innovation status

Innovation status	Is a policy change	Not a policy change	Blank	Total Interventions
Exists in Toronto	84	43		127
Incremental change	103	33		136
New to Toronto	30	2		32
Blank	1		11	12
All Interventions	**218**	**78**	**11**	**307**

C.1.3 Connection counts

After all workshops, there were 1,187 connections, 35% of which were between elements in two different subject areas. Most of the connections (77%) were of the Same polarity. The Supply-Demand simplification was only used for 8 connections.

Table 26: Connection counts by type and subject area

Subject area	Same	Opposite	Supply-Demand	Total Connections
Two subject areas	317	95	1	413
Housing	147	54	3	204
Employment	92	22	0	114
Mental health	34	13	1	48
Financial	43	8	0	51
Social Assistance	38	11	0	49
Services	37	2	0	39
Physical health	33	4	0	37
Education	35	6	0	41
Social & Dignity	29	8	0	37
Criminal justice	22	15	1	38
Child welfare	23	11	1	35

Subject area	Same	Opposite	Supply-Demand	Total Connections
Training	27	3	0	30
Transportation	11	13	0	24
Childcare	13	4	1	18
Other services	6	0	0	6
Newcomers	3	0	0	3
Total connections	**910**	**269**	**8**	**1187**

C.1.4 Loop counts

After all workshops, 13 loop names were assigned in the PRM. Of these: Three were balancing loops, while 10 were reinforcing loops. Eleven involved the Housing and/or Employment subject areas. Six were single paths, while seven had multiple paths. See section A.2.1 for examples and explanation of these types of loops.

C.2 Social Network Analysis metrics for PRM

The Poverty Reduction Model was analyzed with Social Network Analysis (SNA) metrics provided by the Kumu software. This computational analysis yielded the following lists:

- Goals and objectives that are central to reducing poverty, Table 27 to Table 31
- Goals and objectives with the most direct influences, Table 32
- Interventions that influence the most objectives directly, Table 33

C.2.1 Interpretation notes

The SNA computations are merely indicative of tendencies in a causal model of directed connections (with arrows pointing in the direction of causality). The SNA metric algorithms are intended for undirected connections in a social network, which has no goal elements. In social networks, the number of connections (steps) in a path is meaningful, whereas paths in the PRM may be of variable length between an intervention and the goal it intends to influence.

All the SNA metrics are affected (biased) by the variable depth and density of various areas of the model. If the workshops and source documents suggested more elements and connections in subject area, it will have more comprehensive coverage in the PRM, and the metrics will be higher for elements in those areas.

In early tests, the SNA metrics were obviously skewed by the variable depth and density of the early PRM, so the results were not valid input to the prioritization process. After all workshops, the PRM is more comprehensive and the SNA metrics yield more meaningful results.

None of these metrics are weighted, because the connection strength data was not collected from experts. If the strength of causality were known, it could be used to weight SNA metrics for more meaningful analysis of centrality and influence.

All the SNA metrics available in Kumu were tested on the PRM, after all workshops. Only meaningful metrics are included in this analysis. Some are shown for all elements, some for interventions only, depending on which was meaningful.

C.2.2 Top goals and objectives by SNA metrics

Social Network Analysis metrics were found to produce similar lists of important goals and objectives in reducing poverty. Section 5.3.4 combines the following top-ten lists.

Out-degree is the count of direct connections outgoing from an element (Kumu, n.d.-b). In a causal model, high out-degree means that a variable factor can directly influence many other factors. This means there are many paths from the factor to (ultimate) goals, so out-degree is a preliminary indication of factors with higher leverage in the model.

Table 27: Top ten goals & objectives by Out-degree

Type	Subject Area	Element Label	Out-degree
Objective	social-dignity	*Discrimination*	16
Goal	mental-health	*Mental health level*	15
Objective	services	*Access to health & social services*	11
Objective	housing	*Homelessness*	9
Objective	newcomers	*Language ability & cultural knowledge*	9
Goal	physical-health	*Physical health level of individual*	8
Objective	housing	*Supply of low-cost housing*	8
Goal	financial	*Net income*	8
Objective	mental-health	*Addiction*	7
Objective	financial	*Employment Income*	6

Reach "measures the portion of the network within two steps of an element" (Kumu, n.d.-b). It includes paths incoming to and outgoing from an element, so reach is a rough approximation of influence within a causal model. Causality weakens with each step outwards from an element, so the reach measure concentrates on stronger causality. *Discrimination* and *Mental health level* have the highest reach in the PRM.

