Causal Loop Diagrams: a Brief Introduction

1. What's Happening? - The Power of Data

Imagine a group of senior clinical and management staff reviewing data that clearly shows the number of presentations to the Emergency Department (ED) increasing at a higher rate than most other hospitals. Furthermore, the data also points to the fact that the greatest rise is in those over the age of 75. They start asking each other questions, "Why is this occurring?" "Is the increase related to the change in population demographics in our area?" They start putting forward ideas about how to address the problem. "If we improved after-hours primary care would that reduce the numbers coming into hospital?" "What if we improved GP access to specialist advice?" "Should we increase our community services in the local aged-care facilities?" "Would speeding up the discharge process for our elderly patients reduce the overcrowding?"

All of these questions have one thing in common; they are concerned with causality, the relationship between cause and effect. Words such as 'why', 'what if', 'should we', 'would' indicates that they want to know about the relationships between some cause, for example, the discharge process, and some effect, in this case ED overcrowding. The data tells them that the numbers coming into ED are higher than the national average and can provide information that can help answer those questions. The data can help, but it can't actually answer the 'what if' question. Data can tell them how many people are attending ED, but it can't tell them why. It can point to some possible associations, for example, changing demographics, but they are going to have to go beyond the data if they want to find an answer. Because the data can only highlight associations, such as the association between age and higher presentation rates, it cannot on its own, tell them why and, even more importantly, it cannot tell them what the consequences of any intervention would be. It cannot answer the 'what if' questions. The answers to those questions require something more than just the data. The data is necessary, but not sufficient.

2. Why Is It Happening and What Can We Do to Change It? - The Power of Models[1]

One way of understanding causality is to see associations between things we observe in the world. Associations is what Big Data is all about. It is the realm of statistics and powerful chess computers that search an enormous database, very fast, to find the next move that is associated with the highest percentage of wins. This is what our data can help with. Higher rates of ED presentations are associated with age. Those under the age of 5 and over the age of seventy present at higher rates than those in other age groups. Who is most likely to present at ED, who is most likely to be admitted to an inpatient ward, who is most likely to have multiple presentations in a given year? These questions are what databases and statistical analysis answer extremely well. There is no need for the ideas and tools discussed in this training to be used to answer those questions. Data and statistics will answer those sorts of questions extremely well. The data will highlight associations between the presenting condition and length of stay for example, and statistics will tell you how strong that association is.

Data, on its own however, will not provide you with the information you need to go beyond simply seeing things in the world to actually changing them. To go beyond seeing the world as it is, to changing the world, requires you to have a causal model, that is some thought about "what would happen if….?" If observational data is going to assist you to answer intervention questions, then the data has to be supplemented with a causal model. If for example, I have a causal theory that emphasizes the need for integration across the continuum of community, primary and secondary care to improve end-of-life care services, then I am going to ensure some mechanisms are in place to enhance that integration. I can use data on patient admissions to hospital, primary care callouts, numbers living at home at the end of their lives, surveys of carers on their experience of the support they received, and a whole host of other data to inform my causal theory. My intervention is then informed by data that tells me, for example, that those with good home care, require less intervention in the last few weeks and days for their life. The data can also highlight the exceptions to that 'rule', and I can design an intervention to increase home support for those the data tells me benefit from it. But the data, if it is going to inform change, needs a causal model to support what actions are going to work and what effect they are going to have.

[1] This section is based on: Pearl, J., & MacKenzie, K. (2018). The Book of Why: The New Science of Cause and Effect. Allen Lane

A causal model therefore allows me to not just to see things going on in the world but to intervene in it. However, no matter how good my causal model, the complexities of the world will quickly reveal any shortcomings it has, and I am then faced with questions such as, 'Why did it not work as well as we had hoped?" "What if we had invested more in training for family carers?" "What if we had invested more in getting palliative care specialists providing training to GPs?". Answering these "What if things had been different" questions allows us to learn and develop, and these questions cannot even begin to be answered without the ability to imagine a different future. Imagining a different future, allows us to go beyond simply intervening to change something to designing something that does not yet exist. This ability to imagine a different future is, as far as we know, unique to humans, and central to many of our wonderful achievements in science, art, music, and medicine.

