CHAPTER 5 - MULTIPLE CAUSE AND CAUSAL LOOP DIAGRAMS

Causal Diagrams may look very similar to Influence Diagrams. The important difference is what you wish to know:

- If you want to know what influences a situation at a particular moment in time then you use an Influence Diagram. You would use an Influence Diagram if you wanted to know what is influencing me writing this chapter (e.g., the work of other systems scholars, the flexibility of my authoring software, my idea of what potential readers want to know). The core focus is 'what' may lead to change.

- If you want to know how a situation changes over a period of time then you use a multiple cause diagram. In other words, the sequence of causes and effects that in the past have contributed to this chapter right now (e.g., my evaluation of specific drafts of the chapter, the response from reviewers, the amount of time I have already spent on this chapter, the demand on my time of other work). The core focus is about mechanisms - 'how' things change.

- A primary use of a causal diagram is to identify potential leverage points that help address a problem. Thus causal diagrams are much less about gaining insights than generating solutions. This means that before you draw causal diagrams you need to know quite a bit about the problem and solution, and most importantly potential solutions must lie within the boundary of the diagram. Failing to follow this rule is the most common error when drawing causal diagrams, and why they often end up like wiring diagrams.

Multiple cause and causal loop diagrams

There are two distinct traditions of causal diagrams, which I will call 'multiple cause diagrams' and 'causal loop diagrams' although they are often called by different names.

Here is a comparison between the two kinds of diagrams illustrated by the Open University's Systems Diagramming Course. The topic is what influences or causes limits to beer drinking.

On the left is a multiple cause diagram, on the right is a causal loop diagram

What are the main differences you see between them?

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I am deeply indebted to Dave Packer of GKA Incorporated, whose method of constructing Causal Loop Diagrams, Fastbreak, I have used as the basis for this chapter.
There are only two major differences, but they influence when you would use which kind of diagram.

The identified elements of a multiple cause diagram are:
1. An action (e.g., buying more beer)
2. A state of affairs (e.g., loss of inhibition, feeling sick)

In contrast, a causal loop diagram only contains variables. In CLDs, a variable is a key aspect of the situation that:
- may increase or decrease, and
- has behaviour that can be measured over the period of interest, and
- measures the intensity or level of something, and
- may fluctuate or oscillate

The equivalent to the example above would be the number of pints of beer bought, the amount of decreased inhibition, the degree of nausea. In many – but not all - cases these are quantitative measures.

The second difference is the convention for identifying the nature of the relationship between elements, which will be discussed in great detail later.

Choosing between a Multiple Cause Diagram and a Causal Loop Diagram.

Here is the distinction make by the Open University course.

<table>
<thead>
<tr>
<th>Multiple Cause Diagram</th>
<th>Causal Loop Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shows a web of interconnected elements or factors</td>
<td>Shows a web of interconnected elements or factors</td>
</tr>
<tr>
<td>The factors are general or specific events or states</td>
<td>The factors are always specific variables</td>
</tr>
<tr>
<td>Arrows sometimes labelled with nature of causality</td>
<td>Arrows labelled with the direction of the causality</td>
</tr>
<tr>
<td>Helps identify circular loops of causal relationships (aka feedback loops)</td>
<td>Clearly specifies the nature of the feedback loops (positive or negative)</td>
</tr>
</tbody>
</table>
Useful for exploring rough ideas of how changes in factors cause changes in other factors

Adds discipline and clarity because of the need to identify specific variables that cause those changes

This chapter covers both kinds of diagram because so much of the process is the same. In general we will use the phrase "Causal Diagram" or "CD"; and make it clear if we are specifically referring to the extra stages of a 'Causal Loop Diagram' (CLD)

Causal Diagrams are useful ways of diagramming and gaining insights into a situation when its behaviour is either inexplicably stable or things appear to be happening that are appear non-linear. 'Non-linear' means that the 'result' of an action is out of all proportion to the action itself. That behaviour is the result of feedback loops. A feedback loop occurs when a chain of causal relationships form a circle.

