An Evaluation of How Systems Thinking Can Improve Regulation

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A thesis submitted to Te Herenga Waka – Victoria University of Wellington

in partial fulfilment of the requirements for the degree of

Master of Commerce in Public Policy

Te Kura Kāwanatanga – School of Government

Te Herenga Waka – Victoria University of Wellington

February 2022

Abstract

Modern regulators are expected to manage an increasing range of risks, respond to complex factors, and contribute to the management of their regulatory systems. Systems thinking can help understand and manage complexity. While there are examples of systems thinking being applied to regulation and regulatory strategies, there is little empirical evidence as to whether and how it can be applied to improve regulation.

I identify 17 common types of systems thinking, of which I select five (rich pictures, causal loop diagrams, stock and flow diagrams, system archetypes and social systems theory) to apply to the case study of drinking water regulation in New Zealand. Based on a desktop exercise, I then evaluate rich pictures, causal loop diagrams and system archetypes in interactive workshops with 21 regulatory practitioners. The regulatory practitioners enjoyed, valued and were able to apply rich pictures, causal loop diagrams and, to a lesser extent, system archetypes in the interactive workshop and intended to apply them in their work. However, interviews after a month revealed that they had not applied these types of systems thinking in their day-to-day work.

The regulatory practitioners did report using systems thinking concepts to be more systemic when they thought and asked questions about their regulatory system. However, they did not apply systems thinking concepts through any structured process, nor did they construct systems models which could be seen and shared.

My research highlights that increasing levels of individual capability, structural support and effort are required as system thinking progresses from understanding, to communicating, to analysing and finally to acting in real-world situations. Further application of systems thinking in regulation could be supported through further training, more detailed guidelines, organisational support or a more specific government mandate on how regulatory agencies take a "whole-of-system view" of their regulatory system.

Keywords: Systems Thinking, Complexity, Rich Pictures, Casual Loop Diagrams, Systems Archetypes, Regulation, Regulatory Systems, Drinking Water, New Zealand

Acknowledgements

I would like to thank my supervisor, Jeroen van der Heijden (Victoria University of Wellington), for sharing his systemic insights across regulation and systems thinking, as well as his systematic guidance through the process of researching and writing this thesis. I would like to acknowledge the people from the regulatory agencies who participated in my workshops to evaluate systems thinking and the Government Regulatory Practice Initiative (G-Reg) for facilitating the engagement with these regulatory agencies.

I would like to thank my managers for their support in pursuing this research and for giving me flexible work arrangements to complete it.

I would like to thank Andrew Watson, Paul Prendergast, Heather Uwins-England and Nick Hewer-Hewitt for sharing their wisdom and experience as I have learnt about drinking water regulation.

I need to thank my mother, for graciously accepting a draft of my thesis and a red pen as a Christmas present, as the thoughtful feedback and edits she gave in return.

Finally, I need to thank my wife and children for giving me the time and unwavering support to complete this thesis.

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1 Introduction

Modern regulators are expected to manage an increasing range of risks, respond to complex factors, and contribute to the management of their regulatory systems. Systems thinking can help understand and manage complexity. This research will explore the extent to which systems thinking is already applied within regulation and empirically evaluate how systems thinking can improve regulation through a desktop exercise and an interactive workshop.

1.1 Challenges in Regulation

Regulation describes the tools and activities to modify behaviours according to defined standards (Hood, 2001; Black, 2001; Windholz, 2017). There is a growing public expectation that this regulation will reduce a broader range of risks, while the nature of our modern society is increasing the uncertainty of these risks (Windholz, 2017). Regulators need to respond to an increasingly complex range of factors and contribute to the monitoring and improvement of the regulatory system as a whole, referred to as regulatory stewardship in New Zealand (New Zealand Productivity Commissioner, 2014). The need to direct regulator's limited resources more effectively and efficiently has led to the evolution of regulatory strategies from responsive regulation, smart regulation, problem-based regulation, risk-based regulation to really responsive regulation. However, these strategies are not a silver bullet, and regulators face a range of challenges with limited resources.

1.2 What is Systems Thinking?

Systems thinking describes a conceptual framework with a collection of ideas and tools to help understand and manage complexity (Senge, 1990; Checkland, 1981). A system is a set of interacting elements (von Bertalanffy, 1969). System thinking encourages a holistic perspective with an appreciation for how feedback mechanisms can result in non-linear responses and emergent behaviour within a system (Meadows, 2008). Systems thinking tools, theories and approaches provide ways to understand and improve real-world situations.

1.3 Systems Thinking in Regulation

There is an appreciation of systems through the consideration of "regulatory systems" (New Zealand Treasury, 2017) and appreciation that system dynamics of multiple pressures and competing forces are important in regulation (New Zealand Productivity Commission, 2014). While many examples of systems thinking are being applied to regulation, there is a lack of empirical evidence around the improvements they offer (Van der Heijden, 2020). There is an opportunity to investigate how regulatory practitioners can apply systems thinking to understand and improve their regulatory systems.

1.4 Research Objective

This research will provide new empirical evidence on how regulatory practitioners can apply systems thinking to improve the design and implementation of regulation. I will identify what types of systems thinking could be valuable in solving specific challenges in regulation and which of these can be practically applied. Evaluating the application of these types of systems thinking will provide empirical evidence on whether and how systems thinking can improve regulation.

The research objectives are to (1) identify types of systems thinking for regulatory practitioners to apply to improve design and implementation of regulation; (2) provide lessons on when and how to apply systems thinking in regulation and related fields.

1.5 Structure

Chapter 2 reviews systems thinking literature, identifying the 17 systems thinking concepts, tools (for developing and communicating system models), approaches (for driving action), and theories (for analysing real-world situations through a systems perspective). Chapter 2 answers the research questions:

- *What are the different types of systems thinking?*
- *What is the value of system thinking?*

Chapter 3 reviews literature on regulation to describe different regulatory tools, the evolution of regulatory strategies over the past 30 years, and current regulatory challenges in New Zealand. This chapter will also explore the extent to which systems thinking is already present in regulation, particularly the concept of a "regulatory systems". Existing system thinking will guide how system thinking can improve regulation. Chapter 3 answers the research questions:

- *What current challenges in regulation might be addressed by systems thinking?*
- *To what extent is systems thinking already being applied in regulation?*

Chapter 4 develops my primary research question about which specific types of systems thinking, identified in Chapter 2, might address the regulatory challenges from Chapter 3. These types of systems thinking will need to be applied by regulatory practitioners and evaluated within the scope of this research project. Chapter 4 answers the research question:

- *Which types of system thinking can be evaluated, which might be applied by regulatory practitioners to improve regulation?*

Chapter 5 develops a case study of the events, organisations, legislation and regulatory tools involved in the evolving drinking water regulatory system in New Zealand. I use this case study in my desktop application of systems thinking in Chapter 6, providing examples for the interactive workshop in Chapter 7. Chapter 5 answers the research question:

- *How has drinking water regulation evolved in New Zealand?*

Chapter 6 describes my desktop application of systems thinking to drinking-water regulation. This desktop exercise is the first stage of a two-stage evaluation of system thinking in regulation. The second stage is the interactive workshop with regulatory partitioners described in Chapter 7. It is quicker and more efficient to answer my primary research question through the desktop exercise, increasing the likelihood of a more successful interactive workshop with regulatory practitioners. Based on the desktop exercise, I will also develop guidance for how regulatory practitioners can apply systems thinking in the interactive workshop. Chapter 6 answers the research questions:

- *Whether and how can systems thinking be applied to drinking-water regulation in New Zealand?*
- *What value does systems thinking offer drinking-water regulation in New Zealand?*

Chapter 7 presents an analysis of the interactive workshop where I evaluate the application of systems thinking by regulatory practitioners. This evaluation analyses a combination of empirical quantitative and qualitative data from a pre-questionnaire, workshop activities, a post-questionnaire and follow-up semi-structured interviews. I explore the participant's reactions, learnings, behaviour change and results of their application of systems thinking. Chapter 7 answers the primary research question:

- *Whether and how can systems thinking be applied by regulatory practitioners to improve the design and implementation of regulation?*

Chapter 8 concludes this thesis by comparing the findings from my evaluation to the existing literature, refining the workshop design, providing lessons on when and how to apply these systems thinking in regulation, and identifying opportunities for further research.

1.6 Research Boundaries

This research is an academic undertaking to explore the application of systems thinking by regulatory practitioners. It is limited to the design and implementation of regulation, focusing on regulation that reduces the risk of harm. It is not a comprehensive inventory of systems thinking, nor are they a rigour analysis of the most popular types of systems thinking. The research will focus on a range of common types of systems thinking and systems thinking that has been applied to regulation.

1.7 References

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2 Systems Thinking

This chapter categorises 17 types of systems thinking as concepts, tools, approaches and theories to help appreciate complexity in real-world situations. System thinking *concepts* can be used to understand real-world situations by considering them as systems. Systems thinking *tools* provide ways of describing and communicating real-world situations as a system models. Systems thinking *theories* can help analyse and understand real-world situations through a systems perspective. Systems thinking *approaches* provide systematic processes to engage stakeholders and inform actions in the real-world. The 17 types are not a comprehensive inventory of systems thinking, nor are they a rigorous analysis of the most popular types of systems thinking. They have been selected as some of the most common types of systems thinking as well as types of systems thinking which have been applying to regulation. I conclude this chapter by summarising the benefits and limitations of systems thinking. Chapter 4 refines the selection of 17 systems thinking concepts, tools, approaches, and theories to identify which ones might be applied by regulatory practitioners to improve regulation.

2.1 What is a System?

Von Bertalanffy's (1969, p. 33) defined a system as a "complexes of elements standing in interaction", distinguished from its environment by a boundary, through which there may be a flow of energy, information or resources. The behaviour of a system emerges from the interactions between its elements and cannot be attributed to the individual elements (Meadows, 2008). Systems can be classified according to their connectivity, rate of change and their purpose (Checkland, 1981, after Jordan, 1968). The idea of systems has been used to describe a range of things, including individual people (Von Bertalanffy's, 1969), organisations (Beer, 1972), cities (Forrester, 1969), society (Luhmmn,1995), to the environment (Lovelock, 2000) to regulation (New Zealand Treasury, 2017).

2.2 Complexity

The idea of systems is closely associated with complexity, with Boudling (1956) using complexity to classify a hierarchy of systems static structures to mechanical, biological and social systems. Complexity can describe a system's structure and behaviour (Simon, 1962; Senge, 1990; Dekker, 2014). Self-organisation, anticipation and evolution are complex systems' properties (Holland, 1992, Geyer and Rihani 2012; Dekker, 2014). These properties and the involvement of conscious actors (Checkland, 1981) mean that real-world situations adapt in response to how we understand them. In this research, I will use complexity to describe the first challenge to understand a large number of elements, their interactions, and their emergent behaviour; and the second challenge that this behaviour may also change in response to our understanding of it. I consider the relative interpretation of complexity rather than an absolute distinction between complex and not complex. Complexity means there may be a limit to what we can know about real-world situations (Von Hayek, 1969); however, there is no limit to what we can learn (Geyer and Rihani 2012).

2.3 Evolution of System Thinking

Descartes' reductionist method was a driving force behind the western scientific revolution, solving problems by progressively dividing them into smaller parts and examining them to understand the whole. In the 20th century, progress into biological sciences tested the limits of the reductionist method, leading to Von Bertalanffy's (1969) general systems theory to explain the behaviour of biological organisms without resorting to metaphysical "vitalism". General systems theory acknowledged that the whole could be more than the sum of its parts.

Systems thinking still uses reductionist methods to identify a system's elements, interactions and boundary, but uses this with a systemic perspective to appreciate how these parts behave as a whole.

In the mid-20th century, systems thinking, including systems analysis and engineering, was used to understand "hard" real-world situations, such as deterministic, mechanical and electrical applications in defence and aerospace. System thinking has developed further through its application to "soft" real-world situations, involving people, who may be involved in, and respond to our understanding of real-world situations. Associated with the distinction between hard and soft systems thinking is the ontological consideration of whether systems exists in the real-world (Forrester, 2007) or are just a heuristic model that is useful for understanding the real-world situation (Checkland, 1981). Regulation, the focus of this research, involves people. Therefore I will follow an interpretive perspective, considering systems as models to help understand real-world situations. This perspective also appreciates that people have different mental models, through which they see the world and systems thinking can help to surface, share and refine the assumptions, filters and biases in these mental models of the real-world (Senge, 1990; Meadows, 2008; Stroh, 2015).

Systems thinking addresses the first challenge of complexity through the appreciation and modelling of elements, their interactions, and their emergent behaviour. Systems thinking encourages shared and continuous learning, which addresses the second challenge of complexity that this behaviour may also change in response to our understanding (Senge, 1990).

2.4 System Thinking Concepts

System thinking *concepts* can help to understand real-world situations by considering them as systems with interacting elements distinguished from their environment by a boundary. People can use systems thinking concepts to construct their mental models.

2.4.1 Things → Relationships

While a reductionist method divides systems into constituent parts, systems thinking is just as interested in the relationships or interactions between them.

2.4.2 Closed → Open

Classical western science deals with closed systems of elements interacting in isolation from any environment. Von Bertalanffy (1969) recognised that biological organisms were open systems with high degrees of interaction with their environment but could also display a steady-state similar to a closed system through a dynamic equilibrium. Boundaries identify elements as part of a system or part of its environment and identify the interaction between a system and its environment. This boundary may be based on a higher degree of connectivity between elements, the purpose of the system, or an area of decision making authority (Dekker, 2014; Wilson and Haperen, 2015). But systems boundaries can also be based on words or constructs, aligned with a discipline that may be no longer useful for understanding the system (Meadows, 2008). In some situations, we may not know where to usefully draw a system boundary to isolate the problem or understand the relevant interactions between the system and its environment (Checkland 1981).

2.4.3 Linear → Feedback

Many methods for understanding the real-world divide it into a linear sequence of elements, such as events in a causal chain, words in proses or tasks in a plan. Systems thinking appreciates the web of non-linear interactions between elements, particularly circular feedback loops (Stroth, 2015). Feedback loops may be reinforcing, driving either exponential growth or decline within a system, or balancing, helping a system achieve or maintain a specific goal (Senge, 1990). The flow of information can play an important role in feedback loops, particularly for providing feedback on a system's performance controls its operation (Meadows, 2008). Feedback can occur over different frequencies: simultaneous feedback loops break down traditional linear analysis, while delays obscure feedback loops and their impact (Meadows, 2008). The structure of a system will determine the feedback loops, which will determine the behaviour of the system.

2.4.4 Events → Structures

Systems thinking involves moving back and forth between the events, behaviours and structures (Meadows, 2008; Checkland, 1981). Rather than reacting to individual events, systems thinking encourages looking for trends and patterns of behaviours, forecasting and anticipating events, and appreciating the system structures that cause these behaviours (Stroth, 2015). System structures can influence behaviour more than individual people (Senge, 1990,) so there is more potential for sustainable change by addressing structural policies or organisations rather than the observed behaviours.

2.4.5 Design → Emergence

Designing a system to achieve an intended purpose in complex real-world situations is challenging. Systems thinking appreciates emergent behaviours as the purpose of the system and encourages supporting the system's growth in which the desired behaviours will emerge instead of trying to design systems to perform specified tasks (Meadows, 2008; Wilson and Haperen, 2015).

2.5 Systems Thinking Tools

Systems thinking *tools* provide ways of developing models of real-world situations as systems and representations of their behaviour. They can be used to find appropriate boundaries to understand a real-world situation, identify unintended and non-linear interactions, and help appreciate how system structures lead to emergent behaviour. People can use systems thinking tools to construct and communicate systems models in the real world

2.5.1 Rich Pictures

Rich Pictures are a way to record, organise, and understand real-world situations, allowing imagery and humour as a more flexible alternative to linear prose (Bell and Morse, 2013). Monk and Howard (1998) propose that the three main elements of a rich picture are: the structure, including relationships, organisational, physical or geographical; processes including the flow of goods and services, information or influence; and concerns of the stakeholders.

Figure 1: Rich Picture showing the influence of indicators in the agricultural sector in Slovakia (Bell and Morse, 2013, p. 42)

Analysts can develop rich pictures to explore the complexity of real-world situations, or in participatory exercises, where they are more helpful in developing a shared understanding of a real-world situation and motives (Figure 1) Bell and Morse (2013). Rich Pictures need to balance being understandable while not reducing too much relevant detail of the real-world situation to a formal and ridged model (Avison et al., 1992).

2.5.2 Causal Loop Diagrams

Causal loop diagrams use a visual language to model a system as a collection of interconnected feedback loops (Senge, 1990; Stroth, 2015). Through progressively exploring linear cause and effect relationships, causal loop diagrams can help identify and understand feedback loops that create emergent behaviour and unintended consequences.

Elements in causal loop diagrams typically describe things people value, demands or resources and which vary over time (Kim, 2000; Stroth, 2015). Interactions between these elements show how these changes in each variable element will have a similar or opposite impact on another variable. Time delays describe how quickly relationships can react to changes and can lead to the emergence of complex behaviours, including oscillation in stabilising feedback loops (Meadows, 2008).

While causal loop diagrams are a basic tool to model reality as a system, like rich pictures, they must capture enough detail to be understandable and functional (Stroth, 2015). Focusing on the variable elements that significantly impact the overall behaviour and aggregating behaviour patterns over relevant time horizons can support this balance (Kim, 2000).

2.5.3 Stock-and-Flow Diagrams

Stock-and-flow diagrams extend causal loop diagrams with the concept of a variable stock that can accumulate over time (Meadows, 2008). Using the common analogy of a bathtub, a stock of water will accumulate depending on the inflow from the tap and the outflow from the plughole (Meadows, 2008; Stroth, 2015). In the real world, stocks such as inventories and capital provide buffers to help us manage things. Stock-and-flow diagrams can be used to model populations, supply chains and economic capital (Meadows, 2008).

People's natural tendency to focus more easily on stocks rather than flows, then on inflows rather than outflows, can prevent them from appreciating the complexity of real-world situations (Meadows, 2008). Stock-and-flow diagrams can help by identifying and modelling variable elements as first-order stocks that accumulate over time or second-order flow rates that control this accumulation (Kim, 2000)

Stock-and-flow diagrams represent interactions with the environment through sources and sinks outside the system boundary. They can describe stabilising and balancing feedback loops where flow rates depend on stocks (Meadows, 2008).

2.5.4 Systems Dynamics Models

Systems dynamics models extend causal loop and stock-and-flow diagrams using mathematical equations to simulate behaviours over time graphs. These simulations can compensate for our poor mental ability to simulate behaviours or even intuitively appreciate complexity in real-world situations, particularly over long distances or times (Sterman, 2002; Elsawah et al., 2017). In addition, explicit assumptions about interactions and the rigour needed to quantify variables can provide more clarity and better share understanding than qualitative tools (Forrester, 1994, 2007).

The creation of systems dynamics model has shifted from independent analysts providing recommendations (Forrester 2007), to collaborative "group model building", involving people in the modelling process, to facilitate learning and the development of a shared understanding (Vennix, 1996).

Martin et al. (2015) used systems dynamics to understand the effects of changing the laws regulating HIV testing in New York. System dynamics models of HIV cases and how law change would affect testing interpolated existing data and visualised projected behaviour over time for different implementation scenarios. The process developed consensus on the conceptual model and policy outcomes and surfacing aspects of the policy and existing data that were not consistently understood.

2.6 Systems Thinking Theories

Through observing, modelling and analysing real-world situations as systems, scholars have developed systems thinking *theories*. People can use systems thinking theories to help consider real-world situations as a system and gain insights from this consideration. For this research, I have identified a sample of systems thinking theories that have already been applied to regulation.

2.6.1 System Archetypes

Understanding real-world situations as systems shows how the structures of interactions between elements influences behaviours. Some of these behaviours may be unexpected yet occur frequently and can be attributed to the common structures of reinforcing and balancing feedback loops and delays (Kim, 2008, Senge, 1990). These common structures are known as system archetypes and can be used to diagnose specific behaviours emerging from specific structures, suggest management principles and prescribe interventions (Senge, 1990). System archetypes include limits to growth, shifting the burden, success to the successful and tragedy of the commons (Kim, 2008, Senge, 1990; Meadows, 2008; Stroh, 2015). Sparrow (2000) uses the system archetype of shifting the burden to reject ongoing government interventions in regulation. Memorising the system archetypes can help recognise them in real-world situations (Kim, 2008), which is an essential part of systems thinking (Senge, 1990).

2.6.2 Social Systems Theory

Social systems theory uses system concepts to describe modern society as a single system containing multiple functionally different social sub-systems (Nobles and Schiff, 2011). These social sub-systems are distinguished by the different binary codes they use to attribute meaning to communications, typically through a specific medium (Table 1).

Social Sub-System	Code	Communication Medium
Political	Government/Opposition	Power
Legal	Lawful/Unlawful	Law
Economic	Payment/Non-payment	Money
Media	Informative/Non-informative	News
Science	True/Untrue	Truth
Health	Ill/Healthy	Illness

Table 1: Social systems theory sub-systems, codes, and communication medium (Roth and Schütz, 2015).

Social sub-systems self-organise, emerge and evolve through their progressive coding and re-use of communications. Through this self-referencing, they are independent of each other and cannot be directly controlled (Aalders and Wilthagen, 1997). Because a single communication could be coded by multiple sub-systems, although using their different codes will give different meanings to the same communication (Nobles and Schiff, 2011). These multiple meanings create different understandings of real-world situations in different sub-systems, making communications between those sub-systems unpredictable (Nobles and Schiff, 2011). However, through trial-and-error, observation of their environment and refining their understandings of real-world situations, sub-systems may find and re-use communications that reinforce predictable interactions between sub-systems (Born and Goldschmidt, 1997). Social systems theory can describe and understand real-world situations involving communication between different social sub-systems, such as regulation (Born and Goldschmidt, 1997; Perez, 2008).

2.6.3 Viable Systems Model

The viable systems model introduced in the book *Brain of the Firm* (Beer, 1995) models an organisation using five sub-systems based on biological analogies:

- Subsystem 1: Semi-autonomous operational units that achieve the organisation's purpose
- Subsystem 2: Coordinates subsystem 1 through information systems to support decentralised decision making.
- Subsystem 3: Operational management and corporate functions
- Subsystem 4: Strategic planning based on the external environment.
- Subsystem 5: Sets policies to balance between Subsystems 3 and Subsystem 4.

The viable systems model considers Ashby's Law of Requisite Variety (1968), which states that for a system to control its environment, it must have a variety of responses to match the variety of information from the environment. There is a tension for organisations to match the variety of the complex real-world situations they operate while still being managed as a cohesive entity. The viable systems model deals with the tension by progressively amplifying the variety of responses from Subsystem 5 to 1 while progressively attenuating the variety of information from Subsystem 1 to 5. This attenuation and amplification of variety up and down the organisation allow operations to adapt to the environment without the need for strategic interventions maintaining itself and their identity (Devine, 2005, Skyttner, 2006). A viable system also contains and is contained by a viable system (Beer, 1972). This recursion means that Sub-systems 1 to 5 occur at every layer of the hierarchy and reduce the overall variety within the organisation. The recursive hierarchy of the viable system model allows being used to design and analyse networks of organisations, such as the United Kingdom's electricity market (Shaw et al. 2004), including its regulation, and a national system of innovations in New Zealand (Devine, 2005)

2.7 Systems Approaches

Systems thinking *approaches* integrate the learning and insights gained through modelling real-world situations as systems into a systematic process to engage stakeholders and inform actions in the real-world.

2.7.1 Soft Systems Methodology (SSM)

Checkland (1981) developed soft systems methodology (SSM) through a series of action research projects throughout the 1960s and 1970s. This research revealed the limitations in translating the success of systems thinking from "hard", deterministic, mechanical and electrical applications in defence and aerospace to "soft" activities involving people. SSM proposes seven sequential stages which move between considering real-world situations and considering systems models (Checkland, 1981).

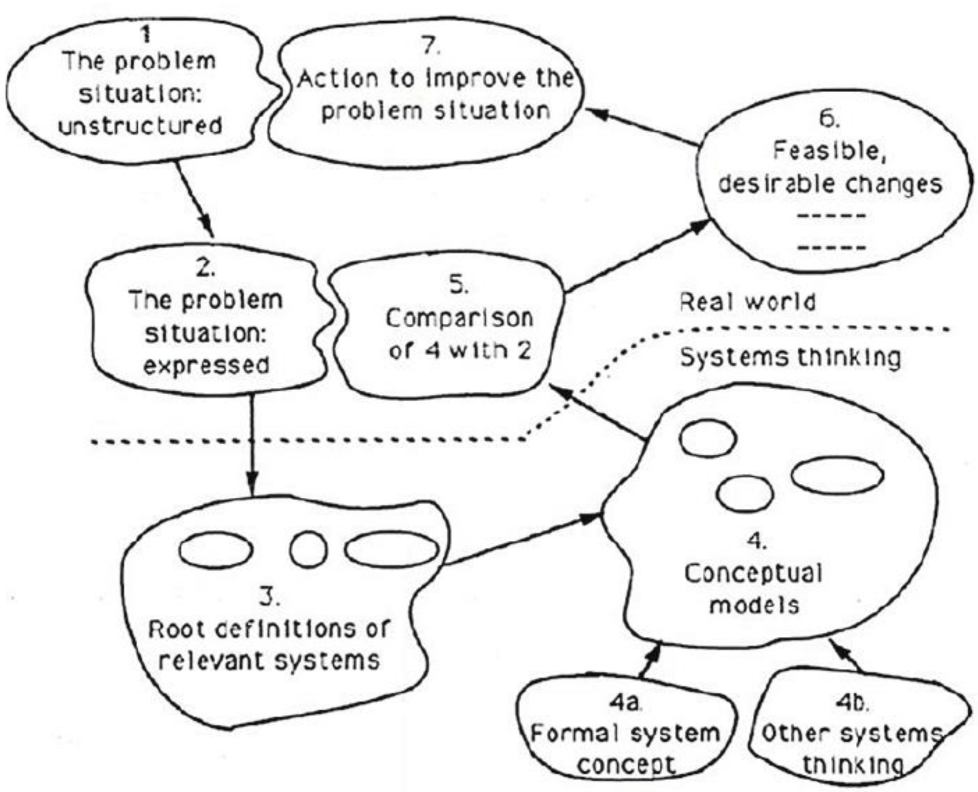

Figure 2: The seven stages of the Soft Systems Methodology (1981, p. 163)

1. *The problem situation: unstructured:* In real-world situations involving people, there can be many perspectives of what could be improved, and specific problems may not be defined or structured. Problem situations describe the general sense of dis-ease perceived by at least one person as worth investigating (Checkland 1981).
2. *The problem situation: expressed:* The situation being investigated needs to be expressed to provide the richest possible understanding relevant to the problem, such as with a rich picture, and should capture the static structures, dynamic processes and general climate. The problem situation may need to be recorded from different perspectives.
3. *Root definitions of relevant systems:* Once the problem is expressed, a range of root definitions should be developed to define systems relevant to the problem situation with a single sentence. A range of root definitions will help identify a range of different improvements. The mnemonic CATWOE captures the elements of the root definition:

- C: Customers (victims or beneficiaries) who are affected by the system's activities.
- A: Actors who carry out the activities within the system.
- T: The Transformation of the systems' defined inputs to defined outputs.
- W: Weltanschauung, outlook, framework, worldview or belief that the activities within the system will lead to the claimed transformation.
- O: The Owner who has authority over the system and responsibility for its performance.
- E: Environmental constraints within which the system must operate.

4. *Conceptual models*: A conceptual model is developed from the root definition, describing "what" is done, not "how" it is done. This abstraction supports the conceptual model's focus on exploring potential changes to address the problem situation rather than capturing the real-world situation (Checkland, 1981). There are different opinions as to if the activities it describes should be limited to five to ten (Checkland,1981) or as many as required for the conceptual model to be "defensible" (Wilson and Haperen 2015)
5. *Comparison of conceptual models with the problem expressed*: Conceptual models can be a source of ordered questioning about the problem situation; used as a non-confrontational approach to validate the situation has been understood correctly; or an object to contrast against the real-world situation;
6. *Feasible and desirable changes:* The development of the root definition and examination of the conceptual models should identify both desirable and feasible changes in the context of the problem situation.

7. *Action to improve the problem situation:* Complex problem situations are seldom solved by implementing a new system. The problem situation might be improved through the participant's learning through this process, changes to static structures, dynamic processes or, more difficultly, attitudes.

2.7.2 Four-Stage Change Process

The four-stage change process described in *Systems Thinking For Social Change* (Stroth, 2015) is a practical approach based on the author's experience driving change for stakeholders across multiple organisations. It develops a common understanding of a real-world situation and a shared vision, creating tension to drive change. The four stages are described below:

1. *Building the foundation for chan*ge: Stakeholders are identified, mapped, and engaged. Focus questions and initial sketches of the current real-world situation bring together different perspectives to develop a common ground and shared purpose. Systems thinking concepts and tools can be used to improve the capacity for collaboration throughout the process.
2. *Facing current reality:* A preliminary system model of the real-world situation is developed and collaboratively refined to bring stakeholders together, surface mental models, grow awareness, acceptance and alternatives. System archetypes could be used to help stakeholders appreciate non-intuitive behaviours.
3. *Making an explicit choice:* Comparing the benefits and costs for the status quo against the shared vision, revealing solutions that synthesise options, exploring trade-offs, or facilitating an explicit choice to change.
4. *Bridging the gap:* Change can be reinforced through a strategic action plan, continuous learning through ongoing stakeholder engagement, using insights from the system model to drive effective and sustainable change and regular evaluations against the goals.

2.7.3 Management Flight Simulators

Management flight simulators provide a controlled environment through which people can test their understanding of complexity in a controlled setting (Kim, 2000). Management flight simulators give participants realistic opportunities to test decisions and strategies by simulating and presenting real-world situations using systems dynamic model and showing trends and patterns through familiar reports and graphs (Kim, 2000). By providing a realistic, but safe environment, participants can increase their understanding of behaviours and underlying structures and question norms and assumptions (Bakken et al., 1992).

Management flight simulators must balance their level of detail between being realistic enough to provide practical contextualised learning (Bakken et al., 1992) with the cognitive load required to recognise trends and patterns (Elsawah et al., 2017). Management flight simulators can manage the participants' cognitive load by progressively exploring a series of increasingly detailed models (Elsawah et al., 2017).

Researchers have evaluated management flight simulators in a range of applications: to teach systems concepts and to think through a generic service quality management model (Bakken et al. 1992); to explore the consequences of different greenhouse gas emissions policies (Sterman et al., 2015); and to increase public understanding of the factors affecting water resource management (Elsawah et al., 2027).

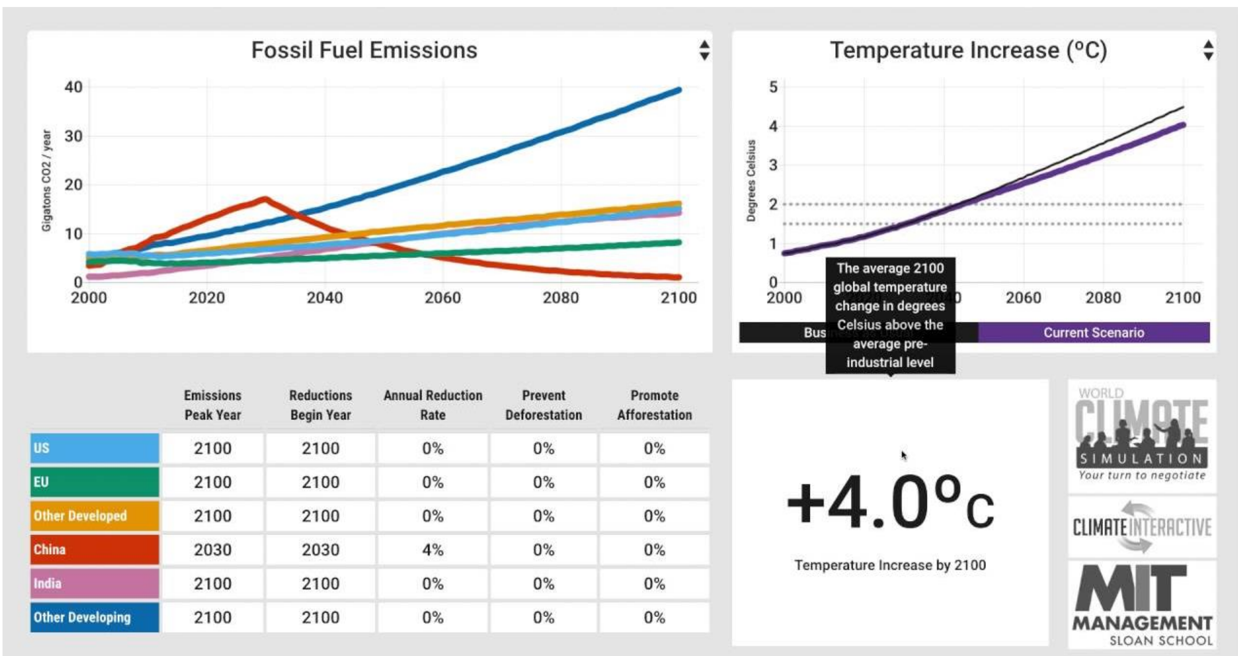

Figure 3: C-ROADS interface where users can set emissions policies and see the resulting climate change

2.7.4 Serious Games

Serious games are designed and played for learning or experimentation rather than entertainment (Susi et al., 2007; Loh et al., 2015; Olejniczak et al., 2018). Real-world situations are represented using pen and paper, physical boards and pieces or digital technologies, potentially through developing a reference systems model. Players can interact with this representation and each other (van Daalen et al., 2014), exploring the behaviours of relevant actors, while game mechanics simulate more predictable actors (Olejniczak et al., 2018). Playing serious games can help challenge mental models and understand and refine their reference system models (van Daalen et al., 2014).

Figure 4: Rural transport game to explore bus service regulation and contracting (Olejniczak et al. 2018, p. 194).

Fantasy, rules, goals, sensory stimuli, challenge, mystery, control, humour, social interaction and skilled facilitation encourage players to engage rationally and emotionally in a high trust learning experience (Garris et al., 2002; Bellotti et al., 2013; van Daalen et al., 2014). As well as being perceived as realistic, a serious game should align with the structures and processes of the real-world situation and the reference system model (Olejniczak et al. 2018).

Examples of serious games include FishBanks, where players explore renewable resources management (van Daalen et al., 2014,) and a rural transport game to explore bus service regulation and contracting (**Error! Reference source not found.**), which helped to understand behaviours in response t o regulation (Olejniczak et al. 2018).

2.8 Systems Thinking in Te Ao Māori

In the context of this research, it is important to explore how the systems thinking might interact with the New Zealand public service's commitment to a greater understanding of te ao Māori (Public Service Commission, 2020). Systems thinking and te ao Māori both emphasise a holistic perspective with an emphasis on the relationships (Taurima and Cash, 1999; Oetzel, 2017; Heke et al., 2019). From my perspective as a pakeha researcher, I see similarities between the te ao Māori concept of whakapapa, "placing each individual within a web of interactions that have evolved through time, impacted by lived experiences and changing environments throughout the course of history" (Heke et al., 2019, p. 23) as an evolving system of interactions between a person, their relations and environment. I also see similarities between the te ao Māori understanding that "the phenomena of the world emerge from reciprocal exchanges (utu) between complementary powers" (Salmond, 2014, p. 292) and behaviours emerging from interactions in a feedback loop. But despite any similarities, the systems thinking concepts, tools and approaches I have presented in this chapter are all works of Westerns academics and practitioners, so they must be distinguished from either a te ao Māori or broader indigenous perspective.

The most value I have gained from systems thinking in helping to understand te ao Māori is the appreciation of fundamentally different mental models of the world. There is space for other worldviews, such as western scientific concepts, to be held alongside te ao Māori concepts, such as river ancestors. In contrast, the monotheistic origins of a western worldview encourage a positivist perspective that there is one single true model of reality (Salmond, 2014). By providing an alternative to the reductionist method, systems thinking shows more ways to understand real-world situations, acknowledging differences in mental models and providing tools to reconcile these systems thinking to help bridge between Western perspectives and te ao Māori (Taurima and Cash, 1999; Heke et al., 2019).

2.9 Benefits of System Thinking

The different system thinking concepts, tools, theories, and approaches can improve real-world situations in three ways.

Firstly, systems thinking can engage diverse stakeholders by developing common systems models (Stroh, 2015). This process may surface and help align different mental models, improve communication and create a shared vision supporting long term change (Bakken et al., 1992; Stroh, 2015; Senge, 1990).

Secondly, systems thinking support individual and shared learning. Systems thinking can help people, even experts (Sterman et al., 2013), overcome our poor intuition towards accumulation (Sterman et al., 2014), exponential growth (Bakken et al., 1992) and causal relationships over long times and distances (Elsawah et al., 2017) or detailed organisational interactions (Kim, 2000,). Facilitating this learning is even more important as flatter organisational structures mean less opportunity to learn while progressively moving up through a hierarchy (Bakken et al., 1992). The collaborative development of systems models provides opportunities for shared learning (Forrester, 2007) and can help create the vocabulary and culture which supports continuous learning (Senge, 1990). Management flight simulators and serious games allow learning through the simulation of real-world situations, which would be otherwise impossible due to time, cost, or safety (Susi et al., 2007).

Thirdly, systems thinking can help identify leverage points to create efficient, effective and sustainable change. By understanding the relationship between the structure and behaviour of a system, small changes can be produced (Senge, 1990). The leverage points may not be intuitive and may require new ways of thinking (Senge, 1990). These may include shifting mental models, aligning rules, authority and incentives, using feedback loops and information flows or adjusting metrics and structures (Meadows, 2008, Stroh, 2015).

2.10 Limitations of Systems Thinking

In dealing with complexity, systems thinking must consider how much understanding is needed to address problems in real-world situations. Because organisations can be understood from different perspectives, have inconsistent structures, and are always in transition, they can be considered a mess, with no way to completely represent them in a system model (Wilson and Haperen, 2015). Social systems theory considers regulation as a series of non-casual, unpredictable communications. (Perez, 2008; Born and Goldschmidt, 1997).

Systems models need to be able to support the understanding and communication about messy real-world situations rather than just replicating their messiness. To achieve this, systems models should be focused around a specific problem situation (Checkland, 1972; Stroh, 2015) or can be developed or presented progressively (Stroh, 2015; Elsawah et al., 2017). With the high complexity of regulation, the best approach may be to shift our focus from prospective to retrospective, cultivating better intuitive judgement (Perez, 2008)

I will explore these considerations in my desktop application of systems thinking to drinking-water regulation in Chapter 6 and in the application of systems thinking by regulatory practitioners through an interactive workshop in Chapter 7.

2.11 Conclusion

Real-world situations can be understood as systems containing elements which interact to produce behaviours. Systems thinking can help to understand the complexity of the elements, interactions, and behaviour in real-world situations and how situations may react to this understanding. Complexity limits how much we can know about real-world situations and requires us to act with incomplete knowledge. Through considering real-world situations as systems, System thinking concepts can help by: considering the relationship between a system and its environment; the implications of circular as well as linear causal chains in providing feedback; how the structure between elements may cause behaviours; and the difference between the intended design and emergent behaviour. Systems thinking tools describe and communicate complexity in real-world situations, while system thinking theories help us analyse this complexity. Systems thinking approaches integrate some of these tools and theories into action to address real-world situations.

Systems thinking concepts are more general ideas, while the tools, theories and approaches are more distinct. Chapter 4 will evaluate the 17 systems thinking to propose a primary research question about what types of system thinking might be applied by regulatory practitioners to improve regulation.

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3 Regulation

For this research, I define regulation as the tools and activities used to modify behaviours according to defined standards (Hood, 2001, Ch 2, p1; Black, 2001; Windholz, 2017, Ch. 1). Regulation is used to maintain public interests where the market cannot, such as due to monopolies, externalities, availability of service or information inadequacies (Windholz, 2017, Ch. 1; Black, 2001). Regulation will often bring together political, legal, economic and scientific perspectives (Levi-Faur, 2010, p1). Although regulation may also aim to reduce transaction costs, my research's primary focus is the role of regulation to minimise the public's exposure to risk (Hood, 2001).

Regulators are expected to respond to an increasingly complex range of factors (New Zealand Productivity Commissioner, 2014). The evolution of regulatory strategies over the past 30 years has increased the diversity of regulatory tools and arrangements. I will initially introduce some of these regulatory tools and the arrangements of who regulates. I then describe the different regulatory strategies that have evolved and their regulatory tools and arrangements. Through these regulatory strategies and reviewing the concept of "regulatory system(s)", I will explore the extent to which systems thinking is already present in regulation. Finally, I will identify current regulatory challenges in New Zealand through a literature review, including the New Zealand Productivity Commission's report on Regulatory Institutions and Practices (2014).