These three levels of causality are important to understand, as each requires different tools and has the ability to answer different questions

LEVEL 1: Seeing things that exists
Collecting and analysing data;

1. What regularities and irregularities do we observe in the world?
2. What is the association, and how strong is that association, between variables of interest?
3. What is the likelihood that 'patient A' presents at ED within the next 12 months?

LEVEL 2: Changing something that already exists
Developing a causal model:

1. What would happen if…..?
2. What are the key variables and how do they influence each other?
3. What is the pattern of behaviour created by these causal connections?

A causal model that uses the observations we get from collecting and analysing data enables us to answer interventional queries.

LEVEL 3: Designing something new, something that does not yet exist
Imagining a new pattern of causality:

1. Imagining a future that is different from the counterfactual

2. What if things could be different….?
3. Designing something that does not yet exist
4. Why did our last intervention succeed, better with cancer patients and less well with those with dementia?
5. What would have happened if we had worked much more closely with aged care facilities?
6. What would it look like and how would it work?

Data and statistics work at level 1. They both give us greater insight into the world as it is. To change the world, the characteristics of causality at level 2, you need a causal model. A causal model that captures your theory about how the world works and how it will respond to the interventions you make. To get to level 3, you have to design something that does not yet exist in the world. Your maps and models have to incorporate imagination, not just analysis.

3. Developing Causal Theories: Causal Loop Diagrams

The best Causal Loop Diagrams (CLDs) are informed by the data **and** by our understanding of how the system works. Complex systems, such as health systems, evolve due to feedback. The myriad of factors interact with each other, feeding back on each other and it is this feedback that determines the future trajectory of how the system is going to evolve. If this is how systems work, then we need to ensure that our causal maps include these feedback loops. Causal maps that focus on the feedback loops in a system are known as Causal Loop Diagrams (CLDs). They are the prime tools we use to develop the causal theories we need to go from LEVEL 1 reasoning to LEVEL 2 and 3. If we want to successfully intervene in the world, we need to understand the feedback mechanism at play.

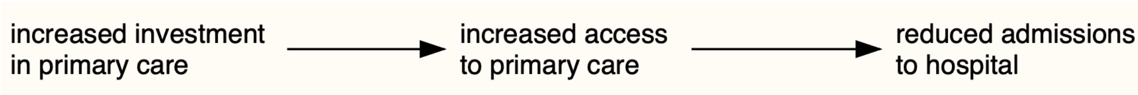
Constructing CLDs

Systems thinking focuses on helping us come to grips with complex problems and models are key devices we use to understand that complexity. CLD s provide a formal language for developing causal theories about the system and, because of their visual nature, communicating that theory to others in a transparent, understandable and testable way. They provide us with a mechanism to describe the key variables in the system and the links between them, bringing them together in a series of feedback loops. By linking a number of these loops together we can create a causal theory about the problem we are faced with.

A CLD consists of four basic elements. These are i) the variables, ii) the links between them, iii) a description of the nature of those links, and iv) a description of the behaviour the system will produce. Let's take an example:

The Case of Diminishing Returns

In NZ, as in many health systems around the world, there is increasing pressure on hospitals. One of the strategies that has been implemented to address this issue has been to increase funding for primary care. The rationale is that by increasing funding in primary care you increase access to primary care and as a consequence reduce the numbers going to hospital. The causal logic is simple:



However, there is another theory that argues that this strategy, on its own, is unlikely to lead to long-term reductions in hospital admissions. This theory incorporates feedback. What is this theory and how would it change the initial causal logic?

