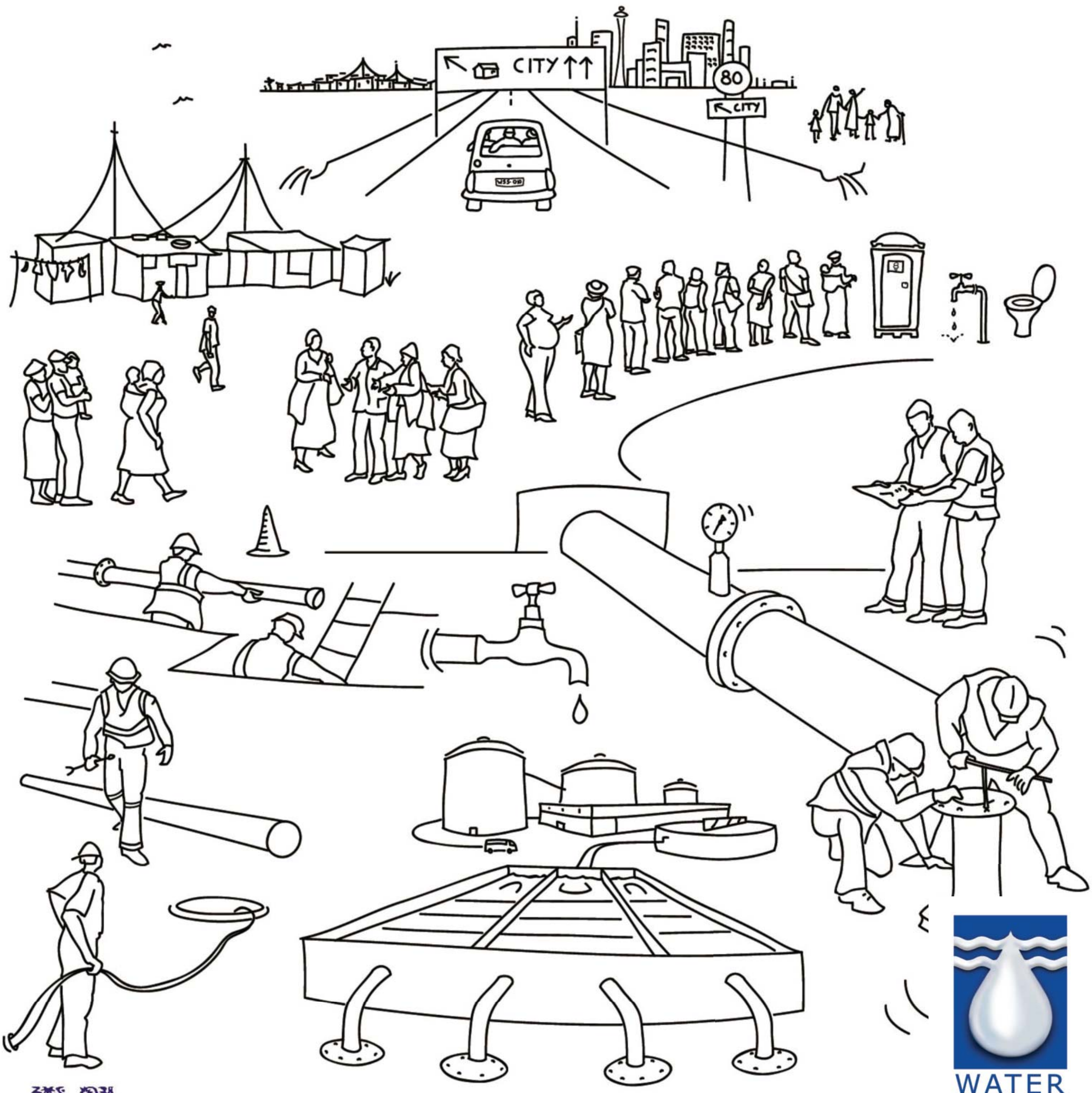
HOW TO...

engage with the challenges facing Water and Sanitation Services (WSS) in small municipalities



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WHO ARE THESE HANDBOOKS FOR?

The user-friendly series of “How to….” handbooks are aimed at staff and stakeholders in catchment management forums (CMFs), catchment management agencies (CMAs) and municipalities. The handbooks are not all written at exactly the same level of “user-friendliness”, it depends on the topic, and target users.

The list below shows which groups are likely to find the handbooks most useful:

TITLE	#	CMF	CMA	MUNICIPALITIES
How to think and act in ways that make Adaptive IWRM practically possible	**1**		√	√
How to think about water for people and people for water: Some, for all, forever	**2**	√	√	√
How to establish and run a Catchment Management Forum	**3**	√	√	
How to manage Water Quality and Water Quantity together	**4**		√	√
How to engage with the challenges facing Water and Sanitation Services (WSS) in small municipalities	**5**			√
How to run a Green Drop campaign in a Catchment Management Forum	**6**	√	√	√
How to engage with coal mines through a Catchment Management Forum	**7**	√	√	√
How to use Strategic Adaptive Management (SAM) and the Adaptive Planning Process (APP) to build a shared catchment future	**8**	√	√	√
How to understand Environmental Water Quality in Water Resources Management	**9**	√	√	√

NOTE: Words marked with an * in these handbooks appear in the glossary at the end of each handbook.

Definition: **Adaptive IWRM:**

Using adaptive, systemic, processes and an understanding of complex social-ecological systems **to coordinate conservation, manage and develop water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.**

A definition based on the Global Water Partnership 2000 definition of IWRM (Agarwal et al., 2000), with specific Adaptive IWRM additions (italics).

[Words marked with * appear in the glossary at the end of the handbook]

Overview

Smaller South African municipalities have many urgent calls on their resources AT THE SAME TIME. • **The need to pay salaries is sometimes more important than other concerns.** • **It is not always clear how different problems affect each other.** • **It is difficult to decide what to do each day.** • **There are always urgent crises to attend to.** • **There are many meetings to attend.** • **Operational and political priorities can be different.** **Thinking of, and talking about your municipality as a SYSTEM will help you to ACT in ways that reduce the impact of these issues.** **This handbook relates specifically to water and sanitation issues.** **Please also read and use the handbook: *"How to think and act in ways that make Adaptive IWRM practically possible".***

This handbook helps municipal stakeholders to think *systemically* and talk about the challenges facing water supply and sanitation services. They can then ACT more productively.

Who is this handbook for?

1. For **municipal employees** (supervisors and managers) who may struggle to communicate to other municipal stakeholders what the challenges of water and sanitation services are;
2. For **stakeholders who interact with municipal managers** (including civil society – such as NGOs, ratepayers' associations, ward committees). It is for anyone participating in a municipal planning process, such as the Integrated Development Plan and the Water Services Development Plan process.

Structure of the handbook:

- Section 1 explains why systems thinking applies to the municipal challenges of Water and Sanitation Services (WSS).
- Section 2 introduces particular systems tools and approaches used in this handbook. There are many different ways of 'thinking about systems'.
- Section 3 is 'learning by doing'. Practical examples guide readers through a process of applying systems thinking tools to municipal WSS.
- Finally, Section 4 builds on these practical examples and answers the question "Now that I have learned the basics of systems thinking and how to apply it to water and sanitation services, how do I communicate what I have learned to others?"

Acronyms used in this handbook	
CLD	Causal* Loop Diagram
CoGTA	Department of Cooperative Governance and Traditional Affairs
DWS	Department of Water and Sanitation
IWRM	Integrated Water Resource Management
SDM	System Dynamics Modelling
NGOs	Non-Governmental Organisations
WSS	Water and Sanitation Services

Section 1: Applying systems thinking to municipal challenges

1.1. Complexity, unintended consequences, and the difficult challenges entailed in providing municipal water and sanitation services.

Small municipalities in South Africa face many challenges in providing water and sanitation services (WSS). In terms of the Constitution, local government is an independent section of government, but many core functions of municipalities depend on other sections of government (such as equitable share and other grants distributed by national government). At the local level, municipal services are delivered in a framework consisting of three parts:

1. technical officials,
2. financial and support officials, and
3. political officials (that is, councillors).

The management part of the municipality works with the political part which also oversees it, but many other government departments are also involved, including the Department for Cooperative Governance and Traditional Affairs (CoGTA), and the Department of Water and Sanitation (DWS).

In order to provide water services to people, municipalities must usually rely on broader water resource management that happens outside the municipal boundaries. In providing sanitation services, local government must ensure that the treated sewage is returned to the environment according to particular standards. This two-part nature of WSS (of reliance on water supply and quality on the one hand, and responsibility for service delivery and discharge quality on the other) can be illustrated using the **urban water cycle**, (Figure 1.1).

Figure 1.1 shows that water for human use in an urban area is first subject to the broader processes and practices of water resource management, which regulate the raw water that is stored (typically in dams). Water is then withdrawn (abstracted) from the dams according to rules, and treated to make it conform to drinking water quality standards before being distributed as bulk water. A managing authority of some kind (usually a municipality) then reticulates* the potable* water to users. As consumers use this water, they produce sewage or wastewater that must be collected and transported to some kind of treatment works before being discharged back to a water source (usually a river).

Note that the urban water cycle here is a generic* cycle that does not show other forms of water supply (such as groundwater from boreholes or rainwater harvested by households), nor does the cycle show any water reuse or recycling.

The many challenges facing WSS provision by small municipalities have the following features:

- they involve multiple stakeholders with multiple interests;
- they are often interconnected; and
- they rely on management aspects that are often outside the municipality's sphere of control.

The South African water law recognises many of these characteristics and provides a framework for an integrated, systemic approach to water management, both for water resources (i.e. water in the environment) and for water and sanitation services (i.e. drinking water and toilets).

How can 'systems' thinking, communicating, and planning help small municipalities?

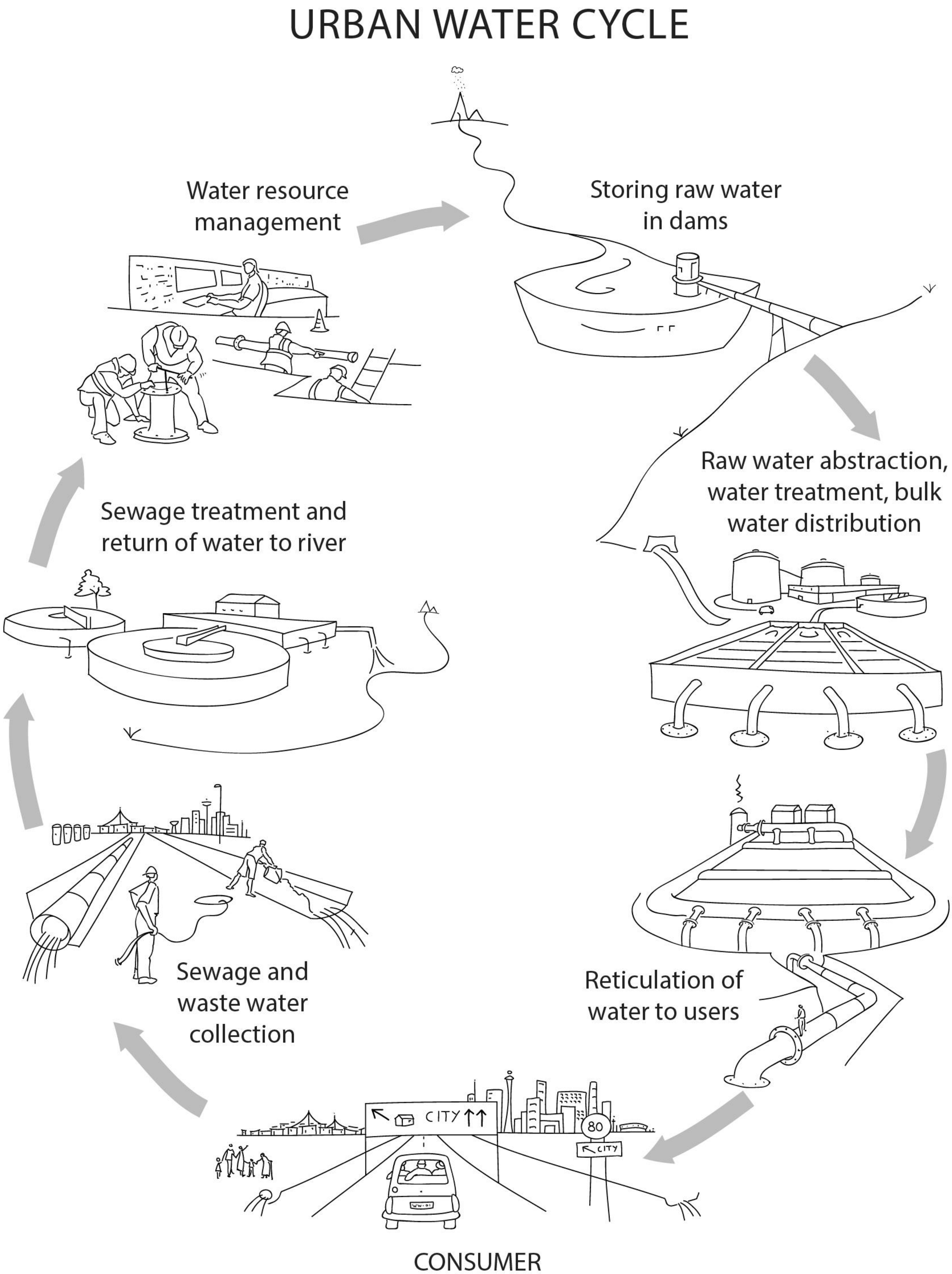


Figure 1.1: Urban Water Cycle

1.2. What does it mean to 'think in systems'?

Systems thinking is based on a holistic* worldview that emphasises *interrelationships* rather than parts, and *patterns* of behaviour *over time*, rather than static* 'snapshots'. This holistic worldview can be defined as a **systems thinking paradigm*** (see the text box below). When applied to water management, systems thinking moves away from "looking at isolated situations and their causes, and starts to look at [the water system] as a system made up of interacting parts" (Simonovic, 2009: 68).

Four types of thinking underpin a systems thinking paradigm (adapted from Richmond, 1993):

1. 'Big picture' thinking: striving to see the 'big picture' and how the component* parts relate and interact;

2. Operational thinking: understanding how things work and affect each other;

3. Dynamic* thinking: recognising that the world is not static and that things change constantly;

4. Closed-loop thinking: recognising that in complex systems, cause and effect are usually non-linear*≠, and that often the end (effect) can influence the means (cause/s).

≠'non-linear' refers to the surprisingly disproportionate* responses between cause and effect.