Identifying the current regulatory challenges will inform the selection of the types of system thinking to address these in Chapter 4. Identifying the elements and interactions within a regulatory system will inform the application of systems thinking in Chapters 6 and 7.

3.1 Regulatory Tools

A variety of taxonomies have been developed to describe the tools through which regulation modify behaviour as well as different arrangements for who applies these tools (Freiberg, 2010). This variety emphasises the lack of a clear boundary around the different tools or arrangements (Gunningham and Grabosky, 1998), and they could instead be defined as a continuous landscape. To understand the size and diversity of this landscape, I will examine the similarities, strengths, and weaknesses of some different types of regulatory tools.

3.1.1 Command and Control

Command and control regulation comprises of rules that set standards (command) which are applied through authorisations and sanctions (control). Hood (2001) has modelled this as a cybernetic control system with the capacity for standard-setting, information-gathering, and behaviour-modification. Standards can be prescriptive, providing a high degree of certainty, or be outcomes-orientated, giving the regulated party more flexibility to decide how they will achieve the regulatory objective. Authorisations and sanctions can take many forms, including licenses, permits, improvement notices, enforceable undertakings, civil and criminal prosecutions (Freiberg, 2010, p21). Command and control provides coercion, which is an essential part of regulation (Freiberg, 2010, p10). However, command and control also require a comprehensive knowledge of the regulated activities; can lead to a fragmented array of regulatory tools with narrow boundaries; can be expensive and difficult to enforce; may lead to economically inefficient outcomes and resistance; and do not encourage regulated parties to go "beyond compliance" (Gunningham and Grabosky 1998, p53). Shifting from prescriptive to outcome- orientated standards may address these limitations. More recently, process-based standards have been implemented to specify the types of management systems to regulated parties need to manage technical, complex and not easily measurable risks (Windholz, 2017)

3.1.2 Market Influencing

One of the reasons for regulation is to address market failure, which it can do by influencing the market through fiscal tools including charges, taxes or subsides (Freiberg, 2010). The government may also set prices and service levels to regulate monopolies. Gunningham and Grabosky (1998) distinguish fiscal tools, such as emissions and effluent charges, from command and control regulation, despite both tools incurring a cost to regulated parties based on a prescribed standard. Fiscal tools do not carry the same moral signal as command and control. It is difficult to set the charges at the correct levels to avoid where they are politically possible but not too low that it is easily acceptable by regulated parties as a cost of doing business.

3.1.3 Market Creation

A regulator may also create a market where one does not exist. Tradable permit schemes where government allocates transferable property rights to permit holders are a typical example of market creation regulation (Freiberg, 2010). Emissions trading schemes are an example of this. Although, in theory, supply and demand in the market should achieve the difficult task of setting prices without extensive information gathering, this requires sufficient elasticity in the market, and the regulator is still responsible for the initial allocation of rights. The regulator will also need to monitor that regulated parties have the appropriate permits (Gunningham and Grabosky 1998).

3.1.4 Information Tools

Information products can address imperfect and asymmetric information, which may prevent people from acting in their best interest and can lead to market failures (Freiberg, 2010). These may take the form of disclosure requirements for individual regulated parties, such as corporate environmental reports, awards for good performance, or community right to know reporting by the regulator. Information tools can be effective in four ways: reporting the information requires introspection, which may have a regulatory effect in itself; the information can highlight and encourage good behaviour; executives within regulated parties would not like to see themselves at the bottom of public performance leader boards; and special interest groups can use this information to apply pressure on regulated parties. Information tools may also concentrate attention on sensational issues or high impact low likelihood risks (Gunningham and Grabosky 1998).

3.1.5 Assistance

Regulators can also provide direct assistance to regulated parties to help them comply, including education to build their capacity, guidelines or grants for safety equipment (Windholz, 2017). Assistance does depend on the assumption that regulated parties are otherwise motivated to comply. Sparrow (2000) invokes the systems archetype of shifting the burden to the intervener and cautions against government interventions that create dependency.

3.2 Regulatory Arrangements

Just as there are various regulatory tools, there is variety in who can design and implement them. There is a continuum from government regulation, co-regulation between government and regulated parties, poly-centric regulation between government, regulated parties and third parties; to self-regulation from regulated parties alone (Windholz, 2017). Self-regulation can be faster, more flexible and more appropriate, fostering a greater sense of responsibility from regulated parties. Still, it may only be intended to give the appearance of regulation (Gunningham and Grabosky 1998). In reality, the government is also present, even in self-regulation, where it may act as a facilitator or exist in the shadows (Windholz, 2017), encouraging regulated parties to regulate themselves to avoid stricter government regulation (Windholz, 2017).

3.3 Why Comply?

This diverse range of regulatory tools and the arrangements through which they are applied are intended to result in compliance from regulated parties. To appreciate this diversity, it is useful to consider the different factors which are required for regulated parties to comply (Table 2)

Table 2: 14 Factors required for compliance (Parker and Nielsen, 2017)

Spontaneous compliance factors	Economic, social and normative motives	1. Social and economic costs and benefits 2. Degree of acceptance of this regulation 3. Respect for the law in general 4. Existence of non-official influence over the targeted group's compliance
	Characteristics and capacities of members of the target population	5. Business model 6. Knowledge of the rules 7. Capacity to comply 8. Respect for the regulator
Enforced compliance factors	Deterrence factors	9. Risk that any violations of the rules will be reported to the authorities 10. Risk of inspection 11. Risk of detection 12. Selectivity of inspection and detection by the regulator 13. Risk of sanction 14. Severity of sanction

Collecting information about these factors and their interactions can support a more systemic understanding of what leads to compliance. This understanding can justify the diversity of regulatory tools and arrangements, as it is unlikely that a single regulatory tool will be able to address all the required factors (Parker and Nielsen, 2017).

3.4 Regulatory Strategies

While the "holy grail" of optimal regulation may elude policy-makers and academics (Gunningham and Grabosky 1998, p. 64), there are various strategies for how regulatory tools and arrangements might be combined.

3.4.1 Responsive Regulation

While it is cheaper to persuade than to punish, Ayres and Braithwaite (1992) also acknowledged that some regulated parties will only comply if it is economically justified, and if a regulator never punishes, a minority of regulated parties will never comply. At the same time, if a regulator punishes too often, that will undermine the sense of responsibility that motivates some regulated parties to comply.

Based on these insights, Ayres and Braithwaite introduced the strategy of responsive regulation, where the regulator would escalate to increasingly punitive regulatory tools (Figure 5) or directive regulatory arrangements (Figure 6), in response to non-compliance from the regulated party. This escalation occurs as part of a "tit-for-tat" game and needs to be able to occur in small enough increments to be politically acceptable. This strategy is often described through the concept of regulatory pyramids. The wide base represents the majority of regulated parties who will comply through a sense of responsibility or in response to persuasion. The punitive tools or directive arrangements at the top of the pyramids provide a deterrence factor, the big stick that enables the regulator to speak softly.

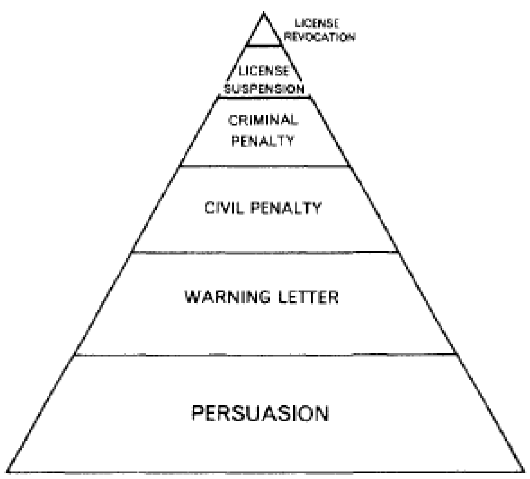

Figure 5: Responsive Regulation enforcement pyramid showing the escalation of enforcement activities (Ayres and Braithwaite, 1992, p. 35

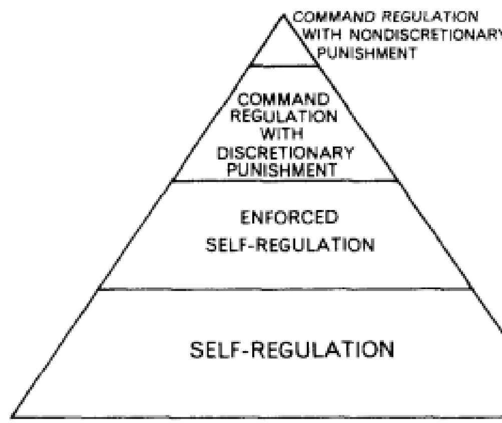

Figure 6: Responsive Regulation enforcement pyramid showing the escalation of regulatory arrangements (Ayres and Braithwaite, 1992, p. 39)

Systems thinking concepts of interacting elements, feedback loops and emergence can be identified in responsive regulation. The idea of regulatory deterrence shows that Ayres and Braithwaite appreciate all the relationships between the regulator and regulated party and how those relationships interact with each other. The escalation process could be conceptualised as a balancing feedback loop, where non-compliance increased the level of sanction, ideally more strongly discouraging further non-compliance. Responsible regulation does not aim to design the best regulatory solution, but to set the condition when the right solution can emerge. The iterative "tit-for-tat" game provides a systematic regulatory approach.

3.4.2 Smart Regulation

Gunningham and Grabosky (1998) build on responsive regulation with their strategy of smart regulation, identifying the different roles that different third parties can play in the regulatory system, where informal social interactions can be as significant as formal legal ones. Third-parties can include Public Interest Groups and different commercial actors but can behave unpredictably, disrupting the certainty of regulatory systems.

Like Responsive Regulation, they advocate the application of multiple regulatory tools but simultaneously, leveraging the interactions between tools to maximise their impact, rather than applying different tools through incremental escalation.

The interactions between different regulatory tools or actors might be complementary, such as a due diligence defence provision in legislation which stimulates the development of corporate compliance programmes; neutral, either as wasteful duplication or as an intentional backup; or counterproductive, such as the use of disclosed information in enforcement which discourages regulated from voluntarily disclosing information.

Systems thinking concepts of interacting elements and a systemic perspective can be identified in smart regulation. Smart regulation appreciates how the interactions of different regulatory tools or actors can affect an entire regulatory system. These effects will depend as much on the intrinsic nature of tools or actors as the broader contextual setting.

3.4.3 Problem Based Regulation

Problem-based regulation shifted the focus from the specific regulatory tools and arrangements to the "craft" of a regulatory practitioner. The strategy is summarised as "Pick Important Problems, Fix Them and Tell Everyone" (Sparrow, 2012, p. 7). Sparrow (2000) prescribed a process to nominate and define problems; determine how to measure impact; develop, implement and monitor solutions; and finally close these interventions. This process would be supported by a problem-solving infrastructure to record and select problems; manage resources; provide reporting and oversight problems; and promote successful solutions through awards and learning.

Problem-based regulation takes a systemic view of regulatory problems. It acknowledges that regulatory agencies have their "own traditions and preferences to slice and dice the universe" that may not always align with problem situations (Sparrow 2000, p. 148). Problem definitions should consider the "interconnectedness of systems" not be bounded by bureaucratic structures (Sparrow 2000, p. 146). Sparrow (2000, p. 149), quoting Senge (1990), refers to the system archetype of shifting the burden to the intervener. This systemic perspective is also bounded by the problem, which is optimally below the level that requires agency-wide solutions, changes in legislation, policy or budgets, but still, require the allocation of resources beyond the means of frontline regulatory practitioners. The problem-solving process and infrastructure provide systematic approaches for regulators to follow.

3.4.4 Risk-Based Regulation

Risk-based regulation proposes that regulators focus their limited resources on managing the greatest risks (Baldwin and Black, 2016). Risk-based frameworks bring together the regulator's objectives, their risk appetitive with an assessment of hazards, scoring of risks and allocation of resources (Black and Baldwin, 2010). By providing a transparent, rational and logical process, risk-based regulation enhances the accountability and legitimacy of the regulation (Windholz, 2017). However, even the quantitative analysis of risks is influenced by subjective assumptions, hypotheses and judgements. More qualitative and participatory approaches can also provide more objectivity and transparency while also helping to identify emergent risks that may not be identified through quantitative analysis (Windholz, 2017).

Risk-based regulation also considers the systemic nature of some risks, which cannot be analysed through a single linear casual chain and must instead be understood through a web of interacting factors. Risk-based frameworks can also provide a systematic approach for regulators to follow.

3.4.5 Really Responsive Regulation

Really responsive regulation aims to address shortcomings in previous regulatory strategies to deal with resource constraints, conflicting pressures, unclear objectives, changes in their environment and the need to assess effectiveness (Baldwin and Black, 2008). Building on responsive regulation's interaction with the regulated party's level of compliance, really responsive regulation also requires regulators to respond to: the attitude of the regulated party, the institutional environment for both the regulated party and regulator, which determines norms of conduct, how resources are distributed and who they interact with; the logical and coherent interaction of different regulatory tools and strategies; the performance of the regulatory regime; and both internal and external changes to policy, attitudes practices and technologies. This responsiveness is achieved through a framework of tasks: detecting non-compliance of the regulated party, responding to develop rules and tools, enforcing through the application of those tools, assessing the effectiveness of these tools, and modifying responses to be sensitive to the performance of the regulator.

Systems thinking concepts or interacting elements, feedback loops and a systemic perspective can be identified in really response regulation. Responding to compliance, attitude, the institutional environment, tools, performance, and changes require regulators to have a "holistic" systematic perspective. It appreciates the interactions between tasks, and through the modification of responses, creates a feedback loop. The framework of tasks does provide a systematic approach for regulators to follow. However, even Baldwin and Black (2008, p. 76) acknowledge that these are "fairly formidable tasks".

3.5 What is a Regulatory System?

The term ‘regulatory system’ is commonly used in the academic and grey literature. However, elements, interactions and boundaries of a regulatory system vary in different contexts, for example, from a single regulatory regime to all regulations in New Zealand (Van der Heijden, 2020).

The evolution of regulatory strategies shows that a regulatory system might include the regulator, the regulated party, regulatory tools, regulatory arrangements, risk, problems, the broader social, political and economic environment and the interactions between these elements. The compliance and attitude of the regulated parties and the regulator's performance might be understood as the emergent behaviour of the regulatory system. This systemic perspective promotes a broader view of regulation, which may be helpful to appreciate the complexity of regulation, but may not directly help manage this complexity. A regulatory system might also include the systematic approaches from the regulatory strategies, with elements and interactions describing how and when regulation occurred. These systematic approaches may provide a useful boundary for regulatory systems and help to manage complexity.

The New Zealand Treasury (2017a, p. 8) defines a regulatory system as “a set of rules, norms and sanctions, supported by the actions and practices of designated agencies, to shape people’s behaviour in pursuit of a broad policy goal or outcome. The regulatory cycle indicates how that system changes and evolves. This definition is illustrated in the context of the regulatory cycle (Figure 7), with the regulatory system shown as a single “black box” and the focus on the elements and interactions with and within the regulatory cycle.

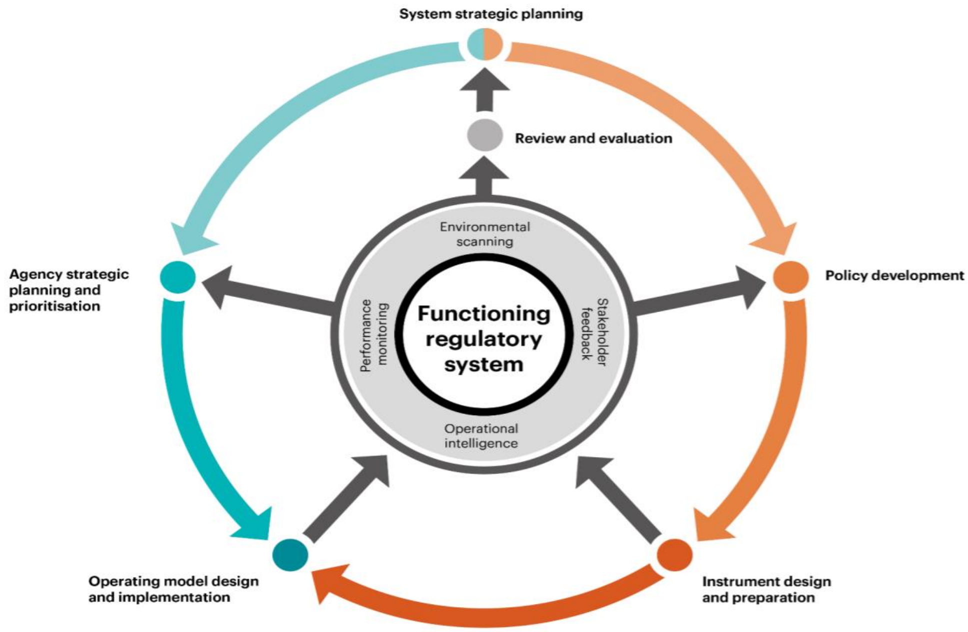

Figure 7: The regulatory system is part of the regulatory cycle (New Zealand Treasury, 2017a, p. 8)

The New Zealand Treasury (2017b, p. 3) also acknowledges that a regulatory system may interact or overlap with the broader legal system and other regulatory systems. It directs regulatory agencies to take a "whole-of-system view … to the care of the regulatory system(s) within which they work". It is unclear if risks or regulated parties are part of the regulatory system from this perspective.

When mapping their regulatory systems, agencies have identified how their regulatory system interact or overlaps with infrastructure (Ministry of Transport, 2019), non-government stakeholders, the physical environment and (Māori) treaty partners (Ministry for the Environment, 2018). However, risks and regulated parties do not feature significantly in these mappings of regulatory systems.

A "whole-of-system view" which includes regulated parties, risks and problems in the regulatory system, would require regulatory agencies to map a variety and volume of interactions and understand the behaviours that may emerge from these interactions. There are differences in the extent to which regulatory agencies map the interactions and understand the behaviours between their regulatory systems and the environments (Ministry of Transport, 2019; Ministry for the Environment, 2018; Land Information New Zealand, 2018). Although these differences may be important to capture the contexts and priorities for different regulators and practical given the scope of this undertaking, they may lead to a different understanding of regulatory systems between regulatory agencies and regulatory practitioners within the same regulatory system. These different interpretations of regulatory systems support the interpretive perspective that systems are a heuristic, a subjective perspective of reality rather than an objective truth.

While the New Zealand Treasury (2017b) has defined the elements, interactions and boundary of a ‘regulatory system’, this definition is much narrower than a “whole-of-system view”, regulatory system maps or regulatory strategies might encourage. In this research, I will consider a regulatory system as all elements or interactions relevant to regulation. Given this subjectivity of relevance and the variety and volume of these elements and interactions, it is likely that different regulatory practitioners will have different mental models of regulatory systems. Systems thinking might help regulatory practitioners to surface these different mental models.

It would be a natural progression from thinking about regulation as a system to practically applying systems thinking to improve regulation. However, this practical application is lacking, and there is little evidence of what forms of systems thinking might be applied to improve regulation (Van der Heijden, 2020)

3.6 Regulatory Challenges

I have reviewed a range of regulatory literature and identified four common challenges, which might be addressed using systems thinking: understanding risk, understanding regulated parties, measuring performance and appreciating complexity.

3.6.1 Understanding Risk

Current thinking in risk scholarship recognises people’s preoccupation with managing risk and the anxiety this causes (van der Heijden, 2019). However, there are three challenges in reducing risk to a measurement. (i) Quantitative risk assessments will typically be based on previous risks and may not consider emergent risks (Black & Baldwin, 2010). Media attention and public fear lead to regulators giving low-occurrence high-impact risks a higher “measurement” than high-occurrence low-impact risks (van der Heijden, 2019). The resulting accumulation of high-occurrence low-impact risks (Black & Baldwin, 2010) may lead to more significant harm. (ii) Quantitative and qualitative risk assessments are fundamentally based on assumptions (Windholz, 2017; New Zealand Productivity Commission, 2014), leading to different understandings of risk (van der Heijden, 2019). (iii) Our understanding of risk is shifting from considering a linear causal chain of events to systemic risk resulting from complex interactions between different factors (New Zealand Productivity Commission, 2014; van Asselt and Renn, 2011)

3.6.2 Understand Regulated Parties

Regulation aims to modify the behaviours of regulated parties (Windholz, 2017). However, the New Zealand Productivity Commission (2014) identifies that regulators do not have a complete view of these regulated parties and have limited influence over their behaviours. In addition, regulated parties may be influenced by multiple overlapping regulatory regimes (Ministry for the Environment, 2018).

3.6.3 Monitoring and Managing Performance

Measuring the performance of regulatory tools can provide feedback and contribute to the continuous improvement of regulation (New Zealand Productivity Commission, 2014). However, only 26% of regulators agree that this feedback takes place between frontline regulatory staff and policy functions and performance monitoring be improved (New Zealand Productivity Commission, 2014). Performance monitoring is also a requirement for regulatory stewardship, and New Zealand Treasury requires regulators to monitor and maintain the performance of their regulatory system (van der Heijden, 2021).

Performance can have multiple dimensions, with both quantitative and qualitative measures of inputs, such as the number of inspections; processes, such as adherence to policies and procedures; outputs, such as if specific goals are delivered; and outcomes, such as if the objectives of the regulation being met by the regulatory systems (Balwin and Black, 2008). Output and outcome measures are less common. New Zealand regulators have started assessing the fitness-for-purpose of their regulatory systems using the common dimensions of effectiveness; efficiency; durability and resilience; and fairness and accountability (Treasury, 2020).

3.6.4 Appreciating Complexity

Regulation takes place within a complex system (Ayto, 2014; Searancke et al. 2014) where problems can not be solved in isolation (Bailey and Kavanagh 2014). Black (2014) identified the complexity of regulatory systems as one of the causes of regulatory from ‘the unintended and unforeseen consequences of the design and/or operation of a regulatory system and its interaction with other systems’. Complex regulatory systems (Ministry of Business, Innovation and Employment, 2016) and the interactions within and between regulatory systems (Ministry for the Environment, 2018) make regulatory systems reporting challenging.

3.7 Conclusion

Through the review of regulation strategies, I have shown how systems thinking concepts of interacting elements, feedback loops and emergence are already being applied in regulatory strategies. The strategies also take systemic views of regulation, encompassing a wide range of different interacting elements. Some regulatory strategies balance their expansive systemic view with more bounded systematic approaches to guide regulators to act in complex real-world situations. Regulatory systems are a popular yet inconsistently applied concept. A regulatory system might not only include the regulator and what tools they are using where, but also who they are regulating and the approach they follow to carry out regulatory tasks. Different regulatory practitioners might have different mental models of regulatory systems. The challenge with any conceptualisation is capturing just enough detail for utility without introducing unnecessary complexity.

The extent to which systems thinking concepts are applied in regulatory strategies and the popular conceptualisation of regulatory systems indicate that regulation might be well-positioned to benefit from further application of systems thinking. My review of regulatory literature identifies four common challenges: understanding risk, understanding regulated parties, measuring performance and appreciating complexity.

In the next chapter, I will evaluate which systems thinking tools, theories, and approaches might address these to propose the primary research question of whether and how can system thinking be applied by regulatory practitioners to improve regulation.

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4 Evaluating Systems Thinking in Regulation

In this chapter, I develop a primary research question by selecting types of systems thinking which might be applied by regulatory practitioners to improve regulation. This primary research question is developed by evaluating 17 types of systems thinking introduced in Chapter 2., based on their value in addressing the regulatory challenges identified in Chapter 3, their ease of application by regulatory practitioners, and the feasibility of evaluating them in this research. The primary research question will be explored and refined through the desktop application of systems thinking in Chapter 6 and answered through an interactive workshop with regulatory practitioners in Chapter 7.

4.1 Selection: One or Many

This two-stage evaluation allows for additional refinement of the types of systems thinking after the desktop exercise and after the workshop exercise based on participant feedback. For these reasons, I am selecting a range of systems thinking concepts, tools, theories and approaches for evaluation to increase the likelihood that some of them can be applied by regulatory practitioners to improve regulation. This approach limits the attention and depth of evaluation of each type of systems thinking. However, it may provide a starting point for regulatory practitioners or further research to explore types of systems thinking in more depth.

4.2 Evaluation Criteria

4.2.1 Value in Addressing Regulatory Challenges

For a regulatory practitioner to apply systems thinking, it would need to be of value to them. Chapter 3 identified the current challenges in the regulation of understanding risk, understanding regulatory parties and monitoring performance. These challenges incorporate aspects of complex interactions between different elements, understanding different mental models, feedback to control systems, which indicate that all types of system thinking may be beneficial in addressing them.

4.2.2 Application by Regulatory Practitioners

The types of systems thinking should be able to be practically applied by any competent professional without needing specialist capability or resources. The types of systems thinking should be able to be applied without structural support, such as legislation, policy, budgetary or management buy-in, as the focus of this research is the application by regulatory practitioners, not regulatory agencies.

4.2.3 Scope of Research

The workshop should involve 9 to 25 regulatory practitioners to provide a sufficient yet manageable sample. Because of their likely time constraints and to maintain participant engagement, the workshop will be limited to a single four-hour session. The workshop is addressed further in Chapter 7. I will select several types of systems thinking and design workshop activities that can evaluate them within four hours.

4.3 Evaluation

Chapter 2 identifies five concepts, four tools, four approaches and three theories that might be applied by regulatory practitioners. From these, I have selected types of system thinking to evaluate which can be (i) demonstrably applied; (ii) applied without specialist capability or resources; (iii) applied without structural support; and (iv) evaluated during a four-hour workshop. Table 3 presents the selection of systems thinking that I will evaluate and refine through the desktop exercise.

System thinking concepts can help people understand real-world situations by considering them as systems through the construction of their mental models. Systems thinking tools use these concepts and construct systems models in the real world, which can be shared and evaluated. For this reason, I will not directly evaluate the application systems thinking concepts but instead, focus on systems thinking tools.

System thinking approaches describe systematic processes which can be applied. Systems thinking theories can be used to analyse real-world situations using systems models but need processes to evaluate how they can be applied.

Rich pictures (Bell and Morse, 2013) and causal loop diagrams (Vennix, 1996) can be developed collaboratively through group work. They can both be prepared with pen and paper, allowing them to be applied without specialist capability or tools. Stock-and-flow diagrams include the concept of stocks (Meadows, 2008) and therefore require more specialist capability. Systems dynamics models require specialist capability to develop quantitative mathematical models and specialist computer software to run these models (Sterman, 2002). Soft systems methodology and the four-stage change process are both systematic processes incorporating systems tools and specialist stakeholder holder management and facilitation skills (Checkland 1981; Stroh, 2015). The systems dynamics models used in management flight simulators and serious games require specialist capability to develop. I would need to evaluate social systems theory, systems archetypes and the viable systems model through a process that did not require specialist capability and resources.

Regulatory practitioners could independently apply rich pictures, causal loop diagrams or stock and flow diagrams without structural support such as legislation, policy, budgetary or management buy-in. Soft systems methodology involves action to be taken, and the four-stage change process requires making an explicit choice to change, both of which may require financial support or management buy-in. Management flight simulators and serious games can be applied to develop an individual's capability or test scenarios without needed structural support.

The application of rich pictures, causal loop diagrams or stock and flow diagrams could be evaluated during a four-hour workshop. All the systems thinking approaches require multiple engagements with stakeholders to develop, refine and use systems models, so I could not evaluate them in a single workshop. I would need to evaluate social systems theory and systems archetypes through a process that could be conducted during a four-hour workshop. It is unlikely that four hours would be enough time to produce the detailed model required for viable systems model theory.

Table 3: Types of systems thinking for evaluation in the desktop exercise

		Can be demonstrably applied?	Can be applied without specialist capability or resources?	Can be applied without structural support?	Can be evaluated during a four-hour workshop?	**Evaluate in Desktop Exercise?**
Concepts	Things → Relationships	✗	✓	✓	✓	✗
	Closed → Open	✗	✓	✓	✓	✗
	Linear → Feedback	✗	✓	✓	✓	✗
	Events → Structures	✗	✓	✓	✓	✗
	Design → Emergence	✗	✓	✓	✓	✗
Tools	Rich pictures	✓	✓	✓	✓	✓
	Causal loop diagrams	✓	✓	✓	✓	✓
	Stock + flow diagrams	✓	~	✓	✓	✓
	Systems dynamics	✓	✗	-	-	✗
Theories	System Archetypes	~	~	~	~	✓
	Social Systems Theory	~	~	~	~	✓
	Viable Systems Model	✓	~	~	✗	✗
Approaches	SSM	✓	~	~	✗	✗
	Four-Stage Change Process	✓	~	~	✗	✗
	Management Flight Simulators	✓	✗	✓	✗	✗
	Serious Games	✓	✗	✓	✗	✗

4.4 Primary Research Question

Table 3 presents a summary of this selection process, from which I proposed the following primary research question:

Whether and how can rich pictures, casual loop diagrams, stock and flow diagrams, system archetypes and social systems theory be applied by regulatory practitioners to improve regulation?

Due to my evaluation criteria, I have selected what could be regarded as entry-level systems thinking, which can be applied within four hours without specialist capability or resources or structural support.

In Chapter 6, I will explore and refine this primary research question through the application of system thinking in my desktop exercise, giving special attention to the capability required to develop a stock and flow diagrams and the processes through which I apply social systems theory and systems archetypes.

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5 New Zealand's Drinking Water Regulatory System

This chapter develops a case study describing the events, organisations, legislation and regulatory tools involved in the evolution of drinking water regulatory system in New Zealand. The range of perspectives, organisations and the ongoing reforms make drinking water regulation a relevant case study to explore the applications of systems thinking to regulation. In this chapter I will: (i) consider the different perspectives involved in drinking water; (ii) explore the evolution of drinking water regulation from the Māori customary regulatory system; colonisation until 1992; the voluntary regulatory system from 1993 to 2008; the legislative regulatory system from 2008 – 2021, and finally the reforming regulatory system from 2021; (iii) present a stocktake of the different drinking water regulatory tools in 1993 to 2008, 2008 to 2021 and 2021 onwards. I have developed this case study using the Government Inquiry into Havelock North Drinking Water reports (2017a, 2017b), reports from the Ministry of Health, other government agencies, and a review of grey literature. In Chapter 6 this case study will inform my evaluation of applying of systems thinking to regulation in a desktop exercise, therefore it is important to consider different perspectives to appreciate different mental models, as well as the different elements, interactions and emergent behaviours in drinking-water regulatory system.

5.1 Perspectives of Drinking Water Regulation

To develop a case study of the drinking water regulatory system, I will examine it from a range of different perspectives: (i) drinking-water is critical to health; (ii) the economic costs in both providing and not providing safe drinking water; (iii) the political dynamics around drinking water; (iv) how drinking water supplies are engineered; (v) the relationship between the environment and drinking-water; and finally (vi) how drinking water is consider in te ao Māori.

5.1.1 Health

The supply of potable drinking water provides significant public health benefits by preventing a range of waterborne illnesses. These illnesses can be caused by giardiasis, campylobacteriosis cryptosporidiosis, salmonellosis, Norovirus, chemical (including disinfection by-products) and radiological contaminants (World Health Organization, 2011). Public health risks can be short term with medium probability and medium impact, such as acute gastroenteritis, or long term with low probability and high impact, such as the potential for cancer caused by nitrates (Chambers et al, 2021)). It is difficult to know how many people get sick from drinking-water, because illness is not always reported and cannot be easily separated from food borne illness. Depending on the methodology and assumptions, estimates range from 18,000 to 34,000 (Ball et al, 2007) to over 100,000 cases per year of drinking-waterborne in New Zealand (Moore et al. 2010). Because of this variation it is hard to accurately compare this internationally, one study estimated 19.5 million waterborne illnesses a year in the United States (Reynolds, 2008), an equivalent to 289,000 cases in New Zealand. The health perspective is reflected in the Ministry of Health being primarily responsible for drinking-water regulation from 1993 until 2021.

5.1.2 Economic

The economics perspective considers the financial costs and benefits of supplying drinking-water, offering framework where different factors can be translated into money which can be easily compared. For example, councils in New Zealand currently spend $1.5 Billion annually on their three water services (drinking water, wastewater and storm water) (Department of Internal Affairs, 2021). In comparison, New Zealanders spent $140m on bottled water in 2017 (New Zealand Beverage Council, 2021). Improving all drinking water treatment plants to comply with the standards would costs of $11.2 to $12.5 million annually compared to annual marginal benefits of $12.5 to $24 million (Moore et al. 2010), however this research excluded benefits of reduced pains, suffering, and risks to New Zealand’s international reputation which could not be easily quantified. The ability for economics to provide a common perspective is limited by the uncertainty in attributing and estimating both costs and benefits, along with the normative values associated with the health and the environment.

5.1.3 Political

Drinking water is the subject of political pressure for both central and local government. Legislation for drinking water needs to be a priority on the political agenda and is subject to changes through the political process. The ability for regulators to undertake enforcement action is also dependent on political appetite. The majority of water supplies are managed by local authorities, allowing councillors to override technical decisions related to their water supply safety. Such a case occurred in the South Island, where councillors, having been told of the risks, chose not to chlorinate a supply serving 80,000 people (Government Inquiry into Havelock North Drinking Water, 2017b).

5.1.4 Engineering

A significant engineering effort is involved in providing a reliable supply of safe drinking water. Cooke (2007, p. 5) describes the history of water supply in the Wellington region as an “engineering story", describing the construction of dams, pipes, tunnels and treatment plants from the 1860s to 2007. Water suppliers, and private engineering consulting and contracting companies acting on their behalf, carry out a range of engineering activities, including planning, designing, operating and maintaining drinking water infrastructure (Government Inquiry into Havelock North Drinking Water, 2017b).

5.1.5 Environmental

All drinking water is sourced from the environment, the protection of which is of "paramount importance" as a barrier to protect drinking water against contamination (Government Inquiry into Havelock North Drinking Water, 2017b). A Colmar Brunton poll showed that 82% of New Zealanders are extremely or very concerned about the pollution of rivers and lakes (Fish & Game, 2018), with this topic "reshaping our political landscape" and being a contributing factor to the National government's election loss in 2017 (Rood, 2019). The Resource Management Act gives responsibilities concerning drinking water sources to both the Ministry for the Environment and Regional Councils. In the Policy Quarterly issue focusing on freshwater (Boston, 2019), four out of 12 freshwater articles referred to drinking water. Our drinking water quality may also diminish the perceived value New Zealand's clean green environment has for food exports, immigration, and tourism (Ministry of Health, 2019).

5.1.6 Te Ao Māori

Te Ao Māori, the Māori worldview, sees all things, including humans, as interconnected (Wheen, 1997). Te Hauora o te Tangata (the health and well-being of people) is related to Hauora o te Wai (the health and well-being of the water) and Te Hauora o te Taiao (the health and well-being of the environment) (Ministry for the Environment, 2017).

The Māori creation narrative describes the world Tane, god of the forest, creating the world by separated his parents, Ranginui, the sky father, and Papatuanuku, the earth mother, to allow himself and his siblings to flourish. In doing this, he took responsibility for their welfare by clothing his mother with trees, plants and birds and adorning his father with stars and comets. Tane's responsibility for the impact of his actions on the environment demonstrates the value of reciprocity in Te Ao Māori (Wheen, 1997).

Te Ao Māori sees the natural world as Atua, such as Ranginui, Papatuanuku, Tane and his siblings, both as gods, ancestors and spiritual beings, sacred with laws that must be obeyed. This narrative explains that everything, including water, contains a Mauri, or life force. This Mauri must be respected and cased for and cannot be abused without consequences (Ministry of Health, 1995).

5.1.7 A Systemic View of Drinking Water Regulation

All these perspectives are relevant to the regulation of drinking water in New Zealand, as they will shape the mental models of people involved and the actions they take. It is interesting to observe the alignment between health, political and economic perspectives and the respective social sub-systems of social theory. Even engineering might be interpreted as a social sub-system, communicated through designs that either solve or do not solve problems. The environmental perspective brings in an intrinsic appreciation for the natural world outside of our society. Te ao Māori brings a more systemic perspective, although it still needs to align with other perspectives.

5.2 The Evolution of New Zealand's Drinking Water Regulatory System

I will consider the evolution of drinking water regulation in New Zealand over five distinct periods: (i) Māori customary regulation; (ii) regulation from colonisation until 1992; (iii) the voluntary regulatory system designed by the Ministry of Health from 1993 to 2008; (iv) the legislative regulatory system from 2008 – 2021, established by the Health (Drinking Water) Amendment Act 2007, including the regulatory failure of the Havelock North drinking water contamination event; and (v) the currently reforming regulatory system from 2021 onwards.

5.2.1 Māori Customary Regulatory System

Māori customary law regulated the use and protection of the natural sources providing drinking water to traditional Māori communities (Wheen, 1997). The regulatory framework provided by Māori customary law is rooted in the Māori creation narrative, in the belief that all things are connected (Wheen, 1997). Everything contains a Mauri, or life force, the protection and preservation of which is a basis for much of Māori environmental management (Wheen, 1997). Kaitaki or guardians are responsible for protecting the Mauri of parts of nature, including water. Kaitaki may be people or Taniwha (protective spirit). If a Taniwha guards a water body, it may be Tapu (sacred) (Ministry of Health, 1995). Rahui is a regulatory tool that someone with Mana (authority) can use to "restrict access to an area or resource" (Wheen, 1997, p. 77). Utu describes the reciprocal exchange resulting from and balancing the misuse of water (Salmond, 2014).

5.2.2 Colonisation to1992

Early European settlers brought Common Law that displaced Māori customary law, shifting the focus from use and protection to allocation and protecting individual rights to water (Wheen, 1997). By the 1860s, official town water supplies grew to include dams, reservoirs, artesian wells and drinking fountains (Pollock, 2014), supported by a "complex system" of legislation developed in a "piecemeal" way (Wheen, 1997). Legislation created powers for District Health Officers to prevent the pollution of water sources (Wheen, 1997), which they used in 1928 to demand action over poor water quality in Wellington. In 1962 the Board of Health began the first grading of public water supplies in New Zealand (Board of Health, 1962).

However, the legislative framework created difficulties in managing catchments and supplies, which crossed borough boundaries (Cooke, 2007). This difficulty was addressed in 1967 by the Water and Soil Conservation Act which established regional water boards to manage all water resources. The 1974 Local Government transferred powers from borough and county councils to local authorities, including purchasing and protecting water sources. This reform continued in 1989, with the aggregation of water and catchment boards into multipurpose local authorities (Derby, 2015).

5.2.3 1993 to 2007: Voluntary Regulatory System

In 1993, during a period of significant restructuring of both local and central government that followed the election of the Fourth Labour Government, the Department of Health became the Ministry of Health. The drinking water legislation they inherited was "fragmented and in some respects dated and deficient" (Ministry of Health, 1995, p. 3). The relevant powers in the Health Act 1956, derived from pre-1920s legislation and did not reflect the need to shift focus from protecting the quality of water sources to water treatment, which resulted from increased urbanisation and agriculture. Also, there was the need to deal with newly-recognised pathogens of concern, such as Giardia and Cryptosporidium (Ministry of Health, 1995). Up until this point, local authorities also relied on government subsidies to improve drinking water supplies (Ministry of Health, 1998). The Department of Health had set up quality management procedures from 1960-84, but these had lapsed (Ministry of Health, 1995). The Department of Health received little information about the quality of drinking water. An independent survey revealed 28% of supplies didn't test the bacteriological quality of water in the distribution network (Ministry of Health, 2019).

As there was no single agency to ensure that communities had adequate and safe drinking water, the Ministry took the opportunity to review the provision of drinking water in New Zealand. Although there were broader governance and structural issues around the provision of water, the ministry concentrated on the public health aspects for which they were responsible (Ministry of Health, 2019).

In 1995 the Ministry of Health adopted a drinking water strategy based on a non-statutory intervention consisting of standards for performance and competency; provision of drinking water quality information; promotion of public health concerns to the public; and self-management quality assurance techniques to the water supply industry (Ministry of Health, 2019).

The Ministry administrated this system, publishing the Drinking Water Standards for New Zealand (1995, 2000, 2005, 2008, 2018), Register of Community Drinking Water Supplies, the Annual Report on Drinking Water Quality and the public health grading of water supplies. The Ministry of Health contracted public health units to engage directly with water suppliers and local government, collate data, conduct surveillance, monitor, and grading, provide technical advice, and approve water safety plans. This contracted relationship was to mitigate against the risk that these operations could be disestablished through a restructure within the Ministry of Health (Taylor in Bell, 2017). A monitoring programme provided a quality "feedback loop" as a trigger for remedial actions (Taylor, 2002, p. 1). However, this was still a voluntary regulatory system for local authority, community and private water suppliers (Ministry of Health, 1998).

This "integrated management system" was designed in which "various components not only complement but mutually reinforce each other" and to "promote maximum interaction and mutual support between the various stakeholders, the public and the media, the drinking-water supplier, and the public health officer" (Taylor, 2002, p. 1). This mix of interacting regulatory tools, along with the deliberate engagement of public stakeholders, aligns with Smart Regulation, while the strategy to "ratchet" improvement in "digestible" steps aligns with Responsive Regulation.