**Constructing Causal Diagrams**

It is extremely easy to construct meaningless and unanalysable causal diagrams. It’s the basic mistake everyone makes their first time – including me. The temptation is to throw every possible factor against the wall and draw lines between them. The trick, as with all systems diagramming, is to be thoughtful and disciplined about the process. And above all be clear about the boundaries – what is in and what is out. Pick what the important relationships may be at the start – you can always change your mind later.

Below is a suggested process. I is based on an approach called Fastbreak that was initially developed by GK Associates in the USA. GKA was one of the early consultancies that used Causal Loop Diagrams. However the process can be used just as well with any causal process (indeed parts like the clustering process can be used in Influence Diagrams also)

Briefly it is this :

1. Identify the purposes of diagramming
2. Identify the key framing and the core problem
3. Decide the boundaries of the problem
4. Identify key factors (events or states for MCDs, and variables for CLDs)
5. Identify relationships between the key factors (ie draw MCD or CLD)
6. Identify and categorise important loops and leverage points for intervention
7. Validating the diagram (if that fits the purpose of the exercise)

What you will need are :

A group of people who know the issue from a wide range of perspectives
Ideally Post It hexagons of two colours\textsuperscript{13}, or large rectangular Post-Its
A clear wall or floor space – at least 3-4 metres wide
Large roll of paper (if you cannot stick things directly on the wall or floor)

\textsuperscript{13} Hexagon shaped Post-Its seem to work much better visually than the traditional rectangular ones, especially for clustering ideas. The major supplier of hexagon shaped Post-Its is Thinkingtools.Net (https://www.thinkingtools.net/category-s/1829.htm), although they really need to do something about the glue they use.
Medium size permanent markers

**Step One : Planning and involvement**

As with all good systems diagramming processes, preparation is key. That's true even when you are drawing the map on your own. But it is especially important when drawing CDs. One reason for this is that CDs - more than any other diagramming process - have an air of certainty about them. You are not in the prediction business but you will be playing with scenarios, which tend to create a sense of certainty, even when unwarranted.

So, issues of who is involved, what assumptions they bring, how the process is facilitated, clarity of purpose and sufficient time are critical. As I show at the end of this chapter, given the same overall problem two different groups of people came up with completely different CDs and drew fundamentally different conclusions from the exercise.

I strongly recommend a facilitator who not only knows how to manage groups processes, but has a strong background in the theory and practice and limitations of CDs be involved. And do not rush the early stages of the process (up to the identification of key issues). Allow participants to tell their stories of their experience within the situation and the issues they encountered.

**Step Two : Identify the purpose of diagramming**

As always this is the first place to start. CDs can be constructed for various purposes. Two common ones are :

1. Explore what may be the key entry points in intervening in a problem. In which case validation with 'reality' is important
2. Explore how different people, stakeholders or whatever perceive is the dynamics underpinning a problem. In which case, you may want to compare and contrast different CDs constructed by different people and gain insights into possible different problem identifications and solutions via those different perspectives.

Decide whether you want to draw a multiple cause diagram or a causal loop diagram. Some people consider that you should always start with a MCD before doing a CLD, because an MCD can avoid you selecting inappropriate variables.

**Step Three : Identify the key problem**

With CDs you *model the problem not the entire situation and that the diagram must contain potential solutions*. This is where many problems with CDs start - people try to diagram the whole situation not the problem. But how do you decide what the problem is? As with Rich Picturing and other diagramming, it is a good idea not to rush to the most obvious problem.

First write down the the key framing. As described earlier, framing is the perspective or viewpoint with which to view the situation. Is is about 'health', is it about 'community empowerment', is it about 'equity', is it about 'economic development'.
The importance of this stage cannot be underestimated.

For CLD’s it is necessary to describe the problem in ways that can be expressed as a series of variable. For instance, 'we have a massive youth justice problem' is fine for a MCD but better identified as ‘too many young people are being convicted of crimes' for a CLD. Thus the key variable you are seeking to explore is 'youth convictions'.

Secondly, for MCDs and especially CLDs it is useful to draw a graph of how the key factor has changed over time; what’s the trend. If it is going up, what's the pattern of the rise. Don’t get hung up about actual numbers and at this stage don't try to determine what may be the reason. You will find this helps you at the analysis stage, when you are seeking to find whether your ‘solution’ is likely to alter the dynamic.

