BURGE
HUGHES
WALSH

The Systems Thinking Tool Box

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".. bump, bump, bump, on the back of his head. It is, as far as he knows the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment and think of it."

Winnie the Pooh - A. A. Milne

Multiple Cause Diagram (MCD) Alias Casual Loop Diagram

What is it and what does it do?

A Multiple Cause Diagram can help an individual or team understand and predict the emergent behaviour of a system. It captures how changes in one or more system elements can have consequential effects on other system elements leading ultimately to understanding a system's behaviour. It can be extremely useful in understanding complex situations in order to:

- scope a system of interest.
- analyse a system to:
  - explain observed behaviour
  - predict future behaviour.

Multiple Cause Diagrams are similar in nature to Cause and Effect Diagrams (sometimes called 'Fishbone Diagrams' or 'Ishikawa Diagrams') but allow more freedom to represent the various levels of contribution to the overall matter of interest. Figure 1 shows an example Multiple Cause Diagram that explains some of the key principles in lean systems thinking.

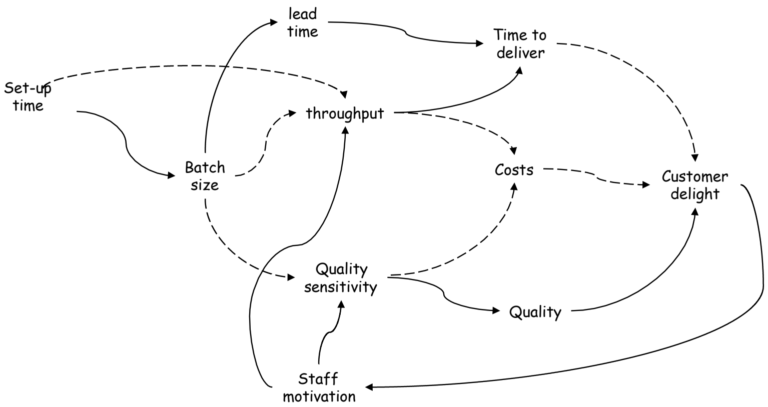

Figure 1: A Multiple Cause Diagram showing some of the principles of lean systems thinking

In Figure 1, the words are the system elements that in this particular example are parameters that increase or decrease. Hence, for example, “Customer delight” can go up or down. The arrows between the elements indicate causal paths, showing the direction of the causality. A full line indicates that an increase in the preceding element will cause an increase in the following element (and vice versa). For example, if the “batch size” increases then the “lead time” will increase. This is capturing reinforcing behaviour (positive feedback).

The dotted lines indicate that an **increase** in the preceding element will cause a **decrease** in the following element (and vice versa). For example, if “batch size” increases “throughput” will decrease. This is capturing balancing behaviour (negative feedback)

The power of a Multiple Cause Diagram, like that shown in Figure 1, lies in its ability to capture, in simple terms, complex situations. The relationships between the elements in Figure 1 are not linear. The diagram also can show where actions will have the most and least effect. If we, for example, examine Figure 1 a desirable outcome would be an increase in customer delight that requires:

- A decrease in the “time to deliver”
- A decrease in the “costs”
- An increase in the “quality”.

The arrows can now be followed back to identify their causes and therefore appropriate actions. We can see from Figure 1 that this will ultimately lead to the recognition that “set-up time” is a key driver since it allows the reduction in the “batch size” etc.

Why do it?

Multiple Cause Diagrams can be used to:

- understand a situation
- solve a problem or issue.

By capturing the behaviour of the system of interest in terms of the causal relationships between the contributory factors. A Multiple Cause Diagram provides a simple method to capturing those causal relationships. A carefully constructed Multiple Cause Diagram can capture the presence of feedback paths in the system and in particular, the occurrence of balancing or reinforcing loops that drive the system’s behaviour. In essence, it is a qualitative model of a system in terms of the dynamic elements within that system. These models can be used through “what-if” experiments to explain observed behaviour and also to predict future behaviour when one or more of the system elements are changed.

Where and when to use it?

A Multiple Cause Diagram is particularly useful:

- Whenever there is a need to investigate and understand a complex situation. It can be particularly useful to untangle the thinking of several experts who have conflicting explanations to some observed behaviour. Typically each expert has part of the overall story and a Multiple Cause Diagram can be a very powerful tool to coalesce these into a single agreed understanding.
- Where there is a need to communicate understanding of a complex situation to explain behaviour and demonstrate the rationale behind a particular course of action. Systems very rarely display purely linear cause and effect but contain complex multiple causal pathways. Humans, on the other hand, tend to treat cause and effect as linear. The Multiple Cause Diagram can be very useful in removing this linear view and demonstrating in a simple format a truer picture of the causal links.
- In identifying potential actions when problem solving. Most system behaviour is a complex causal chain that displays observable intermediate "symptoms". These symptoms are often treated as the "root cause" and drive a corrective action that is sub-optimal. Only through a full understanding of the causality can the true "root cause" be identified.
- To help in decision making by testing out alternate course of action and assessing their impact on the system behaviour. Evolved or self-organizing systems, following a change often display unexpected, and potentially undesirable behaviour. These behaviors are a consequence of complex and subtle feedback loops that existing within the system. Unless these are identified and understood then poor decision-making will follow.

Who does it?