By 1998, most larger local authorities were accepting responsibility for monitoring their water supplies, increasing microbiological monitoring and improvements to supplies. By 2003, improvements from the current strategy had reached a plateau (Ministry of Health, 2019). In 2004, the government's infrastructure stocktake identified poor water quality in some areas due to lack of funding and expertise (Beehive, 2004). To address these issues, the Ministry of Health established the Drinking-Water Assistance Programme (DWAP), comprised of the Technical Assistance Programme and Drinking Water Subsidy Scheme, carried out by public health units for water supplies serving 25 – 5,000 people. These ran from 2005 to 2015 with subsidies of $10m per year for supplies in area of high deprivation (Ministry of Health, 2019).

Without a legislative mandate, the strategy was subject to shifting internal policy and staff priorities within the ministry, nor could it to address water scarcity problems, such as the 1994 Auckland water shortage (Ministry of Health, 1998). In 1995, the Ministry also began consultation on legislative changes to integrate the 36 acts and regulations related to drinking water. This consultation concluded that legislation needed to clearly define roles, relationships and responsibilities, and effective compliance mechanisms. The Ministry of Health favoured "empowering regulations" that set the intent, standards of performance and methods of verification in preference of "prescriptive regulation", which are difficult to draft for complex issues such as drinking water (Ministry of Health, 1998, p. 15).

While cabinet noted the limitation of regulatory power in existing drinking water regulation to protect public health in 1994 (Ministry of Health, 1998), it was not until 2000 that they instructed the Ministry of Health to prepare a Health Act Amendment Bill to provide a statutory mandate (Ministry of Health, 2017). This bill's existence on the political agenda may have created pressure for water suppliers to comply with the standards, which would have otherwise been voluntary. However, as the Ministry of Health "did not consider drinking water was their core business", this bill did not get put on the legislative programme until instructed by a minister (Taylor in Bell, 2017, p. 47). Local New Government Zealand (LGNZ), an association that represents the interests of local authorities, urged the select committee to consider the legislation's practical implications, which they estimated would cost between $150 and $300 million (Local Government New Zealand, 2006). The select committee amended the bill to include affordability as one of the criteria for determining the "practicable steps" water suppliers needed to comply with the standards or allow water suppliers to be implementing a water safety plan. Also, the Act limited prosecutions to intentional offences. These caveats weakened the regulatory powers of the Health (Drinking Water) Amendment Act 2007 (Government Inquiry into Havelock North Drinking Water, 2017b).

5.2.4 2007 – 2021: Legislative Regulatory System

The Health (Drinking Water) Amendment Act 2007 supported many of the Ministry of Health's existing interventions. The Act included powers to issue drinking water standards, mandate the registration of all water suppliers and annual reporting of compliance against the standards from all water suppliers serving more than 100 people. Depending on their size, water suppliers were given up to four years to implement Public Health Risk Management Plans to contribute to water sources' protection and comply with drinking water standards. The Act also enabled the Ministry to appoint Drinking Water Assessors to assess the compliance of water suppliers and competence of their staff and gather information. The Ministry could also issue compliance orders, offences and or apply emergency powers to enforce the Act.

In 2007, National Environmental Standards for Sources of Human Drinking Water Regulations were introduced under the Resource Management Act (RMA) 1991. These standards created explicit obligations for regional councils to consider the impact on the quality of drinking water supplies serving more than 500 people of resource consent decisions and permitted activities in regional plans.

Within the drinking-water regulatory system, local authorities are regulated by both central government under the Health Act and regional councils under the RMA, all of who are funded by the public, and represent the public, although through different sets of elected officials. This creates a political dynamic between elected officials, which can be seen in the Associate Minister of Health's response to a letter from a local authority Mayor, confirming that it was up to local authorities to decide if they could afford to comply with the standards and Drinking Water Assessors needed to approve Water Safety Plans based on long term "potential upgrades" (Goodhew, 2013). The Ministry of Health's enforcement approach reflected this voluntary nature of compliance and the limited political appetite to enforce compliance. This approach promoted education and persuasion as providing the best outcomes and encouraged Drinking Water Assessors to "Speak softly and carry a big stick; you will go far" (Government Inquiry into Havelock North Drinking Water, 2017b, p. 69). This might have been an attempt at a Responsive Regulation strategy which suggests "Regulatory agencies will be able to speak more softly when they are perceived as carrying big sticks" (Ayres and Braithwaite, 1992, p. 6). Unfortunately, compliance orders were deemed "a last resort before prosecution" (Government Inquiry into Havelock North Drinking Water, 2017b, p. 69) and were avoided, lest they failed, setting a negative precedence. As a result, by 2017, no compliance orders had been issued or prosecutions launched (Government Inquiry into Havelock North Drinking Water, 2017b), undermining any perception of a "big stick" and resulting justification to speak softly. This case supports Ayres and Braithwaite's (1992) caution about the detrimental effect of politically impossible sanctions.

Havelock North Water Contamination Event and Government Inquiry

The Havelock North Water contamination event demonstrates how a failure in the existing regulatory system provided a driver for regulatory reform.

In August of 2016, 2 bores supplying the Havelock North were contaminated with campylobacteriosis, contributing to three deaths and illness in 5,500 of the town's 14,000 population.

These bores drew their water from the Te Mata aquifer, which the water supplier thought to be secure and free from contaminants and not requiring treatment. There had been a previous contamination event occurred in 1998, and transgressions were detected in the supply in the previous year. It has been proven through dye tracing and DNA analysis of campylobacter that the contamination occurred when heavy rain caused water to flow from a paddock where sheep were grazing, washing faeces into a nearby pond that entered the aquifer. In this case the regional council failed to meet their responsibilities under the RMA as the “guardian” of the aquifer. However, the water suppliers, the Hastings District Council, made incorrect risk assessments in their Water Safety Plan and failed to meet the required standards for sampling frequency.

The alternative hypothesis was that contaminated runoff flooded the bore heads and entered the supply through loose cable seals. Based on this hypothesis the regional council unsuccessfully prosecuted the district council following the outbreak for their failure to maintain the bore according to their consent conditions.

In either case, Drinking Water Assessors were too hands-off and lenient, not providing appropriate pressure regarding the lack of robust risk assessments or investigation and follow-up regarding high levels of transgressions.

The government found a “critical lack of collaboration and liaison between the Regional Council and the District Council” (Government Inquiry into Havelock North Drinking Water, 2017a, p. 4), evident in the failure to share information, to work together to solve issues and the regional Council’s prosecuting the district council. Neither the regional nor district council fully understood the public health implications where failure could lead to illness or death, and as a result, failed to adhere to the high standard of care required.

The regional council initially did not believe that they had any responsibility for the quality of drinking water, showing that the purpose of the National Environmental Standards for Sources of Human Drinking Water Regulations had not been achieved.

The Havelock North Water Contamination event and resulting Government Inquiry into identified a range of challenges within the current regulatory system and created significant political pressure for regulatory reform. Overall, the legislative requirement to comply with the drinking-water standards had not contributed to any significant increase in compliance from 2009 to 2016. The system was still fragmented, with responsibilities spread, but not always taken, over a range of agencies and other organisations.

The Inquiry also found the environmental regulation for the protection of drinking water lacking. There was no mention of drinking water in the primary legislation (the Resource Management Act 1991), and the terminology in the National Environmental Standards for Sources of Human Drinking Water Regulations, did not consider groundwater drinking water sources. Further promotion and education was required to ensure that regional councils effectively adopted the regulations and took responsibility for protecting drinking water sources.

As the frontline regulatory practitioner, the Drinking-Water Assessors played a critical role, however one that was under resourced and contracted through public health units. The Drinking Water Assessors were instructed by the Ministry of Health to take a “consultative and cajoling approach”, which may have influenced “slackness" and "non-compliance" attitude from water suppliers and reinforced the perception that the standards were optional. All Drinking Water Assessors were also required to have a public health background, where having a more multi-disciplinary group, including with water services expertise, may have been more beneficial. The Ministry of Health’s lack of internal resources and expertise, combined with a reliance on outsourced services, culminated with providing a lack of leadership which was needed across the sector. While the Inquiry accepted challenges for the Ministry of Health to enforce compliance, it did not see this as an excuse to do nothing, criticising the Ministry’s “inept” enforcement policy and lack of leadership.

Following on from the Havelock North contamination event, a joint working group formed between the District Council, Regional Council, and the District Health Board. This was later joined by the neighbouring Napier District Council. The Inquiry recognised the value in this type of collaboration through supporting relationships, information sharing and providing oversight, but also recognised the challenge in establishing and sustaining these groups in a meaningful way if they are not statutorily mandated.

There was now much clearer evidence of the problems and underlying risks associated with the supply of drinking-water than when the Health (Drinking Water) Amendment Act 2007 was introduced. Through climate change, agricultural intensification, population growth and urban sprawl, these risks are also likely to increase over time and be affected by discrete events such as storms or infrastructure failure.

Based on evidence heard and existing international standards, the Inquiry identified the following fundamental principles of drinking water safety for New Zealand to be promoted and used to guide all future reforms:

1. A high standard of care must be embraced
2. Protection of source water is of paramount importance
3. Maintain multiple barriers against contamination
4. Change precedes contamination
5. Suppliers must own the safety of drinking water
6. Apply a preventive risk management approach

In response to the Inquiry's urgent recommendation, minor technical changes were made to the drinking water standards in 2018. In 2019, Part 2 of the Health Act was also updated to give more regard to safety in consideration of "all practicable steps" and clarify obligations for the review and implementation of Water Safety Plans, strengthening the mandatory need for water supplies to comply.

(Government Inquiry into Havelock North Drinking Water, 2017a and 2017b)

5.2.5 2021 Onwards: A Reforming Regulatory System

In parallel with the Government Inquiry, the Three Waters Review, a cross-government initiative, was established in 2017 to investigate further options for the "regulation and supply arrangements of drinking water, wastewater and stormwater (three waters) to better support New Zealand's prosperity, health, safety and environment" (Department of Internal Affairs, 2020).

In July 2020 the Three Waters Reform Programme was also established to improve safety and quality, ensure equitable access to affordable water services, increase resilience, transparency and accountability (Department of Internal Affairs, 2021). The Three Waters Reform Programme brings together three Pou (pillars): (i) regulatory reform with a new Water Services Bill, intended to have more "teeth"; (ii) Taumata Arowai, as a dedicated water services regulator to administer this regulatory regime; and (iii) service delivery reform, to deliver more equitable, affordable and reliable access to water services (Department of Internal Affairs, 2021a).

Regulatory Reforms

The Water Services Act repealed Part 2A Health Act and amended many other Acts, including the RMA. This new regulatory framework retained many of the existing regulatory tools, increasing the potential scale and scope of the regulation while emphasizing that it be applied in a way that is proportionate to the scale, complexity, and risk profile of each drinking water supply. The legislative mandate to be proportionate to risk indicates some consideration to a Risk-Based Regulation strategy.

These reforms also address the lack of Māori input in decision-making processes (Water Services Bill, 2020). Te Mana o te Wai, describes the vital importance of water and the connection between the health of water bodies, the environment and people provides integrated framework for engagement with Tangata Whenua and communities about the quality of their water. Te Mana o te Wai was first recognised in the National Policy Statement for Freshwater Management in 2014. Any person acting under the Water Services Act, must now also give effect to Te Mana o te Wai.

Taumata Arowai

As recommended by the Inquiry, Taumata Arowai an independent crown agency was established as a dedicated water regulator in March 2021 with the Taumata Arowai – Water Services Regulator Act. Taumata Arowai is intended to provide leadership over three waters, regulating drinking water and oversight over environmental performance monitoring of wastewater and stormwater. Taumata Arowai must also give effect to Te Mana O Te Wai.

Service Delivery Reforms

All of the larger and many smaller suppliers are either local authorities or a council-controlled organisation. The local authority service delivery model provides local control of water supplies, but dedicated and aggregated water suppliers, such as the council-controlled organisations of Watercare and Wellington Water, offer the potential for greater efficiencies and improved compliance. Aggregation also aims to lift overall compliance by aggregating smaller, poorer performing suppliers with larger suppliers.

Due to the increasing complexity of water supplies, poor compliance, and underinvestment, the Inquiry recommended supply of water should be shifted out of local authorities and into dedicated and aggregated water service entities. This aggregation would also increase their accountability and independence from political interference, where politicians could overrule decisions impacting on the safety of water supplies, such as the decision whether to chlorinate. Reforming water service delivery has been a politically charged topic, with accusations of the erosion of local "sovereignty" and the fear of privatisation (Government Inquiry into Havelock North Drinking Water, 2017b). However, the Department of Internal Affairs (2021b) estimates that there could be a $110B needed to be invested into three waters over the next 30 to 40 years. As part of this, options are being considered for economic regulation, including price-quality regulation to cap the maximum price or revenue for the new entities and information disclosure requirements.

Central government was able to use $710m of COVID-19 economic stimulus funding to invest in water services as an incentive for local authorities to enter into memorandums of understanding to collaborate in good faith towards the voluntary establishment of dedicated and aggregated water service entities.

By the end of 2021, boundaries for four water services entities have been identified, but objections from both the public and elected members from local authorities have force the government to take a mandatory approach to aggregation. Objections include the loss of local control and the approach to Māori co-governance of the water service entities. A working group with representatives from Iwi/Māori and elected members of local authorities is exploring how representation, governance and accountability for water services entities can be improved in advance of the government introducing a Water Services Entities Bill.

5.3 Drinking Water Regulatory Tools

The evolution of drinking water regulation in New Zealand, also reflects in the changing regulatory tools over the since 1993, which I examine in Table 4.

Table 4: The evolution of drinking-water regulatory tools in New Zealand

	1993 to 2007: Voluntary Regulatory System	2007 to 2021: Legislative Regulatory System	2021 Onwards: Reforming Regulatory System
Command and Control	The Ministry of Health published the Drinking Water Standards for New, setting maximum allowable values (MAVs) and monitoring schedules for a range of contaminants. Legislation did not require compliance with these standards, although it did require building to have a supply of drinking-water (Building Act, 1991) and local authorities to maintain and assess water services (Local Government Act, 2002).	The Health (Drinking Water) Amendment Act 2007 required every drinking-water supplier to take "all practicable steps" to comply with the standards and (cl 69O) allows the Minister of Health to issue, adopt, amend or revoke them. An amendment to the Health Act in 2018 removed "all practicable steps" to comply with the DWSNZ and made it a requirement to comply Medical officers of health could issue compliance orders, including prosecutable offenses. However, no compliance orders up until 2017 (Government Inquiry into Havelock North Drinking Water, 2017b) .	The Water Services Act 2021 still requires every drinking-water to comply with the standards (cl 22) allows the responsible Minister to issue or adopt them although clearly states what they contain (cl 46). The Water Services Act also introduces a graduate set of enforcement tools including powers to direct suppliers (cl 104), obtain information (cl 108), search (cl 112), compliance orders (cl 120-129), enforceable undertakings (cl 130-135) and infringement fees (cl 149-156) and criminal prosecutions (cl 157 – 161).
Market Influencing	The Ministry of Health's Technical Assistance Programme started in 2005 with a Drinking Water Subsidy Scheme of $10m per year for small drinking-water supplies in area of high deprivation.	The Drinking Water Subsidy Scheme ended in 2015.	Central government provided $710m of COVID-19 economic stimulus funding to invest in water services. However, this funding does not apply to supplies not owned by local authorities.

	1993 to 2007: Voluntary Regulatory System	2007 to 2021: Legislative Regulatory System	2021 Onwards: Reforming Regulatory System
Information Tools	The Ministry of Health published a register of supplies with their public health grading; monitored and reported on water supplies compliance with the drinking water standards (Taylor, 2002); and provided recommendations, specifically identifying individual water suppliers and what actions they needed to take (Government Inquiry into Havelock North Drinking Water, 2017b),	The Health Act 1956 (cl 69J) mandated the publication of a register of all drinking water supplies serving over 25 people or community-purpose buildings. An annual report on compliance with the Health Act and drinking water standards for all drinking water supplies serving over 100 people was produced according to the Health Act 1956 (69ZZZB). However, the report was not user-friendly and ineffective in holding non-compliant water supplies to account(Government Inquiry into Havelock North Drinking Water, 2017b).	The Water Services Act 2021 (s54) mandates the publication of a register of all water supplies serving more than a single domestic dwelling. The Water Services Act 2021 (s135) requires the publication of an annual drinking water regulation report on the compliance of water supplies and on safety, risks, hazards, sector capability, and the regulator's performance.
Assistance	The Ministry of Health published the Guidelines for Drinking-Water Quality Management in New Zealand which provides information and advice on managing small drinking-water supplies (Ministry of Health, 2019)	The Guidelines were updated in 2005 to apply to all drinking-water supplies and have subsequently been updated in 2008 and 2017. (Ministry of Health, 2019)	Water Services Act allows Taumata Arowai to issue acceptable solutions, verification methods, (cl 50),templates and models. (cl 52) for specific classes of water supplies such as those serving less than 25 people (cl 49).

5.4 Conclusion

The evolution of New Zealand's drinking water regulatory system can be understood from a range of different perspectives. This evolution can be followed from a customary regulatory system which acknowledged sacred connections with the environment; to the introduction of a fragmented set of legislation and organisations; the leadership from the Ministry of Health, which was limited by legislative mandate; to legislation which took 12 years to eventuate and was diluted by political pressure; to the regulatory failure that has driven the current reforms. This shows a trend towards more centralisation and specialisation, as drinking water regulation now has its own legislation and independent regulatory agency, local authority water supplies are being aggregated into four water services entities, and a trend away from voluntary regulation. This evolution also shows the interactions between the events and political pressure in the regulatory system.

In Chapter 6, I will use the drinking water regulatory systems I have explored in this case study to evaluate how different types of systems thinking can be applied to improve regulation.

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6 Systems Thinking for Drinking-Water Regulation in New Zealand

This chapter describes the desktop exercise I use to evaluate how different types of systems thinking can be applied to improve drinking-water regulation. Through this desktop exercise, I will explore and refine the primary research question, from Chapter 4:

Whether and how can rich pictures, causal loop diagrams, stock and flow diagrams, system archetypes and social systems theory be applied by regulatory practitioners to improve regulation?

I conducted a one-hour time-boxed exercise to evaluate how I can apply each type of systems thinking to improve regulation. As system archetypes and social systems are theories rather than tools, these also require some consideration for how they can be applied in this desktop exercise. Based on this exercise, I will evaluate how each type of systems thinking can improve drinking-water regulation, how easy it is for a regulatory practitioner to apply, and refine the steps through which it is applied in an interactive workshop. My evaluation of types of systems thinking by applying them myself in this desktop exercise will not provide any valid empirical evidence, as I do not consider myself representative of a regulatory practitioner and will be subject to biases. However, it will still be a valuable opportunity to refine my primary research question and better inform the interactive workshop I will discuss in Chapter 7.

6.1 Systems Thinking in Drinking-Water Regulation

The drinking water regulatory system designed by the Ministry of Health in the 1990s was intended to "promote maximum interaction and mutual support between the various stakeholders" with "various components not only complement but mutually reinforce each other" (Taylor, 2002, p. 1), which implies some application of systems thinking. However, duplicate feedback mechanisms may have been intended to be mutually reinforcing, but instead, they fragmented responsibilities and created complexity which obscured accountability (Government Inquiry into Havelock North Drinking Water, 2017a). Based on this existing application of systems thinking and this example of unintended emergent behaviour, it would be valuable to understand how types of systems can be applied to improve drinking water regulation.

6.2 Rich Pictures

Rich pictures are a good starting point to record, organise and understand the complexity of regulatory systems. I based the steps on applying rich pictures on guidance from Monk and Howard (1998), Bell and Morse (2013), Berg and Pooley (2013) and Wilson and Haperen (2015). I drew two different rich pictures of drinking water regulation during my desktop exercise.

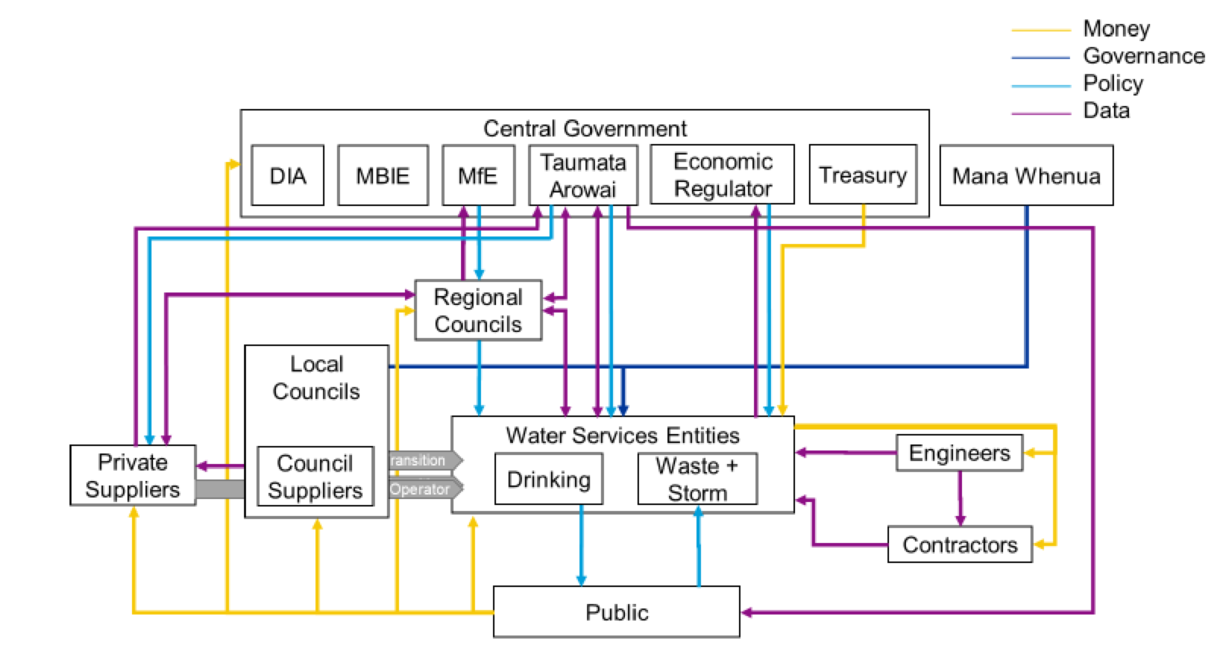

Figure 8:Organisational structures in drinking-water regulation (not a rich picture)

My first rich picture (Figure 8) ended up as a simple block diagram of the organisations currently involved in drinking water regulation. I relied on words instead of imagery to convey meaning and created a representation of reality limited by my existing mental models of the system elements as organisations and interactions through money, governance, policy, and data. My failure to include actual pictures may have reduced the rich picture's ability to surface new mental models (Bell and Morse, 2013), but the fact that I did this as a solitary exercise may have had a bigger impact.

In my second picture, I focused on how a rich picture can help to understand risk. However, I drew a broader picture of the regulatory system, including organisations and regulatory tools. I initially included some text and drew the interactions without colour to avoid limiting the scope of the rich picture. I digitised the rich picture, using basic shapes, the FontAwesome Icon Toolkit (FontAwesome, 2021), no text, and colour coding the interactions (information in pink; representation and taxes in purple; management in green; regulation in light blue; the public in tan; water in blue).

The variety of elements and the number of interactions between the element in both rich pictures indicate a degree of complexity in the regulatory system. I found rich pictures useful for structuring and sharing my understanding of the drinking water regulatory system. Although the diagram of the organisational structures in drinking-water regulation lacked actual pictures, I have used it professionally to communicate the impact of the water reforms and explain the flows of data between different organisations. The Government Inquiry into Havelock North Drinking Water (2017) criticised the range and fragmentation of organisations in the drinking-water regulatory system. Although some rationalisation has occurred with Taumata Arowai replacing the role of the Ministry of Health and District Health Boards, there is still a wide range of organisations involved.

The second rich picture (Figure 9) explores the health impact of unsafe drinking water, the factors contributing to them and their mitigations. The health impacts may be minor or require medical attention. Bacteriological, protozoa and chemical contamination in source water contribute to the risk. Treatment through filtration, disinfection and UV mitigate the risk.

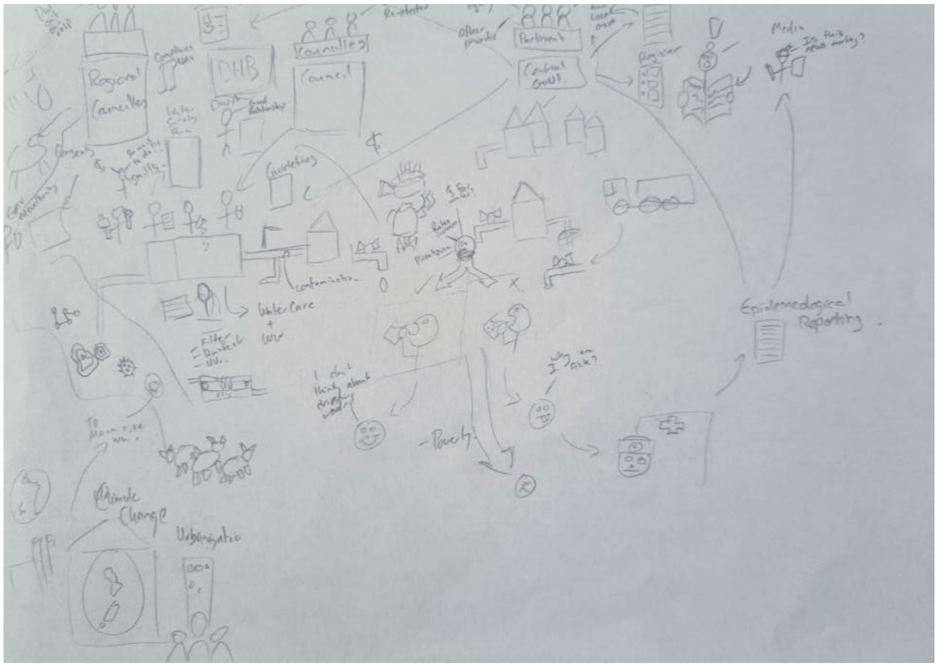

Figure 9: Rich picture of the entire drinking-water regulatory system

This rich picture helps to understand regulated parties by identifying engineers and technicians' roles in building, maintaining, and testing water supplies. The annual report, boil water notices, public health monitoring and the media show feedback in the regulatory system. Showing the range of activities could help identify leading and lagging performance indicators, e.g., whether appropriate treatment is applied (leading) or boil water notices are issued (lagging).

The picture separately represents the organisations, people and governance bodies involved, capturing the range of differing priorities and concerns throughout the regulatory system. The picture shows the different and sometimes contradictory concerns for the drinking water assessors, water services managers and the public. The diverse roles of the public are also shown, including farmers and industrial business owners who may be both positively and negatively impacted by drinking water regulation. Blue glass icons on every person show the universal impact of drinking water regulation.

I found drawing rich pictures to be a relatively easy activity. I tended to use words and focus on specific details. Keeping the discipline of only drawing pictures encouraged a more holistic perspective of the regulatory system, surfacing mental models about the boundaries of regulatory systems and behaviours of different actors.

Based on my desktop exercise, I believe that regulatory practitioners might be able to apply rich pictures to improve regulation. By providing a relatively unstructured approach for considering the interactions and elements in their regulatory system, rich pictures might be a valuable starting point for the applying systems thinking. In the interactive workshop, I will provide guidance to show risks, regulated parties, regulatory tools, regulators, the public, the environment and the interactions between them, contributing to existing guidance to help regulatory practitioners draw rich pictures.

6.3 Causal Loop Diagrams

Through a more structured representation of elements and interactions, causal loop diagrams can build upon rich pictures to show how linear relationships develop into feedback loops that can create emergent behaviour, both intended and unintended. I began my causal loop diagrams with a simple feedback loop between a regulatory problem, monitoring and intervention, based on the drinking water regulatory system from 2007 - 2021. Following guidance from Kim (2000), I elaborated unclear causal interactions with intermediary elements, resulting in Figure 10. I also included time delays, the effects of multiple regulatory tools, limiting factors and unintended consequences.

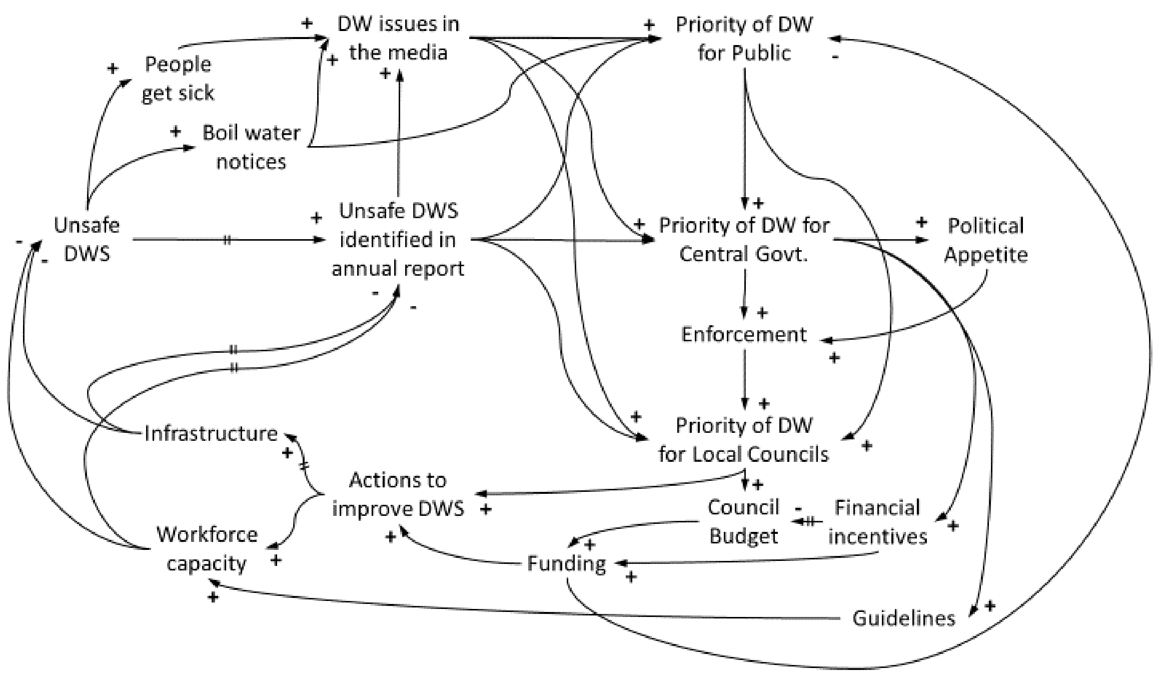

Figure 10: Detailed causal loop diagram showing the feedback loops of multiple drinking-water regulatory tools

The causal loop diagram shows the feedback loops through which drinking water is regulated. There are over 50 different permutations of similar balancing feedback loops in this diagram, following a common pattern of: monitoring (illness, boil water notices, annual report, media); prioritisation (by the public, central government and local councils); and behaviour modification (through infrastructure or workforce capacity). Performance measures could use variable elements or help to validate the interactions. The casual loop diagram in Figure 10 could be used to understand the behaviour of individual, groups or all drinking water suppliers. It does not consider the interactions between different water suppliers, such as significant contamination events or enforcement action for one water supplier impacting the behaviour of other water suppliers.

The biggest challenge in drawing casual loop diagrams was knowing what level of detail to include. In the desktop exercise, I managed this challenge through the time-box. To guide regulatory practitioners through the process of drawing casual loop diagrams in the interactive workshop, I documented the steps which I followed.

Based on my desktop exercise, I believe that regulatory practitioners might be able to apply casual loop diagrams to improve regulation. They provide a more structured tool which can be used to understand, communicate and measure the intervention logic in regulatory systems.

6.4 Stock and Flows

Stocks and flow diagrams add another level of detail to causal loop diagrams through the concepts of stocks of variable elements, which can accumulate over time. To create a stock and flow diagram of regulation, I first needed to determine what stock within a regulatory system to consider. While stocks could represent sources, treatments, and levels of contaminants in drinking water to better understand the risks, this application would provide a more scientific or engineering perspective, which might be less relevant to regulatory practitioners.

Instead, I used a stock and flow diagram to explore "stocks" of different types of regulated parties and the flow between them. I built on the approach used in a stock and flow diagram to model HIV Testing and Care, which identified 16 stocks over the two dimensions of the stage of infection and the level of engagement in care (Martin et al., 2015). I identified different "stocks" of drinking-water suppliers based on their type and size, which were closely related, and their level of capability and compliance (Figure 11).

The flows represent both the shift towards compliance and the aggregation of smaller suppliers into larger suppliers, considering the range of factors that may affect each of those flows. This interaction is not represented as a flow, as it is not a flow of regulated population.

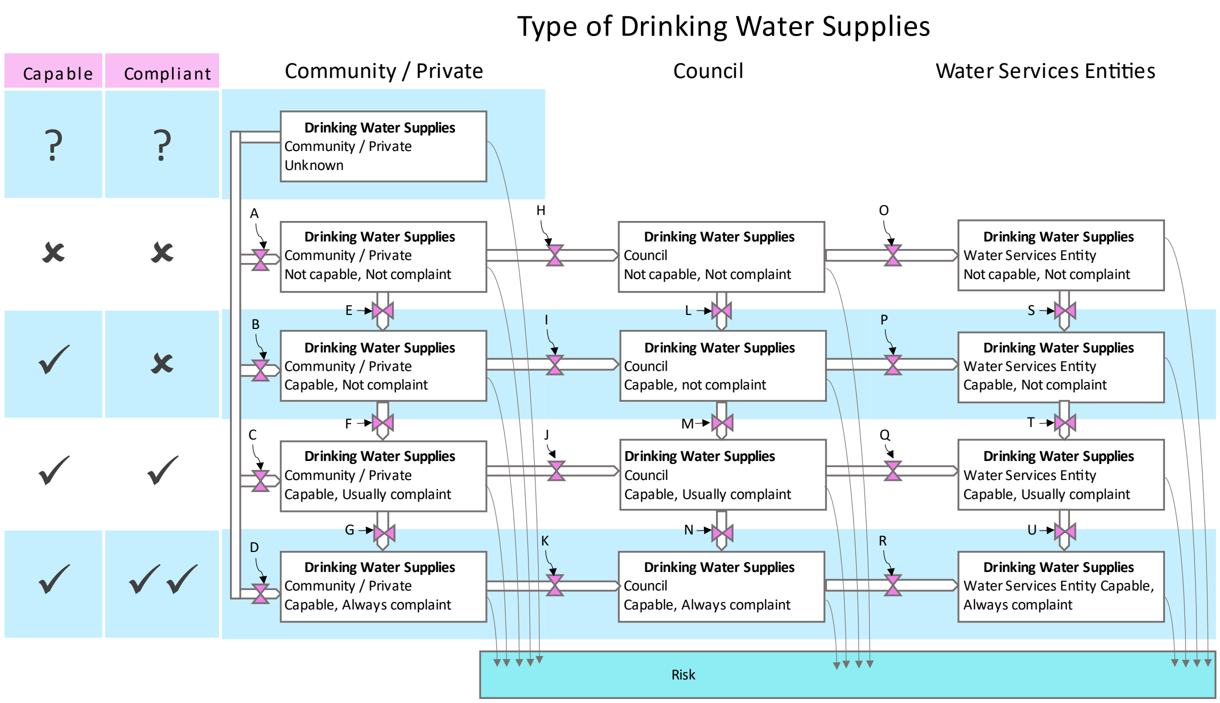

Figure 11: Stock and flow diagram of the compliance, capability, type and size of drinking-water suppliers (DWSs)

Each of these stocks has a different interaction to the risk likelihood and impact of people getting sick from drinking water. This risk could be quantified using disability-adjusted life-years, which aggregates both the quantity and quality of life for the impact of any drinking-water contaminants (World Health Organization, 2011). Calculating disability-adjusted life-years would use the likelihood of contaminants being present, the cause of diseases in different types of water supplies and a severity rating for each contaminant. These values could be estimated based on reported controls, treatments and monitoring of drinking water supplies. Because disability-adjusted life years are proportional to the supplies' population, it might be more relevant to consider this as the stock rather than the number of the supplies. Although there will be a degree of uncertainty in these estimates, this approach would provide a consistent and relative quantification of risk across the entire regulated population, supporting risk-based regulation and prioritising interventions. Different interventions could target different flows:

- A, B, C, D: The identification of community or private supplies;
- H, I, J, K: Transferring community or private supplies into council operations;
- O, P, Q, R: Aggregating council supplies into water services entities;
- E, L, S: Capability development;
- F, G or M, N or T, U: Targeted intervention to improve compliance.

Comparing the estimated impact of each intervention and the net effect on the overall disability-adjusted life-years could be used to inform a cost-benefit analysis for interventions. I found this stock-and-flow diagram helpful in understanding different types of regulated parties and the different activities which might move them towards compliance. The flow of regulated parties towards compliance has similarities with the customer journey through a sales funnel model (Venermo et al., 2020). Future research could examine the application of these sales funnel stock and flow models to regulation.

The type of regulated parties is of particular interest due to the current reform's aggregation of drinking-water suppliers into four water services entities but may be less relevant in other regulatory systems. It was challenging to select relevant dimensions to segment the regulated parties by including willingness, consideration of their infrastructure and workforce capacity, and bacteriological, chemical and protozoal compliance. Considering more dimensions would make the model more complex, harder to draw and harder to understand. This stock and flow diagram should also show backflows to represent degradation in suppliers' capability or compliance.

Including the concept of stocks may allow stock and flow diagrams to represent real-world situations better, but this also makes them more complex to draw and understand. A stock and flow diagram would be necessary for developing a systems dynamics model to quantify risk and test the impact of different interventions, but this would require specialist skills beyond most regulatory practitioners, putting it beyond the scope of this research project. Based on my desktop exercise, I do not consider the additional effort and complexity involved for a regulatory practitioner to apply a stock-and-flow diagram to offer a proportional amount of value compared to a causal loop diagram. I will not evaluate them further in the interactive workshop.

6.5 Systems Archetypes

System archetypes describe common behaviours which emerge from common systems structures. By recognising warning signs, we can also apply common remedies. I reviewed a list of common system archetypes (Senge, 1990) to identify which of these might be used to describe behaviours in drinking water regulation with the help of the causal loop diagram I had developed. Of the ten systems archetypes, I was able to apply the balancing process with delay, limits to growth and shifting the burden to the intervener systems archetypes to drinking water regulation.

6.5.1 Balancing Process with Delay

A standard balancing process with delay occurs in balancing feedback loops where delays in the system's responsiveness lead to repeated or escalating responses. This behaviour is due to the cadence of reactions to the system exceeding the system's responsiveness, resulting in goals being "over-shot" (Senge, 1990). The remedy is to consider how fast the system can react and what reactions might still be trickling through the system. In regulation, this could occur when monitoring processes take a long time to identify and report issues or when interventions take a long time, such as the construction of new infrastructure.

Until 2016 the drinking-water regulatory system had low responsiveness, taking seven years to pass regulatory legislation and not undertaking any enforcement action. It was very far from overshooting. A drive for more responsiveness to improve performance only occurred with the reform following the Havelock North water contamination, significantly realising the risk of illness. However, there will still be time delays to identify and report specific issues or for interventions to have an effect, such as the construction of new infrastructure or the development of workforce capacity. Therefore, it is important to use leading indicators to evaluate the performance of the regulatory system and allow appropriate time to measure the outcomes of the reforms. Otherwise, a perception that the reforms have not succeeded could create pressure to change strategies or even undergo reform before the outcomes are known.

6.5.2 Limits to Growth

The limits to growth systems archetype describe the situation where a growing action in a reinforcing feedback loop diminishes over time due to a limiting constraint causing a slowing action in a parallel balancing feedback loop. The seminal example is how the resource use of a growing population will eventually limit the population growth (Meadows, 1972). At the core of a regulatory system is a balancing feedback loop, rather than a reinforcing feedback loop, but this could still exhibit similar behaviours. The remedy to this behaviour is to address the limiting instead of pushing the feedback loop.

This system archetype could explain the plateau in the performance against drinking-water standards in 2003. The Ministry of Health identified the limiting condition of funding and expertise and addressed them through the Drinking-Water Assistance Programme (Ministry of Health, 2019).

Ayres and Braithwaite's caution about the detrimental effect of politically impossible sanctions could also be described as a variation of this limits to regulation systems archetype, where the political appetite limited the opportunity for enforcement. This system archetype could help understand the minimal performance improvements in drinking-water quality from 2007 to 2021. The limit from the low political appetite resulted in no enforcement actions being taken and created a benign regulatory deterrence. From 2021, The Water Services Act provides graduated enforcement tools, which reduces the political appetite required for their application. However, this will increase their need to be applied to demonstrate their regulatory deterrence.