**Step Four : Decide the boundaries**

Deciding the boundary of the diagram is critical in causal diagrams. Otherwise you end up with an unintelligible wiring diagram. **The most important boundary choice in causal diagrams, especially CLDs, is that the solution to the problem must lie within the boundary of the diagram, and exclude things that may not affect the solution.**

This may appear completely illogical on first reading. However, the key task of a causal diagram – more so than Influence Diagrams - is to identify possible places that offer leverage to address and hopefully resolve a problem. If you have too many items in your diagram, then locating those leverage points will be like trying to find a needle in a haystack. This is why it is always a good idea to explore the issue in detail first, look at the dynamics of the situation, find out what is already known. **Start small - it's much easier to add things to a causal diagram than to take them out.**

Later in this chapter we are going to a particular problem in a chicken farm as an example. The boundaries this investigation could be space (the farm, the chicken coop), time (the last five years, a couple of days), the nature of the problem (variances in my egg production) or a particular framing (the farmers perspective, the foxes perspective, the chickens perspective, the supermarket's perspective).

**Step Five : Identify issues and cluster them**

Write down the issues that relate to this problem within the boundaries you've chosen. [Note - always be willing to expand or reduce your boundaries]

In a group, each person takes three Post its and writes down an issue, an opportunity, and obstacle or a help, or a hindrance .... whatever. Identify one strong opinion and write on a different coloured post-it.

Then each person reads out one in turn (they can pass if they wish) and it gets put up on the wall or floor or paper. It then gets given a number. These Post-Its should be in neat rows like this, each with a number on it from 1 to whatever:
Next is to cluster these ideas into something more manageable. This can be done as a whole group with the facilitator leading the clustering process, or by just allowing people to cluster the ideas in pairs or individuals. It doesn't really matter if you follow the rules. This process can be done surprisingly fast (I've clustered 200 ideas in 20 minutes with 50 people participating), or you can take your time deliberating on each each pairing more carefully.

In a large group you will find there are three kinds of people. There are those who throw themselves actively into the process. There are the spectators who stand back and make often useful but occasional comments. And then there are those who just go and get some coffee or check their phones. Allow all three but make sure everyone participates in the debrief.

The process is this:

1. Start with a pair that seem to go together and place them together on another wall, or somewhere distant from the list. Then repeat for maybe five or six pairs.

2. Then open things out a little and just let people cluster ideas that seem to go together. Make sure that the emerging clusters are physically separate from each other. There will be times when an item could go into two or more existing clusters. Don't argue, put it in all three. The quick way of doing this is to put the post it in one cluster and make another cluster with just the number written on it. That speeds things up a lot.

3. Within a few minutes you will find that people are starting to name the clusters – just let that emerge and allow for people to change the names as things emerge.

4. In the end there will be some post-its that are not clustered. Just let that be … a cluster of one is okay.

5. When that is done, the task is to name the clusters. You will find that this exposes peoples assumptions about what the clusters mean. It's important to allow that debate to happen and allow Post Its to move between clusters and clusters to split or merge. Once everyone has agreed the collection of clusters, take another coloured Post-It, give the cluster a name (another useful source of discussion), write the name and put it on the cluster.

6. Identify factors you want to diagram within each cluster. Identifying key factors is a bit of an art. Here are some questions that will help generate factors:
   - What do key stakeholders want in terms of each cluster?
   - What about the cluster changes over time? Refer to the original graph you drew
   - What are the key choices made (or ought to be made) within each cluster? What helps and hinders these choices?
What are the key uncertainties?

You may want to discuss this as a whole group, or break into smaller cluster groups.

Remember that when drawing CLDs using variables rather than events or states, it is useful to see key factors as a key aspect of a situation that:
- may increase or decrease, and
- has behaviour that can be measured over the period of interest, and
- measures the intensity or level of something, and
- may fluctuate or oscillate

**Step Six: Identify relationships between factors (ie draw CDs)**

Now you are ready to start drawing the CD. But remember you need to keep it as simple as possible without being simplistic. Keep in mind the problem or focal issue you are seeking to gain insight into.

On a piece of flip chart, draw pairs of relationships between what you believe might be key factors. Sometimes it is useful to start with physical factors first (\$, people, things).