A linear relationship is a relationship with constant proportions (e.g. if we add 10% extra chlorine to our water, then our water becomes 10% cleaner; if we add 20% extra chlorine, then it becomes 20% cleaner, and so on). A non-linear relationship is one in which the cause does not produce a proportional response: for example, we push something a little harder, thinking it will only move a little faster, but instead, the little push results in the thing moving much faster than expected.

Example: Think of rolling a rock up a hill. On the way up, you push a lot and the rock moves along very slowly, but then you reach the top of the hill, where each push takes less effort and the rock moves faster along the flat surface until you reach the edge of the next downward slope, where only one push is required before the rock starts rolling down the hill very quickly. In this example, the relationship between the two variables (*effort required to push rock* and *speed at which rock travels*) is non-linear.

In many ways, systems thinking is a more 'natural' or intuitive way of thinking: schools and universities have different departments that teach different subjects, but the real world is not divided up into neatly separated fields that require specific skills only. In the same way, processes and organisations do not exist and operate in isolation, but are shaped by their histories, and are interconnected and interdependent. Everywhere around us we see one thing happening that affects another thing, which after a period of time affects the first thing, and so becomes a cycle.

There are many different ways of 'thinking about systems' and many different schools of systems thought, methodologies and approaches. The particular systems tools and approaches that are used in this handbook are introduced in Section 2.

Section 2: An overview of the relevant systems tools and approaches

2.1. Introducing the particular systems approach used in this handbook:

The approach used in this handbook is based on system dynamics modelling (SDM). SDM is an approach to modelling people's perceptions of systems based on causal* relationships and feedback. SDM can be applied both in groups (where it can be used interactively) and as an analytical activity using computers. (Appendix A provides references for further information about SDM as a method and as a discipline.)

What is 'a model'* and what is 'modelling'?

A model is a simplification of reality that is incomplete and imperfect AND helpful in drawing our attention to the essential parts of a system and how they interact.

Models are not just computer-based – they are all around us. For example, a map is a model of a particular physical space that includes enough detail to help a map-reading traveller find his way. If the map contains too much detail, it will be difficult to read and will therefore be less useful (Sterman, 1991). This shows that models are always *incomplete* representations and that the modeller has to decide what to include in the model and what to exclude.

Another example is weather predictions. We rely on models used by weather forecasters to help us decide whether to take an umbrella to work, or when to irrigate our fields, or harvest our crops. However, everyone knows that the weather forecaster is often wrong (predicting that it will be cold and rainy, and the day turns out to be sunny and windy). This shows that models are fallible*, *imperfect* things, as well as being incomplete representations. We also know they are often right – and we find that helpful for planning.

Is there any point to modelling, then? Models can be useful for many reasons besides predicting or forecasting (where they are often most limited). Models can be used to *help* understand and explain particular phenomena* and they can be used to educate and to demonstrate trade-offs between different options (Epstein, 2008). Appendix A lists a number of other models and modelling approaches that are regularly used in the water sector.

The systems models that are used in this handbook are small models that aim to apply to and give insights into municipal water and sanitation services. The models are **qualitative**, which means that these models do not use numbers, but use logical relations, words, and arrows to 'map' system behaviour at a highly aggregated* level. These models are called causal loop diagrams (CLD) and are introduced in the following sub-section.

2.2. Introducing causal loop diagrams

Causal loop diagrams (CLDs) are mainly variables and arrows – which represent the factors and the links between the factors, respectively. As the name suggests, CLDs show direct causal connections, not correlations* or indirect connections. This is best described using diagrams.

Why do we bother drawing systems diagrams?

"…words and sentences must […] come only one at a time in linear, logical order. Systems happen all at once. They are connected not just in one direction, but in many directions simultaneously. To discuss them properly, it is necessary somehow to use a language that shares some of the same properties as the phenomena under discussion" (Meadows, 2011: 5).

Figure 2.1a below shows two variables: *births* and *population* (note that the names of the variables in the text are *italicised*). We can all understand that these two variables are related to one another, but more than that, a change in one variable will result in a change in the connecting variable: hence, they are **causally connected** (if everything else that may affect these two variables stays the same, then the more the *births*, the greater the size of the *population*).

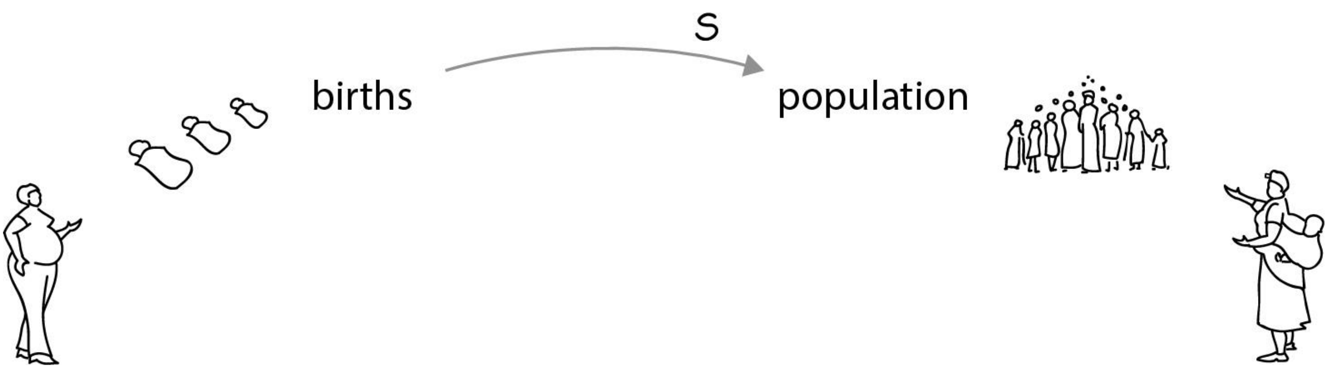


Figure 2.1a: Causal connection between births and population

In a CLD, the way in which variables are causally related is indicated by one of two letters ('s' and 'o') that are positioned on the arrows. The 's' means 'same'; the 'o' means 'opposite'. In the example above, an **increase** in the first variable (*births*) will cause an **increase** in the second variable (*population*).

It is equally important that the opposite also holds true: **a decrease** in the first variable will cause a decrease in the second variable (i.e. if everything else that may affect these two variables stays the same, then the **fewer** the *births*, the **smaller** the size of the *population*). Hence, the 's' on the arrow indicates that the causality runs in the **same** direction**.**

The most obvious second variable that would affect the size of a given population is *deaths*. In the diagram below, we can see that *deaths* has a causal effect on *population*. Here, the 'o' (for opposite) means that a change in the first variable will cause a change in the second variable **in the opposite direction**. Again, this is more easily understood through an example with the accompanying diagram (Figure 2.1b).

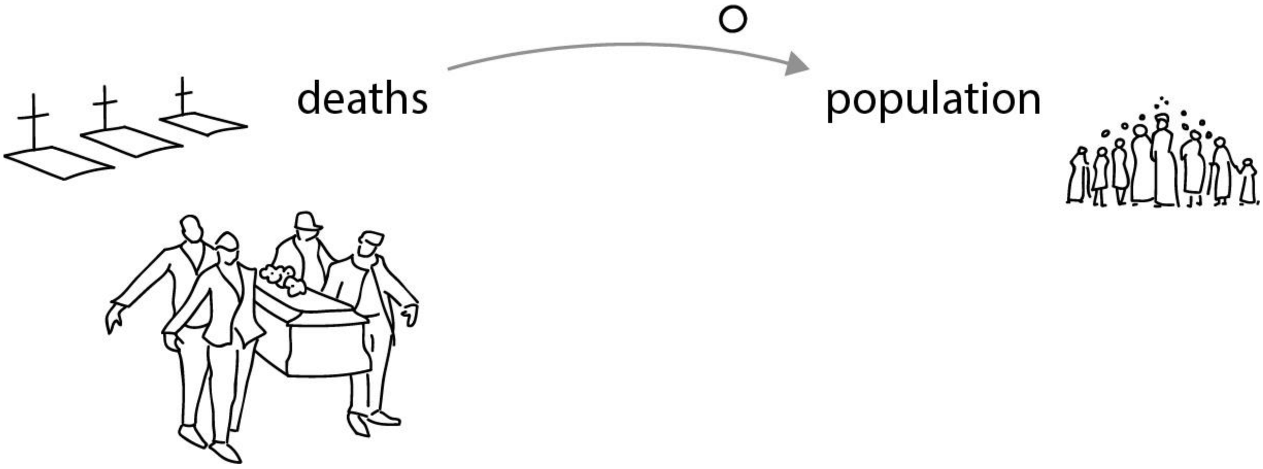


Figure 2.1b: Causal connection between deaths and population

If everything else that may affect the above two variables stays the same, then the **more** the *deaths*, the **smaller** the size of the *population*. Again, the opposite also holds true: the **fewer** the *deaths*, the **greater** the *population*. Hence, the 'o' on the arrow indicates that the causality runs in opposite directions (if the first variable goes up, the second variable goes down, and vice versa).

As mentioned in Section 1, systems thinkers are particularly interested in **feedbacks**. Yes, the number of births affects population size, but what about *population* affecting *births*? Let's examine Figure 2.1c which shows two causal loops connected to one another. The diagram below is best read from left to right. As above, we start with *births* affecting population (remembering that there is 's' relation between the two variables). The new addition is the arrow showing that *population* also affects *births* (the logic here is that the **larger** the size of the population, the **higher** the reproduction rate and therefore, the **more** births). This is our first **reinforcing feedback effect** (which is described in further detail in Section 2.3). The reinforcing feedback effect is formed out of the cyclical causal loop (the more *births*, the more *population*, and the more the *population* the more *births*, and so on).

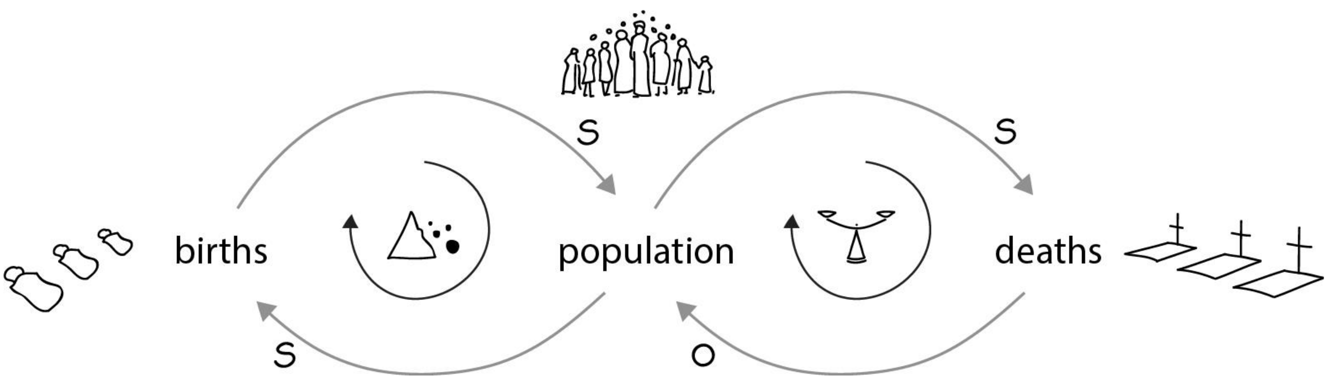


Figure 2.1c: Feedback effects

The right-hand side of the above diagram shows the second feedback loop formed between the interaction of *population* and *deaths*. As mentioned earlier, the number of *deaths* affects the *population* size. The diagram above additionally shows that *population* influences the number of *deaths*. This causal relationship is illustrated with an 's' sign: logically, we would expect that the **greater** the *population*, the **more** the number of *deaths*; however, with everything else being equal, the **more** the *deaths*, the **less** the *population* (hence, the 'o' sign (for opposite) on the arrow of the relation between *deaths* and *population*). The loop formed between *population* and *deaths* is therefore different to the loop formed between *population* and *births*. Whilst the first feedback loop has a **reinforcing** feedback effect, the feedback between *population* and *deaths* has a **balancing** feedback effect. The following sub-section describes these two feedback loops in more detail.

2.3. Going deeper into reinforcing and balancing feedbacks:

The icons below are used to illustrate the two types of feedback loops in this handbook:

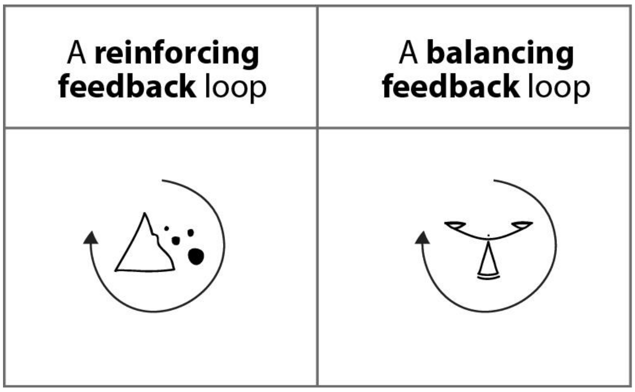


Figure 2.1d: Reinforcing and balancing feedback loops

The icon (on the right) for the **balancing feedback loop** is relatively straightforward to understand. The icon shows a scale with two weights on either end. The scale is balanced, suggesting that the two weights are of an equal size and weight.

The icon (on the left) for a **reinforcing feedback loop** is based on a rockslide and needs more explanation. Imagine a few small stones tumbling down a mountain side: as the stones fall, they dislodge* larger stones which dislodge boulders, and next thing, there is a rockslide to deal with. The more the rockslide continues, the more rocks are dislodged, the quicker the rockslide moves and the more damage it causes. This is what systems thinkers refer to as a *reinforcing cycle*, or in common terms, as a *vicious cycle*.

Another example of a vicious cycle is debt, which the following example explains:

Imagine that a 'loan shark' ('skopper') lends you R100. To make you to pay back the loan as quickly as possible, you are forced to sign a contract agreeing that the loan shark can charge you 15% interest per month, *compounded monthly*. Now imagine that you fall ill, you forget about the small loan, you fail to make any repayments. How do you think your debt will grow?

Let's start with the interest. Interest is usually charged at a fixed percentage of the debt (to distinguish between the interest charged and the amount loaned, the amount borrowed is called '**the principal**'). With compounding, the interest is calculated each month, and is then added to the principal owed to the loan shark.

The following table summarises how your debt grows. The first column shows the month, the second shows the principal as it grows, the third column shows the fixed interest rate (shown as a fraction), and the fourth column shows the interest charged per month.