Considering limits also helps to draw a more representative causal loop diagram. The interaction between funding and the priority of drinking water for the public creates a financial limit to safe drinking water. Without these limits, the causal loop diagram would assume no barriers to safe drinking water. The causal loop diagram presents a wider view of a regulatory system, allowing assumptions like these to be surfaced and challenged.

6.5.3 Regulatory System Archetype: Shifting the Burden to the Intervener

Sparrow (2000) recognised the systems archetype of shifting the burden to the intervener (e.g. regulatory) as a common situation in government interventions. This systems archetype describes the situation where the regulator's actions to support compliance undermine the regulated party's responsibility or capacity to comply. The remedy is to build capacity rather than solve problems and ensure that solutions are temporary.

The Three Waters Reform Programme is at risk of creating a precedent of central government stepping in when local councils underinvest in their water infrastructure by providing financial incentives. The new Water Services Entities will be designed to be more financially independent and sustainable to mitigate this risk (Department of Internal Affairs, 2021).

In the workshop exercise, I will introduce regulatory practitioners to examples of the limits to growth, shifting the burden to the intervener and benign regulatory deterrence systems archetypes, and ask them if they recognise these patterns in their regulatory systems.

Applying systems archetypes in the desktop exercise provided the opportunity to analyse further and draw actionable lessons from the causal loop diagrams. I believe that regulatory practitioners might be able to apply systems archetypes in a similar way to improve regulation.

6.6 Social Systems Theory

Social systems theory describes society as a set of independent sub-systems, including the political, legal, economic, media, science and health (Roth and Schütz,2015). Regulatory actions involve interactions over multiple sub-systems. However, each sub-system communicates in its codes, which are not accessible outside these sub-systems. Therefore, interactions between these subsystems rely on communications which can be interpreted through the codes of multiple sub-systems (Nobles and Schiff, 2011). Organisations operate over multiple sub-systems and can help to link between different sub-systems (Lawson, 2011). Social systems theory can help understand the behaviours of different actors in regulatory systems and the interactions of different regulatory tools. I have evaluated how social systems theory might be applied to improve regulation in my desktop exercises. I first considered how different actors (Table 5) and then how different regulatory tools (Table 6) communicate in different sub-systems.

I evaluated how social systems theory might be applied to improve regulation in four steps in my desktop exercise. (i) I identified how actors receive and transmit communications in different social sub-systems (Table 5). (ii) I identified the social sub-systems in which different drinking-water regulatory tools (2007 to 2021) are used to communicate (Table 6). (iii) I identified the social sub-systems in which the interactions in the rich picture occur (Figure 12). (iv) I applied the same approach to categorising the interactions in the causal loop diagram (Figure 13).

Table 5 shows how every actor communicates in every social sub-system, meaning that there is always an opportunity for meaningful communication within the same social sub-system. There are also risks of communication breakdowns when communications are attempted between different social sub-systems. A local councillor might not respond to (legal) communication around compliance with drinking water standards, but they might respond to (health) communication about protecting the wellbeing of their community. A water services operator might not respond to a (health) communication about providing safe drinking water, but they might respond to a (science) communication in the Drinking Water Standards.

Table 6 shows how regulatory tools in different social sub-systems cause both intended and unintended communications. Some unintended consequences include the potential political opposition to enforcements and the cost to prepare water safety plans. Actors might not consider these unintended consequences if they are not focused on the social sub-systems in which they occur. Tools like the drinking-water quality report and standards can help to translate between different social sub-systems for meaningful communications. It is interesting to observe how every regulatory tool communicates in the economic, social sub-system, which could justify the economic quantification of many cost-benefit analyses

Table 5:How different actors from drinking-water regulation (2007 to 2021) communicate in social sub-systems

Sub-System	**Code**	**Parliament**	**Ministry of Health**	**Water Supplier**	**Councillor**	**Public**
Political	Power	*Receives*: Elected *Transmits*: Legislation and direction	*Receives*: Political direction	*Receives*: Political direction	*Receives*: Elected *Transmits*: Policy and direction	Transmits: Elects
Legal	Law	*Receives*: Legal mandate *Transmits*: Creates legislation	*Receives*: Legislation to enact *Transmits*: Set standards	*Receives*: Legislation and standards	*Receives*: Legal mandate	-
Economic	Money	*Transmits*: Allocates budgets	*Receives*: Budget allocation	*Receives*: Budget allocation	*Transmits*: Allocates budgets	*Transmits*: Pays rates/taxes
Media	News	*Receives*: Influences political agenda *Transmits*: Press statements and interviews	*Transmits*: Answers questions (reluctantly)	*Transmits*: Boil water notices and answers questions (reluctantly)	*Receives*: Influences political agenda	*Receives*: Influences priorities
Science	Truth	*Receives*: Informs legislation	*Transmits*: analysis and justification for legislation and the standards	*Receives*: Influences processes	-	*Receives*: Influences priorities
Health	Illness	*Receives*: Influences political agenda	*Receives*: Influences priorities	*Receives*: Influences priorities	*Receives*: Influences political agenda	*Transmits*: When they get sick

Table 6: How different drinking-water regulatory tools (2007 to 2021) communicate in social sub-systems

Sub-System	**Code**	**Drinking-water Standards**	**Enforcement Tools**	**Financial Incentives**	**Guidelines**	**Drinking-water Quality Report**	**Water Safety Plans**
Political	Power	May trigger political opposition (e.g. chlorination)	May trigger political opposition	May require political approval -	-	Legislative requirement	-
Legal	Law	Legislative requirements and enforceable	A legal tool	May be intended to achieve legal compliance	-	Legislative requirement	Legislative requirement
Economic	Money	Complying with the standards impose costs	Enforcement cost **money** and it may impose fines.	Are money	Cost **money** to prepare and implement	Costs **money** to prepare	Cost **money** to prepare and implement
Media	News	-	May create **news**	May create **news**	-	May create **news**	-
Science	Truth	Based on science	May be based on scientific standards	-	Based on science	Based on scientific standards	Based on scientific standards
Health	Illness	Should prevent **illness**	May be triggered by **illness**.	May be intended to prevent **illness**	Intended to prevent **illness**	-	Intended to prevent **illness**

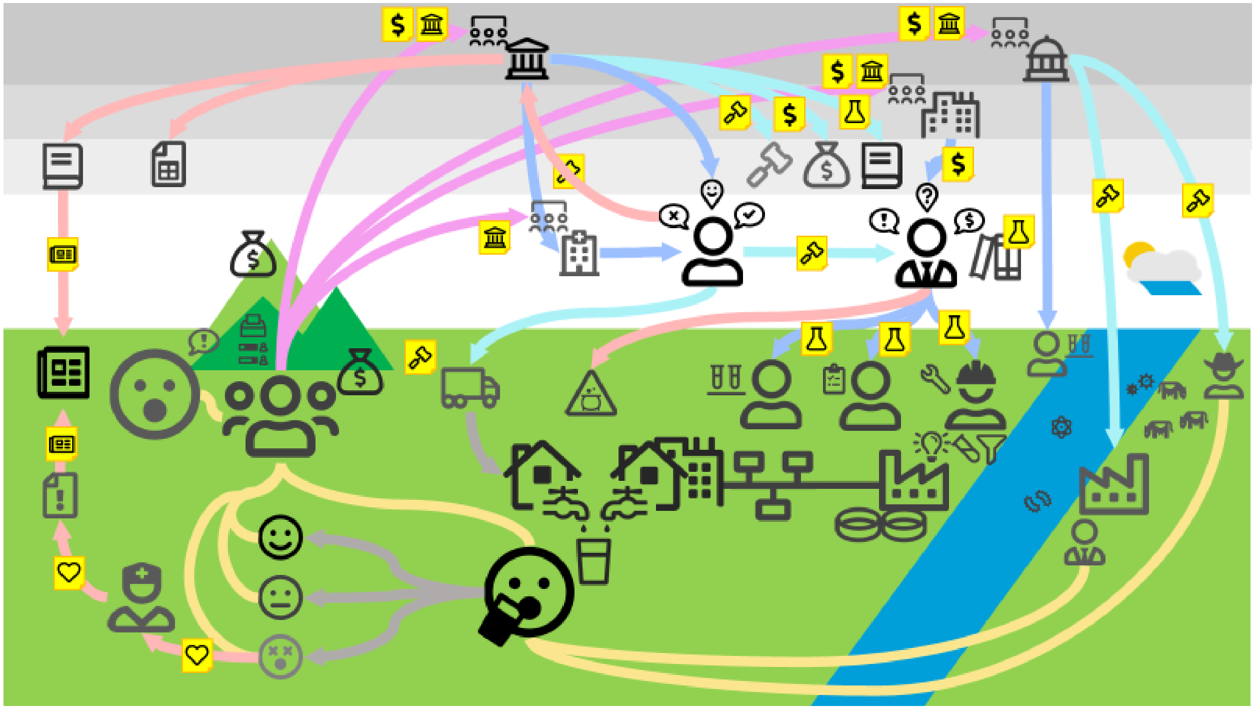

Figure 12: Identification of the social sub-systems in which the interactions occur in the rich picture of the drinking water regulatory system

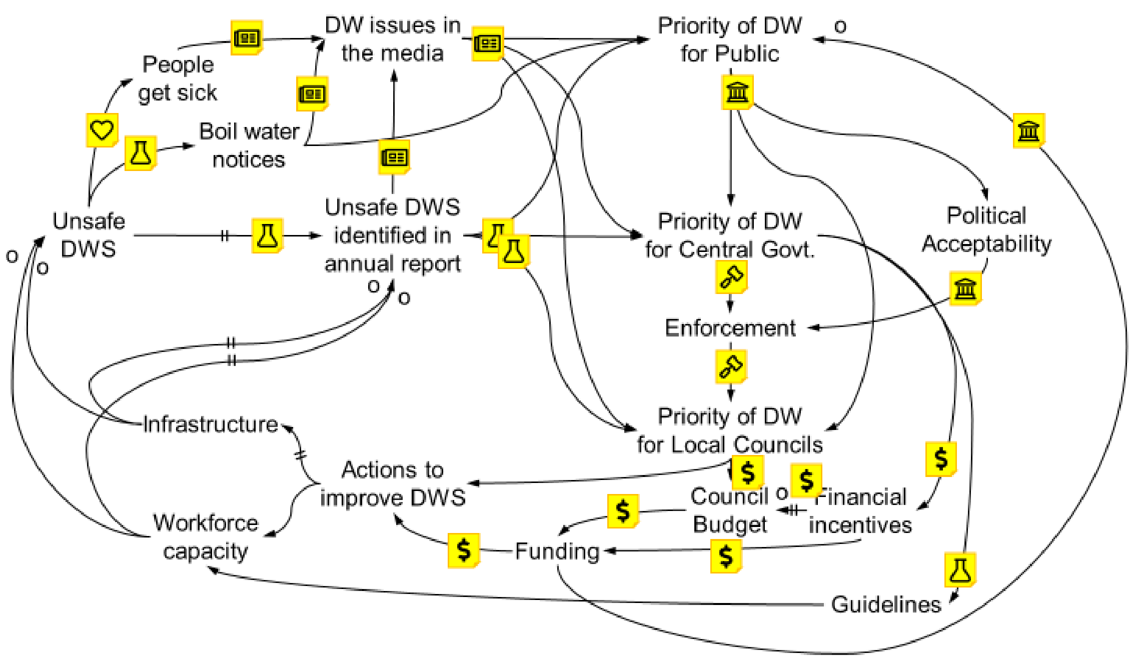

Figure 13: Identification of the social sub-systems in which the interactions occur in the causal loop diagram of the drinking water regulatory system

Most interactions in Figure 12 and Figure 13 occur within a single social sub-system. In Figure 12, the interactions between the public, parliament, regional councillors, and local councillors include political (democratic representation) and economic (taxes and rates) communication. Physical interactions are not categorised, as these are not communications in a social sub-system. We can see how balancing feedback loops depend on communications across all social sub-systems through this exercise. Maintaining these feedback loops requires translations of communications between different social sub-systems to ensure that the feedback occurs.

6.7 Conclusion from Desktop Exercise

Applying systems thinking to drinking-water regulation in New Zealand shows its potential to help address common regulatory challenges of understanding risk, understanding regulatory parties, monitoring and managing performance and understanding complexity.

The rich picture models the factors that contribute to and mitigate the risk of unsafe drinking water and the health impacts of this risk. The casual loop diagram models show factors that might influence the behaviour of regulated parties, identify different variables that contribute to the regulatory system's performance, and the interactions between these variables. The system archetypes were helpful in explaining further the behaviours of regulated parties and the regulatory system performance. The stocks and flows diagram provided a quantifiable approach to measure risk across different regulated parties. Social systems theory can explain why communication between different actors might succeed or fail, how different regulatory tools might be used in these communications and how these communications are essential for effective feedback loops.

The rich pictures and causal loop diagrams show the complexity of the regulatory system's multiple feedback loops and responsibilities. The stock and flow diagram shows the complex relationship between different types of regulated parties and risk. Social systems theory provided a framework to understand this complexity through social sub-systems.

6.8 Refined Primary Research Question

Based on my desktop exercise, I have refined my primary research question to:

Whether and how can rich pictures, casual loop diagrams and system archetypes be applied by regulatory practitioners to improve regulation.

In Chapter 7, I will answer this question through interactive workshops with regulatory practitioners.

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7 Applying Systems Thinking to Improve Regulation

This chapter describes the empirical evidence collected through two interactive workshops with 21 regulatory practitioners to answer the primary research question:

Whether and how can rich pictures, causal loop diagrams and system archetypes be applied by regulatory practitioners to improve regulation?

Using Kirkpatrick's evaluation model (Mathison, 2005), I consider the participants' reactions, learning, behaviour change, and results through observations, group discussion, post-workshop questionnaires, and follow-up interviews. In this chapter, I will (i) discuss the workshop approach; (ii) review the activities through which participants applied systems thinking; (iii) share some general observations; (iv) conclude which of these types of systems thinking can be applied by regulatory practitioners to improve regulation; and (v) how systems thinking can be applied.

7.1 Approach

I initially planned the interactive workshop at the Victoria University of Wellington. From promotion through LinkedIn and the Government Regulatory Practice Initiative (G-Reg) Regulatory Reference Group, 19 participants applied from five regulatory agencies. Due to COVID restrictions, the university could not host the workshop. Fortunately, two regulatory agencies agreed to host workshops in their offices for 21 of their staff in total, allowing me to refine the workshop design between two different groups of people from regulatory agencies.

The workshop lasted for four hours, consisting of an introduction to systems thinking concepts, then facilitated activities to guide participants through applying rich pictures, causal loop diagrams and systems thinking archetypes. The evaluation approach uses the Kirkpatrick model, exploring the participant's reaction and learning and the workshop's impact on their behaviour and actual results for their organisation (Mathison, 2005). The evaluation consisted of five parts: (i) A pre-workshop questionnaire assessed the participants' existing awareness of systems thinking and expectations; (ii) I observed how participants could apply the type of systems thinking in the activities; (iii) I analysed the group discussion about each activity to explore how the participants felt they could complete the activity and how useful they thought it might be; (iv) A post-workshop questionnaire assessed the participants' current level of awareness of system thinking and their reaction, learning, predicted behaviour change, and predicted value of systems thinking using a Likert scale (Table 7); (v) I reviewed my findings with semi-structured interviews with three of the participants reviewed after a month and explored their actual application or impacts of systems thinking.

Table 7: Post-workshop questions for each systems thinking activity

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This activity was enjoyable	◻	◻	◻	◻	◻
I am now able to apply this activity	◻	◻	◻	◻	◻
This activity would be valuable to apply to my work	◻	◻	◻	◻	◻
I intend to share this activity with a colleague in the next month	◻	◻	◻	◻	◻
I intend to apply this activity to my work in the next month	◻	◻	◻	◻	◻

This research aims to evaluate the application of systems thinking by regulatory practitioners, focusing on the activities and participants rather than their regulatory systems or the impact of the system thinking activities. Within the scope of this research, it is easier to evaluate participant reactions and learning. However, the Kirkpatrick Model emphasises the importance of evaluating behaviour change and business results, which I consider through questions about the participant's intentions in the post-workshop questionnaire and the interviews. I did not intend the scale and selection of regulatory practitioners participating in the workshops to provide statistically significant quantitative evidence but still provide empirical evidence to answer the primary research question.

7.1.1 Workshop One

Many of the nine participants of the first workshop worked together, had a good rapport, and shared humour and reflections about their work throughout the workshop. The workshop was held in the boardroom of their office, with participants sitting in groups around the single large board table. The participants worked in different cities and had come together for this workshop and additional meetings. They regretted not having participants from other agencies to share perspectives and learnings. Three participants could not attend the complete workshop (one for a pre-planned call who returned, one due to a family situation and one unexplained).

7.1.2 Workshop Two

A senior manager from another regulatory agency championed workshop two and invited 12 participants from across their agency. This regulatory agency identified different regulatory systems in which it operated. These participants worked in three of these regulatory systems, and some were responsible for regulatory stewardship over all these regulatory systems. Together with another senior manager who had over 20 years of practical and academic experience in systems thinking application, the senior manager champion had an aspiration to develop a community of practice for systems thinking within their regulatory agency. From the systems thinking expert, I also discovered that this regulatory agency had previously applied systems thinking as part of a research project. However, this was not mentioned by any of the workshop participants. The systems thinking expert did not attend the workshop to allow space for other attendees. I arranged the workshop room with four tables to accommodate participants groups based on their regulatory system or stewardship role.

7.2 Evaluation

In both workshops, the participants identified themselves as having a fair to a good understanding of systems thinking. Only one participant acknowledged having no prior awareness of systems thinking. Seven (33%) of the 21 participants had only heard about systems thinking, compared to nine (43%) who had read an article, book or attended systems thinking training. Six (29%) has either applied or observed the application of systems thinking in their work. Three of those who applied systems thinking had not read or attended training about systems thinking, and one of them was unsure of the specific definition of systems thinking. There was almost unanimous agreement on the importance for regulatory practitioners to address the challenges to understand risk better (95%), understand regulated parties (100%), manage performance (100%) and appreciate complexity (90%).

7.2.1 Systems Thinking Concepts

As an introduction, I presented five systems thinking concepts (Figure 14), describing the differences between reductionism and systemic perspectives using plain language and relatable examples. The system thinking concepts stimulated rich discussions demonstrating their appreciation and surfacing common themes throughout both workshops.

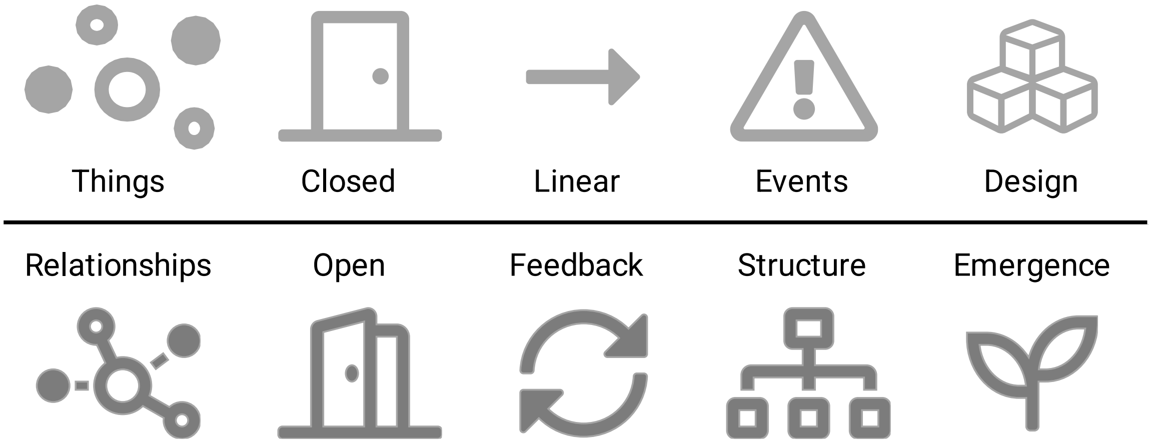


Figure 14: The differences between reductionism and holism presented in the workshop to demonstrate systems thinking concepts

Participants recognised the limitations of controlling individual linear processes or delegating individual responsibilities to managers and teams who can be performance managed, as these may optimise outputs over outcomes. The desire to control outputs may also discourage the collaboration needed to address more complex issues such as improving wellbeing. Participants discussed how interconnections create the need for trade-offs and unintended consequences, with one participant noting, “You pull a lever anywhere in the system... it will impact multiple other parts of the system”. In workshop one, a participant observed that newer legislation promotes a more systemic perspective than earlier legislation. In workshop two, participants described the need to “step back and look at the whole system”. Throughout both workshops, participants were highly engaged in group discussions, into which I needed to intervene to keep to the schedule. I had initially considered system thinking concepts as only introductory material, as they could not be demonstrably applied. After the rich discussions in workshop one, I added them to the evaluation in the post-workshop questionnaire. In the second workshop, all of the 12 (100%) participants enjoyed the concepts, all but three (75%) were able to apply them, all but one (92%) agreed they was valuable for their work, eight (67%) intended to share them, and eight (67%) intended to apply them (Table 8).

7.2.2 Activity 1: Rich Pictures

I introduced participants to rich pictures, then used a PowerPoint animation to demonstrate the progressive creation of a digitised rich picture of the drinking water regulatory system from my desktop exercise (See: 6.2 Rich Pictures). I then provided participants instructions (**Error! Reference s ource not found.**) and gave them 15 minutes to draw a rich picture of their regulatory system in groups of three. Two participants in workshop two had been involved in a similar process to map their regulatory system previously.

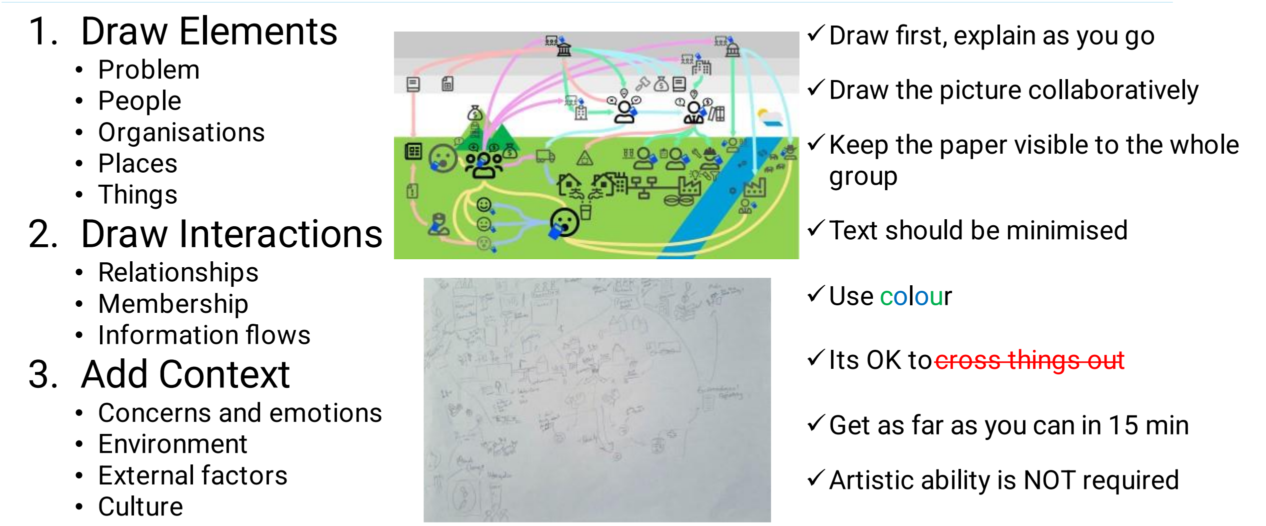


Figure 15: Workshop instructions to draw a rich picture

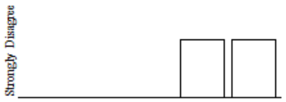
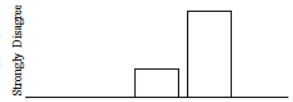
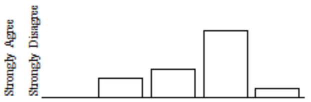
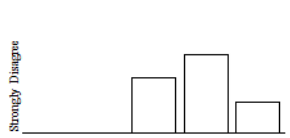
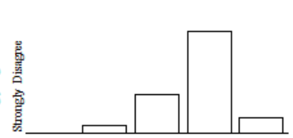
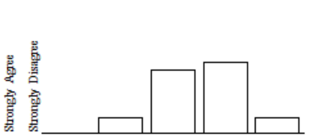
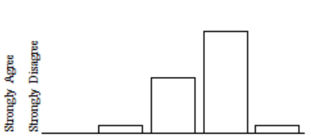
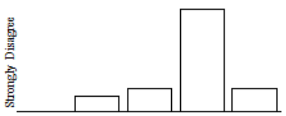
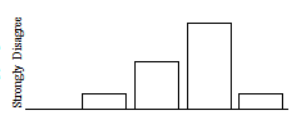
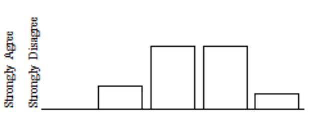
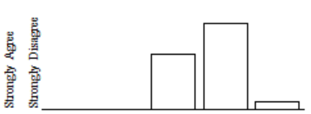
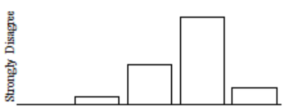
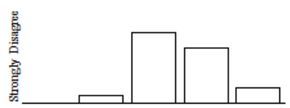
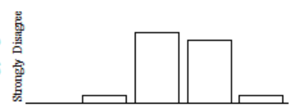
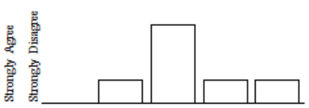
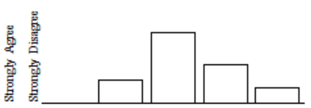
All seven groups positively engaged in the activity and drew rich pictures, including people, organisations, places, things, and relationships. Participants stated that it would be too difficult to describe the nature of the relationships. Participants identified the "frightening" and "horrific" number of relationships in both workshops. Only three of the seven (43%) groups clearly represented a regulatory problem. Two (29%) of the rich pictures did not include either concerns or the environment, and the rest only represented concerns with smiley or sad faces. This activity explores the boundaries around regulatory systems, so it is difficult to objectively assess what would constitute an external factor, although three rich pictures included international bodies or law. There was no other representation of regulatory culture; however, three (43%) of the rich pictures included Māori elements.

I asked the groups to draw their regulatory system boundaries on their rich picture. The participants in workshop one initially claimed that the boundary would include the whole rich picture. The participants in workshop two acknowledged that wherever the boundary was, there would be relevant elements outside of the boundary. In both workshops, participants agreed that different boundaries could capture different degrees of completeness to encompass their regulatory system, based potentially on risk or utility.

Participants in both workshops described the open-ended scope of the activity as daunting, and there was some discussion on whether it would have been better to start by focusing on an outcome. The general opinion in workshop one was that it was better to start broad and “draw the world you’re in”.

From the post-workshop questionnaire, all 21 (100%) of the participants enjoyed the activity, 15 (71%) were able to apply it, 14 (67%) agreed it was valuable for their work, 11 (52%) intended to share it, and 14 (67%) intended to apply it. See Table 8 for complete results. Participants in workshop one generally gave more positive responses. In total, more than half of participants agreed that rich pictures could help them to understand risk (71%), understand regulated parties (62%) and manage performance (57%). The most substantial agreement was that rich pictures could help appreciate complexity (90%). Although three participants gave feedback that more time would have been useful, given that after 15 minutes, the drawing activity was subsiding, this may have been a perception of the “daunting” scope. In workshop one, the participants discussed the value of developing and refining their rich picture further and heat mapping issues.

Table 8: Post-workshop Questionnaire Results

	Agree this activity was enjoyable	Were able to apply this activity	Agree this activity would be valuable	Intend to share this activity	Intend to apply this activity
Systems Thinking Concepts	 **12 (100%)** Workshop One: Workshop Two: 12 (100%)	 **9 (75%)** Workshop One: Workshop Two: 9 (75%)	 **11 (92%)** Workshop One: Workshop Two: 11 (92%)	 **8 (67%)** Workshop One: Workshop Two: 8 (67%)	 **8 (67%)** Workshop One: Workshop Two: 8 (67%)
Rich Pictures	 **21 (100%)** Workshop One: 9 (100%) Workshop Two: 12 (100%)	 **15 (71%)** Workshop One: 9 (100%) Workshop Two: 6 (50%)	 **14 (67%)** Workshop One: 7 (78%) Workshop Two: 7 (58%)	 **11 (52%)** Workshop One: 6 (67%) Workshop Two: 5 (42%)	 **14 (67%)** Workshop One: 7 (78%) Workshop Two: 7 (58%)
Causal Loop Diagrams	 **16 (76%)** Workshop One: 5 (56%) Workshop Two: 11 (92%)	 **13 (62%)** Workshop One: 4 (44%) Workshop Two: 9 (75%)	 **17 (81%)** Workshop One: 7 (78%) Workshop Two: 10 (83%)	 **10 (48%)** Workshop One: 2 (22%) Workshop Two: 8 (67%)	 **12 (57%)** Workshop One: 3 (33%) Workshop Two: 9 (75%)
Systems Archetypes	 **13 (68%) N:19** Workshop One: 2 (29%) N:7 Workshop Two: 11 (92%)	 **9 (47%) N:19** Workshop One: 2 (29%) N:7 Workshop Two: 7 (58%)	 **9 (47%) N:19** Workshop One: 2 (29%) N:7 Workshop Two: 7 (58%)	 **6 (32%) N:19** Workshop One: 1 (14%) N:7 Workshop Two: 5 (42%)	 **7 (37%) N:19** Workshop One: 1 (14%) N:7 Workshop Two: 6 (50%)

Note:

Unless otherwise specified, N (Total) = 21, N(Workshop One) = 9 and N(Workshop Two) - 12

I aggregated the results from five scores (strongly agree, agree, neutral, disagree, strongly disagree) to three (agree, neutral, disagree).

7.2.3 Activity 2: Causal Loop Diagrams

In the same groups, I guided participants to develop causal loop diagrams to model their regulatory systems. I provided a brief introduction, showing a simple causal loop diagram showing a generic regulatory balancing feedback loop between a regulatory problem, monitoring and intervention (Figure 16) and a more detailed example of drinking water regulation developed in Chapter 6 (Figure 10).

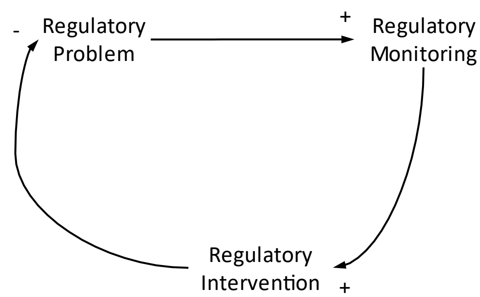


Figure 16: Simple generic casual loop diagram

In groups, participants had five minutes to create their simple causal loop diagram by identifying regulatory problems, monitoring and interventions and then showing their interactions. I then demonstrated the progressive development of the detailed causal loop diagram around the drinking water regulation, following the steps I developed in Chapter 6. In workshop one, I gave the participants these same steps to develop a detailed causal loop diagram within 30 minutes. However, the activity did not resonate with them, and they found it challenging. Therefore, I decided to modify workshop two's detailed causal loop diagram instructions, providing five steps based on the *Systems Practice* guidebook (The Omidyar Group, 2018) provided as part of an online course (Acumen, 2021). Table 9 shows the different instructions provided for the first and second workshops.

Table 9: Causal Loop Diagrams Instructions

For Workshop One	For Workshop Two
1. Describe your regulatory: a. Problem b. Monitoring c. Intervention 2. Add time delays 3. Identify feedback loop 4. Add intermediate steps 5. Add unintended consequences 6. Add limits to regulation 7. And repeat…	1. Pick a Problem Situation 2. Brainstorm Enablers + Inhibitors 3. Identify Variable Factors 4. Analyse Causes and Effects 5. Create Causal Loops

During workshop one, some participants could not align the simple causal loop diagram of regulation as a balancing feedback loop between a regulatory problem, monitoring and intervention, with the approach they took to regulation. They proposed different words to describe their regulatory approach: “problem” to “hypothesis” to “evidence base” to “intervention” to “monitoring” (of intervention). Participants in workshop one also struggled to consider regulation as a circular rather than linear process. One participant attempted to reconcile this by describing:

a causal loop is just a linear way of thinking that loops back on itself. It’s unsafe, we do some work to monitor that it is unsafe, then we do an intervention, then we do some more monitoring to go with the intervention, it’s the intervention working, and then we go, is it still unsafe, so we do some more monitoring.

Participants did not like using nouns instead of actions to describe the variable elements. They also found the “negative” polarity of interactions counterintuitive at times, such as the *reduction* in harm, which they regarded as positive. There was a consensus from participants in workshop one that this activity needed to give people more chance to get out their thoughts before fitting them into the structure of a causal loop diagram.

Despite these challenges, every group in workshop one produced basic and detailed causal loop diagrams and used them to discuss their regulatory system. None of them included time delays, and only one included the polarity of interactions. One group identified limitations in their current monitoring, indicating their current interventions may not be effective. They needed to work with other parts of the government to address the problem and their causal loop diagram that included "Wellington centric ignorance" and "institutional racism". The group used the concept of system boundaries to discuss how their regulatory system focused on people who chose to be regulated and excluded "ratbags". The participants compared this to a two-tier system like undocumented migrants in the United States or potentially unvaccinated people in New Zealand. Through this discussion, one participant observed, "we don't have a realistic view of the system; that's what we're saying in this context… I find that terrifying". Participants drew similarities between this exercise and investment logic mapping, benefits mapping and risk bowties. Other participants saw how causal loop diagrams could be used to should how the causal relationships between different factors contribute to performance measures to help understand what they were measuring and identify better measures.

The participants in workshop two did not encounter any issues following the exact instructions to produce simple causal loop diagrams. They could also follow the revised instructions for the detailed causal loop diagram, which excluded time delays or polarity. The instruction steps could be refined further as there was not enough time to either fully describe or explore the differences between "Enablers and Inhibitors", "Variable Factors", or "Causes and Effects", so these distinctions created unnecessary confusion. One participant noted that causal loop diagrams were limited in representing different regulated parties, and another participant repeated the observation of many interconnections in their regulatory system.

While one participant was unsure of the value of the activity, the others recognised it provided a broader lens to look at a regulatory system that was useful to identify regulatory risk, recognise limitations of legislation and ensure they considered the right factors during the design of regulation.

The post-workshop questionnaire reflected these different experiences. In the first workshop, only five of the nine (56%) participants enjoyed the activity, and four (44%) were able to apply it. However, seven (78%) agreed it was valuable for their work. Only two (22%) intended to share it, and three (33%) intended to apply it. In the second workshop, all but one of the 12 (92%) participants enjoyed the activity, all but three (75%) were able to apply it, seven (83%) agreed it was valuable for their work, eight (67%) intended to share it, and nine (75%) intended to apply it. See Table 8 for complete results. Interestingly, despite the struggle to apply causal loop diagrams in workshop one, most participants agreed that they would be valuable to apply to their work. In total, more than half of participants agreed that causal loop diagrams could help them to understand risk (76%), understand regulated parties (67%) and manage performance (62%). Once again, the most substantial agreement was that causal loop diagrams could help to appreciate complexity (86%). Participants in workshop two responded better, although more than half of workshop participants agreed on each benefit.

7.2.4 Activity 3: Systems Archetypes

For the systems archetype activity, I shared three "regulatory" systems archetypes that I identified through the desktop exercise in Chapter 6 (Figure 17), including a description, early warning signs, remedies and behaviour over time graphs. Behaviour over time graphs represent real-world situations, showing the changes and interactions between different variables over time, focusing on trends rather than specific events (Kim, 2000). I also identified examples or potential examples of each of these system archetypes in the detailed causal loop diagram of the drinking water regulatory system. I asked the participants which of these systems archetypes they could recognise in their regulatory system and to identify other systems archetypes to describe common patterns of behaviours associated with common structures in regulatory systems.

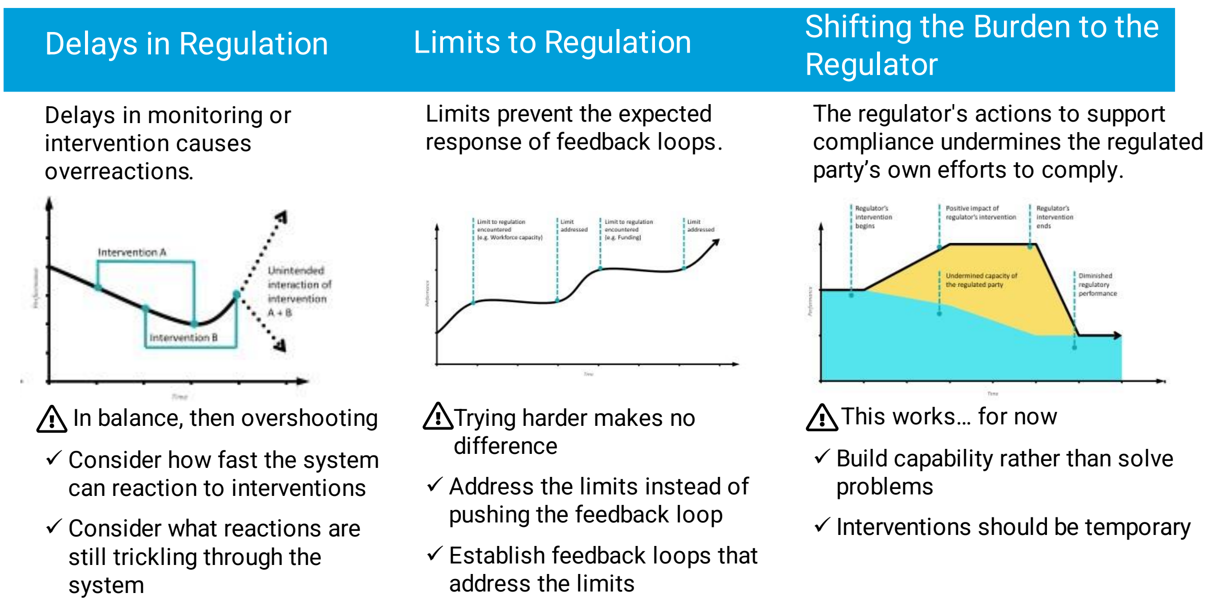


Figure 17: Regulatory Systems Archetypes

In workshop one, participants identified an instance of shifting the burden to the regulator with rules-based regulation, where regulated parties treated compliance as a proxy for safety. They also identified another context where regulators resisted this shift by not providing templates for safety cases, so regulated parties would be more engaged in developing their own. Participants suggested a positive systems archetype of "shifting the burden to the regulated", achieved by explaining the purpose behind regulation, not just setting rules to promote long-term voluntary behaviour change, explaining why not just what. They referred to the quote: "Rules are fools and the guidance for wise men (sic)". But it was noted that “shifting the burden to the regulated” might create a regulatory system focused on “easy” regulated parties who were more likely to change their behaviour voluntarily and exclude regulated parties that were difficult to regulate. This behaviour could be described using the system archetype “seeking the wrong goal” (Meadows, 2008, p. 138). Referring to the current issue around introducing COVID vaccine mandates, participants also identified how mandatory rules could create resistance and the impression of not trusting or dumbing down the population. The group did not explicitly discuss the limits to regulation or the delays in regulation regulatory systems archetypes, despite pointing out the impact of limits in one of the causal loop diagrams they drew. One participant found the behaviour over time chart easy to understand.

In workshop two, all the groups recognised the regulation systems archetypes in their regulation system. The participants described a pattern of learned helplessness from over-regulation, where regulated parties give up responsibility and ownership and ask regulators what to do, which could be described by the shifting the burden to the regulator system archetype. Participants also described the result of the introduction of outcome-based regulation, where regulated parties held the risk. They observed this leading to increasing numbers of guidelines, misaligned judgment of risk between regulated parties and regulators and escalation in audits and assurance activities. One participant described another system archetype of “bad regulatory design”, caused by: (i) not defining regulatory problems well; (ii) assuming that regulation was always the solution; or (iii) having incorrect mental models, for example, assumptions around the effectiveness of market competition in the New Zealand small economy.

The post-workshop questionnaire continued to reflect the different experiences between the workshops. In the first workshop, only two of the remaining seven (29%) participants enjoyed the activity, were able to apply it, or agreed it was valuable for their work. Only one of them (14%) intended to share it and apply it. In the second workshop, all but one of the 12 (92%) participants enjoyed the activity, seven (58%) were able to apply it and agreed it was valuable for their work, five (42%) intended to share it, and six (50%) intended to apply it. See Table 8 for complete results. In total, more than half of participants agreed that systems archetypes could help them to understand risk (63%), understand regulated parties (58%), manage performance (63%) and appreciate complexity (53%). The nature of the activity as a group discussion, rather than following practical steps, reflects the fact that systems archetypes are a theory, not a tool, and could also reflect why participants felt able to apply or were inclined to share the activity.