Table 28: Top ten goals & objectives by Reach

Type	Subject Area	Element Label	Reach
Objective	Social & Dignity	*Discrimination*	0.070
Goal	Mental health	*Mental health level*	0.070
Objective	Services	*Access to health & social services*	0.067
Objective	Newcomers	*Language ability & cultural knowledge*	0.067
Objective	Mental health	*Addiction*	0.061
Objective	Housing	*Homelessness*	0.060
Goal	Physical health	*Physical health level of individual*	0.058
Goal	Child welfare	*Abuse & neglect of children*	0.045
Objective	Mental health	*Level of treatment of mental illness*	0.045
Objective	Mental health	*Access to MH care*	0.045

Closeness is a measure of centrality, based on the number of connections needed to get from one element to all other elements in the model. Closeness is high for central elements with shorter paths to all other elements (Denny, 2014). This metric ignores the direction of a connection. Goals and objectives with high closeness, such as *Discrimination* and *Access to health & social services*, are related to many subject areas of the PRM.

Table 29: Top ten goals & objectives by Closeness

Type	Subject Area	Element Label	Closeness
Objective	Social & Dignity	*Discrimination*	0.123
Goal	Mental health	*Mental health level*	0.116
Objective	Services	*Access to health & social services*	0.120
Objective	Newcomers	*Language ability & cultural knowledge*	0.115

Type	Subject Area	Element Label	Closeness
Objective	Mental health	*Addiction*	0.106
Objective	Housing	*Homelessness*	0.112
Goal	Physical health	*Physical health level of individual*	0.104
Goal	Child welfare	*Abuse & neglect of children*	0.094
Objective	Mental health	*Level of treatment of mental illness*	0.096
Objective	Mental health	*Access to MH care*	0.094

Betweenness is a measure of centrality, measuring "how many times an element lies on the shortest path between two other elements" (Kumu, n.d.-b). High betweenness indicates an element that bridges less-connected parts of the model, such as *Access to health & social services*. Intervening in an objective with high betweenness, such as *Mental health level,* could have effects in multiple subject areas. This metric ignores the direction of a connection, so the results should be seen as an approximation.

Table 30: Top ten goals & objectives by Betweenness

Type	Subject Area	Element Label	Betweenness
Goal	Mental health	*Mental health level*	0.096
Objective	Services	*Access to health & social services*	0.062
Objective	Financial	*Employment Income*	0.059
Goal	Social & Dignity	*Quality of Life*	0.051
Objective	Housing	*Homelessness*	0.050
Objective	Training	*Access to training & postsecondary*	0.046
Objective	Social & Dignity	*Discrimination*	0.042
Objective	Employment	*Access to employment*	0.040
Objective	Newcomers	*Language ability & cultural knowledge*	0.036
Goal	Physical health	*Physical health level of individual*	0.034

Eigenvector is a measure of centrality, measuring "how well connected an element is to other well connected elements" (Kumu, n.d.-b). In the PRM, Eigenvector is highest for *Employment income*, *Gross income* and *Quality of life*. This metric ignores the direction of a connection, which explains why it highlights both *Quality of life* (an ultimate goal) and income, which is a major determinant of quality of life.

Table 31: Top ten goals & objectives by Eigenvector

Type	Subject Area	Element Label	Eigenvector
Objective	Financial	*Employment Income*	0.031
Objective	Financial	*Gross income*	0.031
Goal	Social & Dignity	*Quality of Life*	0.029
Goal	Mental health	*Mental health level*	0.025
Objective	Social & Dignity	*Social desirability*	0.023
Objective	Social Assistance	*Social Assistance income*	0.020
Goal	Employment	*Population Employed*	0.019
Objective	Employment	*Job retention*	0.019
Goal	Financial	*Population in Poverty*	0.019
Goal	Social Assistance	*Ease of transitioning from SA to Employment*	0.018

C.2.3 Top elements by in-degree

In-degree is the count of direct connections incoming to an element. In a causal model, high in-degree means that a variable factor can be directly influenced by many other factors. It might identify major factors in the model.