Table 2.1a: Compounded interest on a loan

Month	Principal	Interest rate (as a fraction)	Interest charged per month
0	R100.00	0.15	R15.00
1	R115.00	0.15	R17.25
2	R132.25	0.15	R19.84
3	R152.09	0.15	R22.81
4	R174.90	0.15	R26.24
5	R201.14	0.15	R30.17
6	R231.31	0.15	R34.70
7	R266.00	0.15	R39.90
8	R305.90	0.15	R45.89
9	R351.79	0.15	R52.77
10	R404.56	0.15	R60.68
11	R465.24	0.15	R69.79
12	R535.03	0.15	R80.25

The greater the principal, the greater the interest charged on the principal, which is then added to the principal as the total amount owed (as the above table shows). The next month, the same interest rate is applied, but now the principal has grown, becoming 15% larger. By the end of month 12, the principal is now about **R535**. This adding and compounding dynamic is called **exponential* growth**.

The diagram below summarises the exponential growth dynamic using a CLD that is based on the same principles (and using the same symbols) introduced in Section 2.3. In the CLD below, we see that the more the *interest paid*, the more the *principal*, and the more the *principal,* the more *interest paid,* and so on.

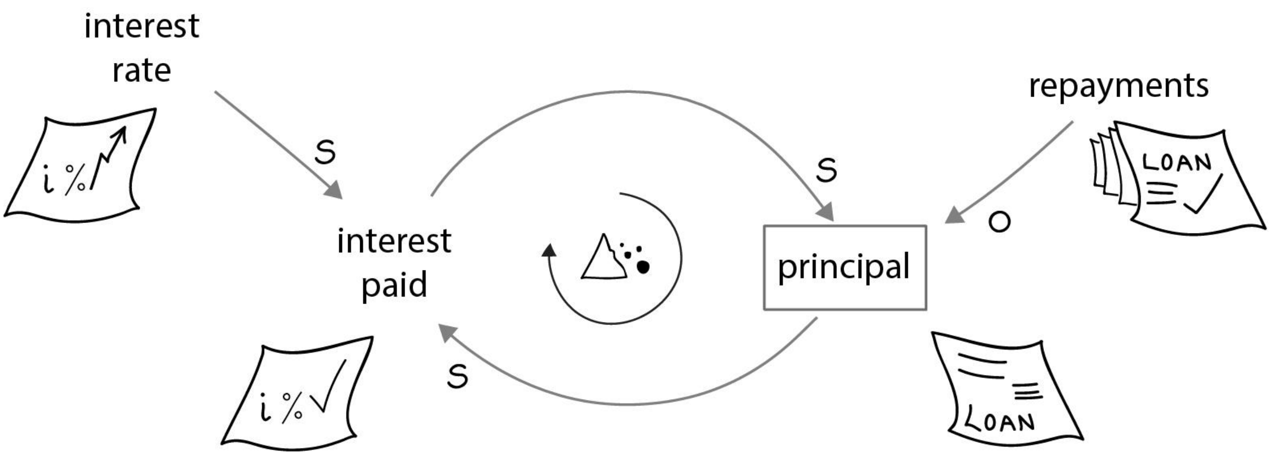


Figure 2.2: Exponential growth

To really appreciate exponential growth, let's look at how the debt will grow over a five-year period. If the debt is R535 at the end of month 12 (i.e. Year 1), how big do you think the debt will be at the end of month 60 (i.e. Year 5)?

The answer is displayed on a year-to-year basis in the below table. Remember that we started with a R100 debt that grows at an interest rate of 15% per month, compounded monthly. At the end of Year 5, that R100 debt has become a massive debt of **R438,400**, which shows the power of exponential growth.

Table 2.1b: Exponential growth over a five-year period

Year 1	R535
Year 2	R2,863
Year 3	R15,320
Year 4	R81,940
Year 5	R438,400

Note that Figure 2.2 includes a box around one of the variables (*principal*), which was not shown in the first population CLD in Section 2.2. In System Dynamics, a variable with a box around it refers to a **stock**. A stock variable is anything that **accumulates** (whether that's money in a bank; water in a tank; etc.). In the debt example above (Table 2.1b), the *principal* accumulates as the debt grows larger and larger. Figure 2.2 also indicates how to prevent the *principal* from accumulating, namely by regularly making *repayments* (note that there is an 'o' on the arrow that shows the causal connection between *repayments* and the *principal*: the **more** the *repayments*, the **less** the *principal* owed to the loan shark; the reverse is that the **less** the *repayments*, the **greater** the *principal* owed to the loan shark).

There are many examples of **stocks** in municipal WSS: some stocks are things you cannot physically hold (such as revenue gained from providing WSS to municipal residents and businesses); other stocks are materials (such as the quantity of chlorine held in a municipal depot); finally, stocks can be things like the amount of trust people may have (or not have) in one another. These municipal examples show that a key aspect of stocks accumulating is that **it takes a certain amount of time**. For example, filling a reservoir is an accumulation process that may take several hours or days to complete. Similarly, it takes time for the debt to grow (as shown in the month-by-month and year-by-year breakdown in the debt example provided above).

2.4. Introducing the main metaphor (example) used in this handbook

The institutional framework within which WSSs are provided and regulated in South Africa is advanced. This framework consists of many different laws:

- from the Constitution (1996)
- the National Water Act (Act No.36 of 1998)
- the Water Services Act (Act No.108 of 1997)
- the municipal legislative framework (see the text box below)

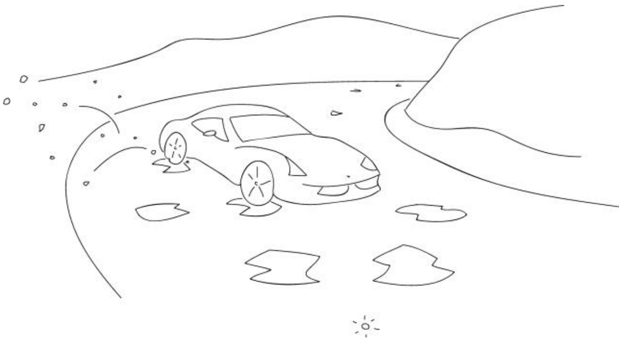
What is the municipal legislative framework for local government?

The municipal legislative framework is composed of the following four laws (along with the laws' subsequent amendments):

1. The Municipal Demarcation Act (No. 27 of 1998)
2. The Municipal Structures Act (No. 117 of 1998)
3. The Municipal Systems Act (No. 32 of 2000)
4. The Municipal Finance Management Act (No. 53 of 2003).

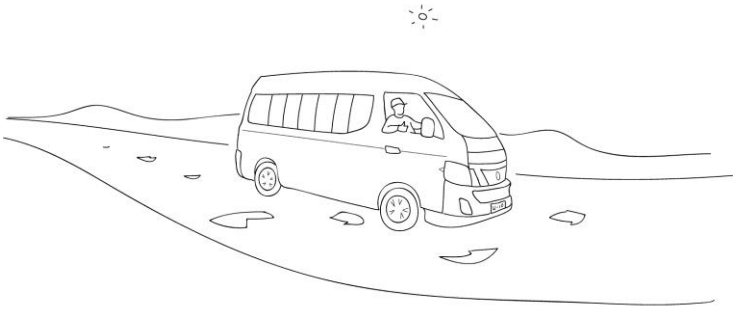
In the rest of this handbook, we use a metaphor to help describe WSS in the context of municipal service delivery. We use the example of transport because everyone has to use transport in their daily lives. We will link the example of transport to WSS.

When considered globally, this institutional framework embodies the principles of **integrated water resource management** (IWRM) and **developmental local government**. The advanced institutional framework can be compared to a fancy sports car (imagine a Porsche, BMW or Ferrari).



But what happens if you drive a fancy sports car on dirt roads, or on a tarred road with many potholes? You will quickly have a flat tyre, or worse!

The reality is that municipal WSSs in South Africa are like that tarred road with potholes. The 'potholes' in municipal WSSs include aging infrastructure, protesting residents, and multiple crises that often need urgent attention. In order to navigate such an environment successfully and safely, hardy vehicles are required rather than fancy and fast sports cars. The ideal vehicle is one that is capable of transporting more people, more robustly* and with fewer break downs.



South Africa has such a transport system: minibus taxis. The taxi system transports millions of South Africans to and from their homes and their places of work on a daily basis. In order to deliver their service, taxis require drivers and mechanics; they need maintenance to be done on the taxis themselves, roads to drive upon, and petrol to run the taxis (as shown in Figure 2.3). But, like most systems, the taxi system does not function as well as it could – it could do with improvements at various points.

Throughout Section 3 of this handbook, we will be using taxis as a metaphor for water and sanitation services in practising systems thinking by 'learning by doing'. Table 2.2 (below) provides a summary of the important systems thinking concepts that are used in causal loop diagrams, as introduced in this section.

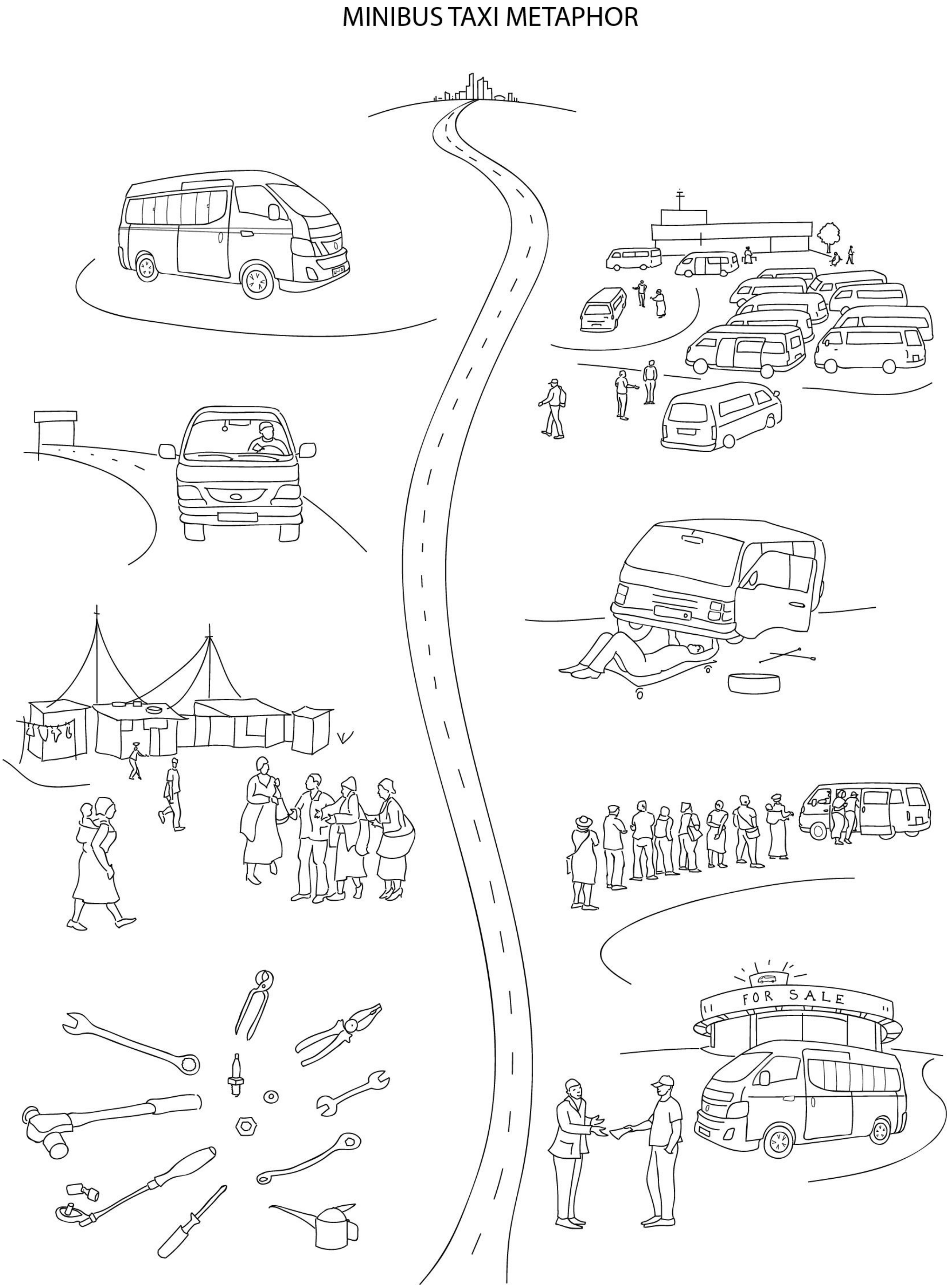


Figure 2.3: Illustration of the minibus taxi metaphor.

Table 2.2: Concepts and Descriptions

Concept	Description
variable	A variable is a factor – i.e. something that may cause a change in another thing. In the text description of CLDs, variables are *italicised*
stock	A variable with a box around it is a **stock variable**. A stock can be anything that accumulates (whether money in a bank account or water in a tank)
	An arrow between two *variables* indicates a causal link running in a particular direction
	S = same, indicating that the causality runs in the same direction (an **increase** in *variable A* will cause an **increase** in *variable B*, and vice versa)
	O = opposite, indicating that the causality runs in the opposite direction (an **increase** in *variable A* will cause a **decrease** in *variable B*, and vice versa)
	A **reinforcing feedback loop**, which has an amplifying, self-multiplying, or runaway effect. This can result in a vicious cycle (if the runaway behaviour is undesirable) or a virtuous cycle (if the behaviour is desirable). The direction of a reinforcing feedback loop (whether it turns clockwise or anti-clockwise) reflects the direction of the causal loop making up the feedback
	A **balancing feedback loop**, which has a stabilising effect. As Dana Meadows notes, a feedback loop "opposes whatever direction of change is imposed on a system. If you push a stock too far up, a balancing loop will try to pull it down. If you shove it too far down, a balancing loop will try to bring it back up" (2011, p.28). The direction of a balancing feedback loop (whether it turns clockwise or anti-clockwise) reflects the direction of the causal loop making up the feedback

Section 3: Practising systems thinking

System thinking gets into practice through practise.
(Kim and Senge, 1994: 279)

Section 3.1: Practising Systems Thinking with Minibuses

Systems thinking is best learned through practice. In this section, we use a 'learning by doing' approach with two exercises which are applied to water and sanitation services (WSS) and illustrated using causal loop diagrams (CLDs). For ease of reference, the CLDs are labelled and numbered (as Figure 3.1 to Figure 3.11). Each diagram is accompanied by a description and each exercise is followed by a debrief* that summarises the lessons.