As mentioned earlier CDs should not try to model the whole of a situation, only model enough of the situation to reflect the problem and help resolve it. From here on I’m going to take a very simple situation (more more simple that would normally need a causal diagram) to illustrate the activities needed and the diagramming conventions.

So let’s assume that you are a chicken breeder and having terrible trouble keeping a consistent supply of chickens to meet demand. You have a hunch that foxes predating the chickens may have something to do with it, but want some idea what is going on and what you can do about it. [Granted this is hardly an issue needing something as powerful as a CD to resolve, but bear with this example]

So we have three factors, chickens, eggs and foxes. Notice that the organisation that purchases the eggs is not included. That’s because the 'purchase' factor isn’t regarded as relevant. They purchase all the eggs that the farmer wishes to sell and the farmer wishes to maximise that number. Nor is any factor relating to individual chicken’s productivity - we already believe that this is unlikely to contain a solution to our problem.

This is the point where the conventions of drawing a Multiple Cause Diagram and a Causal Loop Diagram start to differ. However, the process is pretty much the same. As you can see from the diagram at the beginning of this chapter, CLDs have more information because of the extra precision required when dealing with variables rather than events or states. To avoid confusing you too much, the following instructions focus on drawing a CLD.

Just recall that the factors involved in our diagram (foxes, chickens and eggs) will be expressed differently in the two diagrams.

For instance, in the multiple cause diagram, we would explore the relationship between
events and states. For instance:

Supply of fertile eggs
Availability of chickens for sale
Fox population

Whereas in a causal loop diagram we would be exploring the relationship between specific variables:
Number of eggs
Number of chickens
Number of female foxes

So now let's construct the causal diagram.

Consider the first two variables in that production system; the number of chickens and the number of eggs.

You would identify the pair relationship in the following way:

\[ \text{Number of Chickens} \rightarrow \text{Number of Eggs} \]

The convention is that the arrow demonstrates the direction of causality (strictly speaking the flow of resources). The chickens you sell are highly prized so you breed them yourself. And to breed them you need chickens to lay eggs. The more chickens you have, the more eggs you have. Fewer chickens, fewer eggs. Because both variables change in the same direction - they increase or decrease together, it is termed a 'positive' relationship and in a CLD you symbolise this relationship with a plus sign $\oplus$ or in another convention the letter S denoting that the variables change in the same direction.

In fact, there is another relationship here, because, as you will be familiar from the famous chicken/egg question, eggs create chickens.
So far, relatively simple. However, as stated earlier the farmer suspects that her chickens form a major part of the local fox population’s diet. She assumes that as the chicken population increases the population of foxes could increase also.

So that’s another ‘positive’ - same direction - relationship:

On the other hand, the more foxes there are then more chickens will be eaten, so the number of chickens reduce. This is show by a negative sign ‘−’, or in some conventions a D (standing for Different)

So now we have to put these variables together.

Let’s start with the two relationships between eggs and chickens.

Here is how they would be expressed using CLD conventions

Notice the much bigger + sign. This denotes what is known as a positive feedback loop;
more chickens, more eggs, more eggs more chickens. Indeed, if there were no constraints to this cycle you would end up with infinite chickens and eggs.

Now let's do the same with the chicken/fox relationship.

This has a big - sign and is known as a balancing loop. That's because the two relationships combined work in opposite directions to each other. An increase in chickens would lead to an increase in foxes which would lead to a decrease in chickens which would lead to a decrease in foxes which would lead to an increase in chickens ... and so on. If several 'buts' have just popped into your head, then just hold them there for a minute.

Put these two loops together.

Having done that the farmer also got an insight that foxes really like eating eggs as well as chickens. She assumed that while this may significantly affect the number of eggs and hence future chickens, it wasn’t a major part of the fox diet so would be unlikely to affect the population of foxes. So she added only one more relationship. If you look carefully that adds a second balancing loop between foxes and eggs via chickens. Hence the circle with a minus sign.
But there is one more convention in Causal Loop Diagrams; relative delay. The various relationships do not proceed at the same speed. Eggs become fertile chickens much faster than foxes starve. Thus that relationship has a 'delay'. This is indicated by two parallel lines on the slower relationship. Clearly, the decision to identify a particular relationship as ‘slow’ is a relative one, and should not be used unless you suspect that the impact of this feature of the relationship between the variables is important enough to affect your overall conclusions. In this case the farmer judged it was. So the final diagram looks like this:

And by comparison this is how a Multiple Cause Diagram might illustrate the same thing.