7.2.5 Workshop One vs Workshop Two

The different experiences between workshops one and two can offer considerations for applying systems thinking and delivering workshops in more general.

- Workshop one was held around a table in a formal board room, and workshop two was held in a more traditional workshop layout with groups around small tables. Participants may be able to better engage in activities in a less formal where they are sitting in groups.
- The regulatory agency in workshop one primarily regulated systems created by people, while in workshop two, the regulatory agency regulated biological systems. One participant acknowledged that systems are thinking resonated with her early studies in biology. By dealing with great complexity in biological systems, the regulatory agency may have had more of a need and more of a familiarity with the ideas of systems thinking.
- The regulatory agency in workshop two had existing systems thinking experience and expertise.
- Workshop two had more participants who had been specifically recruited from across their regulatory agency, which may have contributed to better engagement.

The multiple interacting factors and small sample size prevent any firm conclusions on the different experiences. Workshop two may have run better simply because I was more practised from workshop one.

7.3 Conclusion From Interactive Workshop

Participants reported their awareness of systems thinking before and after the workshop. Only five of the 21 (24%) participants reported an increase in their level of system thinking, while four (19%) reported that their level of systems thinking decreased. This decrease may be due to those participants now having a better awareness of the scope of systems thinking and knowing what they do not know.

Slightly less than half (48%) of participants agreed that they could apply systems archetypes or were valuable for their work. Over half participants agreed that they enjoyed and could apply the other activities. Over half of the participants also agreed that these activities were valuable for their work and helpful in understanding risk, understanding regulated parties, managing performance, and appreciating complexity.

The positive engagement with systems thinking concepts demonstrates that most participants can think about their regulatory systems systemically. Rich picture scored the highest across most criteria, likely because it was an “easy”, enjoyable, and less structured starting point. However, more participants agreed that causal loop diagrams were valuable for their work and helped understand risk, regulate parties, and manage performance. This response may be because causal loop diagrams gave participants a more structured tool to focus on a particular challenge.

A lower number of participants intended to apply or share the activities (32% to 67% depending on the activity). The workshop's measures for behaviour change and results relied on self-reported assumptions and predictions. They were subject to positive bias, potentially due to a halo effect of enjoying the activities.

After a month, the three participants I interviewed gave positive feedback for the workshop. However, none of them had applied or shared the rich picture, causal loop diagrams or system archetype activities, nor were they aware of any of their colleagues who had. They either did not have the “bandwidth” or did not have appropriate situations to apply them in their day-to-day work. They all shared their appreciation for the system thinking concepts described these as “grist to the mill” to help them think more systemically about regulation and ask the right questions about their regulatory systems. One participant explained that the system concepts were more universally appliable than the tools: “tips” he could apply, rather than complete “recipes”. Another participant emphasised the importance of systems thinking to tackle complex problems such as well-being and the importance of governance boards to apply systems thinking.

In the workshop, regulatory practitioners enjoyed, were able to and valued using rich pictures, causal loop diagrams and, to a lesser extent, system archetypes. However, this did not translate to regulatory practitioners applying systems thinking in their day-to-day work to improve the design and implementation of regulation. Regulatory practitioners enjoyed and valued systems thinking concepts in the workshop and used them in their day-to-day work. Regulatory practitioners could demonstrably apply systems thinking in a workshop environment, considering real-world situations as systems, constructing, and sharing systems models. However, in their day-to-day work, their application of systems thinking was limited to using concepts, which only constructed mental models which could not be demonstrated or shared.

The following section will share lessons to support further system thinking workshops and applications. These interactive workshops with regulatory practitioners provide four insights which I will explore in the following and final chapter’s conclusion to this research: (i) systems thinking influences the way people understand, communicate, analyse and act; (ii) the application of systems thinking requires both individual and organisational capability and investment; (iii) systems thinking needs to help drive action as well as develop understanding; and (iv) a systemic view of a regulatory system may not align with boundaries of legislation and organisational divisions.

7.4 Lessons

The interactive workshops also provided lessons for applying systems thinking, informing the design and delivery of future workshops or systems thinking activities.

7.4.1 Systems Thinking Workshop

The regulatory challenges I identified through the literature review provided little value in the workshop, as these were too generic. I could have used the workshop to explore real problems that were priorities for the participants. This may have required initial engagement or more time in the workshop, at the expense of the breath of activities, but might have increased the "stickiness" of the activities and results they offered. This would have shifted the workshop's focus from individual capability development closer to the original intent to apply systems thinking to improve regulation.

Although I tried to recruit a range of regulatory practitioners to attend, all the participants were primarily from a regulatory policy space. Including compliance officers or other frontline regulatory practitioners may have led to richer discussions and surfaced a more diverse range of mental models of regulation.

7.4.2 Systems Thinking Concepts

Although systems thinking concepts were not presented as an application of systems thinking, they generated rich discussion in both workshops, leading me to evaluate them in the questionnaire after workshop two, where they scored as high or higher than all the other activities. Systems thinking concepts could be further contextualised through a set of targeted questions in a more structured activity (Table 10). A more structured activity could prepare participants for further activities or be delivered as a stand-alone activity.

Table 10:Targeted questions to contextualise systems thinking concepts

Reductionist	Things	Closed	Linear	Events	Design
Systemic	Relationships	Open	Feedback	Structure	Emergence
	What are the things in your regulatory system? What relationships are there between the things in your regulatory system?	What is something important to your work that is outside of your regulatory system? How do you engage with it?	Give an example of how you work through a linear process. How might feedback turn this into a circular process?	What events are important in your regulatory system? What are the behaviours that cause these events? What structural issues cause these behaviours?	What is your regulatory system designed to do? What does your regulatory system actually do?

Further research could take a structured approach to assessing participants overall level of systems thinking, rather than focusing on specific types (Table 11). Skills 1-5 in Table 11 are relevant to systems thinking concepts, tools (rich pictures and causal loop diagrams), theories (systems archetypes), and approaches that could be used in further research focused on skills.

Table 11: A Structure for Assessing Systems Thinking (Plate and Monroe (2014))

Skill 1	Recognizing Interconnections
Skill 2	Identifying Feedback
Skill 3	Understanding Systems at Different Scales
Skill 4	Differentiating Types of Stocks and Flows
Skill 5	Understanding Dynamic Behavior
Skill 6	Creating Simulation Models
Skill 7	Incorporating Systems Thinking into Policies

7.4.3 Rich Pictures

Observations and feedback from my desktop application and the interactive workshops could contribute to guidance on the drawing of rich pictures (Monk and Howard 1998, Bell and Morse 2013; Berg and Pooley, 2013 and Wilson and Haperen, 2015).

- It is effective to demonstrate the progressive creation of a rich picture through PowerPoint animation.
- Rich pictures do not need to initially distinguish different types of relationships; it is more important to capture them. Guidance may indicate relationship types only as prompts for participants, and further elaboration can explore the different types of relationships. Based on this research, these relationships can include governance, information flows, financial, policy, management, membership, activities, and physical flows.
- Rich pictures can tend towards capturing a broad landscape rather than focusing on a specific problem or even a problem situation. More direct instructions could guide participants to draw their problem situation at the centre of their picture. This focus could also help guide what needs to be included in the rich picture, making the activity less daunting. However, it is also important to accept and appreciate the tendency and benefit of rich pictures in capturing a broad perspective.
- Alternatively, a rich picture of an entire regulatory system might also be used to identify and describe problem situations collaboratively.
- Rich pictures may be biased against representing abstract concepts, as they can be harder to draw than physical things. This challenge might also provide an opportunity for participants to think critically and creatively about how to represent them, for example, drawing markets as a handshake.
- Participants may be less inclined to include emotions and concerns in their rich picture. The facilitator could give more prompts to include concerns, guidance to use text to describe concerns (Monk and Howard, 1998), a set of icons (Berg and Pooley, 2013), or emoticon for participants to use (Figure 18).
- Participants may find drawing a rich picture of their regulatory system daunting, so it is important to acknowledge this, assure them that this activity is timebound and they are not expected to draw their whole regulatory system.
- Placing the paper in landscape orientation rather than portrait creates more space for multiple participants to draw.
- Participants may choose to stand up to allow for more dynamic engagement.

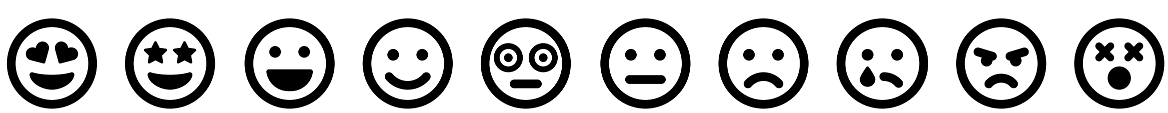


Figure 18: Emoticons to show concerns in rich pictures (using FontAwesome, 2021)

7.4.4 Causal Loop Diagrams

- Observations and feedback from my desktop application and the interactive workshops, particularly the challenges in workshop one, could contribute to guidance on the causal loop diagrams (Kim, 2000; Meadows, 2008; Stroth, 2014; The Omidyar Group, n.d).
- Focus the causal loop around a specific problem situation relevant to the participants.
- It might not be necessary to include the basic casual loop diagram to identify a regulatory problem's feedback loop, monitoring and intervention. Instead, a range of examples of basic regulatory feedback loops could be provided.
- Appreciate causal loop diagrams are a structured model of real-world situations which may not align with participants' mental model. Beginning the exercise by brainstorming relevant elements can provide participants with an unstructured entry point to engage with causal loop diagrams.
- Include more guidance for focusing the scope of causal loop diagram only on variable factors and interactions that significantly impact the situation. For example, do not include, or even remove, variable factors that have little impact if they are halved or doubled (Kim, 2000) or add visual complexity that detracts from the ability to see the whole system without contributing to the understanding (The Omidyar Group, n.d.).
- Participants could use behaviour over time chart to capture the behaviour of variable factors over time and represent events to support the construction of the causal loop diagram.
- The number of steps taken to identify the elements for the causal loop diagram should be scaled the time available. It may be sufficient to begin brainstorming to identify variable elements, use these to create linear causal chains, and then link them into causal loops.
- Identifying the polarity or time delays of interactions can be excluded from the initial construction of causal loop diagrams to simplify the process for participants. These could be added in an additional activity or through the interpretation of narrative descriptions to identify feedback loops as balancing or reinforcing through the narrative (Scott, 2014).
- Involving a diverse range of stakeholders and partners, including regulated parties, might lead to a more useful causal loop diagram.
- Thirty minutes is enough time to draw a causal loop diagram and gain some insights. More time would be required to refine the causal loop diagram, identify leverage points for a problem situation, or identify and agree on specific actions to take.

7.4.5 Systems Archetypes

As a system thinking theory, I needed to design specific steps to evaluate systems archetypes through the workshop, which involved group discussion. I could have created a more structured activity with templates where participants could "fill in the blanks" to describe the specific behaviours, structures and remedies for the occurrences of systems archetypes in their regulatory systems. I could have also better integrated the systems archetypes into the causal loop diagram activity. Before creating the causal loop diagram, systems archetypes could be used to inform the behaviours and interactions to be represented; or, after, to analyse behaviours and identify remedies.

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8 Conclusion

This chapter concludes my research which identified and evaluated types of systems thinking that can be applied by regulatory practitioners to improve regulation. My research found that regulatory practitioners could apply systems thinking during an interactive workshop but their experiences from the workshops did not in translate to their day-to-day work. In this conclusion, I will reflect on the implications of these findings for systems thinking, regulation, New Zealand's drinking water regulatory system, and for a regulatory practitioner.

8.1 Research Findings

Systems thinking can help people understand and manage complex real-world situations containing many interacting elements, with emergent behaviour that cannot be attributed to the individual elements and may also change in response to our understanding. Systems thinking can engage a diverse range of stakeholders by developing and sharing common systems models; support learning by explaining causal interactions, emergent behaviour and testing scenarios; and identifying leverage points to take the right actions to lead to change.

Regulation includes tools and activities used to modify behaviours according to defined standards, particularly to reduce the public's exposure to risk. Different regulatory strategies have emerged over the last 30 years that, intentionally or not, apply systems thinking concepts to help develop more systemic perspectives of regulation and systematic approaches guiding regulators to act. Regulatory systems are a popular concept in regulation but can be considered at different scales, with different boundaries and may include any elements or interactions relevant to regulation.

I categorised 17 different types of systems thinking as concepts, tools, theories and approaches according to how they relate to the real-world (Table 12). Systems thinking concepts can be used to understand real-world situations by considering them as systems. Systems thinking tools can be used to construct and communicate systems model of real-world situations. Systems thinking theories can be used to analyse real-world situations. Systems thinking approaches use systems models to inform action better to change these real-world situations. I selected five types of systems thinking to apply to the case study of drinking water regulation in New Zealand, then evaluated three of these in interactive workshops with 21 regulatory practitioners (Table 12), collecting empirical evidence to answer my primary research question:

Whether and how can rich pictures, causal loop diagrams and system archetypes be applied by regulatory practitioners to improve regulation.

The regulatory practitioners enjoyed, valued and were able to apply rich pictures, causal loop diagrams and system archetypes in the interactive workshop and intended to apply them in their work. However, interviews after a month revealed that they had not applied them. I had initially not intended to independently evaluate systems thinking concepts, as I assumed that they would be applied through systems thinking tools. However, when I described the systems thinking concepts in the introduction to the workshop, they led to rich discussion with the participants. Participants reported that systems thinking concepts were enjoyable, applicable, and valuable to their work. After one month, they had used them to be more systemic when they thought and asked questions about their regulatory system. Participants explained that they did not have the "bandwidth" or appropriate situation to apply the more structured and detailed systems thinking tools or theories. The systems thinking concepts were easier for them to apply. However, systems thinking concepts are only ways to understand real-world situations by considering them as systems. Unlike systems thinking tools, they do not construct and communicate systems models, which could be a foundational step in taking a "whole-of-system view", as regulatory agencies are mandated by the New Zealand Treasury (2017, p. 3). It would also be difficult to attribute the understanding provided by systems thinking concepts to action leading to improvement in regulations. The misalignment between the regulatory practitioner's ability, perceived value, intention and their failure to apply systems thinking tools to regulation could be attributed to: (i) a perceived or actual lack in their ability to apply systems thinking independently; (ii) the challenge in identifying how systems thinking might be applied to a specific problem; or (iii) individual and organisational roles and responsibilities that are constrained by boundaries that do not permit the effective application of systems thinking. These challenges might be resolved through some combination of (i) further training to build confidence in applying systems thinking and guidance to apply it to specific problems, even beyond the boundaries of their role as regulatory practitioners; (ii) more detailed guidelines on how systems thinking might be applied to regulation, with more examples and case studies; (iii) organisational support from regulatory agencies; and (iii) a more specific government mandate on how regulatory agencies take a "whole-of-system view" of their regulatory system.

Table 12: The evaluation of how systems thinking can be applied by regulatory practitioners to improve regulation

		Can be demonstrably applied?	Can be applied without specialist capability or resources?	Can be applied without structural support?	Can be evaluated during a four-hour workshop?	Evaluated in Desktop Exercise?	Evaluated in Interactive Workshop?	**Participants agreed they were able to apply?**	**Participants used in day-to-day work?**
Concepts	Things → Relationships	✗	✓	✓	✓	✗	~	**✓ (75%)**	**✓**
	Closed → Open	✗	✓	✓	✓	✗	~	**✓ (75%)**	**✓**
	Linear → Feedback	✗	✓	✓	✓	✗	~	**✓ (75%)**	**✓**
	Events → Structures	✗	✓	✓	✓	✗	~	**✓ (75%)**	**✓**
	Design → Emergence	✗	✓	✓	✓	✗	~	**✓ (75%)**	**✓**
Tools	Rich pictures	✓	✓	✓	✓	✓	✓	**✓ (71%)**	**✓**
	Causal loop diagrams	✓	✓	✓	✓	✓	✓	**✓ (62%)**	**✗**
	Stock + flow diagrams	✓	~	✓	✓	✓	✗	**-**	**-**
	Systems dynamics	✓	✗	-	-	✗	✗	**-**	**-**
Theories	System Archetypes	~	~	~	~	✓	✓	**✓ (47%)**	**✗**
	Social Systems Theory	~	~	~	~	✓	✗	**-**	**-**
	Viable Systems Model	✓	~	~	✗	✗	✗	**-**	**-**
Approaches	SSM	✓	~	~	✗	✗	✗	**-**	**-**
	Four-Stage Change Process	✓	~	~	✗	✗	✗	**-**	**-**
	Management Flight Simulators	✓	✗	✓	✗	✗	✗	**-**	**-**
	Serious Games	✓	✗	✓	✗	✗	✗	**-**	**-**

8.2 Implications for Systems Thinking Research

8.2.1 Systems Thinking for Understanding, Communicating, Analysing and Acting

Through this research I have explored the capability and effort required to apply the different categories of systems thinking. Regulatory practitioners quickly and positively engaged with systems thinking concepts, finding them the most enjoyable, valuable and applicable and used them in their day-to-day work. This evidence indicates that systems thinking concepts require the least individual capability and no structural support, such as legislation, policy, budgetary or management buy-in.

Regulatory practitioners found systems thinking tools (rich pictures and causal loop diagrams) enjoyable, valuable and applicable in a workshop environment, however, this application did not translate to their day-to-day work. This evidence indicates that regulatory practitioners had the individual capability to apply tools, but further structural support might be required for these systems thinking tools to be used in their day-to-day work. Fewer regulatory practitioners found systems theory (systems archetypes) enjoyable, valuable and applicable in a workshop environment, indicating a higher level of individual capability required to apply them.

I excluded systems thinking approaches from the evaluation because they would require too much individual capability, structural support, and effort to evaluate in the scope of this research. However, as systems thinking approaches include action to drive change in real-world situations, regulatory practitioners may have been more likely to apply them in their day-to-day work. Further research could explore how systems thinking approaches might improve regulation, evaluate stakeholder engagement and inform action, and the types of structural support required for this.

My research highlights that increasing levels of individual capability, structural support and effort are required as the use of system thinking progresses from understanding to communicating, to analysing and finally to acting in real-world situations (Table 13). Professional and academic systems thinking initiatives should consider how the individual capability, structural support and effort will limit how systems thinking can be used.

Table 13: How categories of systems thinking relate to the real-world and the individual capability, structural support, and effort they need.

Category of System Thinking	**Relation to Real-world**	**Individual Capability Needed**	**Structural Support Needed**	**Effort to Apply**
Concepts	Understanding	Low	Low	Low
Tools	Communicating	Low	Medium	Medium
Theories	Analysing	Medium	Medium	Medium
Approach	Acting	High	High	High

My consideration for how systems thinking relates to real-world situations reflects the separation of the stages of soft systems methodology between the real-world and thinking about the (Checkland, 1981). Communicating and acting happen in the real-world, while understanding and analysing happen when thinking about the real world. There are also similarities with Plate and Monroe's (2014) categorisation of Stave and Hopper's (2007) proposed taxonomy of systems thinking skills into remembering, understanding, applying, analysing and evaluating/creating (Figure 19).

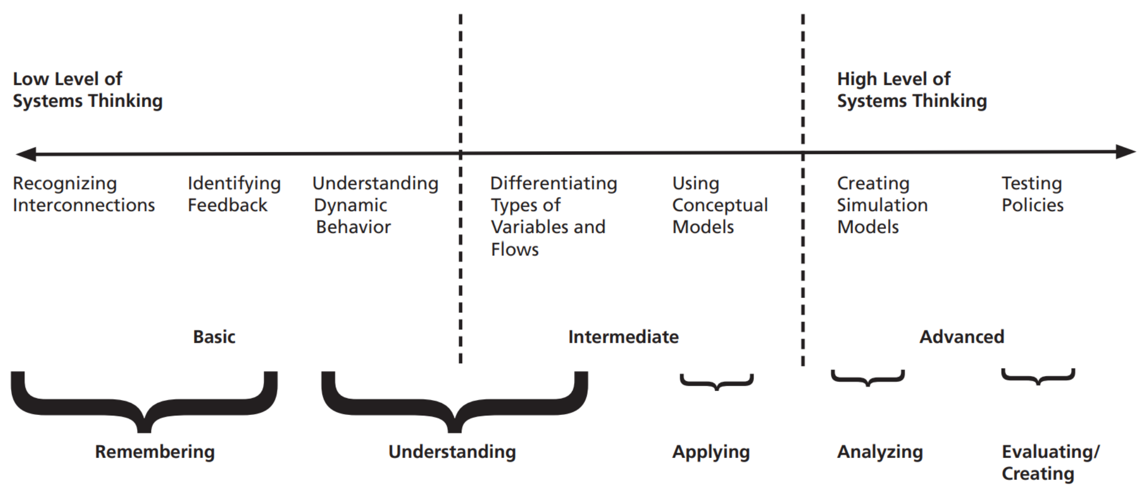

Figure 19: Plate and Monroe's (2014) categorisation of Stave and Hopper's (2007) proposed taxonomy of systems thinking skills

The taxonomy of skills does not focus on the difference between systems thinking as a mental process and systems thinking applied in the real-world. Further research could consider this boundary further compare the difference between developing systems thinking skills, and applying these skills in the real world.

Senge (1990) considers individual learning as less important than organisational learning, with systems thinking as the “Fifth Discipline” required for a learning organisation. Further research could explore the interactions between an individual’s learning of systems thinking skills and an organisation's learning to apply systems thinking.

8.2.2 Systems Thinking Without Models

The selection of types of systems thinking for my evaluation focused on systems thinking tools as they could be demonstrably applied and fit within the scope of this research. My focus on systems thinking tools to construct and communicate systems models as real-world artefacts align with Meadow's (2008, p.172) guidance to "expose your mental models to the light of day".

However, the greater level of engagement with systems thinking concepts in the workshop made me reconsider the focus on systems thinking tools. Could systems thinking concepts still change how people understand, communicate, analyse, and act in the real world without using systems thinking tools to construct systems models? How are important systems models as real-world artefacts which can be seen and shared? Are they just visual representations that appeal to a certain type of person? Are systems models a simplification of complex real-world situations that can be conveniently understood and measured by external researchers but may lack subtle but significant details understood by practitioners? Or does the construction of systems model as a real-world artefact have a transformative effect on systems thinking, just as writing has transformed spoken language, giving it a permanent form, which can be analysed and more widely shared and vastly greater vocabulary (Gleick, 2012)? Finally, how does system thinking that focuses on constructing a systems model as real-world artefacts align with indigenous approaches and oral tradition? Further research could explore these questions further and how systems thinking might lead to action in the real world without constructing systems models.

8.2.3 Knowing Enough to Act

Systems thinking cultivates a greater appreciation for the complexity in real-world situations, helping people to understand real-world situations involving many interacting elements and behaviours which cannot be understood by looking at those elements in isolation. This complexity means accepting that while there will always be more to learn about a situation, there will always be something we do not know about it. By providing an option to better understand complexity, systems thinking can also become a barrier to acting with incomplete information. The workshop participants discussed the risk of "paralysis by analysis" or "perfect becoming the enemy of good enough". Systems thinking approaches have different ways to guide people from understanding to action. Soft systems methodology and four-stage change process both emphasise the purpose of a systems model to bring stakeholders together and facilitate discussion, rather than accurately representing reality and have systematic processes for participants to go from understanding to action. Management flight simulators and serious games create simulated environments where participants can safely test actions. Professional or academic initiatives to apply systems thinking should consider how they guide participants from understanding to action.

8.3 Implications for Regulation

8.3.1 Boundaries of Regulatory Systems

Systems thinking can help identify the regulator, the regulated party, regulatory tools, regulatory arrangements, risk, problems, the broader social, political, economic environment, their interactions, intended and unintended behaviours in a regulatory system. However, this type of systemic view of a regulatory system may not align with the boundaries of legislation and organisational divisions. Gunningham and Grabosky (1998) use the analogy of the little boy and a hammer to describe the misalignment between the regulator's tools and the problems they are trying to solve. A workshop participant described this situation, with regulatory teams established around specific tools. Another workshop participant also recognised how the need to control outputs within organisational boundaries was a barrier to collaboration.

Systems thinking can help understand how structural issues influence regulatory systems, such as legislation and organisational arrangements. Further research could explore the alignment between legislation and organisational arrangements and regulatory systems, its effect, and how it changes structural reform to collaboration between individuals. For example, the Public Service Act (2020) now provides interdepartmental ventures and executive boards as vehicles to support cross-agency working arrangements, such as the delivery of Te Aorerekura - the new National Strategy to Eliminate Family Violence and Sexual Violence (New Zealand Government, 2021).

8.3.2 Systemic and Systematic Regulatory Strategies

The systemic and systematic nature of systems thinking offers lessons for adopting regulatory strategies and. Systems thinking approaches develop a systemic understanding that drives action through a systematic process. Regulatory strategies also provide a way of developing a systemic understanding of regulation and a systematic approach to taking action (Table 14). Regulatory strategies should be adopted as a systemic way of understanding and a systematic way of acting; otherwise, like systems thinking tools, they could lead to “paralysis by analysis”.

Table 14: The systemic perspectives and systematic processes of different regulatory strategies

		Systemic Perspective	Systematic Process
8.3.3	Responsive Regulation	Considers escalation using regulatory tools and arrangements based on the history of compliance	“Tit-for-tat” escalation
8.3.4	Smart Regulation	Considers the combination of multiple regulatory tools and arrangements	None
8.3.5	Problem Based Regulation	Considers the structural constraints of regulatory agencies	Problem-solving process and infrastructure
8.3.6	Risk-Based Regulation	Considers risks quantitively, qualitatively and systemically	A framework to aligning objectives, risk appetite assessment of hazards, scoring of risks and allocation of resources
8.3.7	Really Responsive Regulation	Considers compliance, attitude, institutional environment, regulatory tools, performance and change	A framework of tasks: detecting non-compliance, responding, enforcing, assessing and modifying

8.4 Implications for Drinking Water Regulation

I have researched the evolution of the drinking water regulatory system in New Zealand, which revealed a dynamic complex of perspectives, organisations, legislation, regulatory tools and arrangements. Although my primary purpose was to evaluate how systems thinking might be applied to drinking water regulation, I also identified several implications for drinking water regulation.

The Havelock North drinking water contamination event can be attributed to the behaviours of both regulatory practitioners as “consultative and cajoling” and regulated parties as “slack(ness)" and "non-compliant" (Government Inquiry into Havelock North Drinking Water, 2017). These behaviours can be attributed to structural conditions of dispersed responsibilities, legislation that was weakened by the legislative process and political interference. Although reform has changed these structural conditions, other structural conditions may lead to unintended behaviours and events.

The design, and re-design of the drinking water regulatory system, has aimed to address the fragmentation of legislation and responsibilities. The centralisation and specialisation of drinking water regulation with the Water Services Act, the establishment of Taumata Arowai and the aggregated water services entities may better align with problem situations in the regulatory system. However, specialisation may create new boundaries that need to be crossed, such as the Ministry of Health's drinking water policy function and the proposed separate economic regulator. Through the process of drawing rich pictures, I identified the different actors and agencies within the drinking water regulatory system and the relationship between them (Figure 8). This could support cross-agency collaboration, for example, through information sharing between Taumata Arowai and regional councils.

There is enough complexity in the drinking water regulatory system to warrant a healthy level of humility about how much can be known about how it is behaving. Social systems theory would recommend that any communication should also be attuned to the code of the recipient's political, economic, health, media, scientific or other social sub-systems. Communications about drinking water that is not compliant with the scientific standard may be meaningful to a water supplier, but the health implications of this may need to be explained for the public to understand and engage.

Funding constraints have often been a limiting factor in drinking water regulation, which both the Drinking-Water Assistance Programme (2005-2015) and Three Waters Reform Programme (2020 onwards) have sought to address. This limit can be interpreted as "regulatory" system archetype of limits to regulation, which also considers the limits from workforce capacity and political appetite.

In the 1990s the Ministry of Health designed a drinking water regulation to bring stakeholders to complement and support each other, but instead, a complex and fragmented regulatory system emerged. In 2007, legislation designed to strengthen this system was diluted through political interference, contributing to the Havelock North drinking water contamination event. This demonstrates that despite best intentions to design a regulatory system, unexpected behaviours and unintended consequences will emerge. As the drinking water regulatory system is being re-designed through regulatory reform, it is now important also to consider what behaviours might emerge.

8.5 Reflections for A Regulatory Practitioner

My research has helped me understand the complexity of the drinking water regulatory system by translating pages of text into rich pictures and causal loop diagrams. Systems thinking can help to understand, communicate and analyse real-world situations, although for it to improve regulation, it needs to drive action. As an academic researcher, it is easier for me to focus on understanding, communicating and analysis than to take action.

At the end of 2021, I was fortunate to join Taumata Arowai as their Data and Insights Manager. As a regulatory practitioner, I will now use systems thinking to help me and my colleagues help to understand, communicate, and analyse real-world situations. But more importantly, as I engage other agencies, partners and regulated and look to inform the actions I take, this research will guide me in applying systems thinking to improve regulation.

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Appendix A: Slides from Interactive Workshop

VICTORIA UNIVERSITY OF WELLINGTON
TE HERENGA WAKA

How Might Systems Thinking Improve Regulation?

Research Workshop
11th November 2021

Michael Howden
Masters of Commerce - Public Policy candidate,
School of Government

Agenda

8:00	Welcome
8:15	Introduction to System Thinking
8:45	**Activity 1**: Rich Pictures
9:15	**Activity 2**: System Archetypes
10:00	Morning Tea
10:15	**Activity 3**: Causal Loop Diagrams
11:30	Wrap Up
12:00	End

Objectives

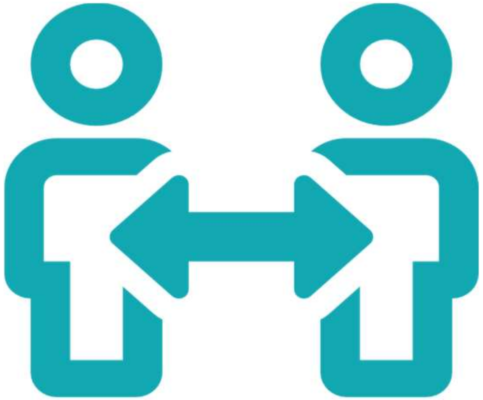
Practical Objectives:

- Increase your understanding of systems thinking
- Be able to apply systems thinking to regulation
- Identify feedback loops in regulation
- Appreciate emergent behaviours in regulation

Research Objectives:

- Evaluate how systems thinking might be practically applied to regulation
- Evaluate how systems thinking might improve regulation

Introductions



- Who are you?
- Why are you interested in systems thinking?

What is System Thinking?

“A bad system will beat a good person every time.”
W. Edwards Deming

“A system is never the sum of its parts its the product of their interaction.”
Russell Ackoff

“Business and human endeavours are systems...we tend to focus on snapshots of isolated parts of the system. And wonder why our deepest problems never get solved.”
Peter Senge

“All things appear and disappear because of the concurrence of causes and conditions. Nothing ever exists entirely alone; everything is in relation to everything else.”
Buddha

What is a System?

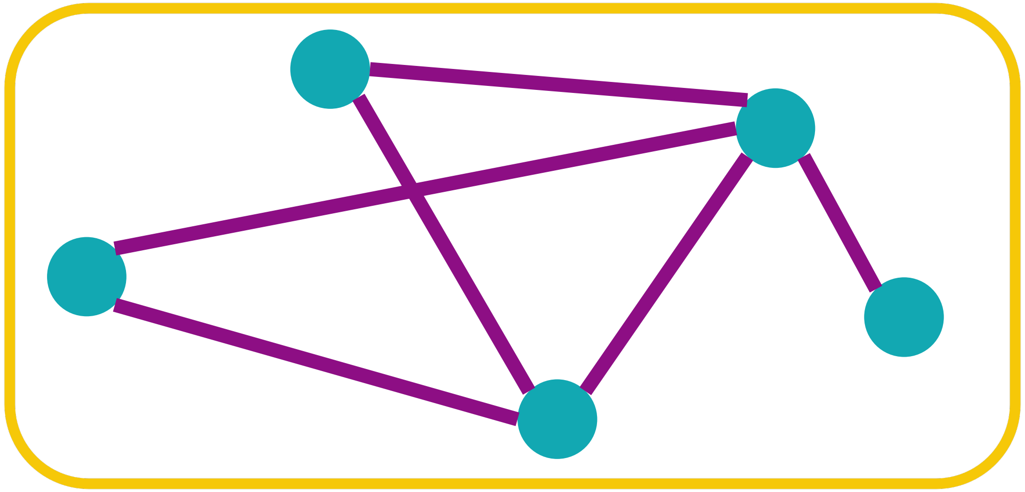
"A system is a set …

…of things…

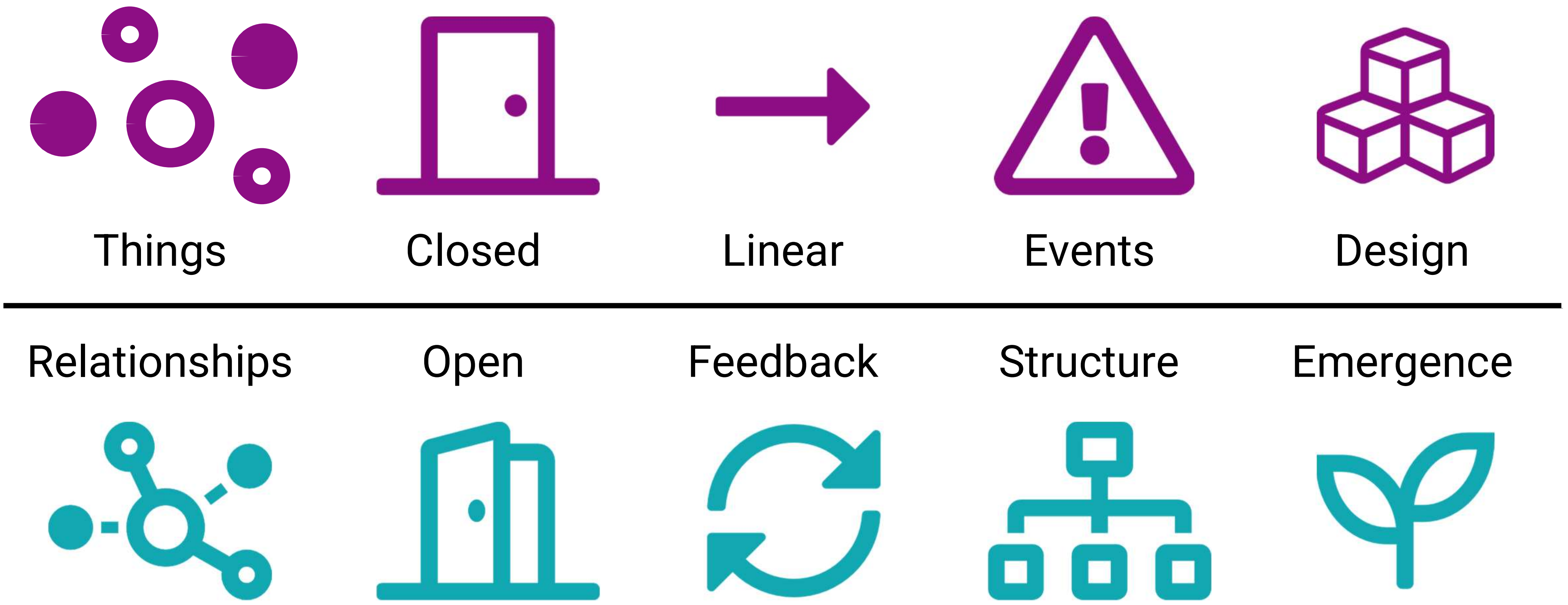
…interconnected…

…in such a way that they produce their own behaviour over time."

Donna Meadows, 2008



System Thinking Concepts



Benefits of System Thinking

- Engage diverse stakeholders
- Support shared learning and grow intuition
- Identify leverage points

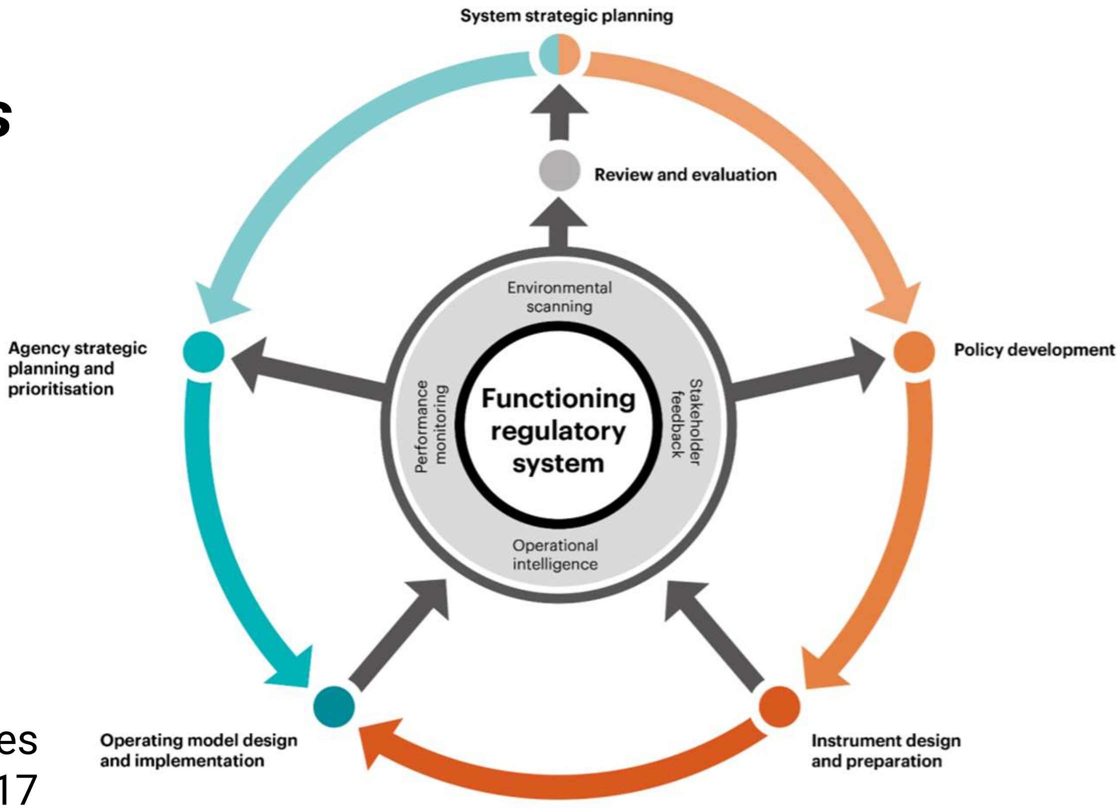
Regulatory Challenges

- Understanding risk
- Understanding regulatory parties
- Monitoring and managing performance
- Appreciating complexity

What is a Regulatory System?

*“a set of **rules, norms and sanctions**, supported by the **actions and practices of designated agencies**, to **shape people’s behaviour in pursuit of a broad policy goal or outcome**. The regulatory cycle indicates how that system changes and evolves.”*

Building Effective Regulatory Institutions and Practices - New Zealand Treasury (2017



Activity 1:
Rich Pictures

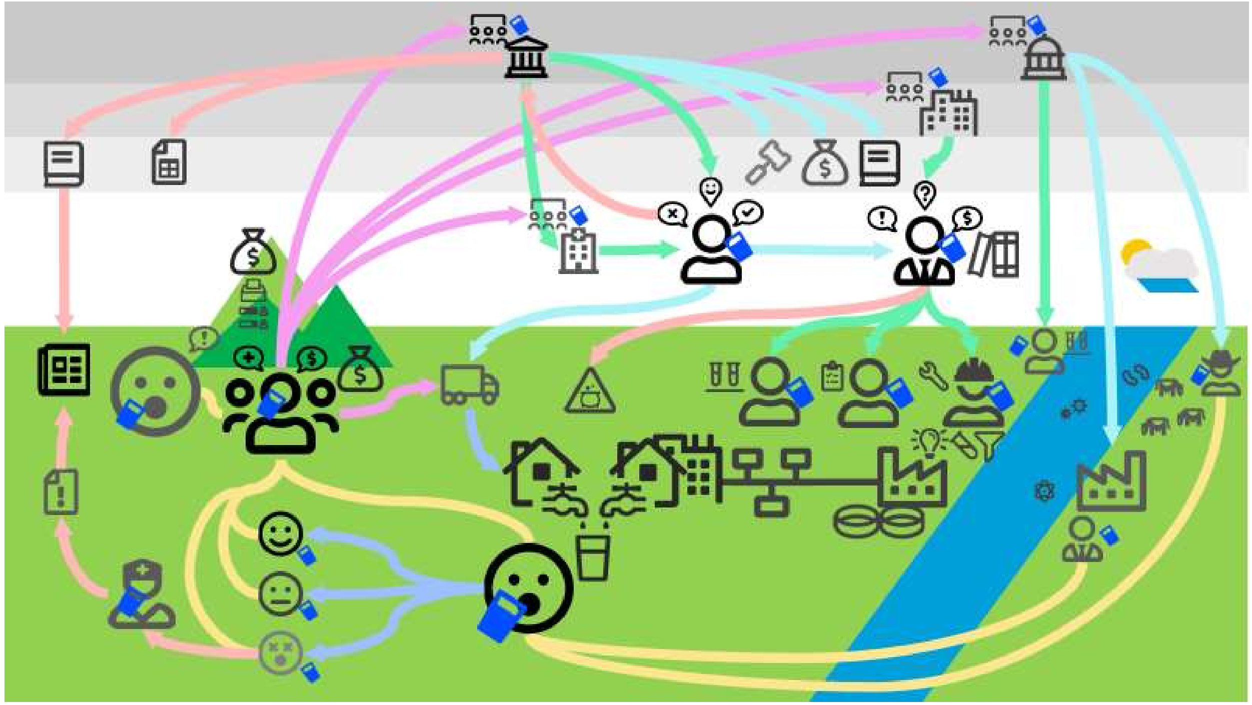
What is a Rich Pictures?