Remember that feedback, as informed by our foundation of systems thinking, can either be balancing (controlling, goal-seeking) or reinforcing (exponential growth). The image of a ball rolling downhill inside the reinforcing loop reminds us of the rapid growth potential of this type of feedback (as introduced in Section 2). The scale inside the balancing loop reminds us that the nature of this feedback type is to control systems – making them more stable, and slowing down the reinforcing loop. The interaction between these two kinds of feedbacks can help us think about systems more generally. As introduced in Section 2.4, these concepts are so universal that we will spend the rest of the handbook using these two kinds of loops to discuss MINIBUSES!

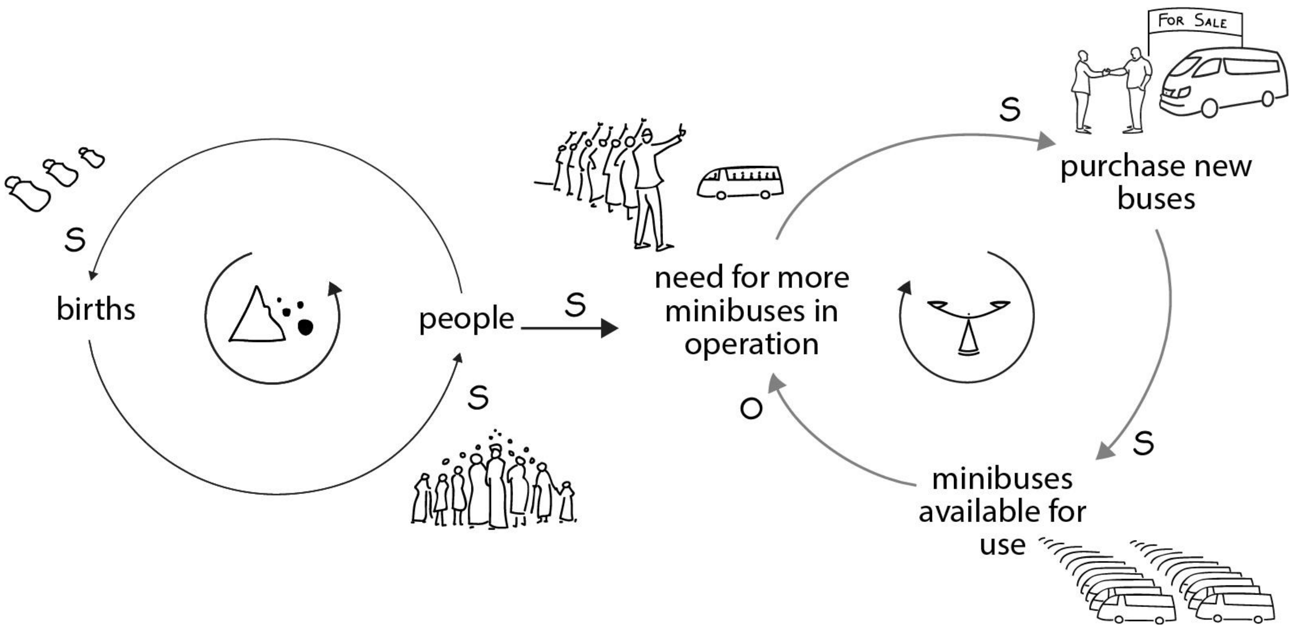


Figure 3.1: A diagram of reinforcing and balancing feedback loops, using minibuses as an example.

As an example, take the simple reinforcing and balancing loop shown in Figure 3.1. As more *people* occupy a given settlement (including more mothers), more *births* take place. This growth in population drives *the need for more minibuses in operation* to take mothers, their children, and everyone else where they need to go.

Let's compare the system in Figure 3.1 with Figure 3.2 where minibuses have been replaced with water and sanitation services (WSS). As in Figure 3.1, population growth drives *the need for more WSS*. In order to meet the need, municipalities can *build new infrastructure* which will increase the total physical capacity, therefore increasing *WSS available for use*.

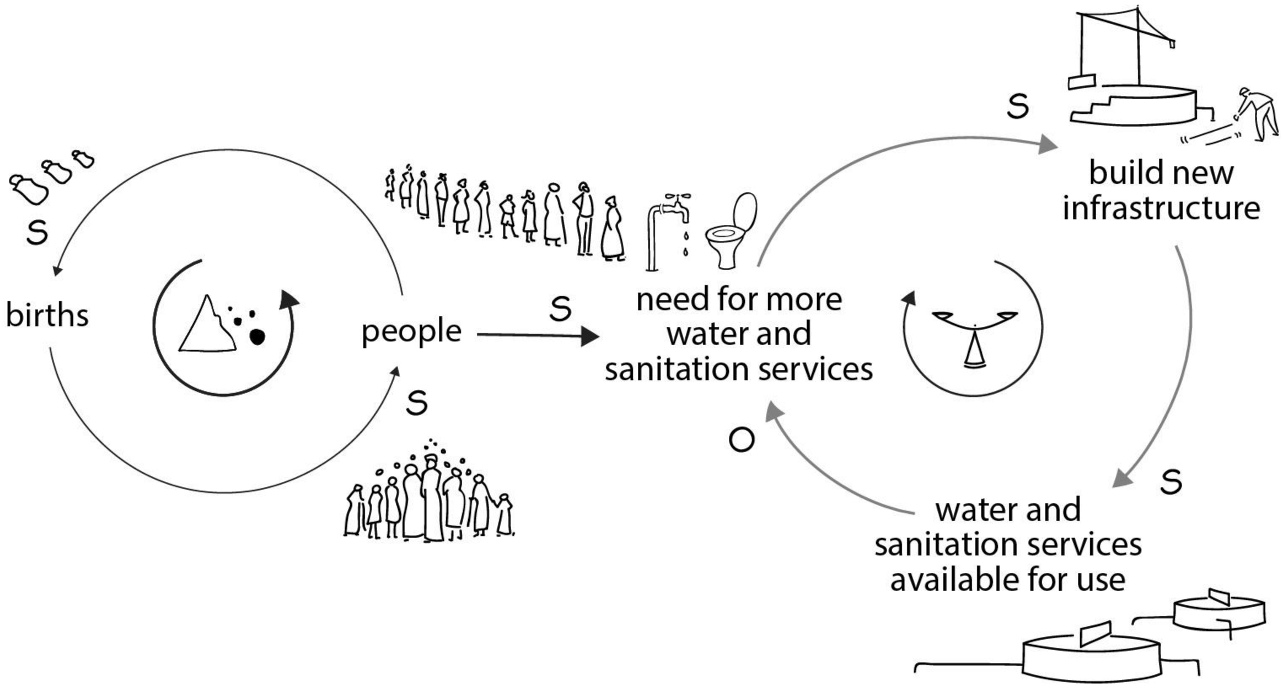


Figure 3.2: The basic feedback system adapted to WSS.

But is that all that is needed? Can we simply buy more minibuses and build new infrastructure? Someone must drive the bus, collect money from passengers and ensure that they arrive at their destination. This idea is captured in Figure 3.3, with a new feedback loop. Can you decide whether it is balancing or reinforcing?

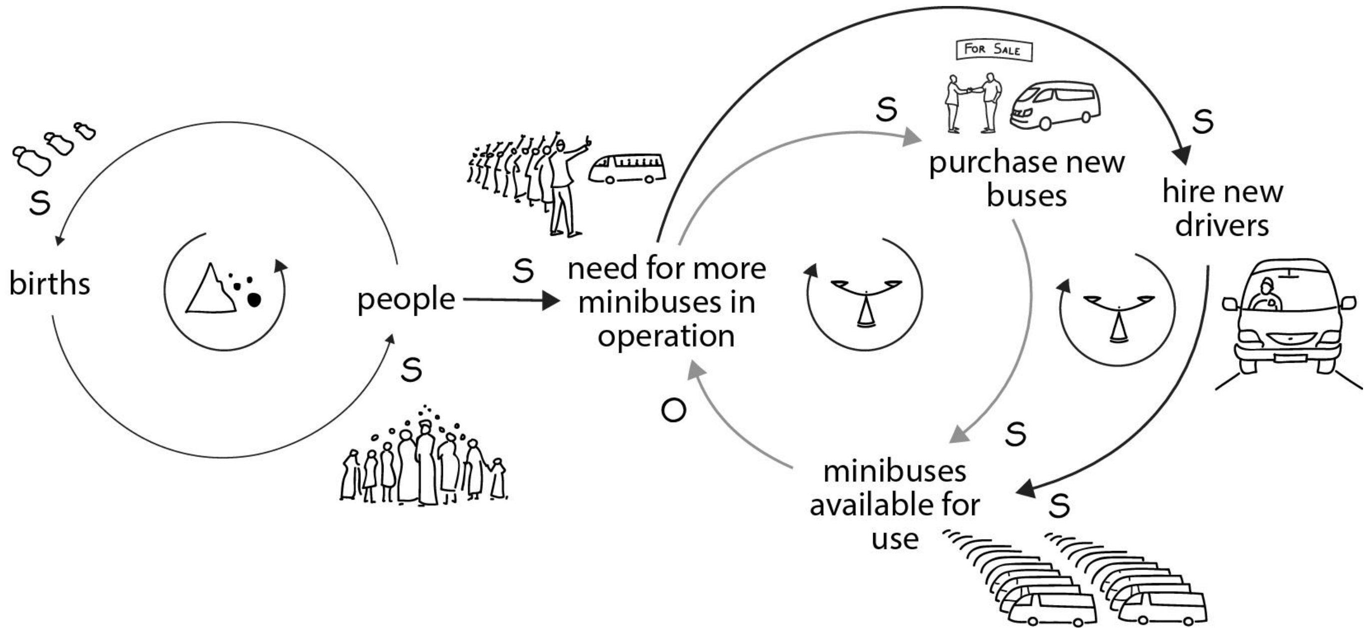


Figure 3.3: Drivers are another critical component of the minibus service system.

The same goes for municipal WSS – simply building a new plant or installing new pipes will not make the service function properly. A ‘driver’ is needed.

Exercise 1:

Try out some causal loop diagramming yourself. Re-draw the simple system for WSS from Figure 3.2, add a new feedback loop (like the one in Figure 3.3). Introduce a new variable – what would you consider to be the equivalent of a driver for WSS?

Debrief:
Compare the CLD you drew, to the CLD shown in Figure 3.4 below. You should have recognized that the additional loop in Figure 3.4 is indeed a balancing feedback. In drawing this yourself, you may have come up with different titles than 'managers and operators' but you should recognize that people occupying those roles are essential to deliver WSS: people to check pumps, open valves, treat the water with chemicals – there are many different tasks that have to be carried out within the WSS facilities.

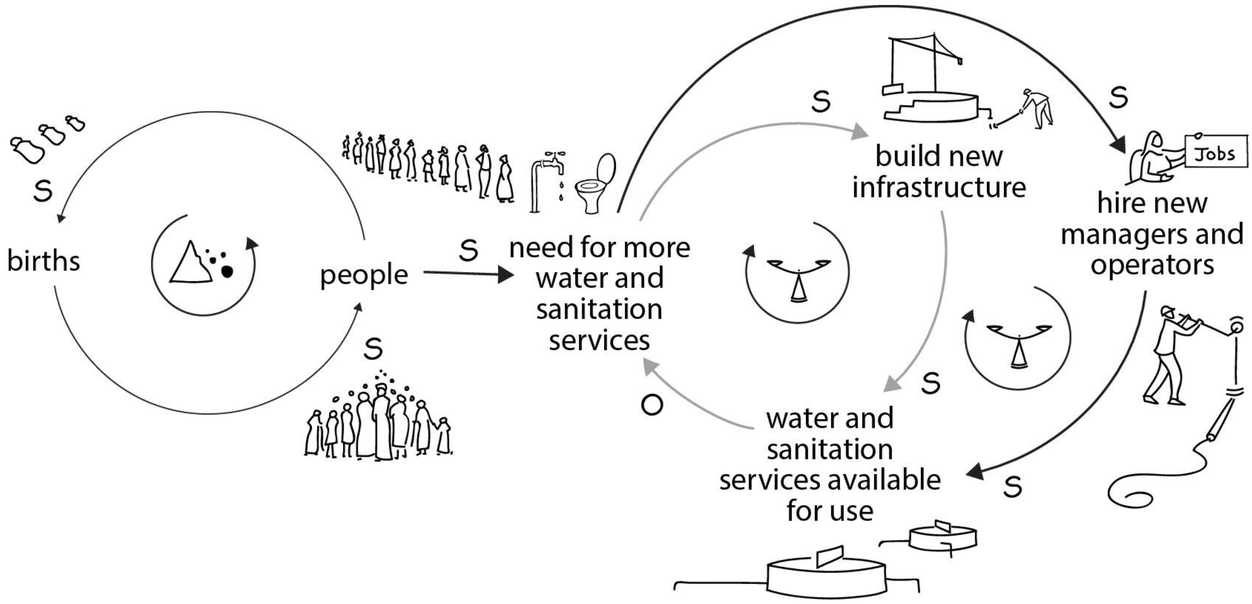


Figure 3.4: Example of the minibus metaphor converted to WSS.

We will now continue to expand systems thinking about WSS, using the metaphor of minibuses. Let's explore the concept of **obsolescence***, or the way in which the use of minibuses (or infrastructure) leads to a breakdown of some of the physical elements necessary to the service function. To do this, we must recall the concept of **stocks** that was introduced in Section 2.3. Remember that stocks are used in CLDs to indicate a variable that can **accumulate**. Look back at Figures 3.3 and 3.4 and compare them to Figure 3.5 below.

In Figure 3.5 the stock variables have been included to show that the variables *people* and *minibuses available for use* are stocks (i.e. variables that can accumulate). Remember that a key aspect of something accumulating is that **it takes a certain amount of time** (as introduced in Section 2.3). It takes time to hire drivers. Qualified individuals must be recruited or located; they must go through some kind of administrative process to become official minibus drivers. Similarly, to purchase a new bus, the owner of the minibus company must find the necessary money. The bus must also be registered in order to be legal.