In the PRM, the in-degree metric is high for some goals and objectives, not other element types. Examining the blooms around the PRM elements in Table 32 shows there can be many reasons for high in-degree. It can indicate a major factor affected by many smaller objectives and interventions such as existing government programs. In-degree is also higher for topics that received more attention in the workshops and source documents, meaning it is biased by the variable depth of the model. When a major element is split up (section A.2.4), its in-degree is artificially reduced.

Table 32: Elements with highest in-degree

Type	Subject Area	Element Label	In-degree	Why many incoming?
Objective	Housing	*Supply of low-cost housing*	22	Interventions generated
Goal	Social & Dignity	*Quality of Life*	16	Goals & objectives lead to this fundamental goal
Objective	Training	*Access to training & postsecondary*	15	Many issues identified, Many existing interventions
Objective	Services	*Comprehensive support & referral*	15	Common property of many interventions
Objective	Employment	*Likelihood of being hired*	14	Many issues identified
Objective	Employment	*Ability to find & apply for job openings*	14	Many issues identified
Objective	Employment	*Job retention*	13	Many issues identified
Goal	Social Assistance	*Ease of transitioning from SA to Employment*	12	Many issues identified
Objective	Housing	*Ability to pay rent*	12	Many issues identified
Goal	Physical Health	*Personal safety level*	12	Many issues identified
Objective	Housing	*Quality of Housing*	11	Many issues identified
Objective	Employment	*Qualification for jobs*	11	Many issues identified
Goal	Physical Health	*Physical health level of individual*	11	Many issues identified
Goal	Mental Health	*Mental health level*	10	Multiple major influencers
Objective	Social & Dignity	*Social support network*	10	Multiple similar concepts
Objective	Employment	*Number of jobs (filled + open)*	10	Many existing interventions
Objective	Transportation	*Difficulty of commute*	10	Many issues identified
Objective	Employment	*Merit-based hiring*	10	Interventions generated

C.2.4 Top interventions by out-degree

The PRM interventions with high out-degree are each influential on multiple objectives, either as a key factor in one subject area (such as *Funding for housing*) or as a system-wide intervention (such as *Coordination across agencies*). In the PRM, *Government support for collective services* is directly influential on funding in all subject areas.

Comparing the out-degree metric and the expert ratings from YSM might reflect on the meaningfulness of the quantitative metric and also on the reliability of the expert ratings. Interventions on the Short-List and Promising List sometimes but not always had high out-degree. Those with high out-degree appear in Table 33. The promising and short-listed interventions with lower out-degree are in Table 34. (Interventions without an Impact rating were added during Workshop 5.) There was a low statistical correlation between out-degree and YSM's Impact scores. (The correlation coefficient was 0.049, which rose to 0.080 after excluding the outlier *Government support for collective services*).

Table 33: Interventions with highest out-degree

Subject Area	Intervention	Out-degree	Short-listing	Impact
Services	*Government support for collective services*	15		4
Physical Health	*Funding for healthcare*	8		6
Housing	*Funding for housing*	8	Too general	6
Other Services	*Life skills education*	8	Short-List	6
Housing	*Rethink approach to housing*	8	Too general	6
Other Services	*Library services*	7		1
Social Assistance	*OW intensive case management by agencies*	6		5
Employment	*Wraparound supports for path to employment*	6	Short-List	6
Housing	*Wraparound supports in housing*	6	Promising	6
Transportation	*Bicycle lanes & supports*	5		1
Services	*Coordination across agencies*	5		6
Employment	*Job programs for youth*	5		6
Social Assistance	*Savings allowed on SA*	5	Promising	6

Subject Area	Intervention	Out-degree	Short-listing	Impact
Social Assistance	*Social Assistance rates*	5		4
Social & Dignity	*Social support programs*	5		5
Housing	*Stackable Benefits*	5	Promising	6
Child Welfare	*Supports for youth transitioning out of child welfare*	5		5

Table 34: Promising and short-listed interventions with lower out-degree

Subject Area	Intervention	Out-degree	Short-listing	Impact
Housing	*Portability of rent subsidy*	3	Short-List	6
Housing	*Housing First model*	2	Promising	6
Criminal Justice	*Legal assistance for pardons*	2	Promising	
Housing	*National housing strategy*	2	Too general	6
Housing	*Trusteeship of rent*	2	Promising	5
Services	*Cost-benefit analysis of poverty reduction*	1	Just Do It	
Social Assistance	*Disincentives for transitioning off SA*	1	Too general	6
Social Assistance	*Supports for transitioning off SA*	1	Too general	6