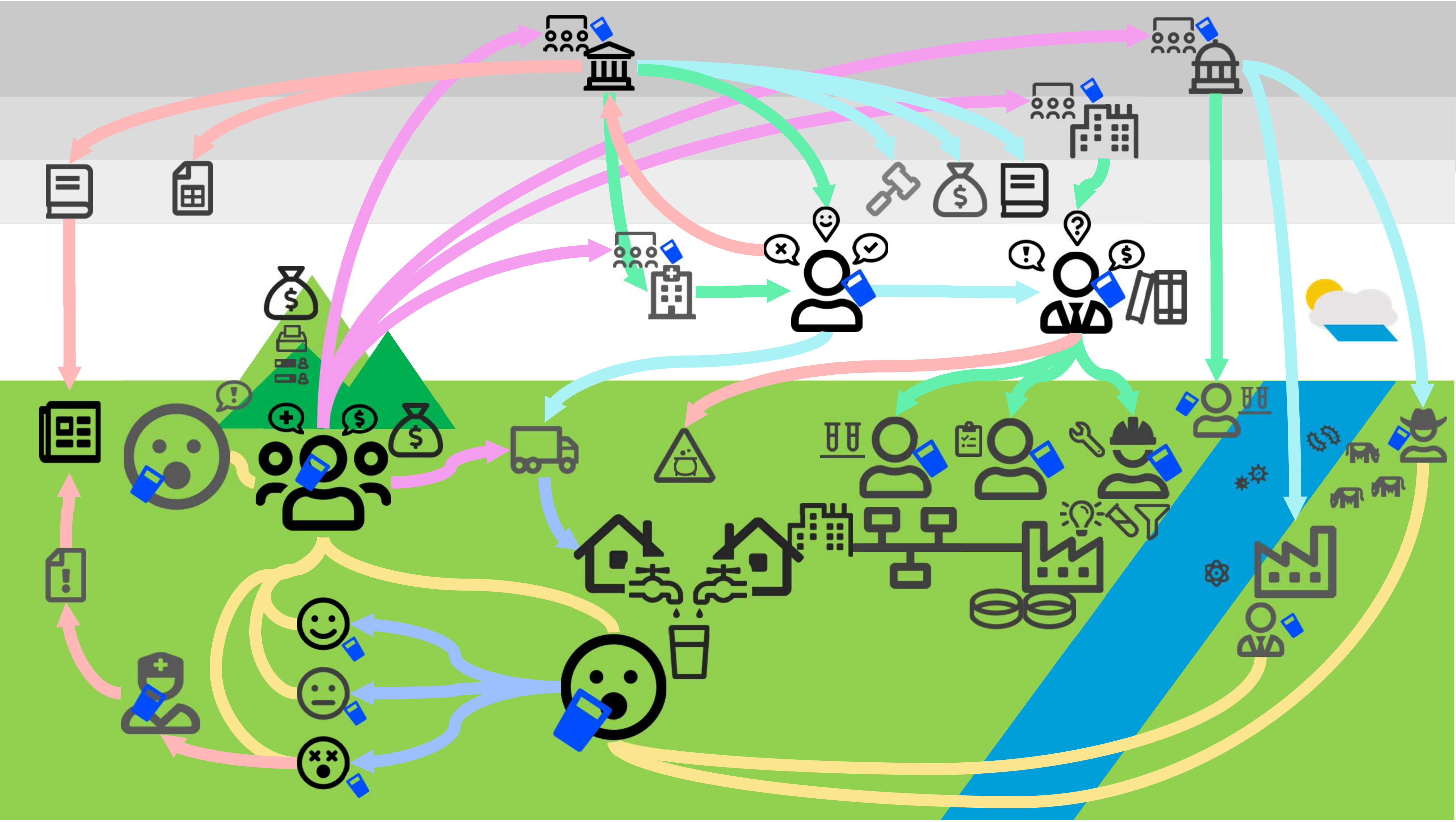
- Record, organise, understand and communicate the messiness of real-world situations
- Playful and creative process
- Unstructured

Bell, Simon, and Stephen Morse. "How People Use Rich Pictures to Help Them Think and Act." *Systemic Practice and Action Research* 2013.
https://doi.org/10.1007/s11213-012-9236-x

How to draw a Rich Picture?

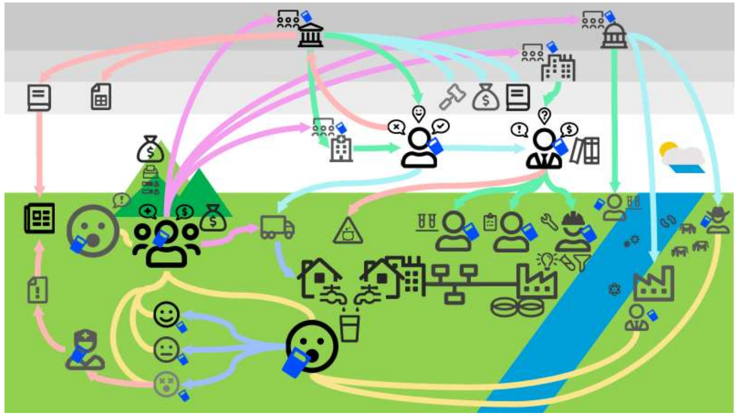
1. Draw Elements
2. Draw Interactions
3. Add Context

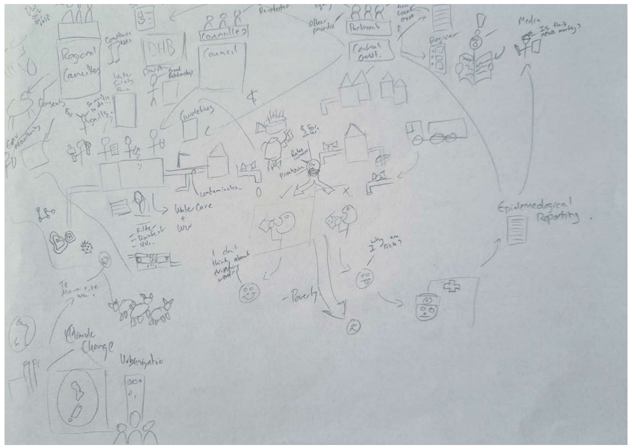




Draw a Rich Picture

1. Draw Elements
    - Problem
    - People
    - Organisations
    - Places
    - Things
2. Draw Interactions
    - Relationships
    - Membership
    - Information flows
3. Add Context
    - Concerns and emotions
    - Environment
    - External factors
    - Culture





- ✓ Draw first, explain as you go
- ✓ Draw the picture collaboratively
- ✓ Keep the paper visible to the whole group
- ✓ Text should be minimised
- ✓ Use colour
- ✓ Its OK to ~~cross things out~~
- ✓ Get as far as you can in 15 min
- ✓ Artistic ability is NOT required

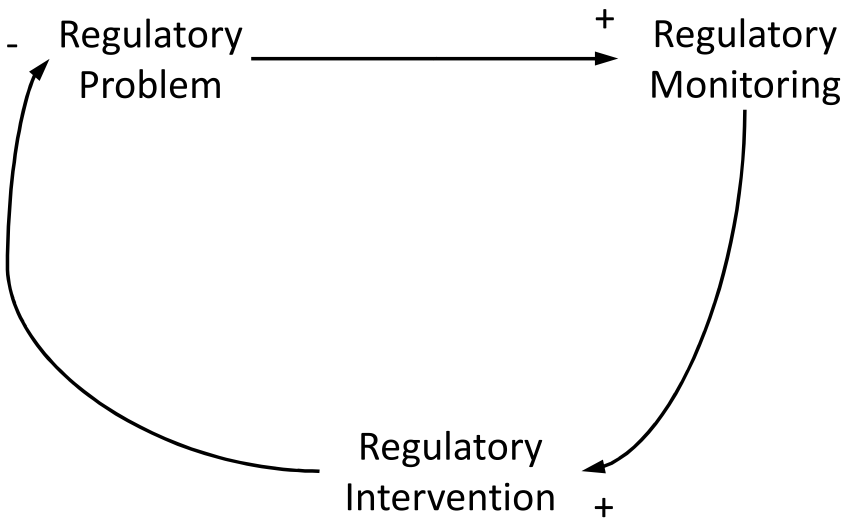
Reflections on Rich Picture

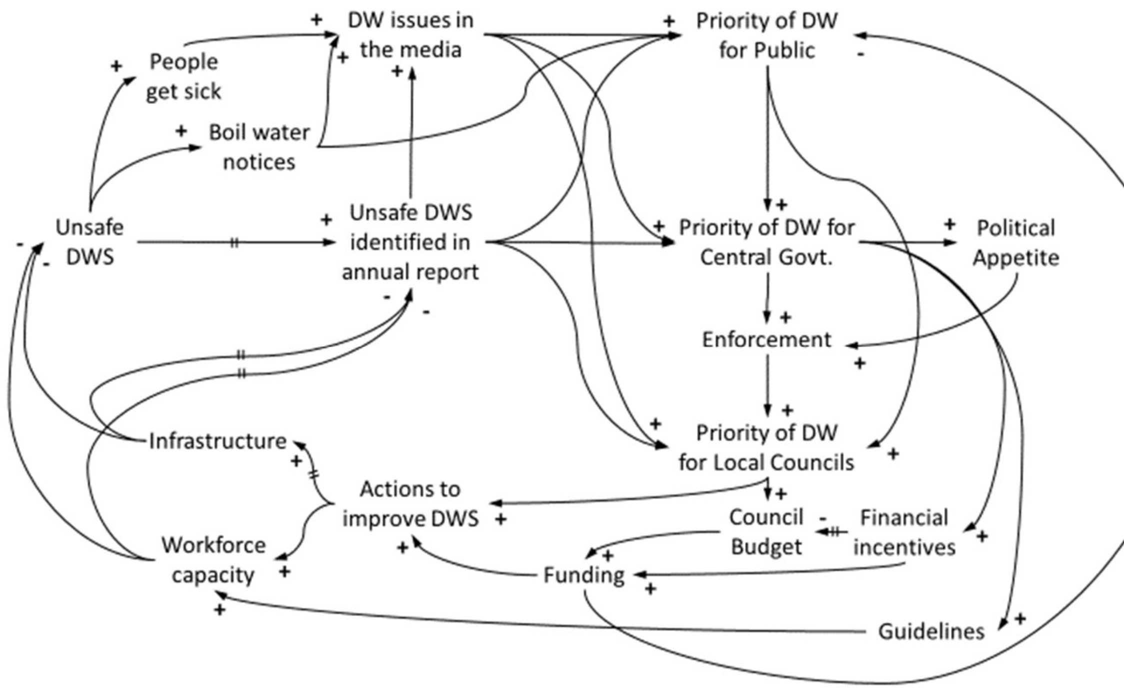
- How easy was it to draw a rich picture?
- What insights did you gain?
- How useful was it?

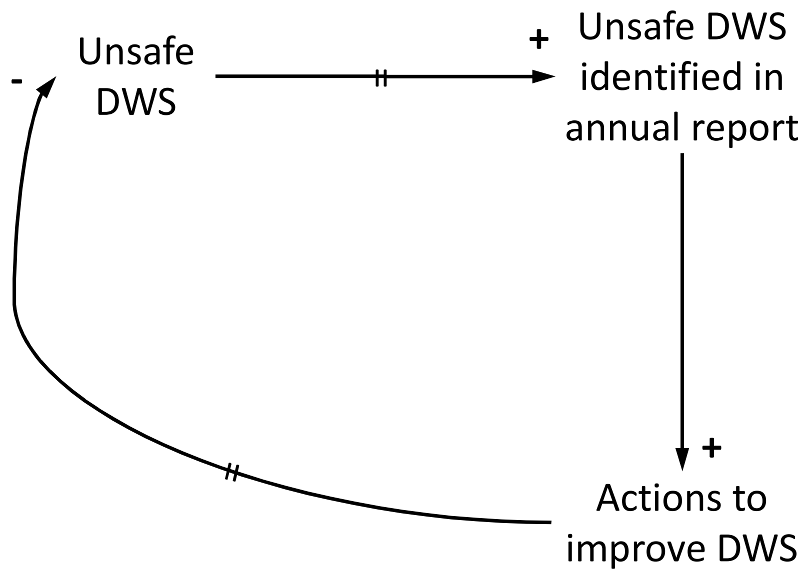
- Where did you draw the boundary of your regulatory systems?

Introduction to Causal Loop Diagrams

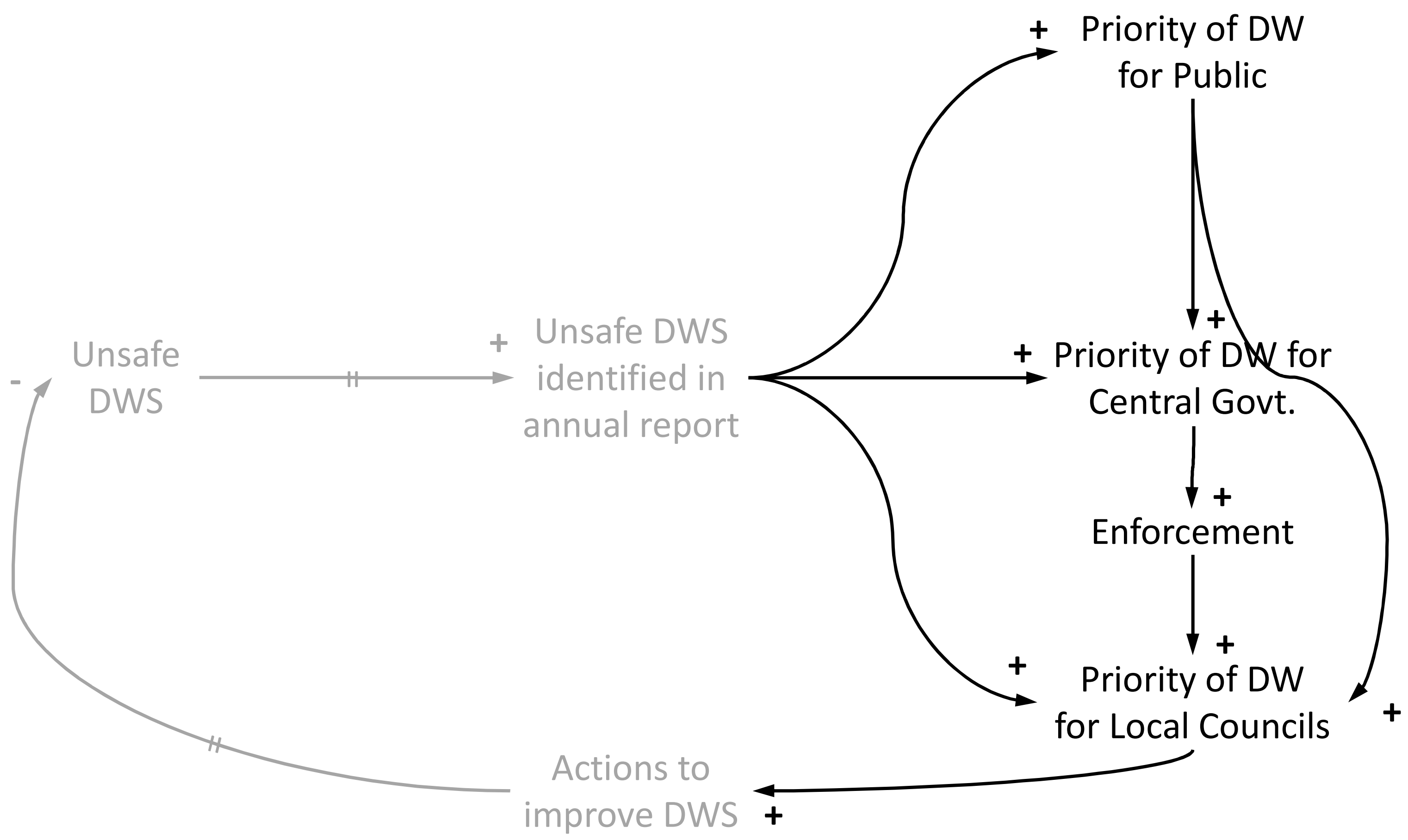
What is a Causal Loop Diagram?



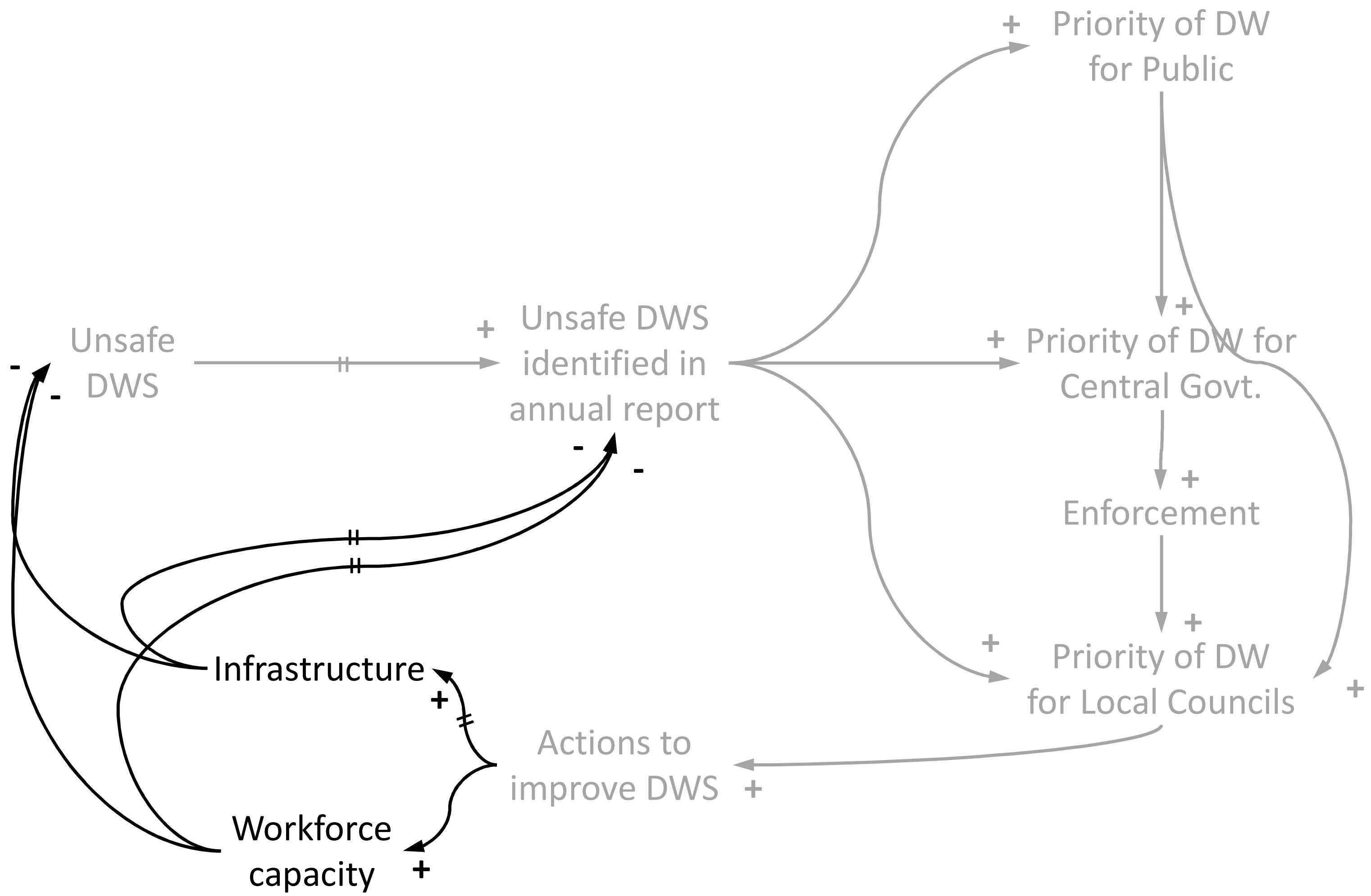


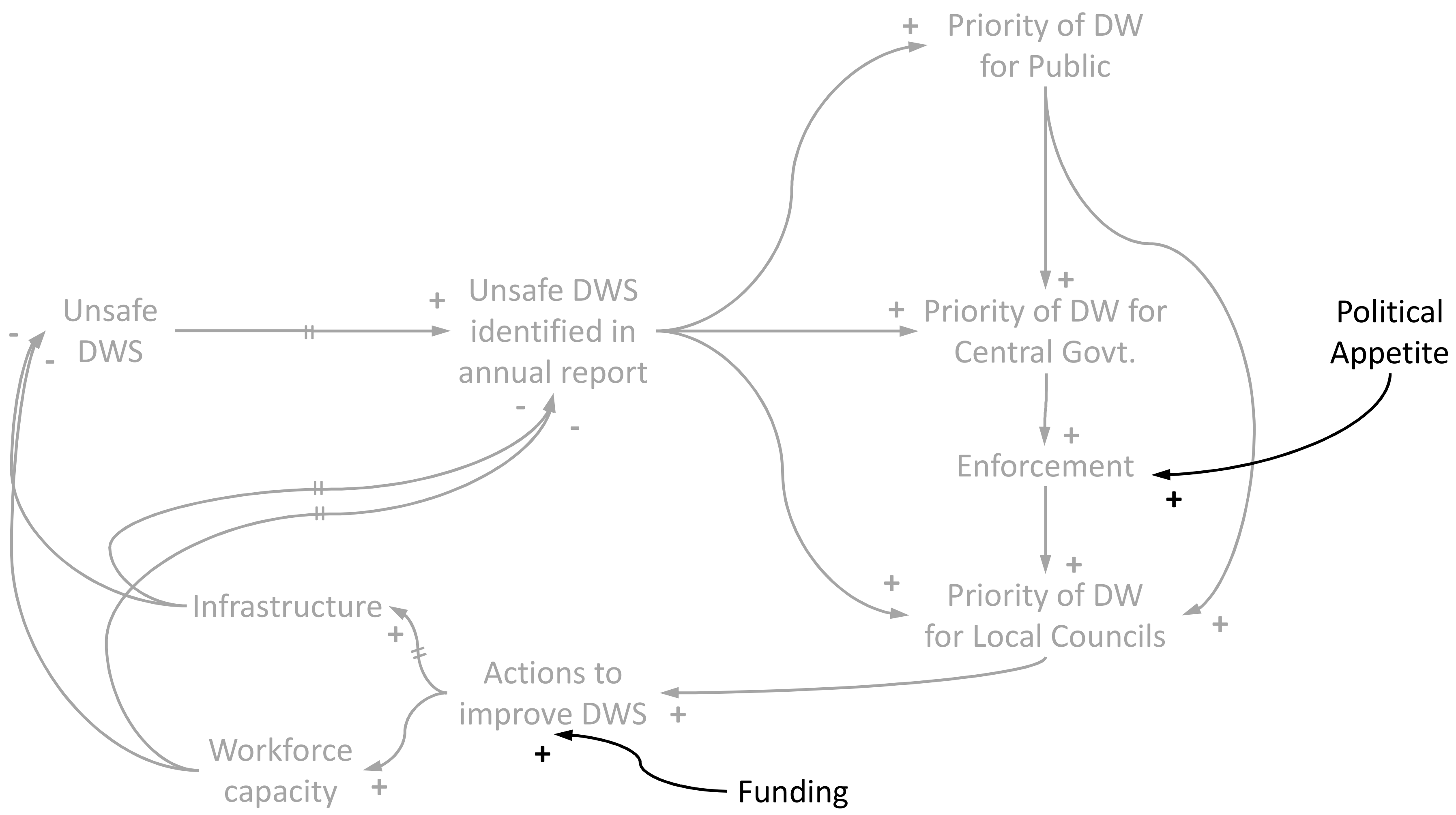


DWS = Drinking Water Supply



DW = Drinking Water


Priority of DW
for Public
Unsafe
DWS
Unsafe DWS
identified in
annual report
Priority of DW for
Central Govt.
Enforcement
Priority of DW
for Local Councils
Infrastructure
Actions to
improve DWS
Workforce
capacity


Priority of DW for Public
Unsafe DWS
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Priority of DW for Central Govt.
Political Appetite
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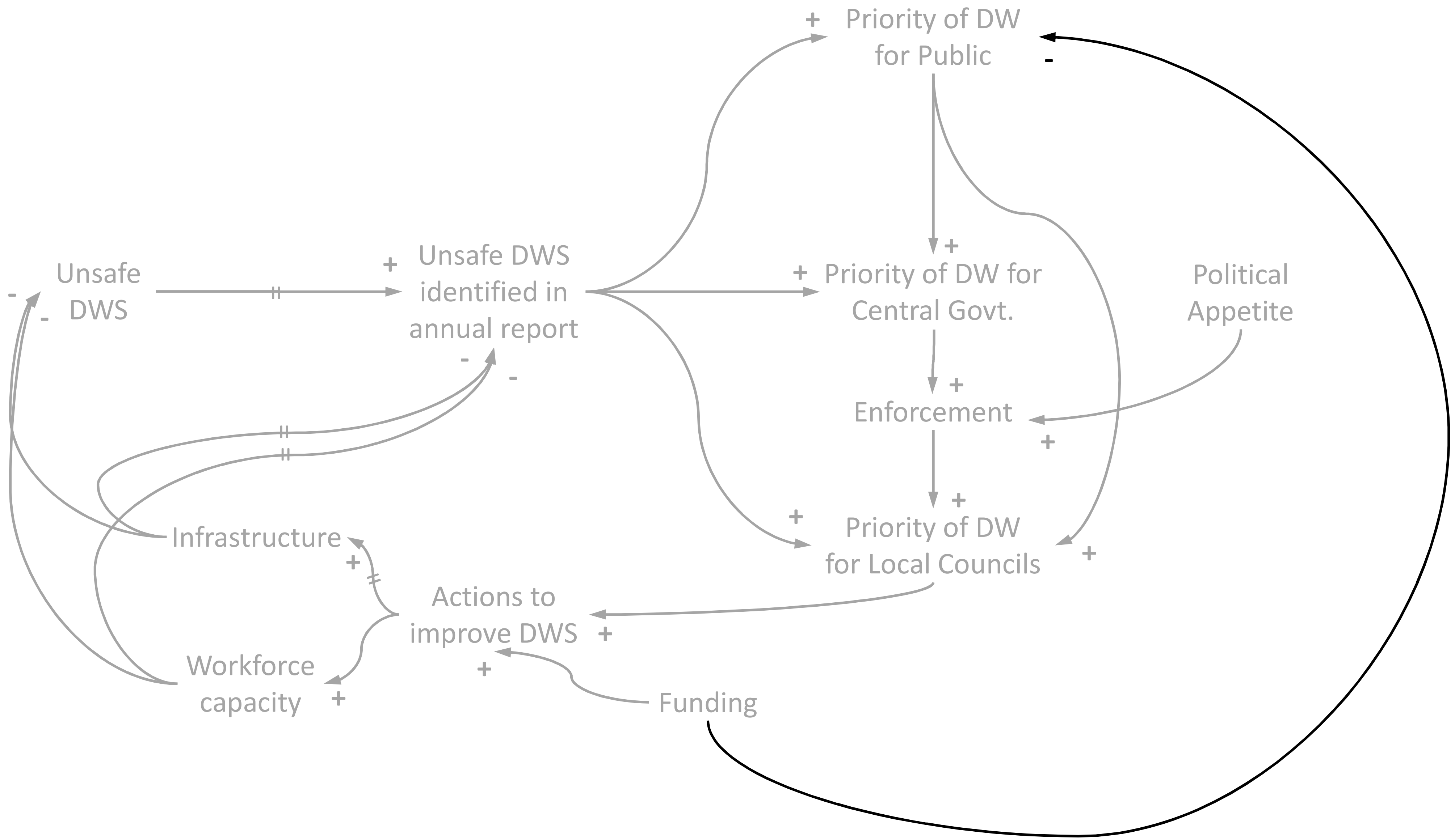
Infrastructure
Priority of DW for Local Councils
Actions to improve DWS
Workforce capacity
Funding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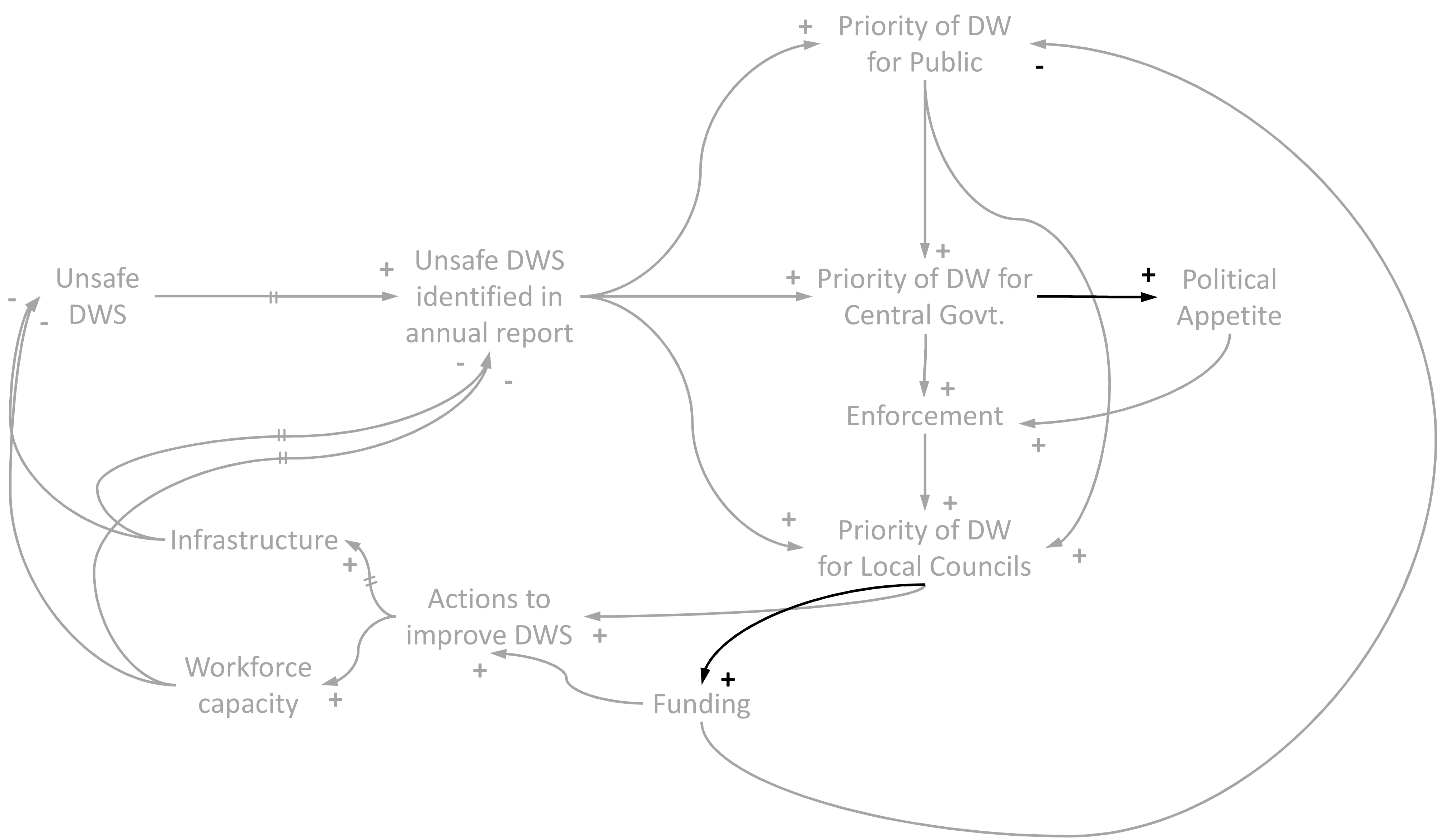
Actions to improve DWS
Workforce capacity
Funding



Priority of DW for Public
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Priority of DW for Central Govt.
Political Appetite
Enforcement
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Actions to improve DWS
Workforce capacity
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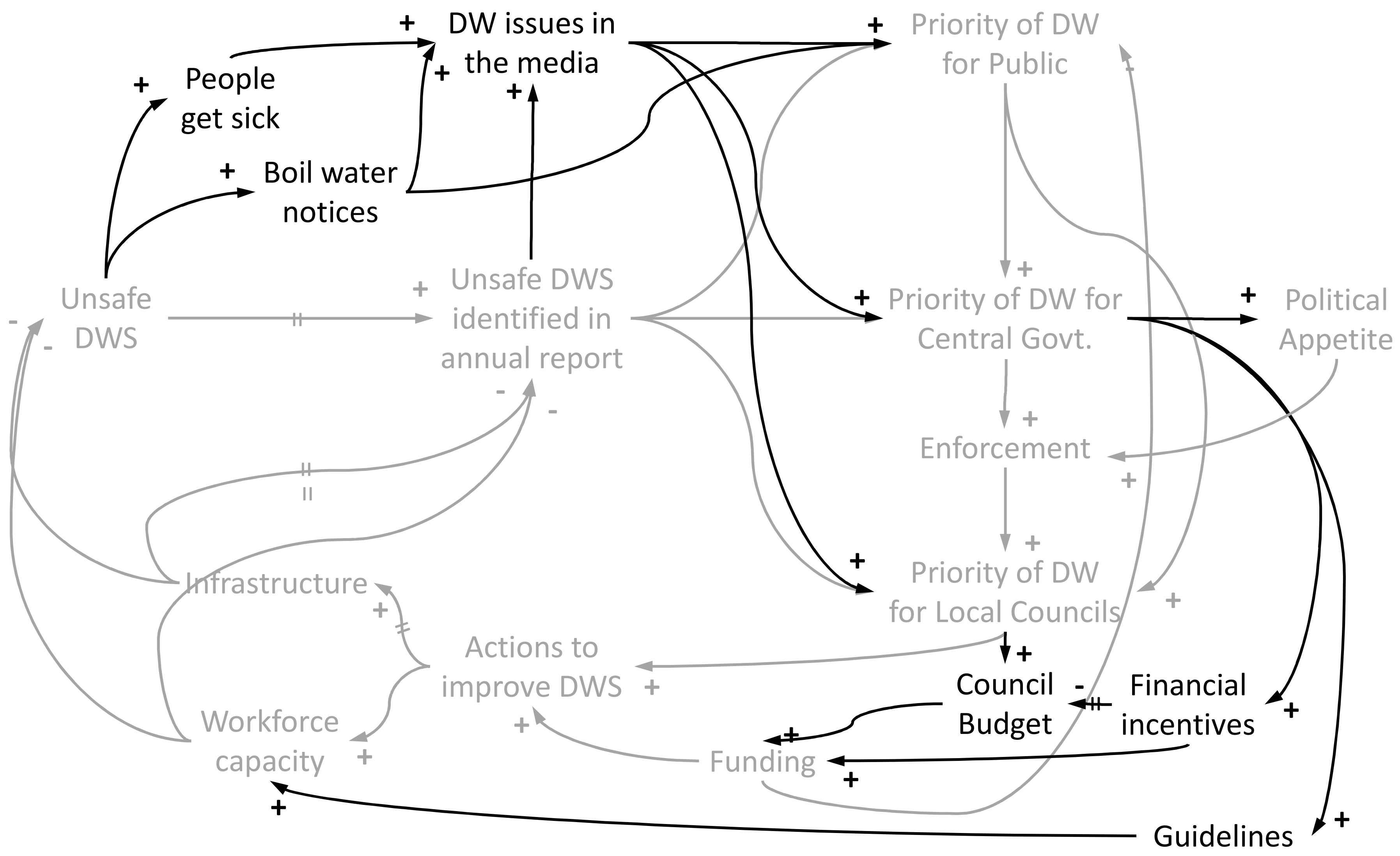
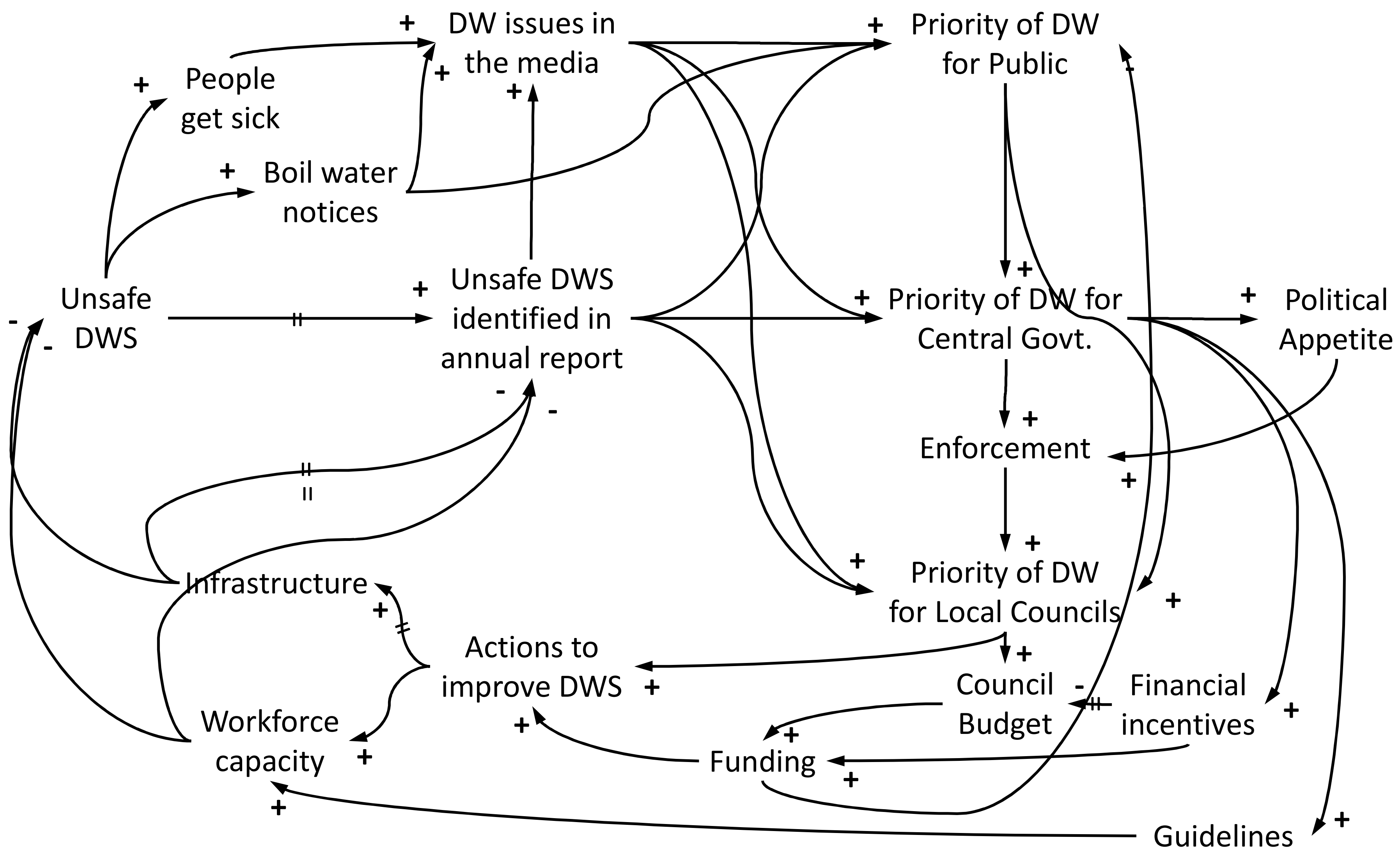


DW issues in the media
People get sick
Boil water notices
Priority of DW for Public
Unsafe DWS
Unsafe DWS identified in annual report
Priority of DW for Central Govt.
Political Appetite
Enforcement
Infrastructure
Priority of DW for Local Councils
Actions to improve DWS
Council Budget
Financial incentives
Workforce capacity
Funding
Guidelines