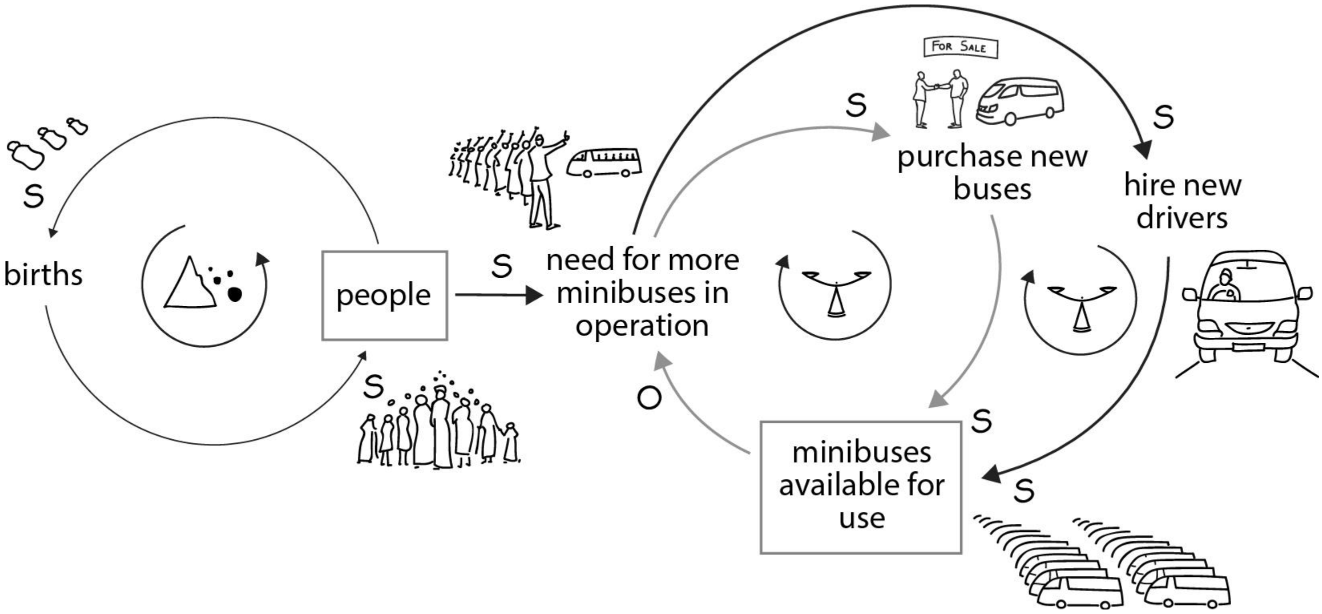


Figure 3.5: Introducing the concept of stocks to be used in CLD diagrams.

All these processes take time and we often underestimate these delays. In the case of the minibus company this delay can lead to not enough buses being available to meet the customer need. However, recognizing their fleet of 'minibuses available for use' is a **stock,** and applying systems thinking principles can help to prevent this issue.

Seeing variables as stocks also helps us consider more carefully how we use them, because not only do they take time to accumulate, but they also **take time to break down**. We will explore this concept in the remainder of this section.

First, we expand the minibus CLD to include an additional distinction between available minibuses and those actually in use, as shown in Figure 3.6.

This expanded CLD includes another stock, *minibuses in use* (those on the street, transporting people), which distinguish them from 'minibuses available for use' (those in the garage, not being used). However, the more the minibuses are used, the greater the rate of wear and tear, which *over time* leads to fewer available minibuses. This is also a balancing feedback loop. This framing brings us to Exercise 2.

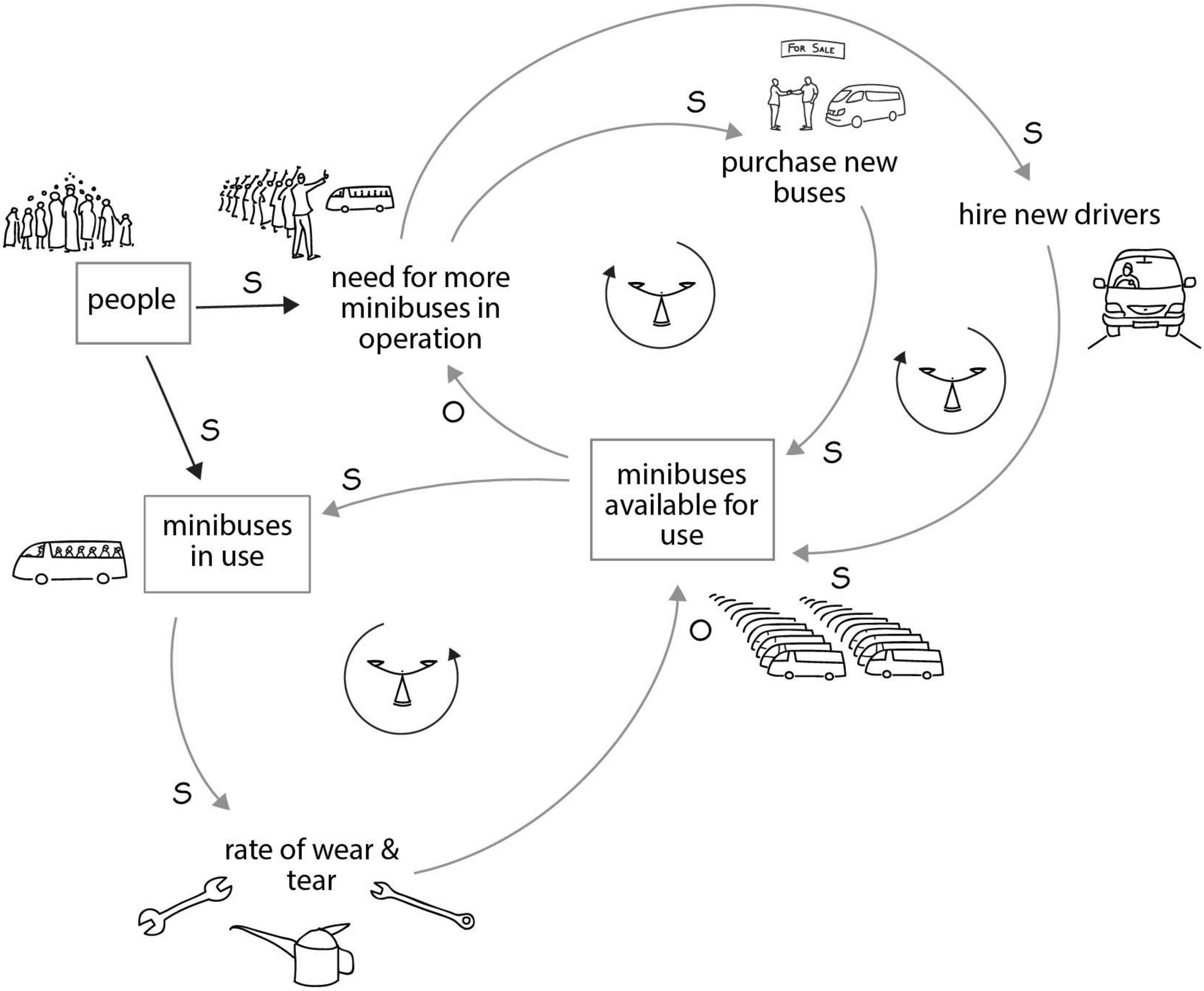


Figure 3.6: Distinguishing between minibuses available for use and minibuses actually in use allows us to explore the idea of wear and tear.

Exercise 2:

Exercise 2, Part 1 Consider a sudden increase in people using minibuses. How will you meet this sharp increase in demand? (Hint: Consider what you've just learned about **delays**.) What do you expect to be the outcome for the stock of 'minibuses available for use'?

Expand the diagram from Figure 3.6 using the space below and include new variables as needed. Do you uncover any new loops? If so, are they balancing or reinforcing?

Exercise 2, Part 1 Debrief:
Figure 3.7 shows a solution to the previous exercise. If you are like many people, you will respond to the short-term increase with a short-term response – ‘using the minibuses beyond their designed capacity’. In the real world, this might mean taking the buses for more round-trips each day, putting extra pressure on both the drivers and the buses themselves. Doing this creates a new reinforcing loop and drives a reduction of the available minibuses. Based on the diagram, do you think this new policy is sustainable over a longer period of time?

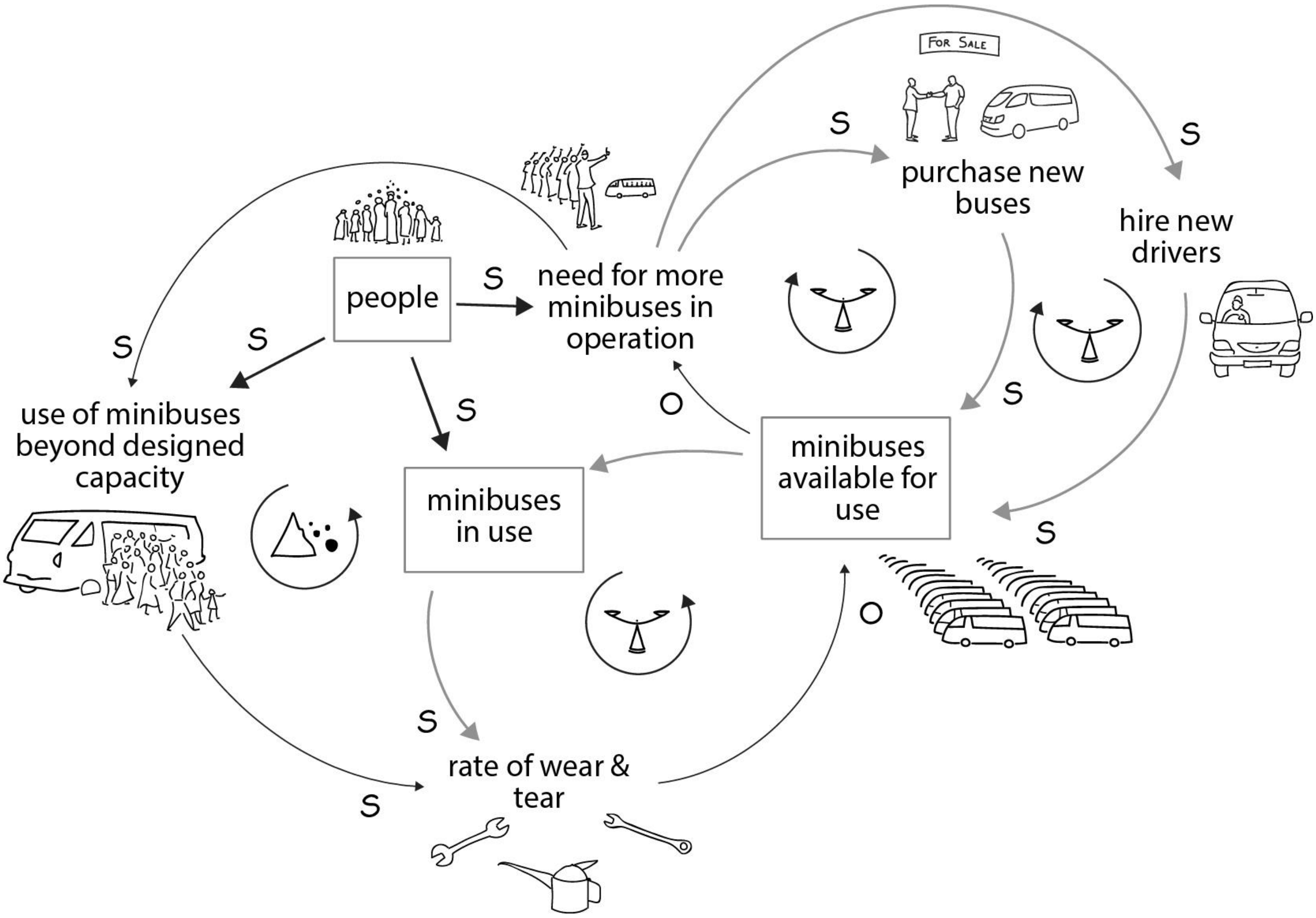


Figure 3.7: Expanding the CLD in Exercise 2. Using a short-term solution can set off a reinforcing cycle that reduces the company’s ability to provide their minibus services.

Exercise 2, Part 2: For part 2, imagine that the increase in demand is sustained; would you apply the same solution as shown in Figure 3.7? Again, think about delays involved and expand the diagram in the space below to **include a new stock and new feedback** that can work against the reinforcing loop. (Hint: You may need to break down the connection between ‘wear and tear’ and ‘minibuses available for use’)

Exercise 2, Part 2 Debrief:

How does this CLD in Figure 3.8 compare to your conceptualisation* from the previous page?

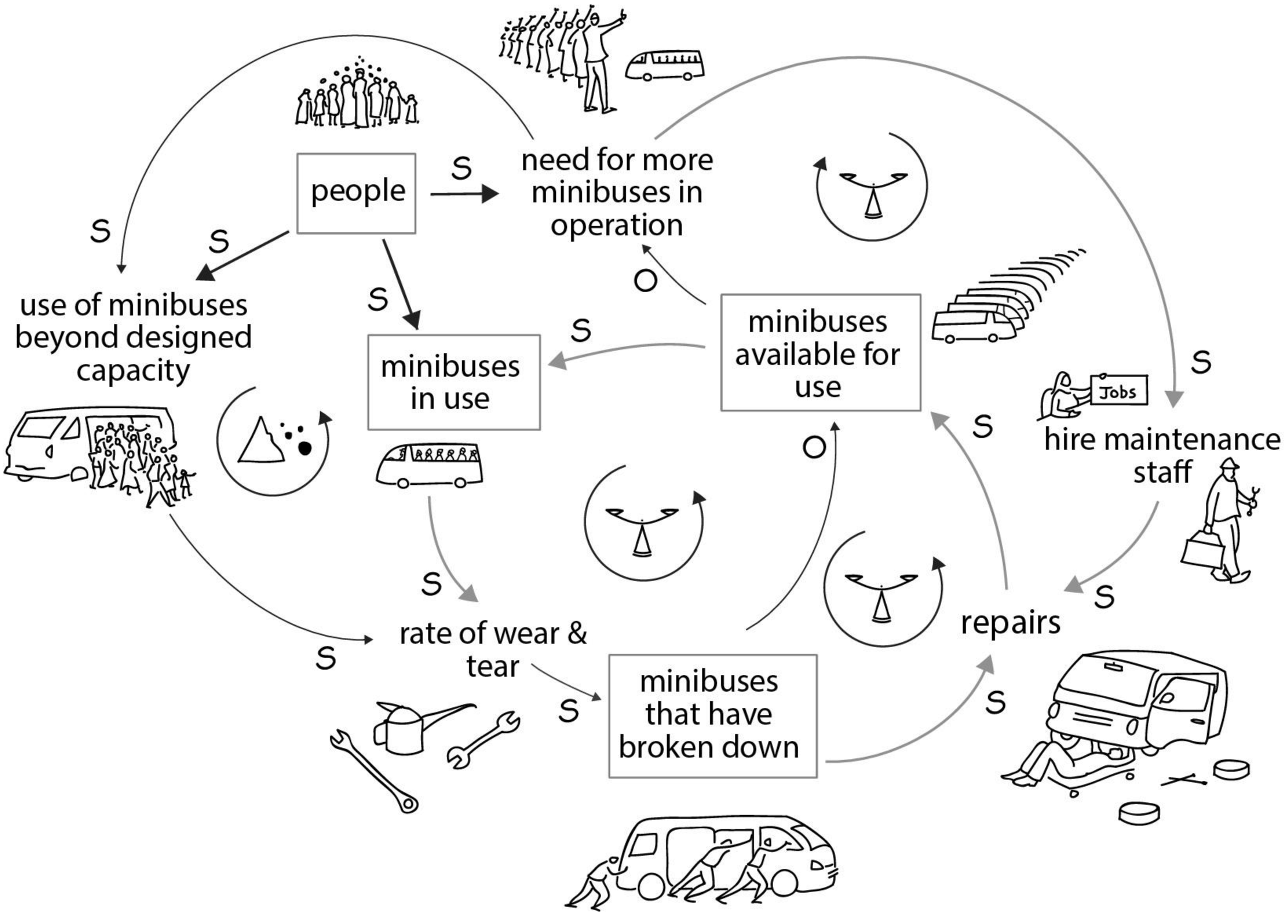


Figure 3.8: Knowing about stocks, delays, and considering longer-term implications of management policies can make management of service delivery more sustainable.