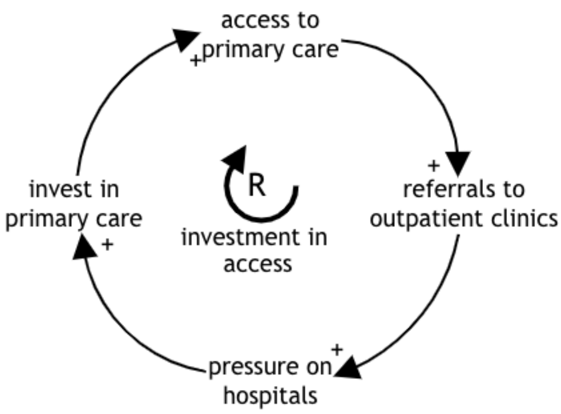
STEP 1 – Establish the Key Variables

To develop a CLD we have to establish the key variables that are important to the issue. Remember that a variable is something that can change over time. In this case '*pressure on hospitals*" and "*investment in primary care*" are important elements of the story. This theory argues that increased investment will lead to increased '*access to primary care'* which in turn will lead to an increase in the number of '*referrals to outpatient clinics'*. This is because as more patients are seen in primary care there will be a need for more patients to access the diagnostic skills and resources not available in primary care. This will then feedback and increase '*pressure on hospitals'*. The key variables in our initial model are therefore:

- pressure on hospitals
- investment in primary care
- access to primary care
- referrals to outpatients

STEP 2 – Draw the Links

Having identified the variables, we can now fill in the links by determining how one variable affects the other. In CLDs the links are labelled as '+' or '-'. If variable B moves in the same direction as variable A, the link from A to B would be labelled with a '+'. If variable B moves in the opposite direction as variable A, the links from A to B would be labelled with an '-'. In this theory the increased investment in primary care leads to increased access, hence a '+' link. This increased access leads to increased outpatient referrals and then increased *'pressure on hospitals'*. This is shown below:



Note that all the links are '+', so that an **increase** in one will lead to an **increase** in the other. It is also true in this theory that a **decrease** in investment in primary care would lead to a **decrease** in access to primary care. This would lead to a **decrease** in referrals to outpatients and a **decrease** in the pressure on hospitals. So, whatever direction you start in, that change is only going to be amplified around the system.

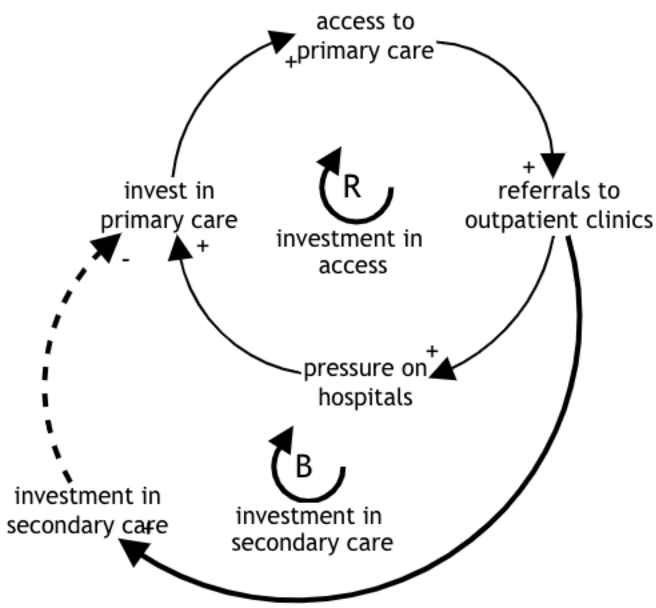
STEP 3 – Determine System Behaviour

So, in this simple model, increased investment in primary care is, over time, going to lead to even more investment, which in turn will lead to even more. More pressure in the hospital leads to more investment in primary care, which leads to more access and therefore more referrals. This then further increases pressure on the hospital and so to further investment in primary care. This system behaviour is described by the 'R' (reinforcing) in the loop we have labelled as *'Investment in access'*.

This does not look like a plausible theory however as somebody, sometime is going to say, this is not working. It is not that the links we have created are necessarily wrong. It may simply be that the model is incomplete. It does not currently provide a plausible theory about investment in primary care. But rather than starting again, if we are comfortable that the CLD as it stands captures some important links but is incomplete, we look for other variables. And go through the same three steps again.