DW issues in the media
Priority of DW for Public
People get sick
Boil water notices
Unsafe DWS
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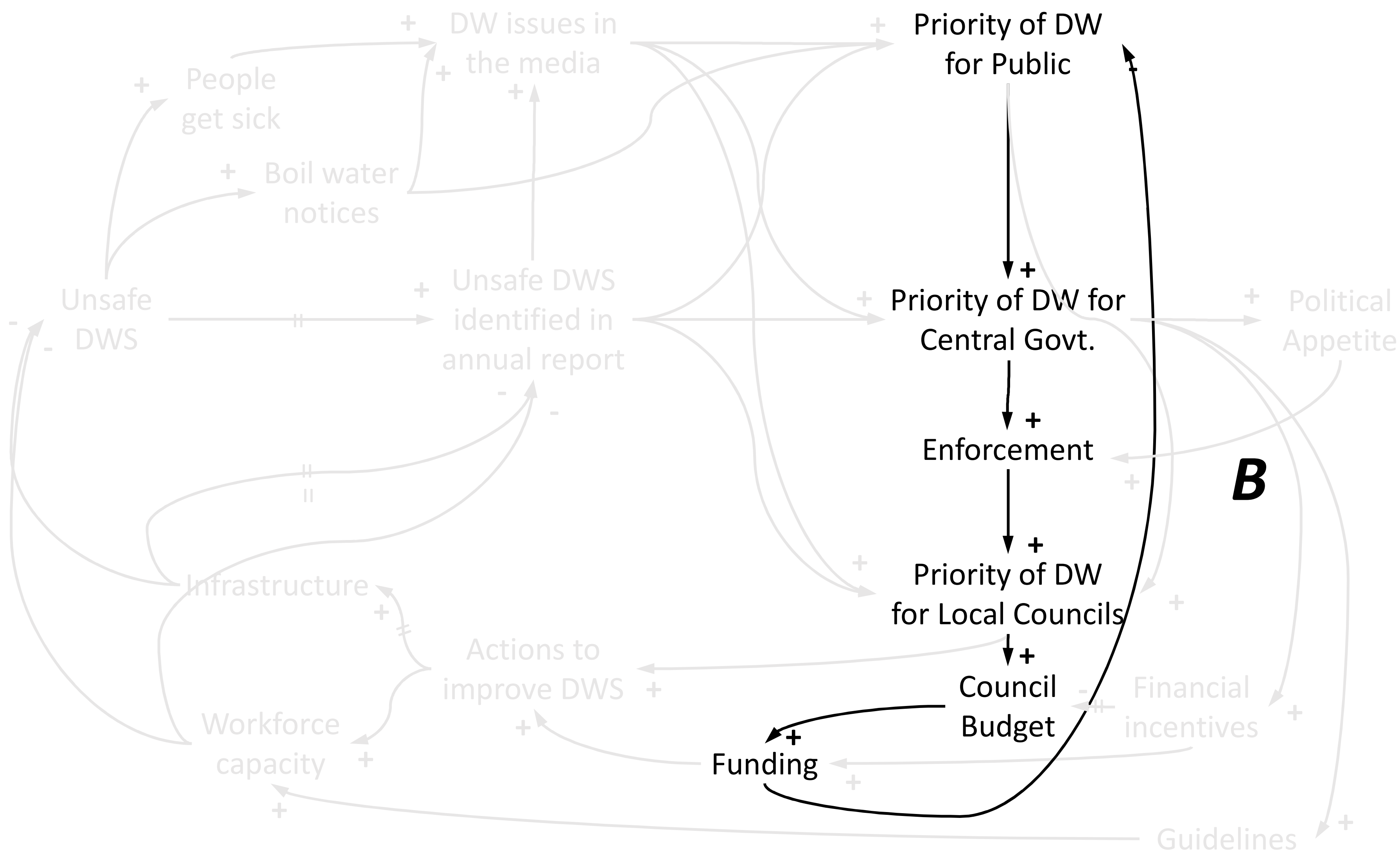

DW issues in the media
People get sick
Boil water notices
Unsafe DWS
Unsafe DWS identified in annual report
Priority of DW for Public
Priority of DW for Central Govt.
Political Appetite
Enforcement
B
Priority of DW for Local Councils
Infrastructure
Actions to improve DWS
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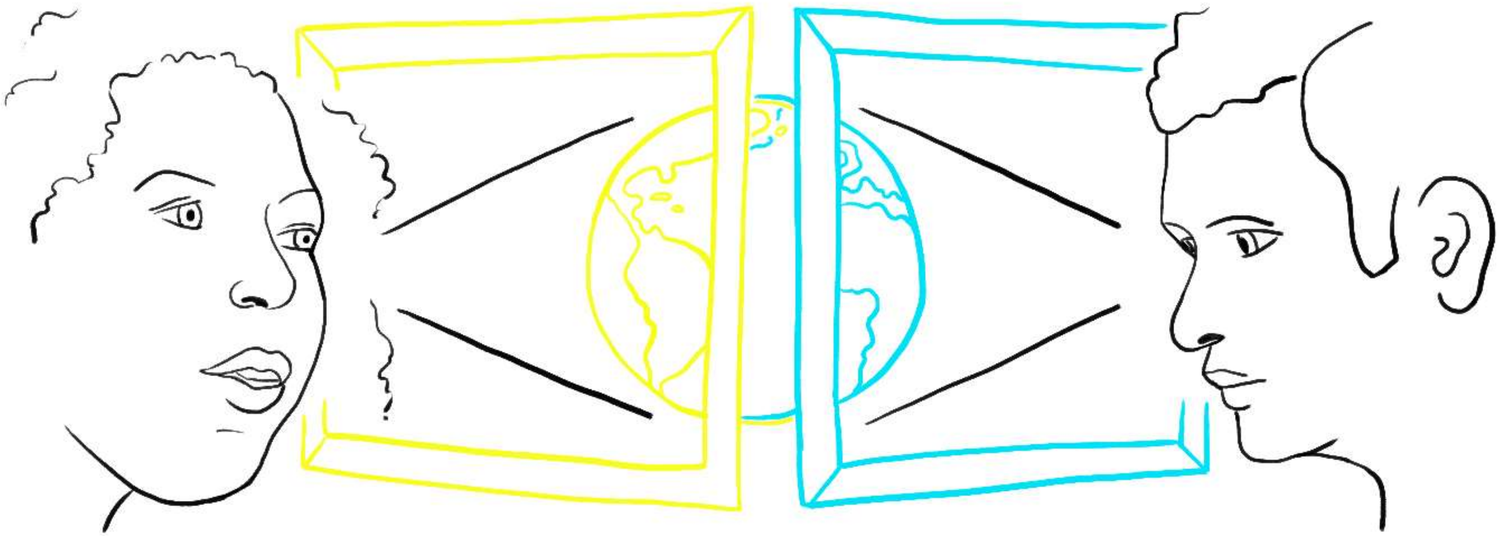
Financial incentives
Funding
Guidelines

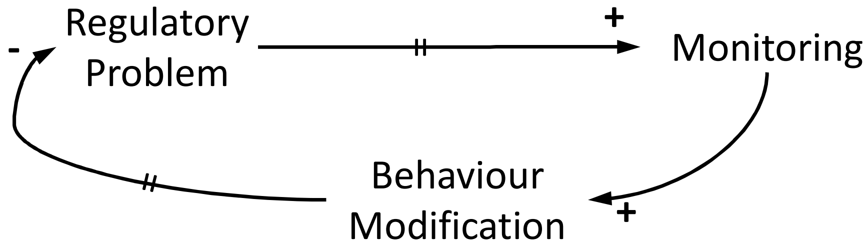
Activity 2:
System Archetypes

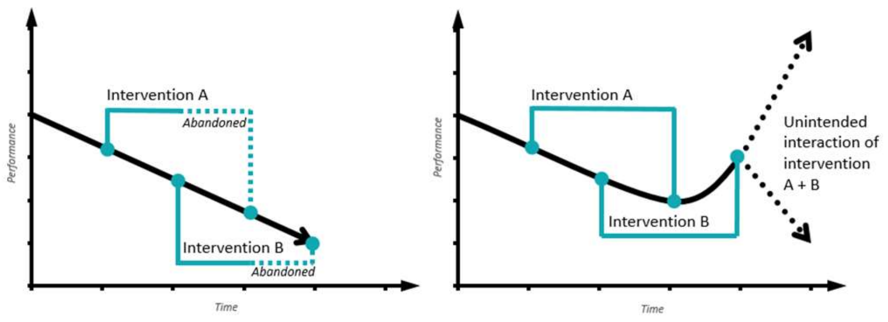
What are System Archetypes?



- Common behaviours emerge from common structures
- If we recognise warning signs, we can learn from them
- Different System Archetypes have different remedies

Regulatory System Archetype: Delays in Regulation

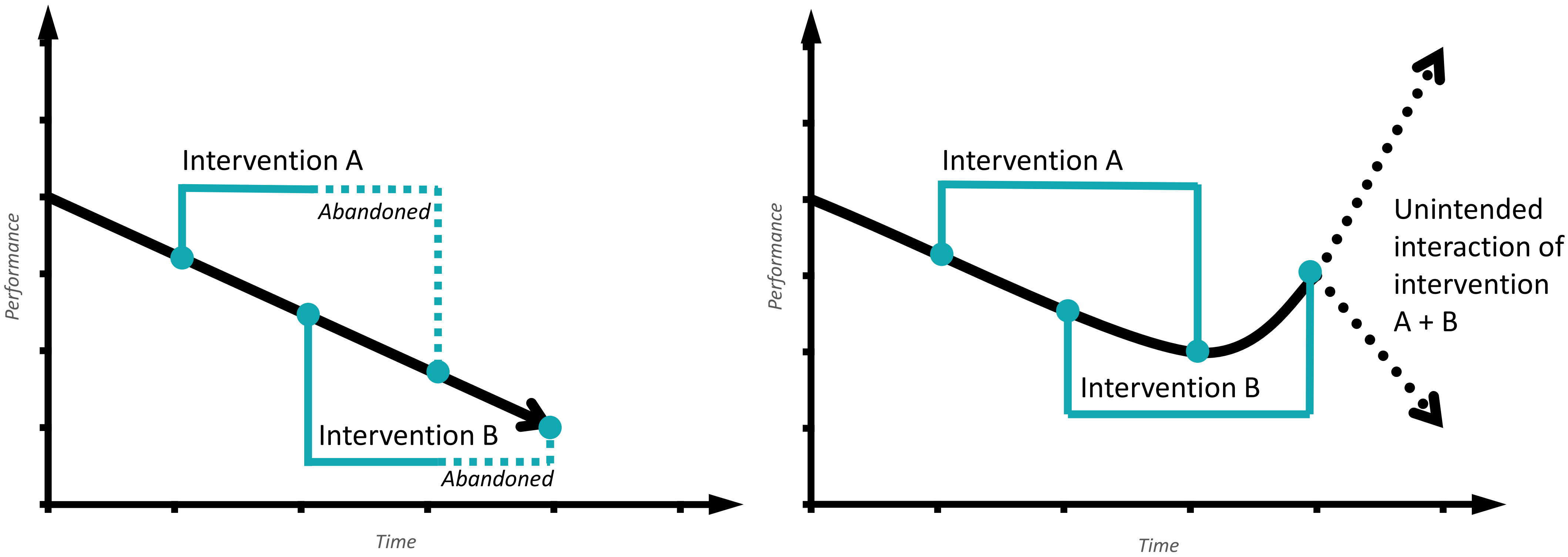


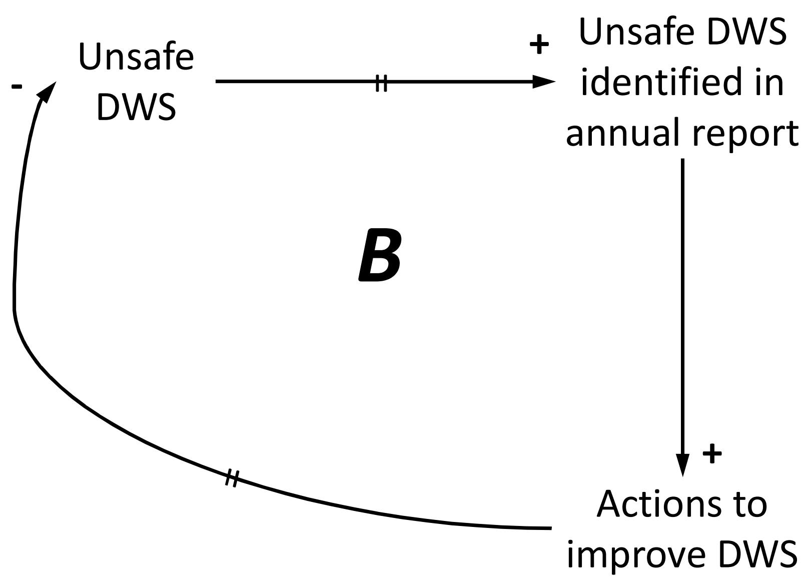


Delays in monitoring or interventions causes overreactions.

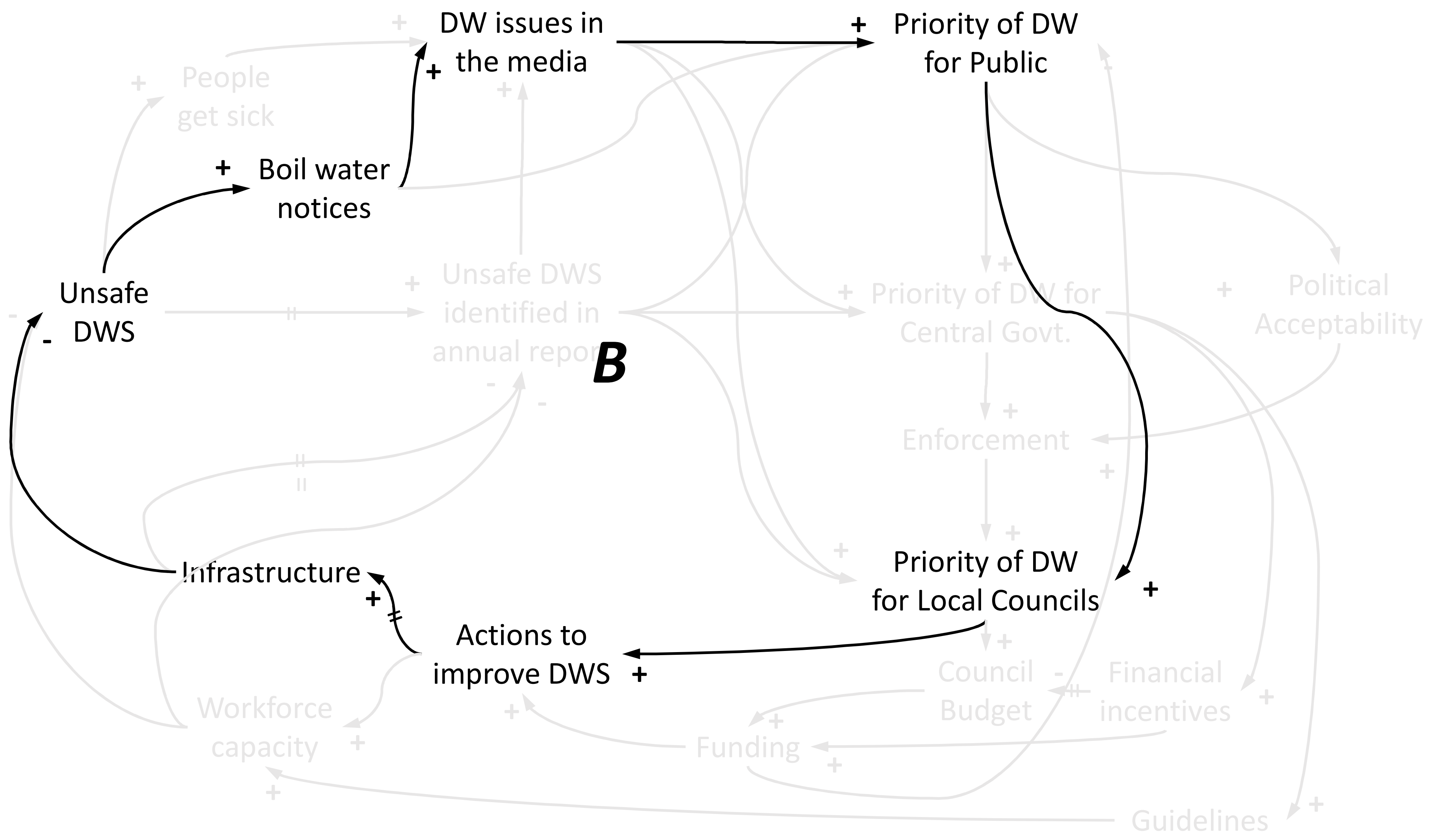
⚠In balance, then overshooting

- ✓Consider how fast the system can reaction to interventions
- ✓Consider what reactions to interventions are still trickling through the system

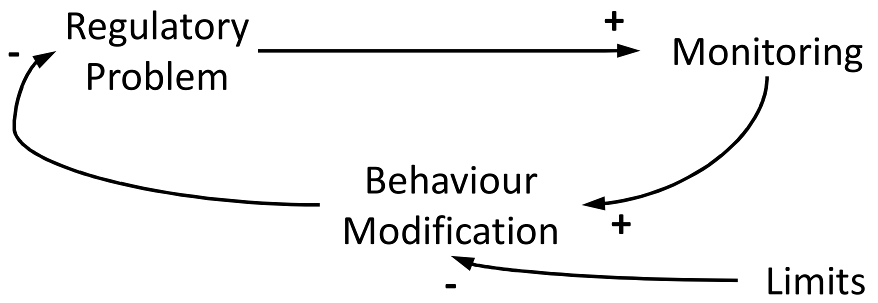

Intervention A
Abandoned
Intervention B
Abandoned
Performance
Time
Intervention A
Intervention B
Unintended interaction of intervention A + B
Performance
Time

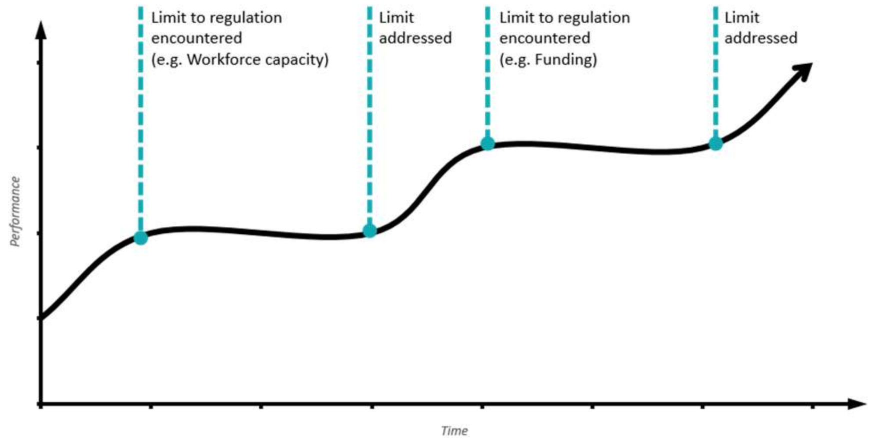


Unsafe DWS
+
Unsafe DWS identified in annual report
-
B
+
Actions to improve DWS


DW issues in the media
Priority of DW for Public
People get sick
Boil water notices
Unsafe DWS
Unsafe DWS identified in annual repor
B
Priority of DW for Central Govt.
Political Acceptability
Enforcement
Priority of DW for Local Councils
Infrastructure
Actions to improve DWS
Workforce capacity
Council Budget
Financial incentives
Funding
Guidelines

Regulatory System Archetype: Limits to Regulation



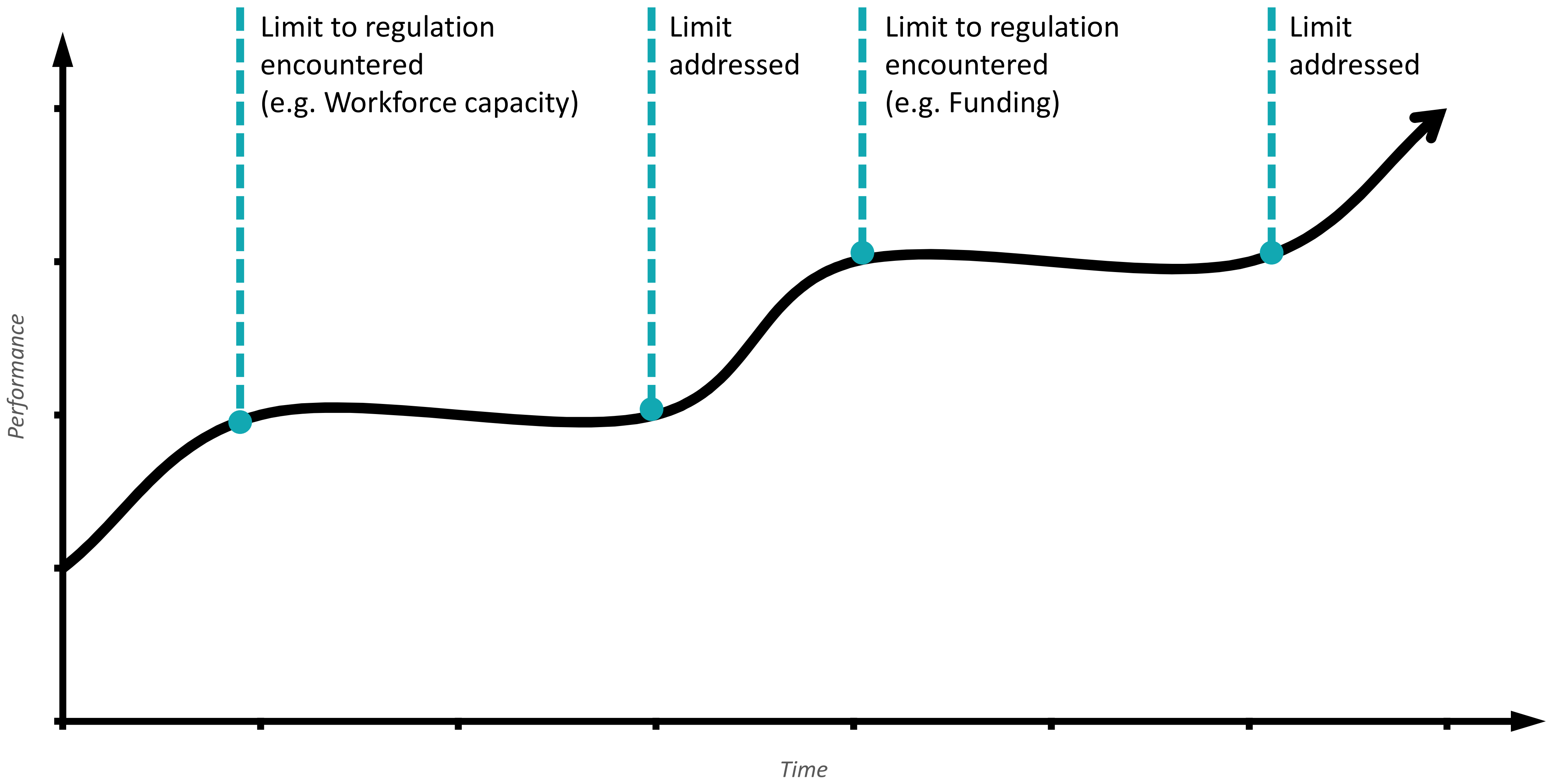


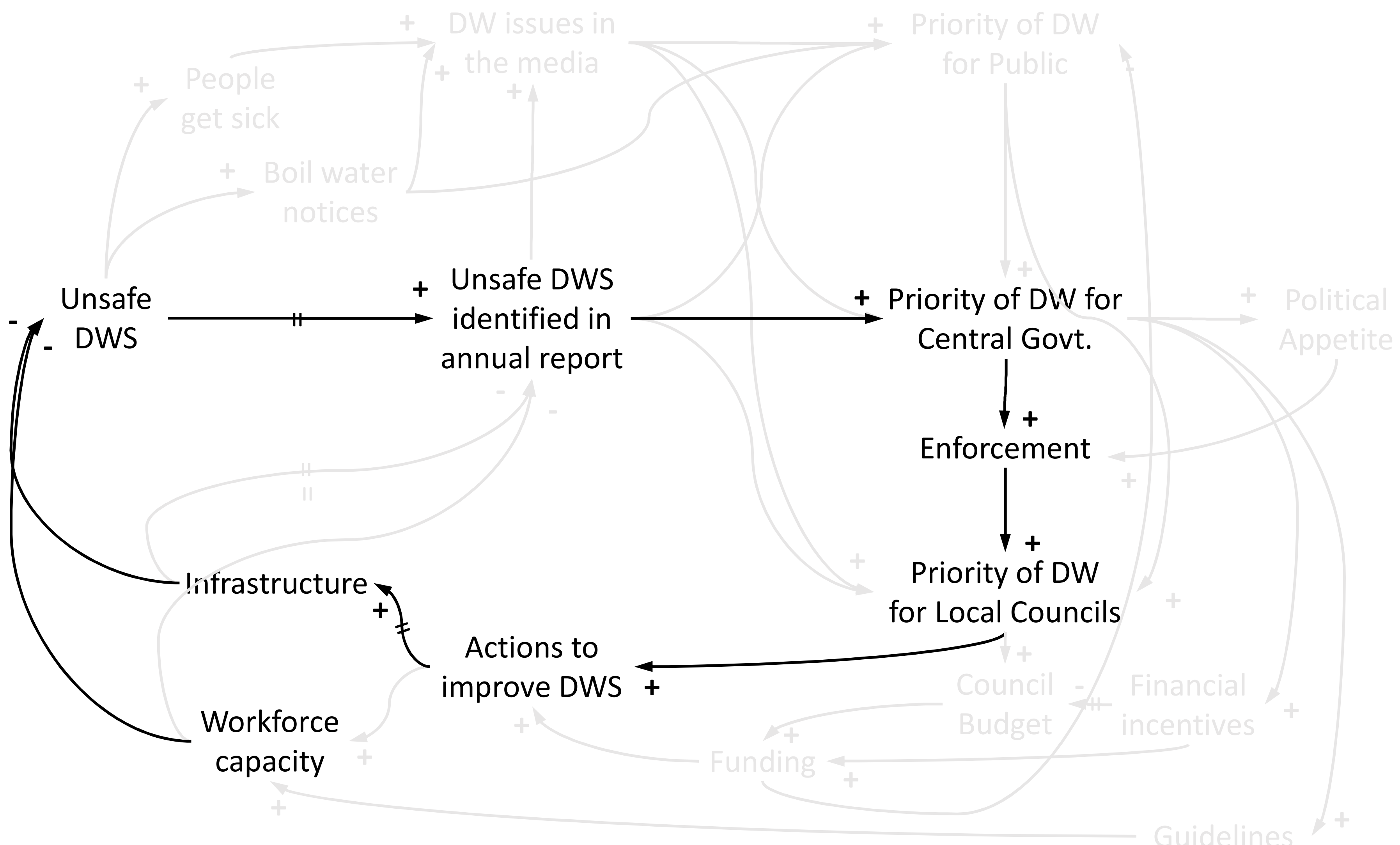
Limits prevent the expected response of feedback loops,

e.g. Limits to enforcement create a benign regulatory deterrence

⚠ Trying harder makes no difference

- ✓Address the limits instead of pushing the feedback loop
- ✓Establish feedback loops that address the limits


Limit to regulation encountered (e.g. Workforce capacity)
Limit addressed
Limit to regulation encountered (e.g. Funding)
Limit addressed
Performance
Time



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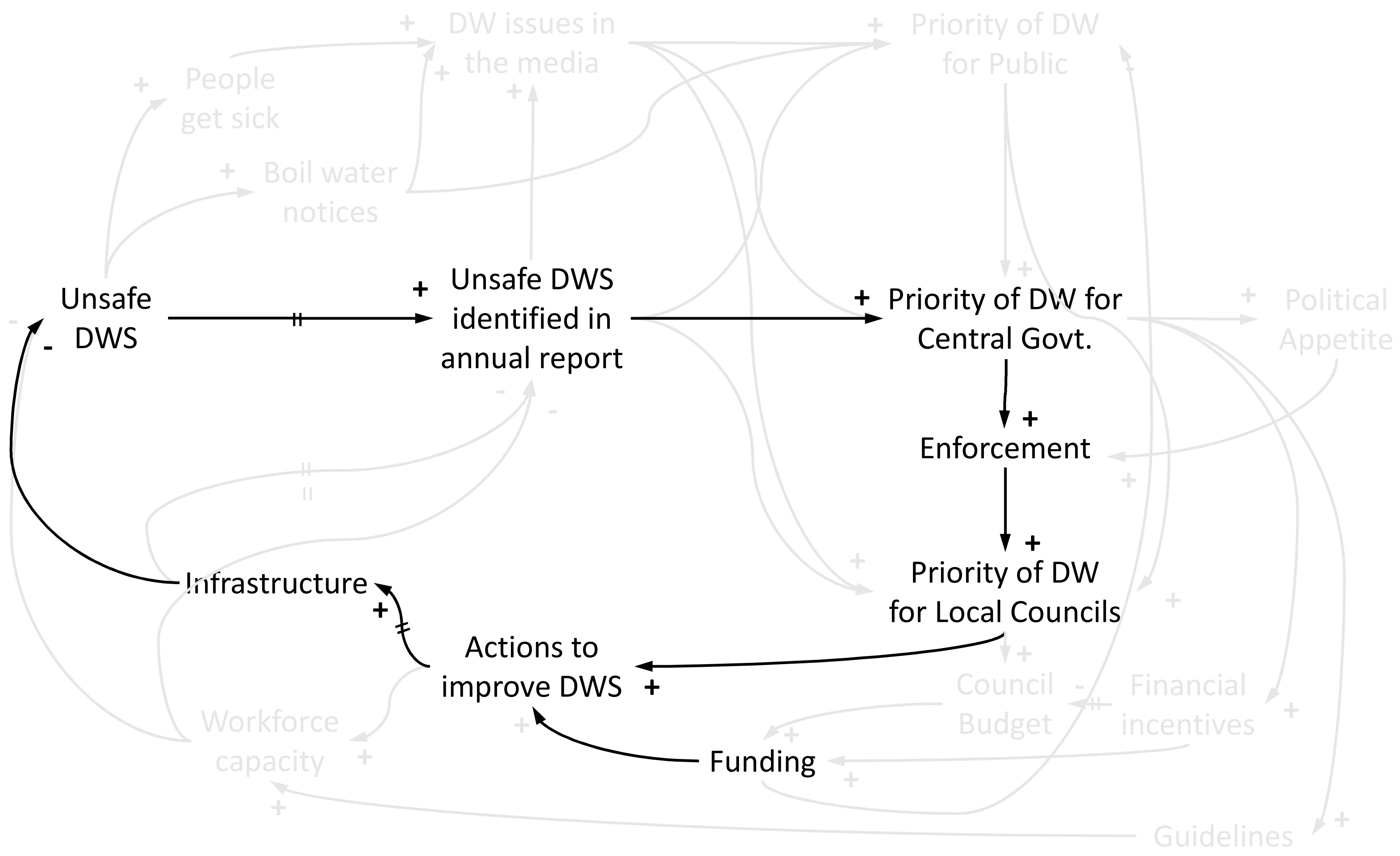

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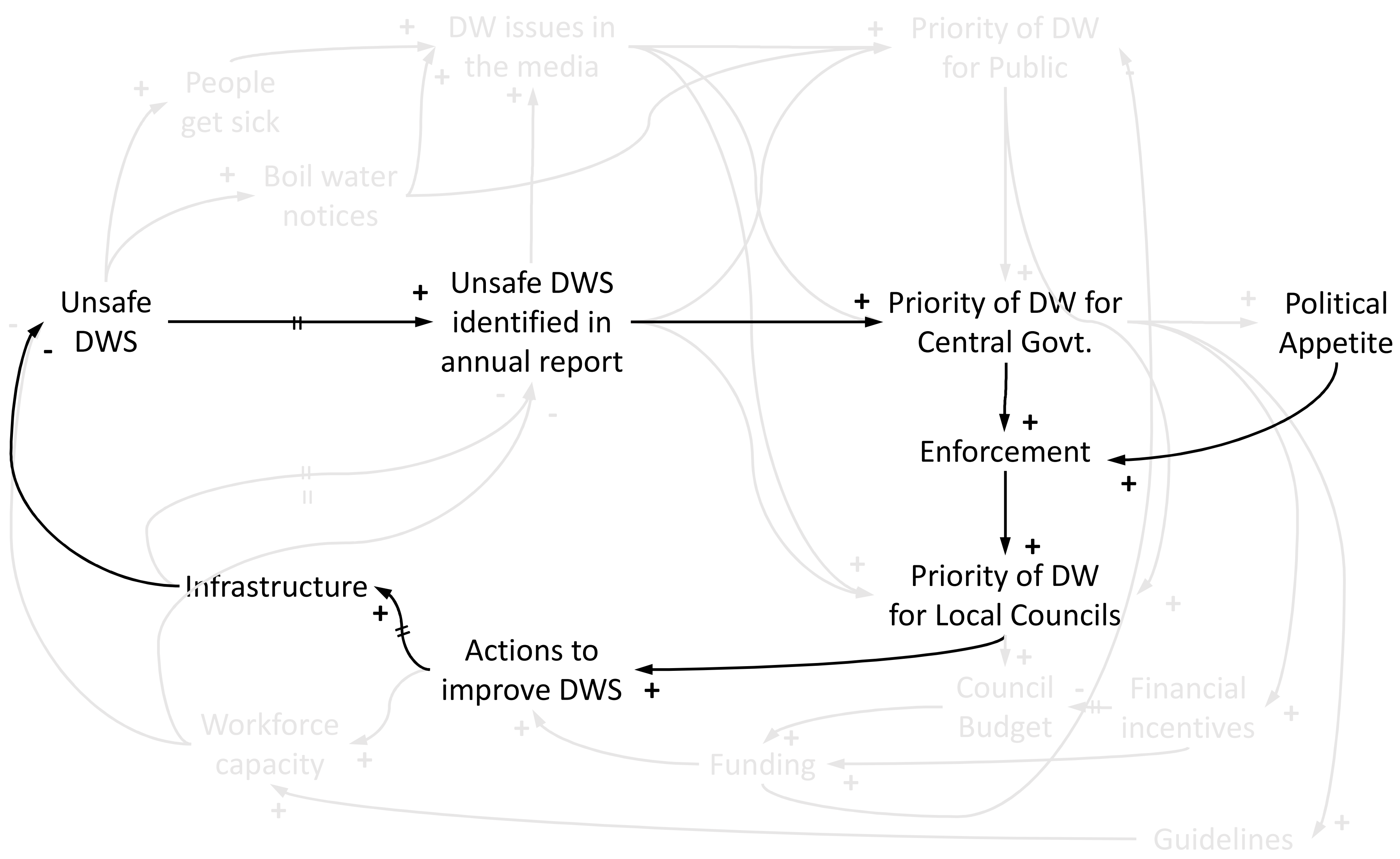

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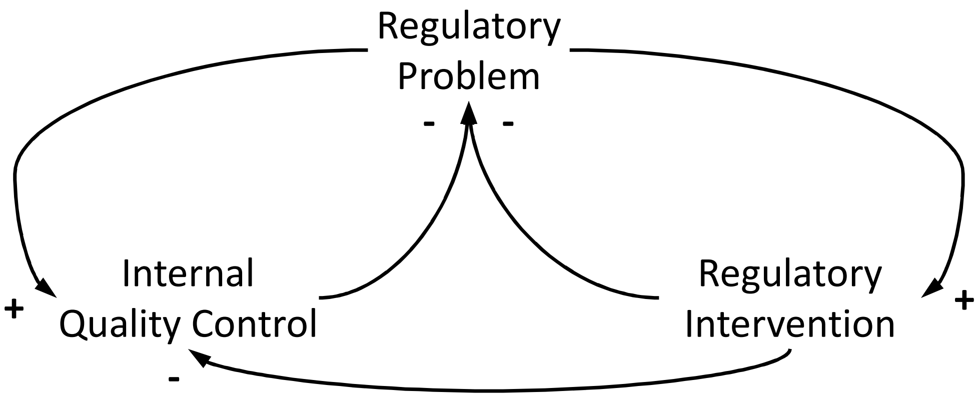
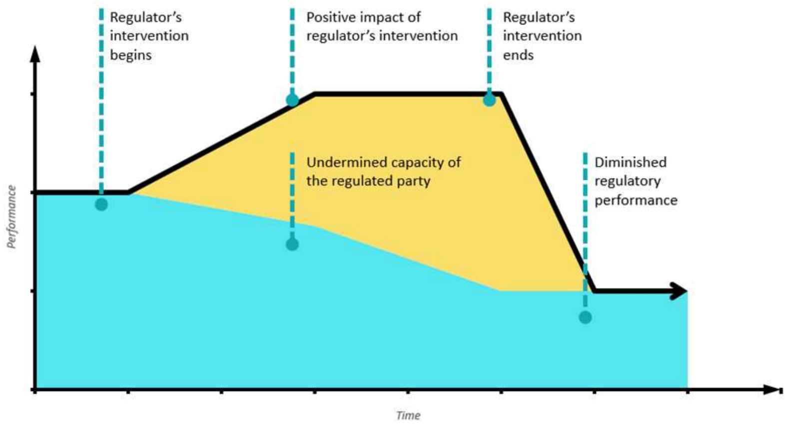
Regulatory System Archetype: Shifting the Burden to the Regulator

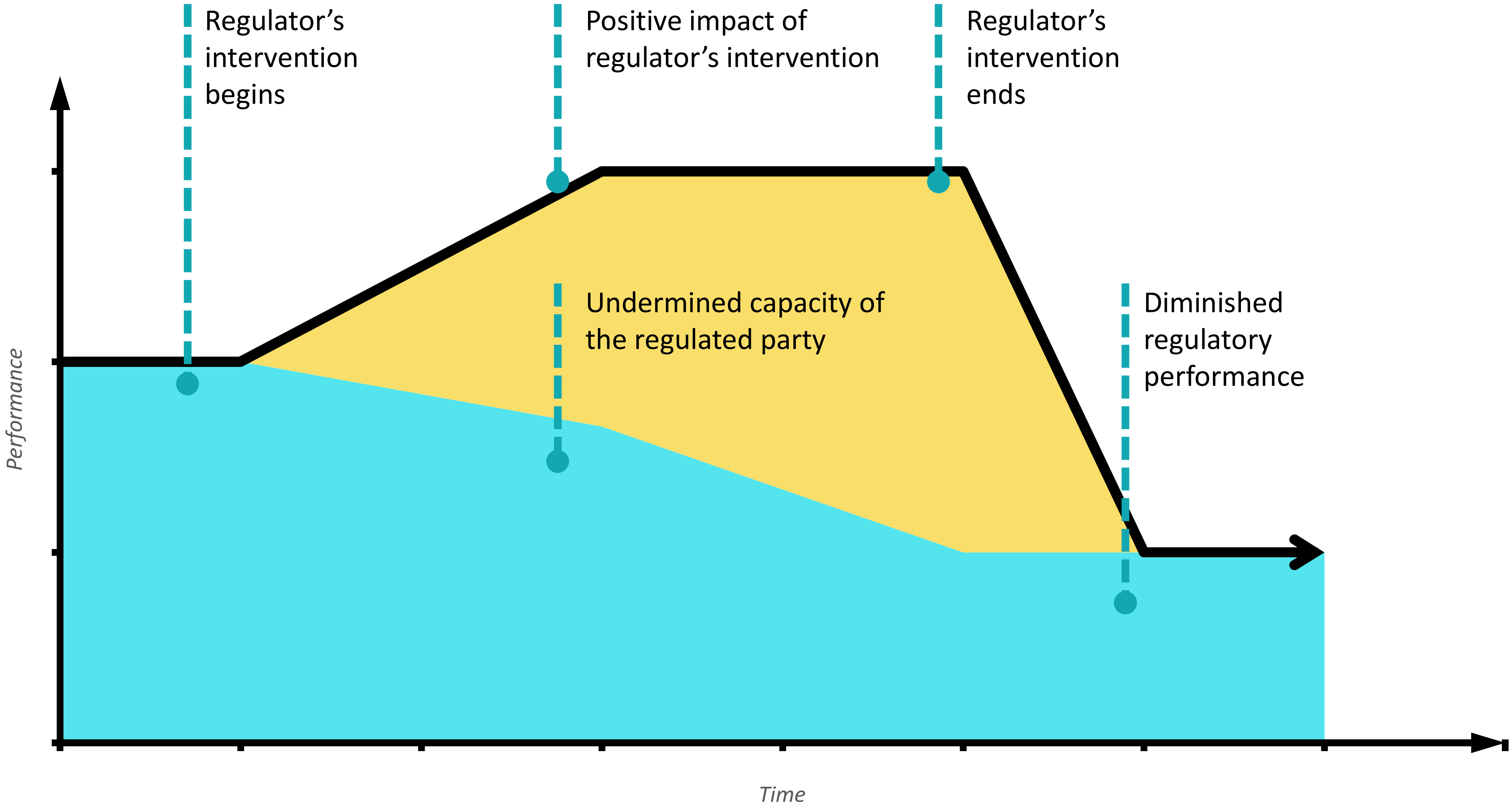




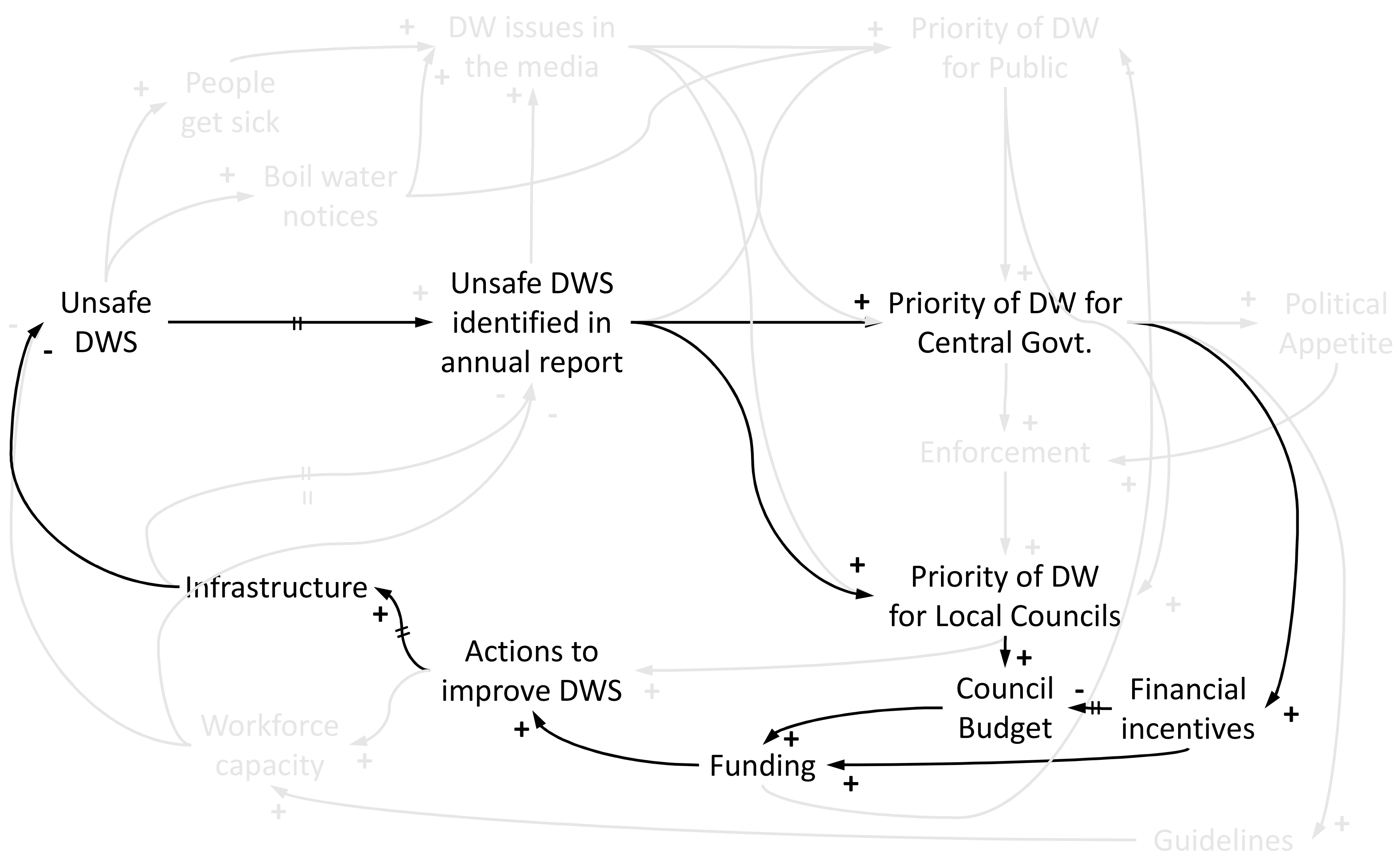
The regulator's actions to support compliance undermines the responsibility or capacity of the regulated party to comply.