Though we cannot predict the future, systems thinking can show us more about the common challenges that emerge when we try to deliver services on time. As you learn more about the way the system works, you can apply this knowledge to your management strategies – avoiding unwanted, unintended consequences.

We will now continue to explore the relationship between the design of the system and its behaviour in the context of WSS. Specifically, we emphasize the way in which managers can fall into ‘traps’ – management challenges that arise if we use linear thinking instead of systems thinking.

Section 3.2: Avoiding systemic 'traps' in WSS

The issues that we have explored using minibuses to illustrate these basic dynamics helps to highlight the management traps, but these occur in all kinds of other systems. The word 'trap' reminds us that these kinds of management decisions are easy to fall into, and lead to unintended and often unwanted outcomes. However, you can avoid many of these traps by using the systems thinking point of view that you have practised in the previous part of Section 3.

This section investigates systems traps in the context of WSS. The main traps we will focus on are:

- underestimating delays
- using 'quick fixes'
- the burden of maintenance and operations.

For example, we've seen previously that lack of maintenance can make it impossible for a minibus company to provide transportation services to its customers. Now we explore these ideas in the context of WSS.

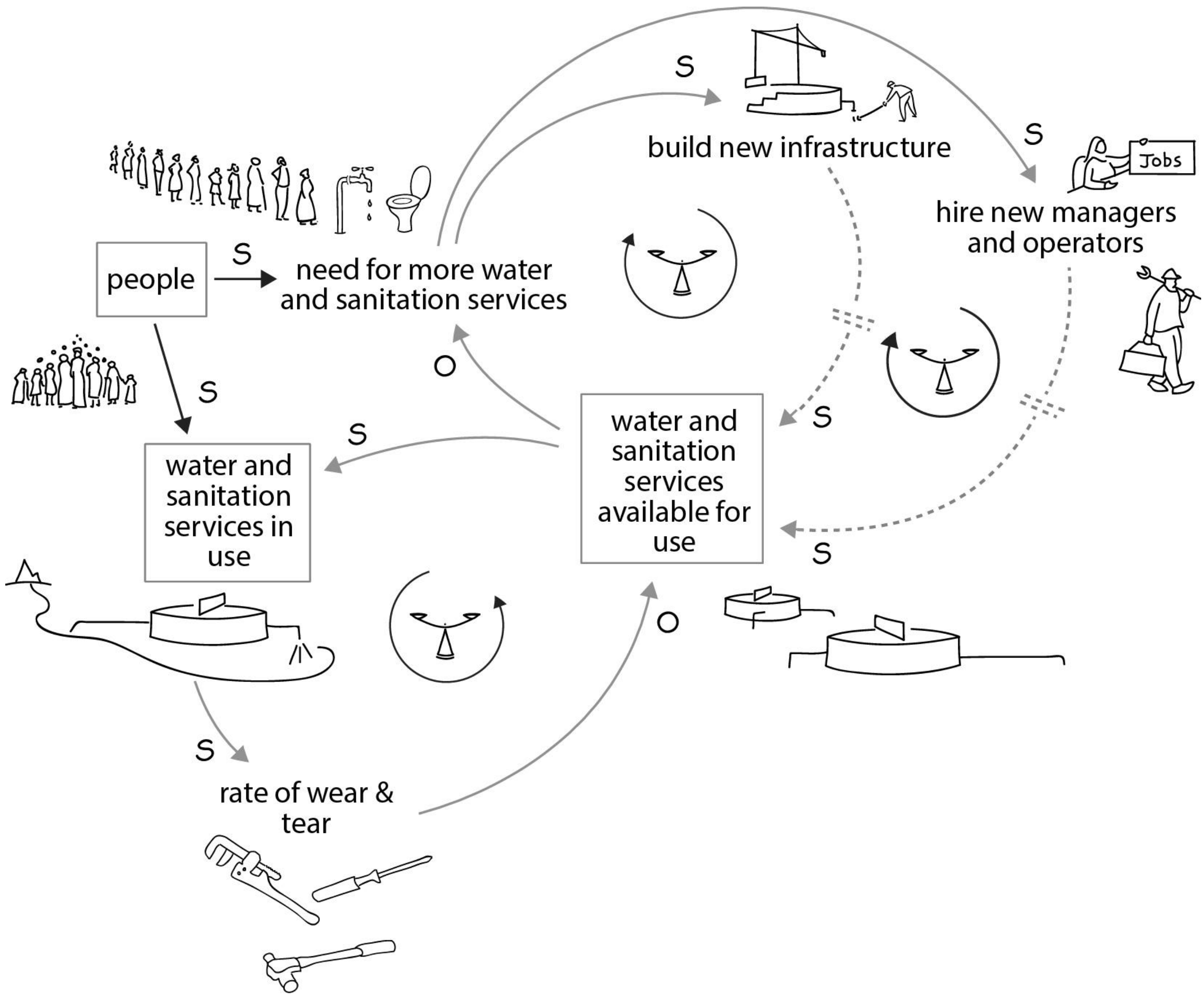


Figure 3.9: This CLD highlights one of the system traps, 'Underestimating Delays' in the context of WSS.

The 'Underestimating Delays' Trap: Any time that you recognize a stock in your system (something that can accumulate, or build up over time), expect delays. To examine this trap, look at Figure 3.9, paying careful attention to the dotted lines. Notice both dotted lines have a mark through them; these lines point out where there are delays in the system. When the 'need' grows as a result of population growth, new infrastructure may be needed. However, building new infrastructure can take several years. Funding must be allocated, a tender issued and assigned, and, of course, the actual infrastructure must be constructed. Once built, new managers and operators may be needed: the description of the position must be created and posted, candidates interviewed and, once hired, the individual(s) chosen may still need time to move to the municipality in order to start work. All of these processes take time. In your experience as a municipal manager have you found that you know how long each process will take?

If you are like many people, you probably underestimate these delays. This is a common challenge when applying systems thinking, especially when starting off. Professor Jay Forrester, the founder of the field of system dynamics, says:

> *"The beginner almost invariably underestimates the length of delays and time that will exist in our social systems. He overlooks the long educational delays. He fails to appreciate the persistence of prejudice and past personal experience. He fails to examine the sequential steps through which an action must go, and may estimate a total overall time so short that it is a physical impossibility in the actual system." (1961, p.453)*

Here are two excellent first steps in overcoming delays:

1. Become more aware of these kinds of delays,
2. Develop a more conservative estimate of the length of time needed to accomplish basic tasks.

***The 'Quick-Fix' Trap**:* In many cases, we fail to recognize delays and end up falling into the second system trap of 'quick-fixes'. Municipal managers can be tempted to use WSS beyond the designed capacity. This kind of action may be the result of budgetary constraints preventing longer-term solutions from being funded, such as investment in infrastructure, or training of managers and operators. However, if we continue to underestimate delays, the quick-fix option can lead to disastrous consequences.

For example, let us return to the reinforcing loop shown in Figure 3.10 below. You might underestimate how long a spike in demand will last, which fuels the reinforcing feedback loop driving wear and tear of infrastructure. Doing so could lead to a critical pump breaking down or an over-pressurised supply line bursting. As shown in the previous system trap, it often takes months or years to repair such damage, which can occur in a matter of weeks or months! Beware of quick-fixes as short-term solutions because they can cause troubles that persist for much, much longer.

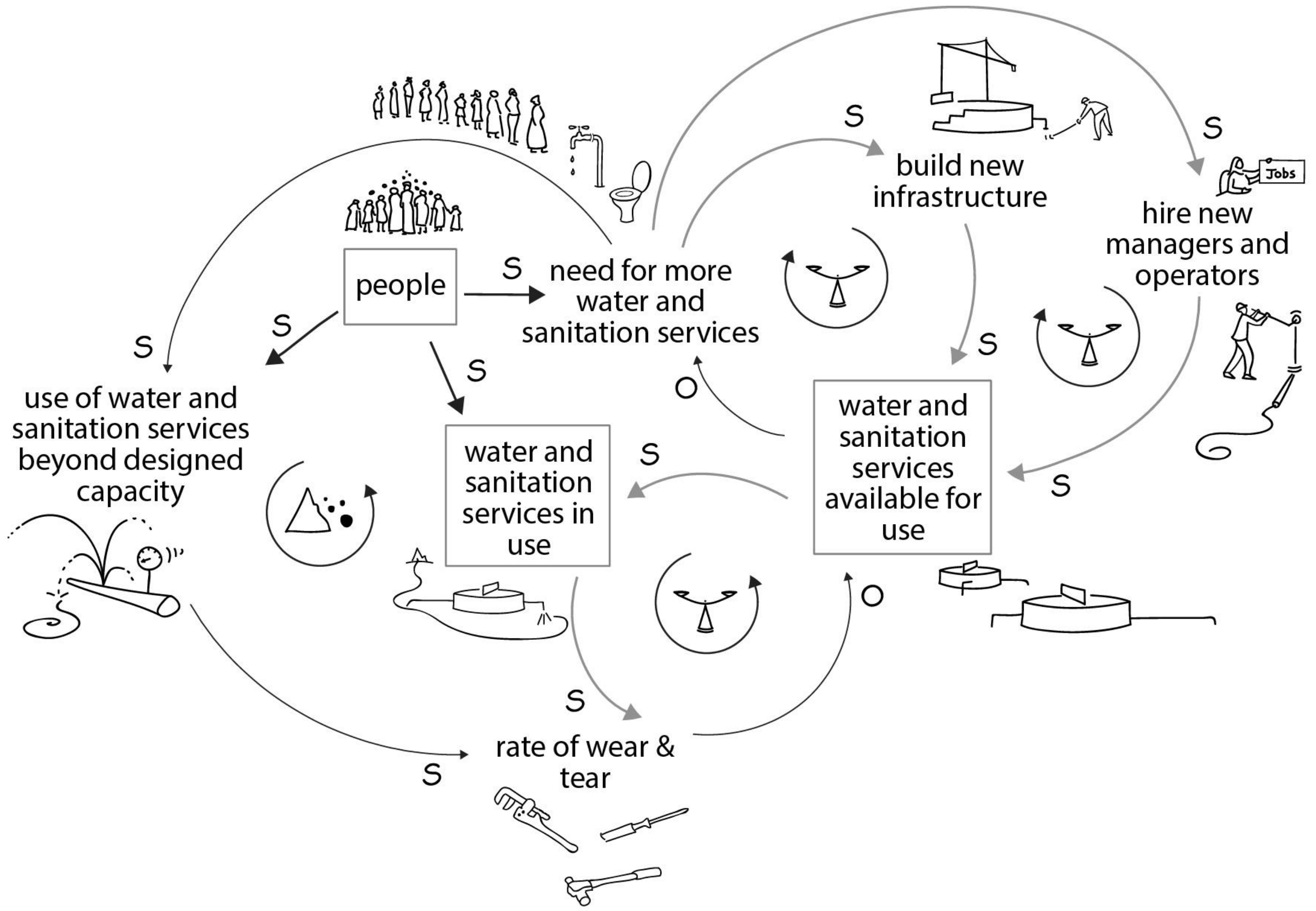


Figure 3.10: CLD showing how quick-fixes can lead to long-term troubles.

***The 'Maintenance and Operations Burden' Trap**:* Our final trap emphasises maintenance and builds on our understanding of delays and quick-fix solutions. There are two elements to this trap:

1. *quality* (type of infrastructure and/or manager) and
2. *quantity* (total amount of infrastructure and/or number of managers).

In order for WSS to be delivered successfully, both of these elements must work in coordination. Look at Figure 3.10 above: simply building more infrastructure (quantity) will not make the plant run successfully; managers and operators with appropriate skills must also be recruited (quality). For example, a new, highly-technical process for wastewater treatment may require specially skilled operators to run it. In such a case, you should consider if it is possible to align these two elements. If your municipality is located far from a city where skilled operators can be found, you could consider installing a less demanding wastewater treatment plant.

Let's extend this line of thinking to Figure 3.11, in the context of maintenance: a highly technical wastewater treatment plant may require highly skilled maintenance staff to keep it operational. Not only will it be difficult to find the skilled staff required, but once identified, it may take longer to train these staff to operate the newer plant.