STEP 4 – Around the Loop Again

The second version adds another variable, 'investment in secondary care'. This diverts funds away from primary care, putting a limit on how much further investment primary care will receive. This is shown below:

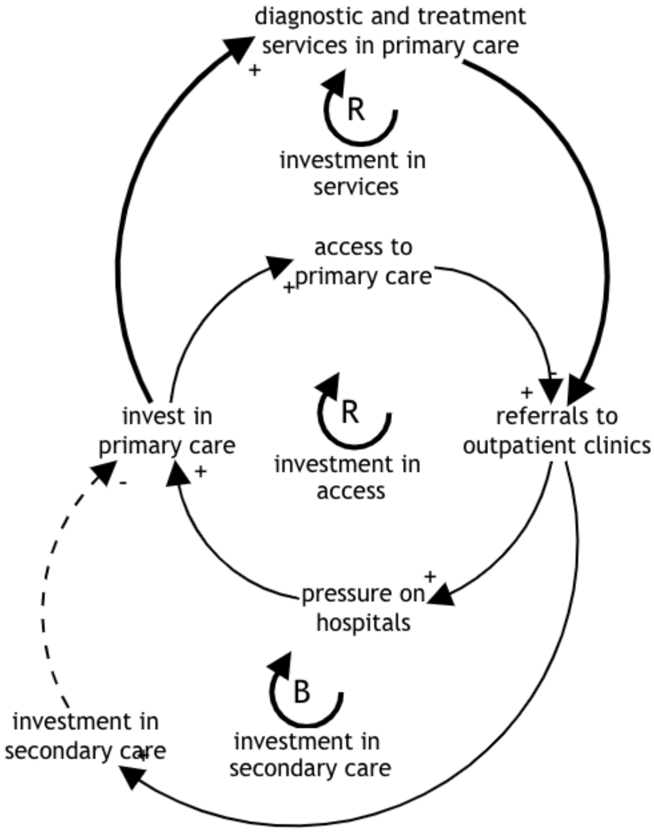


The logic here is that if *'referrals to outpatient clinics'* increase then there will be pressure to increase the resources those clinics have to cope with the increased demand. Given limits on funding, an increase in funding for outpatient clinics will lead to a decrease in funding elsewhere, and in this model that elsewhere is primary care. No matter how strong the belief that investing in primary care is the way to go, if we are to ease the pressure on hospitals, the short-term pain experienced by outpatient clinics will likely result in a diversion of available funding and therefore a reduction in funding for primary care.

This new loop is a balancing loop, described by the 'B' in the loop we have described as *'investment in secondary care'*. It will always bring the investment in primary care to some 'balance point'. Follow the logic around the model: an **increase** in what we *'invest in primary care'* will lead to an **increase** in *'access to primary care'*. That will lead to an **increase** in *'referrals to outpatient clinics'*, which then leads to an **increase** in *'investment in secondary care'*. This then leads to a **decrease** in the amount we *'invest in primary care'*. Go through the loop again, this time starting with a **decrease** in the amount we invest in primary care. If you follow it through carefully you will come back around the loop to find that the logic leads to an **increase** in what we invest in primary care. This loop we have labelled as 'B', a balancing loop. This means that it will not lead to an ever-increasing amount invested into primary care. While a lot of detail is still left out this theory is more plausible than our initial one.

STEP 5 – …. And Again

Let us assume for the moment that there is enough in the model for us to ask the question, "What could we do differently to break through this dynamic, where investing in primary care leads to increased pressure on hospitals, which then leads to pressure that decreases investment in primary care?" It is a cycle that is unlikely to lead to long-term sustainable improvements in care. Version 3 adds another variable '*diagnostic and treatment services in primary care*'.



The logic here is that rather than utilising the increased investment in primary care to only increase access, some funds could also be used to increase both diagnostic and treatment services available in primary care. This would reduce the flow-on effect of increased '*access to primary care*' leading to increased '*referrals to outpatient clinics*', as more of those patients who need these services could now find them in a primary care setting.

We now have the beginnings of a causal theory that not only describes what is currently happening but highlights some potential opportunities for intervention. If supported by the data we have, it becomes even more powerful. Above all else however, it provides an explicit and testable theory about how the world works and how we believe it would work given different intervention strategies. It is visible, therefore debatable, and because it has a clear method for development it can be modified and improved to the point that it provides a rich and robust description. It takes our understanding forward by adding a causal model to the data that we have at our disposal and together they provide a much more solid basis on which to act.