⚠This works… for now

- ✓Build capability rather than solve problems
- ✓Interventions should be temporary



Regulator's intervention begins
Positive impact of regulator's intervention
Regulator's intervention ends
Undermined capacity of the regulated party
Diminished regulatory performance
Performance
Time



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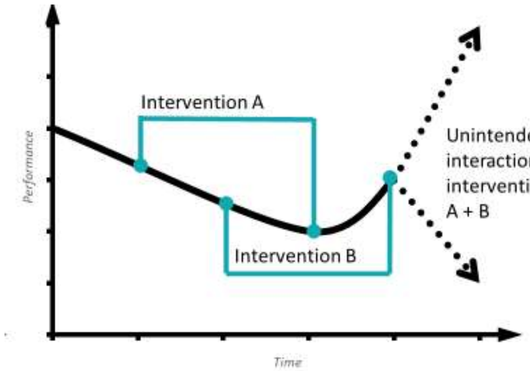
Regulatory System Archetypes

Delays in Regulation

Delays in monitoring or intervention causes overreactions.

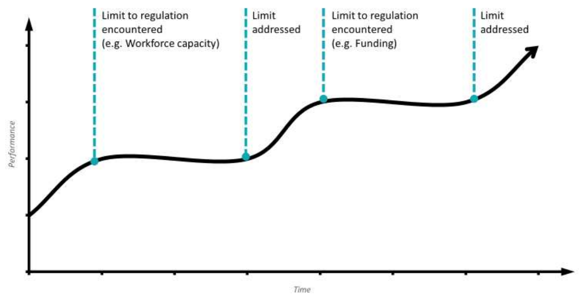


⚠ In balance, then overshooting

- ✓ Consider how fast the system can reaction to interventions
- ✓ Consider what reactions are still trickling through the system

Limits to Regulation

Limits prevent the expected response of feedback loops.

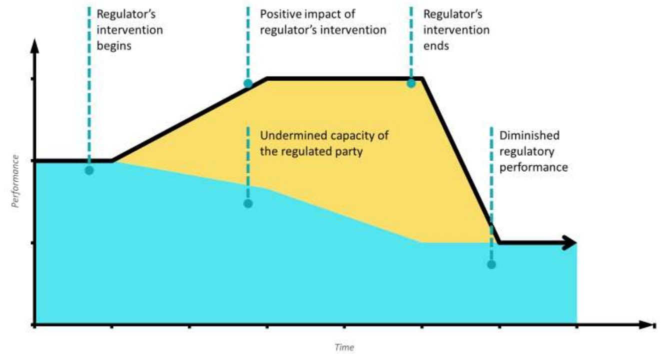


⚠ Trying harder makes no difference

- ✓ Address the limits instead of pushing the feedback loop
- ✓ Establish feedback loops that address the limits

Shifting the Burden to the Regulator

The regulator's actions to support compliance undermines the regulated party's own efforts to comply.



⚠ This works… for now

- ✓ Build capability rather than solve problems
- ✓ Interventions should be temporary

Regulatory Systems Archetypes

- Do you recognise any of these system archetypes in your regulatory system?
- What behaviours do they cause?
- What other patterns of behaviour do you observe in your regulatory system?

Reflections on Regulatory Systems Archetypes

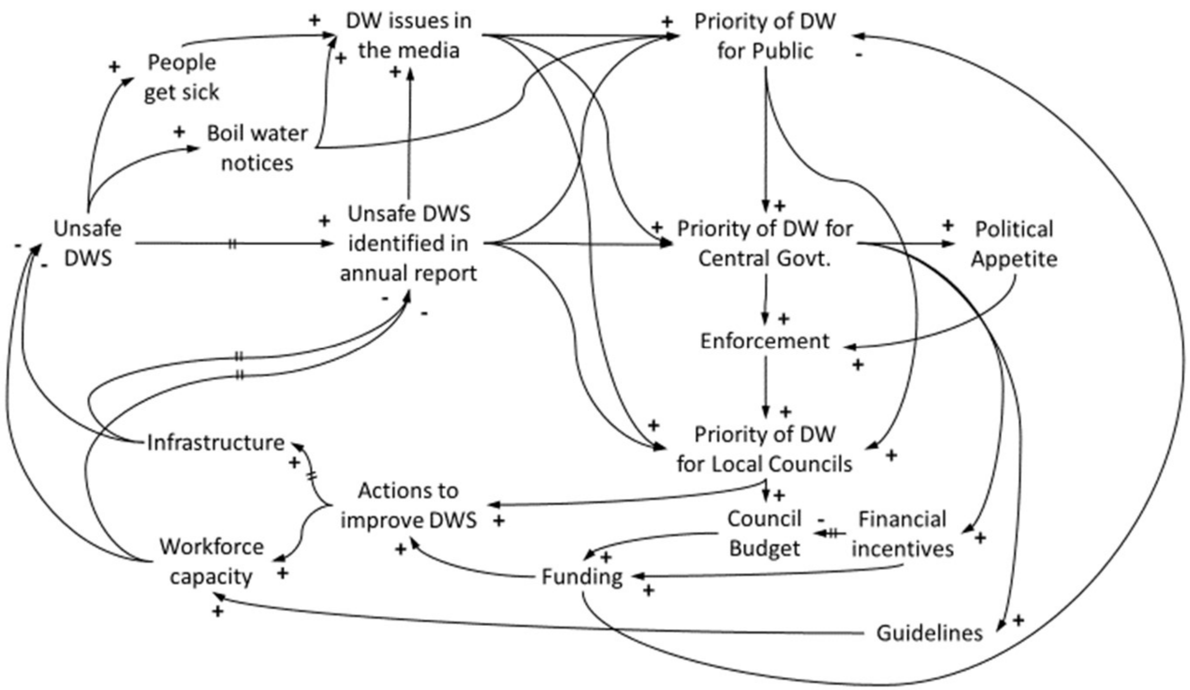
- How easy was it to recognise regulatory systems arcehtypes?
- What insights did you gain?
- How useful was it?

Morning Tea

E Rongo, e Rongo	Rongo matane
Homai ngā tipu	Share with us your food
Hei whakakī i te tīnana	As sustenance for the body
Hei oranga	For life
Au eke au eke	
Hui e, taiki e!	Draw together! Affirm

Activity 3:
Causal Loop Diagrams

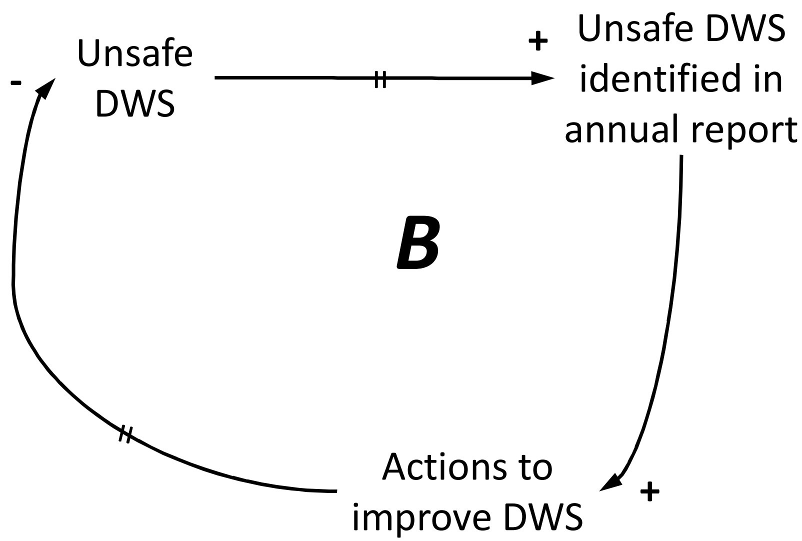
What is a Causal Loop Diagram?



- Structure representation of elements and interactions
- From linear interactions to feedback loops
- Record complex intervention logic
- Identify unintended consequences and emergent behaviours

How to draw a Causal Loop Diagram (1)

1. Describe your regulatory:
   a. Problem
   b. Monitoring
   c. Intervention
2. Add time delays
3. Identify feedback



DWS = Drinking Water Supply

Tips

Elements should: • Be nouns • Vary over time
$\xrightarrow{+}$ Positive Interaction
$\xrightarrow{-}$ Negative Interaction
$\xrightarrow{\#}$ Time Delay
Odd number of negatives **B**alancing Feedback Loop
Zero or even number of negatives **R**einforcing Feedback Loop

How to draw a Causal Loop Diagram (2)

1. Pick a **Problem Situation**

2. Brainstorm **Enablers + Inhibitors**

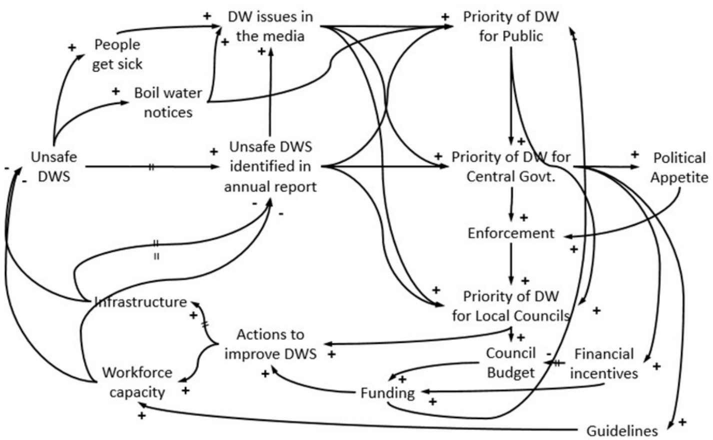
3. Identify **Variable Factors**

4. Analyse **Causes and Effects**

5. Create **Causal Loops**

How to draw a Causal Loop Diagram (3)

1. Describe your regulatory:
   a. Problem
   b. Monitoring
   c. Intervention
2. Add time delays
3. Identify feedback loop
4. Add intermediate steps
5. Add limits to regulation
6. Add unintended consequences
7. And repeat…



Tips

Elements should:

- Be nouns
- Vary over time

+

Positive Interaction

−

Negative Interaction

Time Delay

Odd number of negatives
Balancing Feedback Loop

Zero or even number of negatives
Reinforcing Feedback Loop

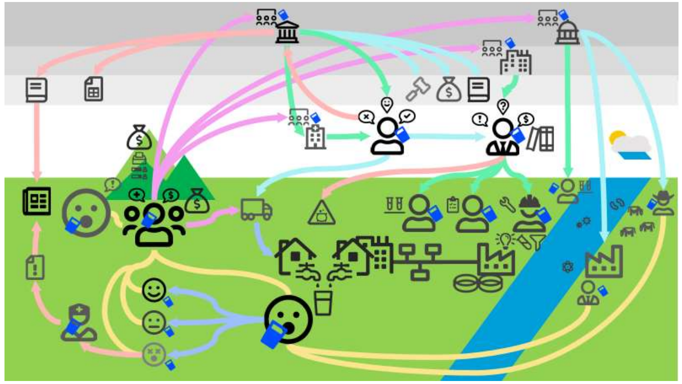
Reflections on Causal Loop Diagrams

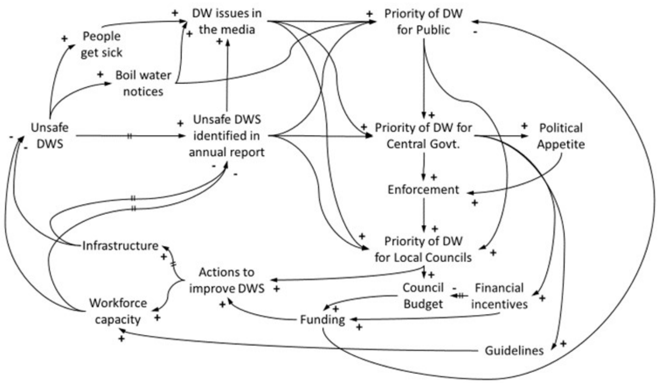
- How easy was it to draw a causal loop diagram?
- Which approach best reasonates?
- What insights did you gain?
- How useful was it?

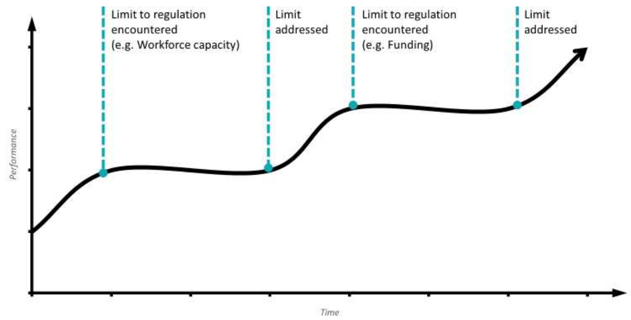
Wrap Up

Reflections on All Activities

- How did the different activities compare?
- Does this change how you think about your regulatory system?
- What next for you?



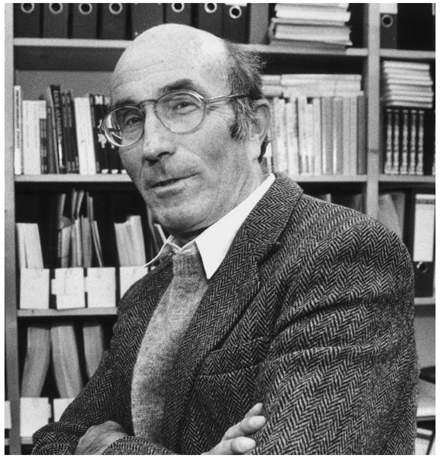




Other Types of Systems Thinking

- Social systems theory
- Stock and flow diagrams
- Systems dynamics models
- Management flight simulators
- Serious games
- Soft Systems Methodology
- Four Step Change Process

Social Systems Theory



Niklas Luhmann

- Modern society containing multiple functionally different social sub-systems
- Each sub-system has its own code for communication
- Sub-systems cannot directly interact
- Linkages between sub-systems can emerge

Political	Government / Opposition
Legal	Lawful / Unlawful
Economic	Payment / Non-payment
Media	Informative / Uninformative
Science	True / Untrue
Health	Ill / Healthy

Luhmann, Niklas. *Social Systems*. Stanford University Press, 1995.

Nobles, Richard, and David Schiff. *Observing Law through Systems Theory,* 2012.

Social Systems Theory

How different actors from drinking-water regulation (2007 to 2021) communicate in social sub-systems

Sub-System	Medium	Parliament	Ministry of Health	Water Supplier	Councillor	Public
Political	Power	Receives: Elected Transmits: Legislation and direction	Receives: Political direction	Receives: Political direction	Receives: Elected Transmits: Policy and direction	Transmits: Elects
Legal	Law	Receives: Legal mandate Transmits: Creates legislation	Receives: Legislation to enact Transmits: Set standards	Receives: Legislation and standards	Receives: Legal mandate	Receives: Is their water complaint?
Economic	Money	Transmits: Allocates budgets	Receives: Budget allocation	Receives: Budget allocation	Transmits: Allocates budgets	Transmits: Pays rates/taxes
Media	News	Receives: Influences political agenda Transmits: Press statements and interviews	Transmits: Answers questions (reluctantly)	Transmits: Boil water notices and answers questions (reluctantly)	Receives: Influences political agenda	Receives: Influences priorities
Science	Truth	Receives: Informs legislation	Transmits: analysis and justification for legislation and the standards	Receives: Influences processes	Receives: Influences priorities	Receives: Influences priorities
Health	Illness	Receives: Influences political agenda	Receives: Influences priorities	Receives: Influences priorities	Receives: Influences political agenda	Transmits: When they get sick

- Risks of communication breakdowns between different social sub-systems.
- Every actor communicates in every social sub-system, so there is always opportunity for meaningful communication.

Local Councillor

~~Compliance with drinking water standards~~

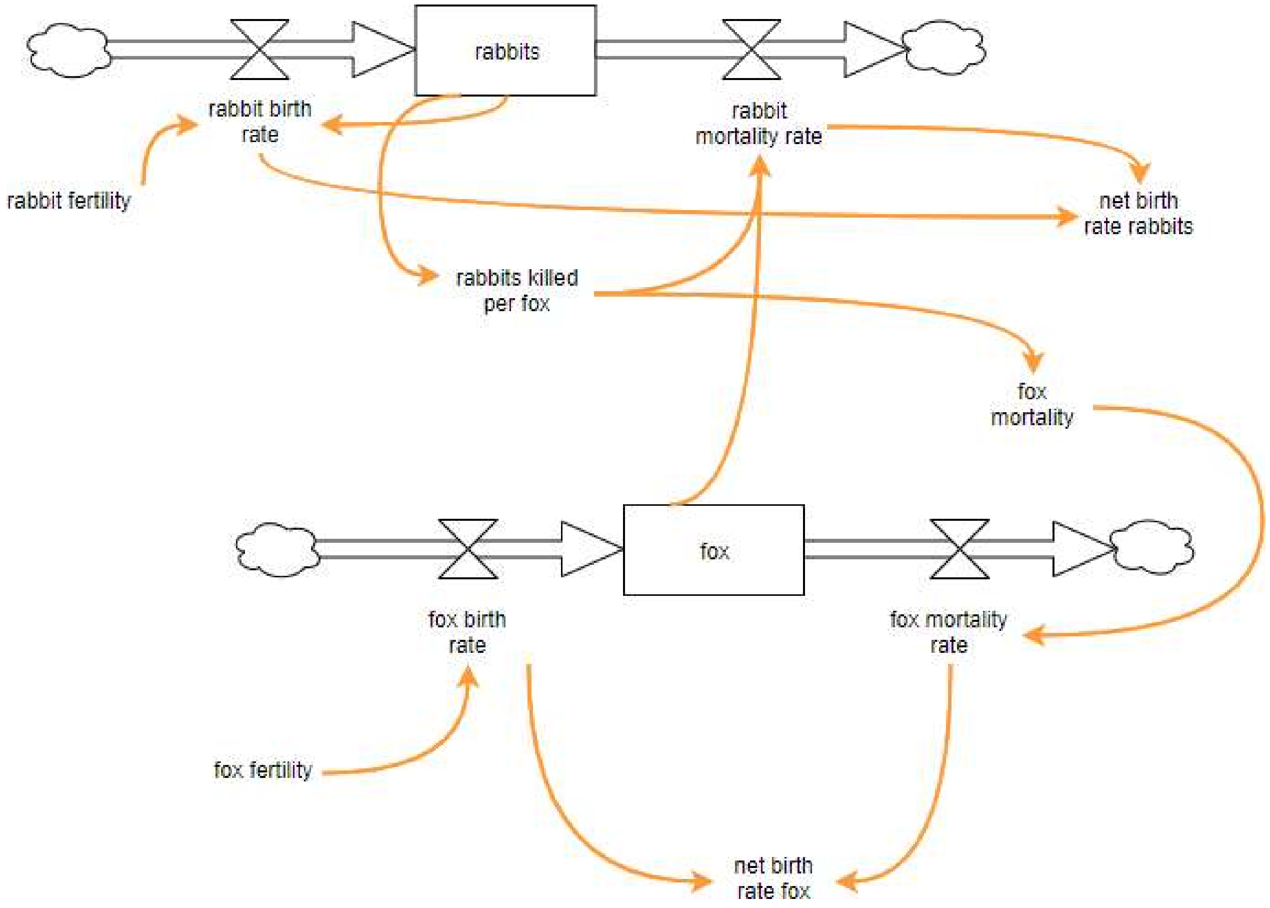
Protecting the wellbeing of their community.

Water Services Operator

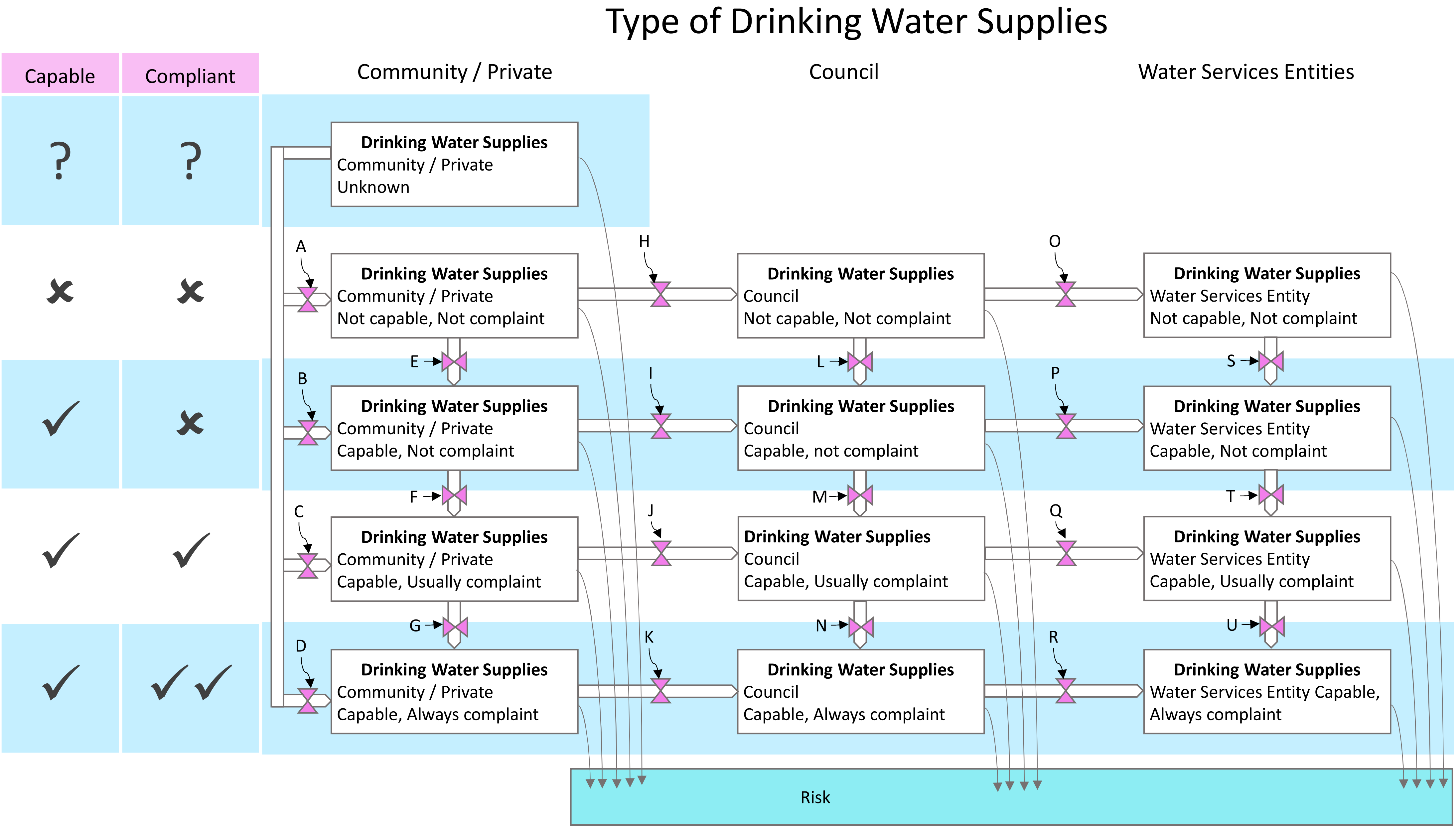
~~Providing safe drinking water~~

Meeting the drinking water standards

Stock and Flow DiagramS

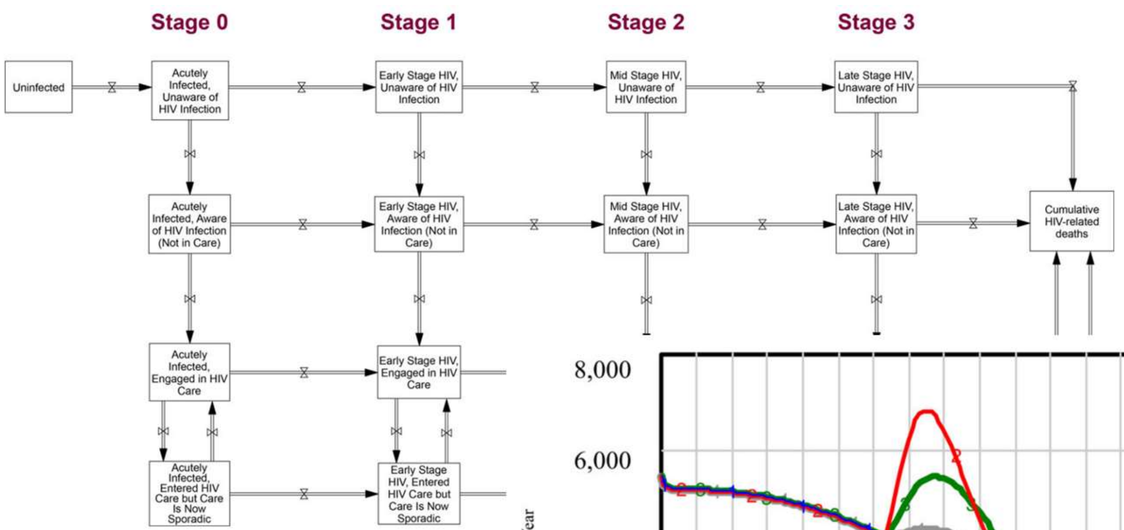


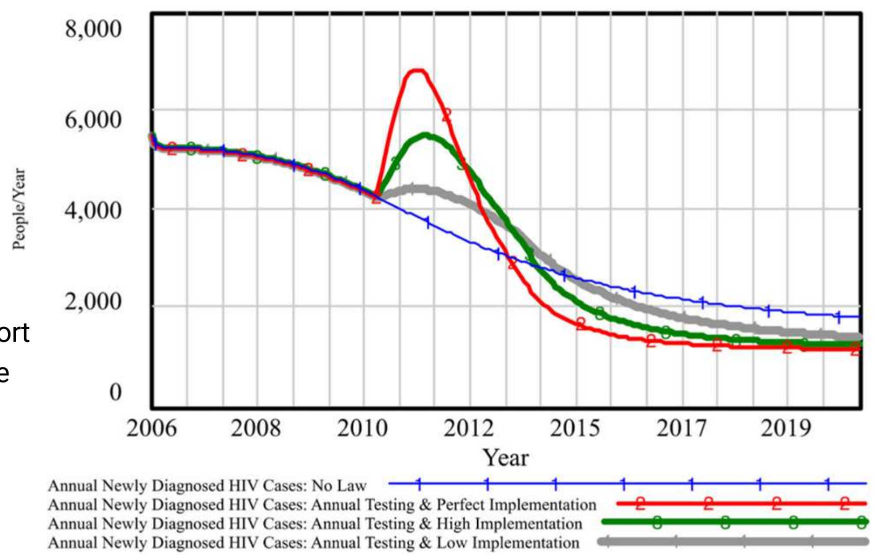
- Extension of causal loop diagrams
- Introduce stocks which can accumulate
- Could be used to model the flow of regulated parties from low to high compliance/capability



Type of Drinking Water Supplies
Capable
Compliant
Community / Private
Council
Water Services Entities
?
?
Drinking Water Supplies
Community / Private
Unknown
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
Drinking Water Supplies
Community / Private
Not capable, Not complaint
Drinking Water Supplies
Council
Not capable, Not complaint
Drinking Water Supplies
Water Services Entity
Not capable, Not complaint
Drinking Water Supplies
Community / Private
Capable, Not complaint
Drinking Water Supplies
Council
Capable, not complaint
Drinking Water Supplies
Water Services Entity
Capable, Not complaint
Drinking Water Supplies
Community / Private
Capable, Usually complaint
Drinking Water Supplies
Council
Capable, Usually complaint
Drinking Water Supplies
Water Services Entity
Capable, Usually complaint
Drinking Water Supplies
Community / Private
Capable, Always complaint
Drinking Water Supplies
Council
Capable, Always complaint
Drinking Water Supplies
Water Services Entity Capable,
Always complaint
Risk

Systems Dynamics Models



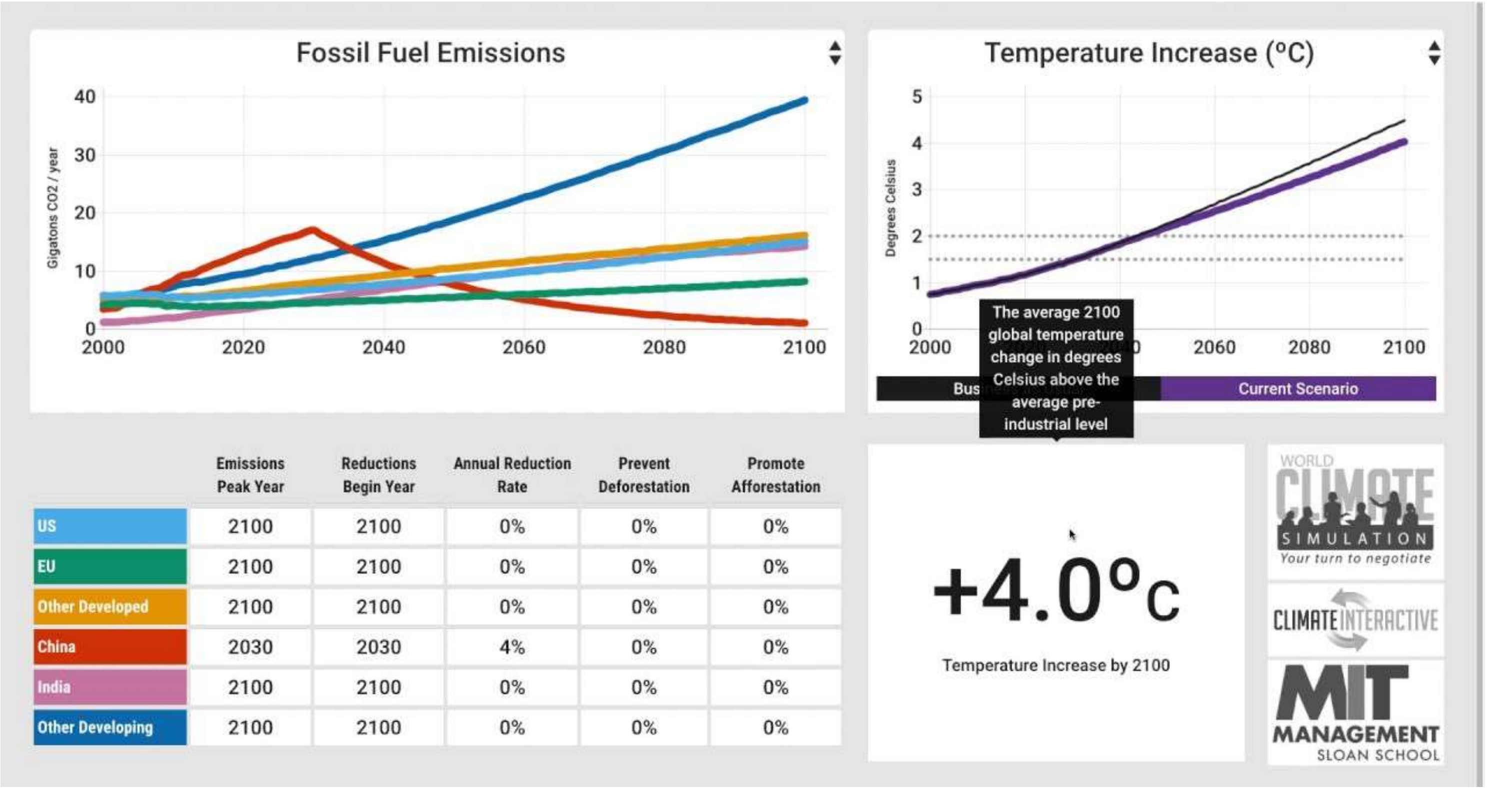


Martin et al. “Policy Modeling to Support Administrative Decision-making on the New York State HIV Testing Law.” *Journal of Policy Analysis and Management*
https://doi.org/10.1002/pam.21797

- Computer simulation of the behaviours of systems models
- Requires explicit assumptions and quantification of variables

E.g. Understanding the effects of changing the laws regulating HIV testing

Management Flight Simulators



	Emissions Peak Year	Reductions Begin Year	Annual Reduction Rate	Prevent Deforestation	Promote Afforestation
US	2100	2100	0%	0%	0%
EU	2100	2100	0%	0%	0%
Other Developed	2100	2100	0%	0%	0%
China	2030	2030	4%	0%	0%
India	2100	2100	0%	0%	0%
Other Developing	2100	2100	0%	0%	0%

https://www.climateinteractive.org/tools/c-roads/

- Using system dynamics models
- Test decisions and strategies
- Supports learning

E.g. C-ROAD allows people to explore the likely consequences of greenhouse gas emissions policies

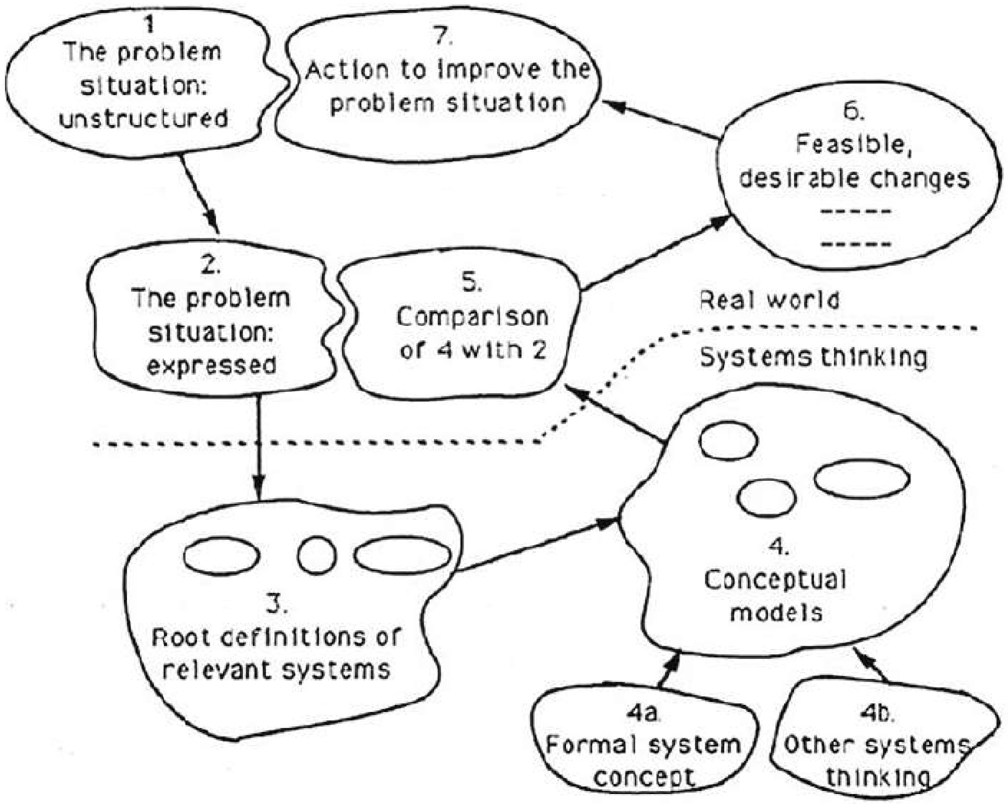
Serious Games

- Representations of real-world situations
- Players can interact with each other and the game
- Sensory stimuli, challenge, humour and encourage players to engage rationally and emotionally to learning

E.g. Exploring bus services regulation and contracting in rural Poland with a serious game which anticipated unexpected response to policies.

Olejniczak, Karol, Michał Wolański, and Igor Widawski. “Regulation Crash-Test: Applying Serious Games to Policy Design.” *Policy Design and Practice* https://doi.org/10.1080/25741292.2018.1504372

Soft Systems Methodology



Checkland, Peter. *Systems Thinking, Systems Practice*. 1972

- The 7 stages move between considering real-world situations and considering systems models
- Systems model provide a deliberate level of abstraction to explore solutions rather than to represent the real-world.
- Systems are a just a mental heuristic for thinking about messy real-world situations

Four-Stage Change Process

- Practical change management approach
- For engaging multiple stakeholders
- Uses the tension between a common understanding of the real-world situation and shared vision to drive change

Stroh, David Peter. *Systems Thinking For Social Change: A Practical Guide to Solving Complex Problems, Avoiding Unintended Consequences, and Achieving Lasting Results*. 2015.

Next Steps…

Interactive Workshop

Post-questionnaire

Interviews

Workshop Report

Thesis

Webinar

Ka whakairia te tapu	Restrictions have been moved aside
Kia wātea ai te ara	May the pathway be cleared
Kia tūruki whakataha ai	To return to everyday activities
Kia tūruki whakataha ai	To return to everyday activities
Haumi ē, Hui ē, tāiki ē	Bind together - all together

THANK YOU!