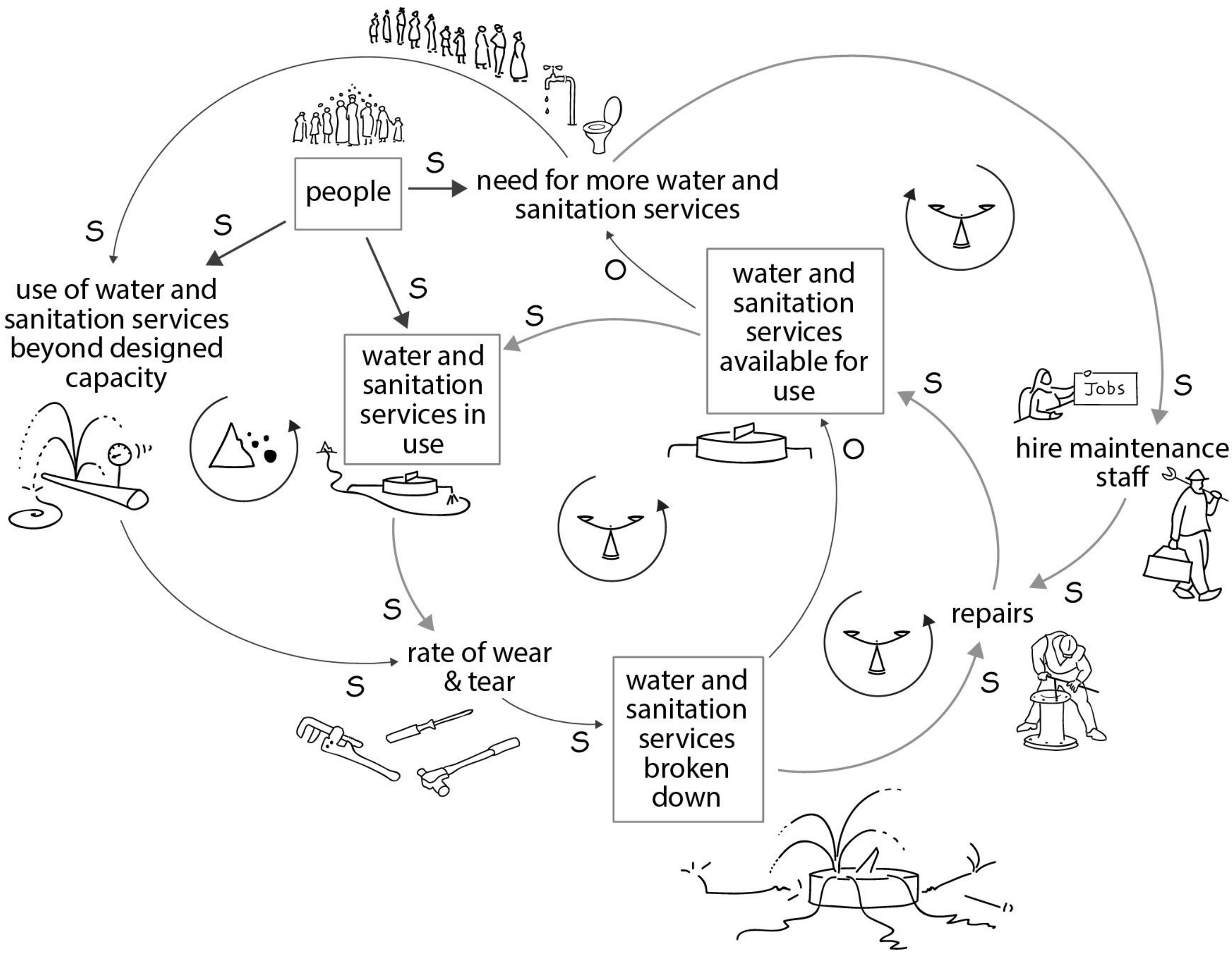
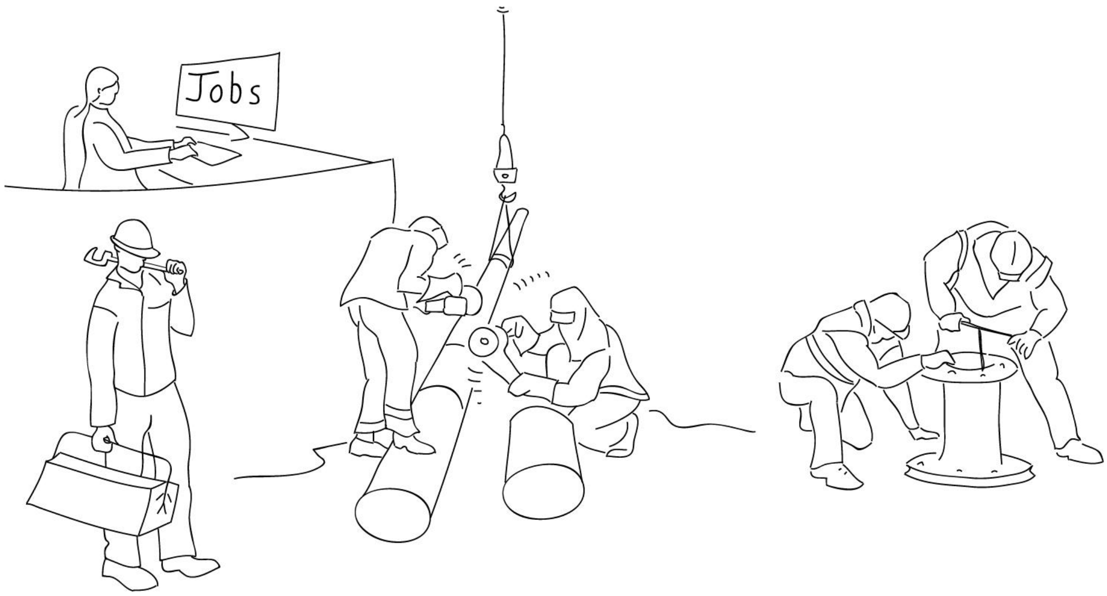


Figure 3.11: We often underestimate the burden of maintenance when we want to secure larger, more impressive infrastructure.

3.3. Summary

In this section, you were able to put your systems thinking skills into practice. We began with the example of a minibus company (which is a service) in order to become more familiar with the basic structure of a service-based system. WSS is also a service-based system and so we can learn lessons from practising with the minibus example. We ended by formally identifying the system 'traps' that arise, based upon the nature of a service delivery system.

You are now equipped with a basic understanding of systems thinking because, as mentioned in Section 3.1, the best way to learn is through practice. In the fourth and final section of this 'How-to Handbook' we make some suggestions about how to communicate these insights to other individuals involved with municipal management. This communication is a very important step to achieving better management through systems thinking.



Section 4: Systems thinking activities

Section 4.1: Introduction

Section 4 builds on the practical examples used in Section 3 and addresses the question "Now that I have learned the basics of systems thinking and how it can be applied to water and sanitation services, how do I communicate what I have learned to others?"

One of the very best ways to test your knowledge of a concept is to be able to communicate that same concept to others. There are many cases in your role as a municipal official or manager when being able to communicate systems thinking concepts can help you to present and defend your ideas successfully to other people who are involved in the decision-making process.

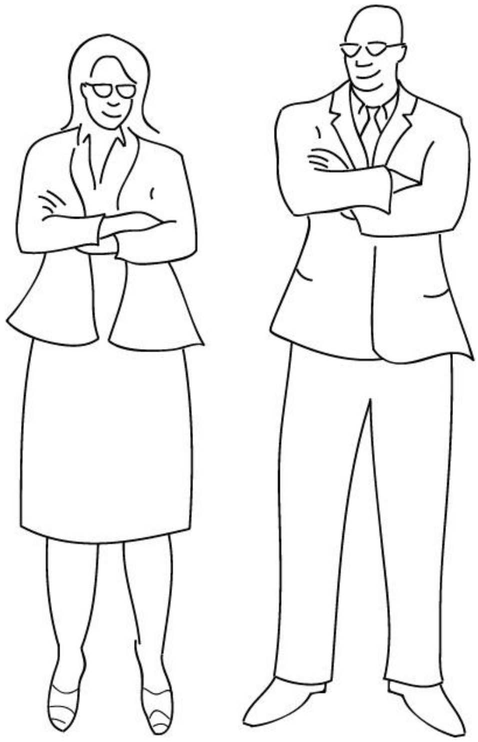
In this section, which draws on examples from *"The Climate Change Playbook"* by Dennis Meadows and others (2016), we provide a series of practical activities that you can apply in different settings. Each activity has been chosen and developed in order to highlight specific systems thinking principles. During each activity and after it, it is important to reflect on these principles and link them to your own water services and sanitation (WSS) management system (particular advice for doing so is provided in the text box below). Two useful references for further assistance with facilitation are *The Climate Change Playbook* (2016) and the *Systems Thinking Playbook* (Sweeney and Meadows, 2010).

How to debrief after an activity

1. Describe problems and events that took place in your WSS.
2. Consider how the game relates to current management challenges within your own WSS system.
3. Relate elements from activities to the problems raised in step 1 above.
4. Start a discussion about whether or not these same problems occur in your WSS management system.
5. Talk about how to solve the most important challenges in the game.
6. Transition to solutions in the real system.

Section 4.2: Activities

Activity 1: Arms Crossed



Time required:
- 5-10 minutes plus additional time for debrief.

Concepts covered:
- Paradigms (see Section 1.2 for a reminder of what **paradigms** are)

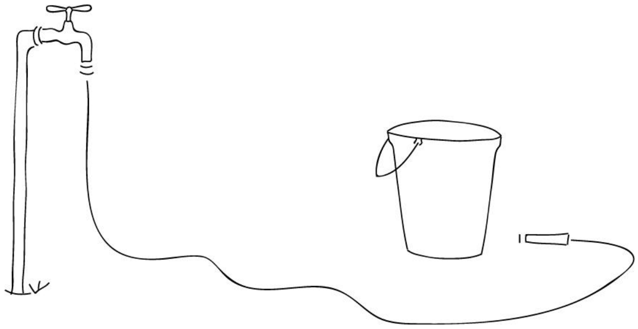
Materials needed:
- None

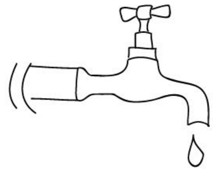
Directions:
1. Introduce the exercise with a discussion about different paradigms (i.e. different ways of seeing the world, which influence how people approach particular challenges).
2. Ask everyone to put down any items they are holding (this is a good way to check if everyone is paying attention).
3. Next, ask everyone to cross their arms. Now ask them to look down and remember which wrist was on top before unfolding their arms.
4. Repeat this process a second time.
5. Ask those who had the same wrist on top both times to please raise their hands. Probably, most, if not all, will have the same wrist on top. Make sure to note this before moving on.
6. Now, ask everyone to cross their arms so that their other wrist is on top. This will be challenging, and some people may be unable to do it on their first try (including you, so make sure you try it before you start leading the exercise!).
7. Draw parallels between this routine ‘habit’ of crossing arms and other routines or habits relating to operating or managing WSS.

Notes and debrief Ideas:
- During steps 5 or 6 it is a good idea to initiate discussion. You might ask a participant to describe their morning routine at work step-by-step. Another option is to identify a policy (either formal or informal) that is followed at the workplace. What are the standard ways of working that everyone follows?

Recommended application:
This activity is most useful when you are working with a large group (e.g. working with community members) or when you are short on time and want to quickly stir up discussion about different ways of thinking. The facilitator can ask questions like “Were you aware that you changed arms/used the same arm?” The facilitator can guide participants to think about the fact that doing the same thing over and over again forms a habit and that once formed, these habits are difficult to change.

Activity 2: Don't Spill!

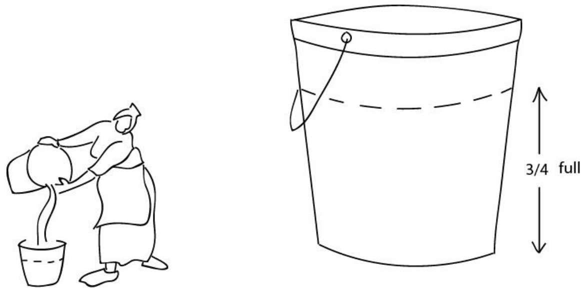




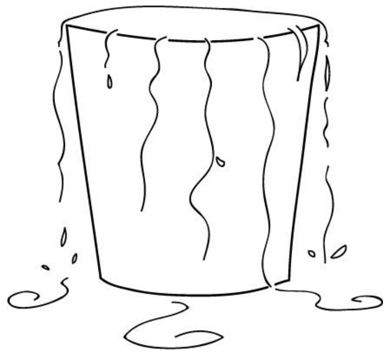
Time Required:
- 20 minutes, plus additional time for debrief.

Concepts covered:
- Delays
- Stocks and accumulation

Materials needed:
- Bucket or basin with a line drawn approximately ¾ of the way from the top. (Alternatively, use any container that will hold water.)
- Hose and tap, or anything you can pour from that holds a larger volume than the bucket.



Directions:
1. Place the bucket where all participants can easily see the water level. Begin with any level of water you want.
2. Designate a participant to open and close the tap (if you are using a hose and tap). Explain that they should try to turn the tap **fully open or fully closed**. Likewise, if pouring from another container instruct them to try to be consistent.
3. Now, ask for a volunteer to be the 'manager' for the activity. The volunteer should be seated so they can see the bucket, and be easily heard by the operator.
4. The operator is not allowed to speak during the activity, and takes direction only from the designated manager.
5. The goal of the manager is to fill the bucket completely without causing it to go over the line.
6. Rotate managers and repeat as useful, and/or fun.
7. *Extra*. To extend the activity, you may add an additional operator who can be directed to drain the bucket by the manager.

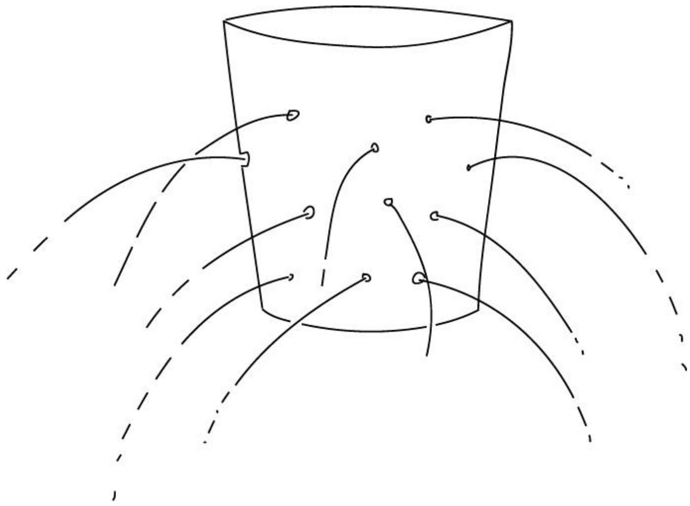


Notes and debrief ideas:
- When facilitating the activity, it is up to you if you want to introduce the concept of a stock before or after beginning the activity. Whenever you choose to do so, check that everyone understands the concept of stocks by asking participants to think of examples of stocks they encounter in their job or personal life (see Section 2.3 of this handbook).
- If appropriate for your participant group, it is sometimes useful to encourage friendly competition and offer prizes (regardless of how small) for anyone who achieves the desired level of water in the bucket.