Notice how much more specific the Causal Loop Diagram is. The factors in the MCD could be represented by many different variables (e.g., the availability of eggs could include variables such as size, brownness, timeliness, freshness), but the farmer chose the actual
number of fertile eggs because that was the most appropriate to the issue.

However, in both cases, even with only three variables you can see how complex things can become and how easy it can be to get completely lost in what is going on. Too many variables and you have absolutely no way of working out what might be going on. This is why selecting a few key variables and being clear about the boundaries becomes clear.

**Step Seven – Identify, categorise and analyse important loops**

Although a diagram is a simple representation of the problem situation, it still has to reflect that situation. In validating the diagram, ask yourself whether the behaviour described in the narratives reflect what you actually see over the time period you selected. If not, then maybe you need to look again at your diagram. If yes, then you can be reassured that the leverage points you identified may well be real points of intervention.

So how can you begin to do that. Well experienced readers of CD, who can spot well known patterns can gain deep insights. But you are just starting out, so here are some simple things you can do that will give you some initial ideas.

One of the first things you need to do is to locate your reinforcing loops and balancing loops. Take a look at the diagram below:

![Diagram of loops](image)

How many loops do you think are represented? [How many circles can you make by going through a variable only once?]

Some people find it useful to name the loops. The 'generating interest' loop, or the 'marketing beer' loop. Keep the names focused and specific. A 'saving the world' loop is not especially useful even if the ambition is laudable. You might even find the discussion about what the loop can be called a valuable and insightful task since it will expose different people's perspectives.

Having done that, identify which ones are 'balancing' loops and which ones are 'reinforcing' loops. [Hint: balancing loops will have an odd number of negative (O) directions, reinforcing loops will have zero or an even number of negative (O) directions, because an even number of 'opposites' cancel each other out]. That’s how I worked out that the
fox/egg relationship was a balancing loop; while it had two positives crucially it had one negative.

The illustration above has four loops in total – two balancing and two reinforcing.

Reinforcing :  A – B – C - A, A – D – E – B – C - A


If one of the purposes of using CLD is to approximate to reality then now is the time to compare the diagram you have with the reality. If it is to gain insights on perspectives then use the following steps to generate discussion.

So, if in real life B behaves something like this (with B being the x axis and time being the y axis):

Then B is part of a very powerful reinforcing (ie positive) feedback loop somewhere.

If you have a pattern like this then B is part of a pretty strong balancing loop somewhere.

The left hand pattern indicates that there is a delay somewhere in the balancing loop that causes the pattern to oscillate before reaching a balance, the right hand pattern indicates that the dynamics are more or less equal.

But you might just get a much more complicated and unstable pattern. That’s particularly likely because B is part of four loops. Given that B is part of four loops, you might move to G (part of only one balancing loop) or A (part of a balancing loop and a reinforcing loop) and
explore how they behave in real life.

Alternatively you could consult what is known as ‘system archetypes’. These are a collection of common patterns, often with descriptive names like ‘shifting goals’, ‘success to the successful’ and ‘tragedy of the commons’ that can provide further cues. An internet search on ‘system archetypes’ will generate many references.\(^\text{14}\)

Once you feel you have captured the key dynamics of the loops, it's time to tell yourselves a story. Start at one of the variables and walk yourselves through the diagram and while doing so, tell yourselves the story or create a narrative of what you are observing. You can do this as an individual, group or collective process and then compare and contrast the stories. Perspectives are important – each of you may see the same thing, but explain it in different ways. Do some explanations make more sense that others? Are any of the stories telling you something you already know, if so maybe add some things that are uncertain. Does the story make sense?

If at some stage you feel that the story can be enhanced, or you could gain deeper insights by introducing some extra variables. For instance, in our chicken breeder example the farmer may alter the proportion of breeding stock to selling stock according to the number of number of chickens - thus adding a variable in between ‘eggs’ and ‘chickens’. But be very careful. Remember that the more things you add the harder it is to gain insights. Take this for example. It was developed specifically to demonstrate that you cannot tell insightful stories if you include too many variables.