Recommended application:
This activity can be used in the same way as the previous activity, provided you have more time at the beginning of the meeting and don't mind getting a little wet!
- Ask which method worked best, and why.
- Ask what was different about each strategy.
- This exercise can be initiated with discussion regarding delays and their implications for proper management of a system.

Activity 3: Springing a Leak

The next two activities are the most complicated of the activities in this handbook, so we advise you to lead up to them using a mix of the previous activities. You could also link these activities with one of the exercises from Section 3, depending on your audience.



Time Required:

- 15 minutes for each mode of use (see directions), plus additional time to debrief between exercises.

Concepts covered:

- Delays
- Stocks and accumulation
- Overuse

Materials needed:

- Bucket or basin with several holes of varying size along the sides of the bucket. You will cover the holes with Prestik, so ensure that some towards the top of the bucket are larger (and harder to cover).
- Hose and tap (or anything you can pour water from).
- Prestik for plugging holes.

Directions:

1. *Simulate normal use:* Begin with half of the holes in the bucket loosely plugged, pouring water in at a constant rate.
2. At this point, do not provide the participants with any additional Prestik, but direct them to stop the leaks however they can. Pour consistently, simulating a standard demand.
3. *Simulate overuse:* Repeat steps one (1) and two (2), this time pouring faster.

Notes and debrief Ideas:

- Be generous when adding water during the overuse portion of the activity (step 3). Focus on trying to break down any plugged holes and create as much chaos as possible.
- Ask participants what caused the chaos.
- If maintenance is suggested as a solution, encourage participants to describe what steps must be taken and what materials are needed in order to perform maintenance.

Activity 4: Maintenance

This activity builds on the previous one, emphasising the importance of maintenance for WSS.

Time Required:
- 20 minutes, plus additional time for debrief.

Concepts covered:
- Maintenance

Directions:
1. Assign a participant to be in charge of maintenance and give her/him extra Prestik along with a towel to dry off surfaces to make the Prestik stick better to the bucket.
2. Next, explain in front of the group that, as the maintenance manager, this 'maintenance' participant may request that the water pouring stop, for up to 30 seconds at a time, to allow maintenance activities.
3. Perform the exercise, simulating normal use and overuse as done in Activity 3.
4. Rotate managers and repeat as useful/fun.

Notes and debrief Ideas:
- This can be combined with Section 3 diagrams that highlight maintenance activities.
- Ask participants to compare the outcomes from Activity 3.
- You may need to coach the maintenance manager regarding the use of the towel.
- It is recommended you do the first part of the activity in the morning, and allow some time to pass before returning for the second part. That way, you can review concepts a second time before beginning the discussion about maintenance.

Recommended application:
Use this activity at longer meetings (full-day or half-day) when you can schedule the necessary time to run the activity, as well as prepare materials. The specific focus on maintenance can support a planning meeting with the same emphasis, or a training meeting aimed at improving the performance of employees.

Section 4.3: A day in the life of a municipal technical director

Let’s consider a typical day in the life of Thami (a fictional Technical Director of a small municipality in Limpopo) in order to highlight a few ways in which the tools in this handbook could help.

1. *When Thami arrives at work on Monday morning, he finds that three pipes burst during the weekend because of pressure mismanagement. Thami then discovers that there are no replacement pipes in stock at the municipal depot. Now pipe replacements must be ordered from Jo’burg whilst the residents continue to be without a stable water supply.*

How can the tools in this handbook help Thami?

One of the most important systems principles described in this handbook is the different effects of **delays** (see Section 2.3 and Figure 3.9). People typically underestimate these delays, forgetting, for example, that replacement pipes may take time to be delivered. Usually, buying new pipes will require getting three quotes from three different suppliers and will then await approval from municipal supply chain management. Then there’s the time it takes for the replacement pipes to be transported between the provinces.

Thinking about **stocks** of maintenance supplies is useful here (see Figure 3.5 and onwards). Remember that stocks take time to change. Thami needs to ensure that his maintenance managers all understand the importance of having ready access to replacement parts.

2. *While Thami considers what to do about the broken pipes, a councillor comes in to his office to complain about a development in her ward. Apparently, few of the houses have running water or flushing toilets on a regular basis, even though the houses are connected to the municipal network. Thami reminds the councillor that two years ago, he had warned her that the existing bulk infrastructure (including reservoirs and treatment plants) could not support the proposed development without refurbishment or expansion. The funds were not made available for improving the existing bulk infrastructure, but the housing development went ahead nonetheless.*

How can the tools in this handbook help Thami?
A simple CLD like Figure 3.2 shows that an expanding population will increase the need for more water and sanitation services. Remember that people needing more WSS must be **balanced** by making more of these services available for use.

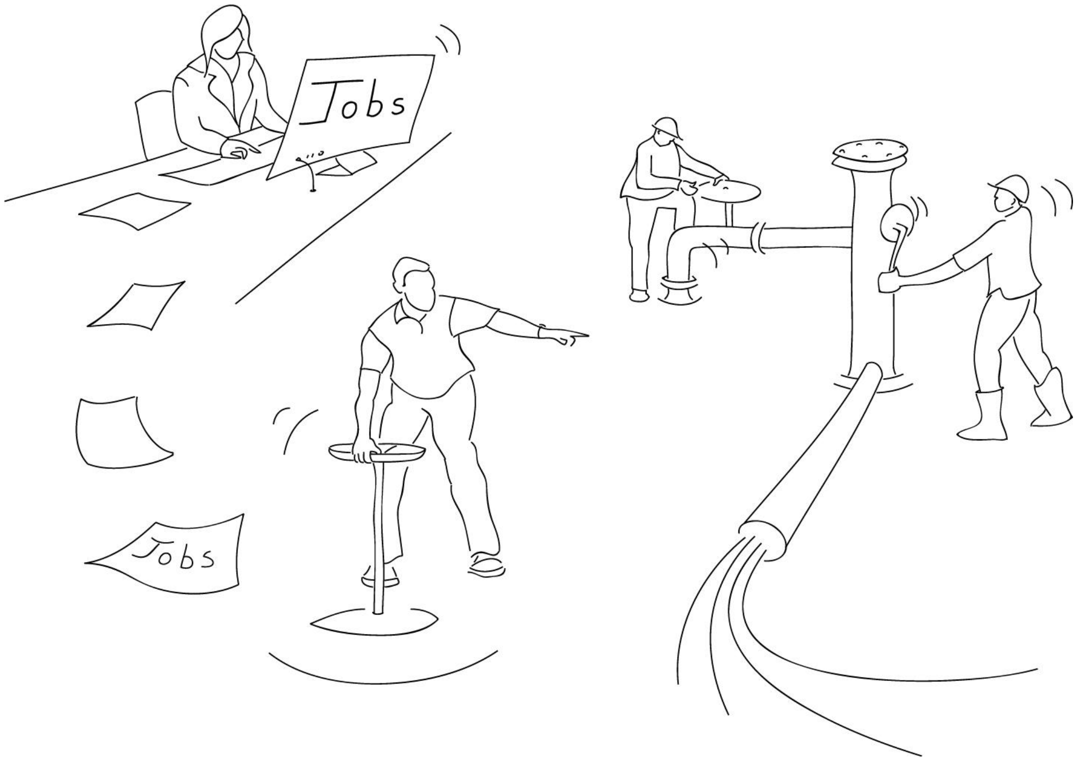
Challenges like the one described above can present opportunities. For example, the councillor may think that the problem lies in the availability of untreated water when actually the problem lies in the infrastructure capacity. Thami can use diagrams like Figure 1.1 to describe to the councillor the different components of the Urban Water Cycle. He could also use Activity 3 and Activity 4 to show the importance of maintaining the current infrastructure alongside the importance of *not* over-using this infrastructure.

At a deeper level, systems thinkers typically look for situations in which short-term benefits (e.g. over-using infrastructure to meet a higher demand) come at the cost of long-term difficulties (e.g. infrastructure breaking faster because the usable life span has decreased as the infrastructure has been overused). Connecting as many houses as possible to the municipal network may meet an immediate problem, but unless the supporting infrastructure is adequate and unless it is being maintained properly, then over time, residents will have taps and toilets in their houses but will lack water of a suitable quantity and quality to consume. Activity 1 is a simple way of highlighting how people do things, and see things, differently. In Thami's case, the municipal councillor is responding to a different set of (more-immediate) priorities to those of the technical directorate.

Remember that systems thinking is less about specific insights or specific diagrams or models, and far more about a general way of thinking, planning, and acting, which tries to consider interconnections, unintended consequences, and feedbacks.

Section 4.4: Conclusion

This handbook has applied systems thinking to municipal WSS challenges, showing why a systems approach can be useful (Section 1) and providing a particular systems tool and an approach (Section 2). To assist municipal stakeholders in applying the tool practically, readers were encouraged to adopt a 'learning by doing' approach in Section 3. This final section provides short activities that illustrate systems principles and which stakeholders can use to help communicate systemic challenges. We hope that this handbook will assist in some way towards achieving sustainable, equitable and efficient services in line with the National Water Act and in line with South Africa's constitution.



GLOSSARY

aggregated – combined into a collection.

causal – describing and explaining links between cause and effect.

component – a part of a machine or piece of equipment, e.g. the fuel tank is a component (part) of a motor car.

conceptualisation – concept, idea, image.

correlation – a connection or relationship between two things that may not be based on cause and effect.

debrief – explanation and discussion.

dislodge – knock something so that it becomes loose and free.

disproportionate – something that is bigger (or smaller) than it should be in comparison to something else, e.g. *He has a disproportionate amount of the work*.

dynamic – changing over time.

exponential – increasing in a way that becomes more and more rapid OR decreasing in a way that becomes more and more rapid.

fallible – capable of being wrong, of making mistakes.

generic – general, common, universal.

holistic – complete, whole; including all parts.

model – a simplification of reality that is incomplete and imperfect, but can be helpful in drawing our attention to the essential parts of a system and how they interact.

non-linear – not moving in one direction only; indirect relationships between things.

obsolescence – the process of wearing out and no longer being useful.

paradigm – a way of looking at something, at a situation, or the world in general (also known as a ‘worldview’).

phenomena (plural), phenomenon (singular) – something that exists, can be felt, seen, tasted, heard, etc.

potable – safe for humans to drink.

reticulate – an activity that creates a network, e.g. a network of pipes that supply water and remove sewage.

robustly – in a determined and strong way; capable of ‘taking a knock’.

static – having no movement, change, or action (the opposite of ‘dynamic’).

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Appendix A: General modelling resource

This appendix provides general information about modelling approaches and tools that may be of interest to municipal stakeholders who are the intended audience of this guide. Although the appendix gives a broad array of tools and approaches, it is selective rather than comprehensive.

A.1. Further information about system dynamics modelling (SDM)

Further information about system dynamics can be found at: www.systemdynamics.org and via the introductory video at https://www.youtube.com/watch?v=MSo8kqbLDlw. Details of the South African chapter of the international System Dynamics Society can also be found online.

The following free (online) e-book offers a comprehensive overview of SDM and provides practical exercises:

Pruyt, E. (2013). Small System Dynamics Models for Big Issues: Triple Jump towards Real-World Complexity. Delft: TU Delft Library. http://doi.org/10.1007/SpringerReference_7284

As noted in the introduction in Section 2.1, SDM is both a qualitative and a quantitative approach. The causal loop diagrams used in this handbook can be drawn in a number of software packages, including Stella (http://www.iseesystems.com/) and Vensim (www.vensim.com). Both of those software packages also allow for developing quantitative SD models. Vensim has a Personal Learning Edition (PLE) that is freely available.

For an online, open-access paper describing a quantitative application of SD, see Clifford-Holmes and others (2015). This paper analyses the ‘modes of failure of South African local government in the water services sector’ and is what this handbook is based upon.

A.2. Technical software packages for municipal management of WSS

	Name	Description	Software/reference
1	SAP Enterprise Management	Useful for asset management, for example, helping to formulate different strategies for different assets (for example, whether to run the asset to failure versus early replacement).	SAP Africa (https://www.sap.com/africa/index.html)
2	Water Distribution and System Optimisation (WADISO)	WADISO was developed for the analysis and optimal design of water distribution systems. The software assists with planning the optimal pipe, pump, and tank sizes, and includes water quality modelling (for drinking water).	GLS Software, a South African company, develops and operates the three pieces of software described here. See: http://www.gls.co.za/software/products.html
3	Sewer System Analysis (SEWSAN)	SEWSAN is a computer program that simulates, analyses and assists with the optimal design of sewer reticulation systems. The software calculates the spare capacities in sewer systems (whilst accounting for leakages).	
4	WADISO and SEWSAN interface to Treasury (SWIFT)	SWIFT links to the National Treasury, assisting with municipal billing. It also links the water distribution model and the sewer model, enabling accurate modelling of water demand and effluent production within a municipality.	

A.3. Overview of other forms of modelling of potential interest

The following reference is a freely available and useful description of various modelling types and approaches (both qualitative and quantitative):

Badham, J. (2010). A Compendium of Modelling Techniques. Retrieved November 27, 2013, from http://i2s.anu.edu.au.

This compendium includes a brief description of other qualitative modelling approaches (besides CLDs) such as Scenario modelling and Mind-mapping and Concept Mapping. Other quantitative modelling approaches of potential interest are summarised in the following table.

	Name of modelling approach	**Description**	**Software/reference**
1	Spatial modelling using Geographic Information Systems (GIS)	A GIS is a system for capturing, storing, checking, manipulating, analysing and displaying spatial data.	ArcGIS (https://www.arcgis.com/features/index.html) is the main software package
2	Spreadsheet modelling	Spreadsheet models built in Excel are probably the most common form of modelling	Microsoft Excel (usually included as part of Microsoft Office)
3	Water Resources Modelling Platform (WReMP)	A hydrological yield model for simulating water flow volumes, which is routinely used within water quantity management.	Contact IWR Water Resources: http://www.waterresources.co.za/index.html
4	Water Quality Systems Assessment Model (WQSAM)	WQSAM uses the relationship between flow volume and water quality to simulate water quality variable loads.	How to manage Water Quality and Water Quantity together https://www.ru.ac.za/iwr/research/wqsam/
5	Statistical models	This includes econometric models that are often used to explore socio-economic phenomena.	Excel (see above); SPSS (http://www.ibm.com/analytics/us/en/technology/spss/); R (Open Source)

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