\textit{An important caveat}

The critical thing to remember (and a common mistake make when analysing CLDs) is that you cannot \textit{predict} how G will behave, because you do not know the relative strengths or the timings of each relationship. But you can get overall clues about how G is likely to behave and whether it is a major point of leverage.

\textbf{Step Seven : Identify possible leverage points for intervention}

Once you have gained a good understanding of your diagram, and depending on your purposes for constructing a CLD, to may want to identify some leverage points that address the particular problem for which you drew the CLD in the first place.

You may find these questions useful to pose of your diagram and you story:

\textbf{SCALE}

What conclusions can you draw from the context of the CD? What was included in the CD

\(^{14}\) https://en.wikipedia.org/wiki/System_archetype
and what has been excluded? What might be any differences if you expanded or reduced the scale and scope of the CD?

SOLUTIONS
What levers points did you identify. What kinds of solutions do these leverage points suggest? What assumptions are you making about those leverage points?

DATA
What kind of data did you use to construct the CD? Who did it come from? What data was privileged and what data was excluded or marginalised. What might be the implications of this for your conclusions?

VARIABLES
What variables were excluded from the CD? What was the rational and how appropriate was that. What assumptions were made about the relative 'power' of the relationships between variables? How confident are you that the assumptions were correct? What consequence for your conclusions is there if those assumptions were incorrect?

PURPOSE
What thoughts do you now have about the purpose of the CD? What have you learned? What have you confirmed?

FRAMING
Was the framing appropriate? Earlier in this chapter I stressed that initial framing of causal mapping was important. Different perspectives on the issues, create different understanding of the dynamics. Below is a classic case that show how two different CLDs of the same problem situation but with different framings lead to fundamentally different diagrams (and of course different potential solutions) The situation of interest was how to bring about sustainable consumption within social and economic limits in Hungary. One diagram was developed by a group of consumer 'experts' and another by a panel of 'non-experts' drawn from a local community. Notice that even the leverage points are different. The red circles are variables with high leverage potential.15

The 'expert' framing focused on the lack of sustainable consumption at the national level:

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The 'non-expert' framing was about existing strong communities of sustainable consumption at the local level:

HAS IT HELPED GAIN INSIGHTS INTO HOW TO ADDRESS THE PROBLEM?

And finally ask yourself whether the story the diagram tells enables you to spot where you could intervene to resolve the problem. If you don’t gain any insights on sites for leverage then you have not drawn an appropriate diagram.

Remember the golden rule.

Model the problem not the situation. Here’s what happens when you are tempted to model the situation and not the problem. I challenge you to find any specific insights that could help you identify leverage points. Too many problems are represented here.16

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16 In all fairness to this diagram, it was drawn to demonstrate that the situation in Afghanistan was almost impossible to understand or address.
A CODA: CAUSAL LOOP DIAGRAMS AND SYSTEM DYNAMIC MODELLING

There is a lot of confusion about the nature and purpose of Causal Loop Diagrams and diagrams that illustrate System Dynamic modelling. Many people often assume they are the same thing, or that CLDs are a precursor to system dynamic modelling. In fact, it’s not possible to construct a system dynamics model directly from a causal loop diagram since modelling requires additional information and sets of assumptions. [Which is not to say that you cannot use a CLD to inform the development of a system dynamic model]

There are two very important differences.

1. Causal loop diagrams are predominantly focused on the relationship between variables in a situation; how movements in one variable affect an adjacent variable. In contrast, system dynamic modelling is concerned with how 'stocks' (ie resources such as people, things, knowledge) are affected as they 'flow' through a system.
2. CLDs are 'diagrams'; illustrations that guide thinking. System dynamic models can be expressed in diagrammatic form, but the purpose is to model the situation dynamically, generally via computer simulations. There is a decade old debate within the system dynamic community how useful CLDs are in generating system dynamic models, and the visual worth of just using the 'stock' and 'flow' diagrams beyond informing the development of the computer simulation. Given that this workbook focuses on using and interpreting diagrams, I have not included system dynamic modeling.