An individual or team can create multiple Cause Diagrams. However, it is at its most powerful when used by a team. This is primarily because most humans will have their perspective on a situation that is likely to be only part of the whole understanding. It is therefore important that the team comprises members who have knowledge about the situation or problem. There is, however, no reason why this core team cannot be supplemented with additional members who have limited experience of the situation or problem. This can help ensure that "obvious" or "basic" information is not excluded; experts often mentally "self-censor" ideas non-experts do not.

There is great benefit in terms of quality of output and time efficiency if people, who are familiar with to tool and its use, facilitate the sessions.

How to do it?

Constructing a Multiple Cause Diagram is not an easy task. It can take several hours and several attempts to get a satisfactory diagram. It is important to remember that a Multiple Cause Diagram is model of a situation – and all models are wrong! In other words, we are constructing this model of reality to help us accomplish something and we must always keep the purpose of why we are constructing the diagram in mind. The construction process is highly iterative and the final diagram is likely to emerge after many hours of hard, and frustrating work. There are two approaches that can be used in the construction of a Multiple Cause Diagram:

- Indirect approach
- Direct approach

It is also important to understand what we are fundamentally doing when constructing a Multiple Cause Diagram: we are generating information about the system or situation of interest and organizing that information.

Indirect Approach to Constructing a Multiple Cause Diagram

The indirect approach recognises that there are two distinct activities involved in putting together a Multiple Cause Diagram. The first is concerned with identifying the various elements that will make up the diagram. The second is identifying, capturing and testing the causal relationships between the elements

Stage 1: Generate information about the system or situation of interest

There are various ways of generating information about a system or situation of interest that include the use of tools like Spray Diagrams and Affinity Diagrams. Both of these tools capture the thoughts and associated ideas from a team (or individual) in an organized form. It is the fact that there is some structure in the output of the tool that make either suitable as starting point for generating a Multiple Cause Diagram. On a personal note I always use the Spray Diagram if I know the desired outcome is a Multiple Cause Diagram.

Figure 2 shows a partial Spray Diagram [1] that was generated by a small team to explore the consequences of a "rise in the price of crude oil". It is typical of the output that can be produced within 15 or so minutes. It comprises elements of the situation that logically related (potentially casual) and others that are not.

In using a Spray Diagram to help construct a Multiple Cause Diagram it is important to make sure the "central" situation or problem is clearly defined. It is also important to note that the Spray Diagram is a "means to an end" and it itself should not be pursued for completeness. Its purpose is to provide a source of information for the construction of a Multiple Caused Diagram.

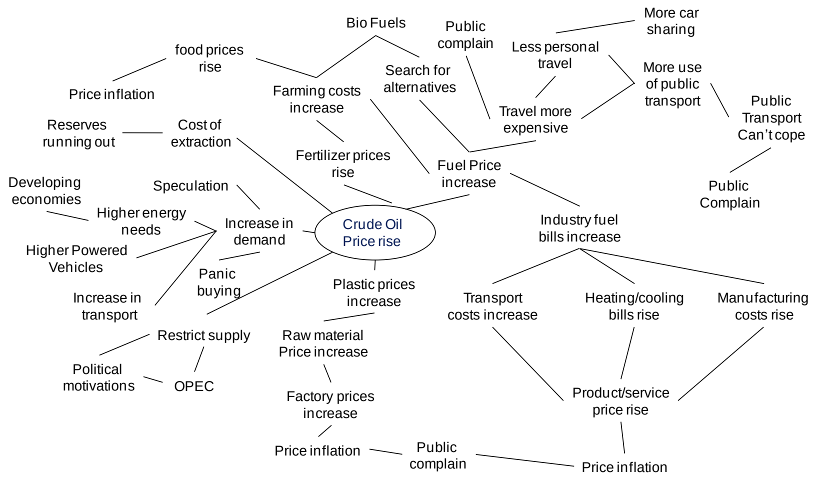

Figure 2: Spray Diagram of the factors that contribute to "Crude Oil price rise"

Stage 2: Identify, capture and test the causal relationship between elements of the system of interest

Stage 2 is where we put together the Multiple Cause Diagram. The starting point is to define the focus of the diagram. This could be the "central" situation or problem from the Spray Diagram. However, a common and often useful approach is to rewrite this as a neutral measure or parameter that can either increase or decrease. For example, returning to the Spray Diagram in Figure 2 where the central situation is "cruel oil price rise" – this can be written as the neutral parameter "Crude Oil Price". This particular metric can increase and decrease. Neutralising the focus encourages us to be more holistic by thinking about "both sides of the fence". We can identify factors that will contribute to both an increase in crude oil price and also factors that will lead to a decrease. Furthermore, it is also possible to treat the focus itself as a factor that causes other parameters to change. That is, what would be the consequence of a crude oil price change?

The second step in constructing a Multiple Cause Diagram is to review the Spray Diagram for <u>relevant</u> factors that cause a change in the focal parameter. It is also possible to generate other factors that cause a change in the focal parameter at any point. Indeed, as the logic of the diagram becomes clearer, it is highly likely that other factors not on the Spray Diagram will emerge.

Figure 3 shows the first level of the Multiple Cause Diagram with four primary factors identified. Note on the Multiple Cause Diagram an arrow is used to indicate the casual path. It is a change in the "Cost of supply" that will **cause** a change in the "Crude oil price".

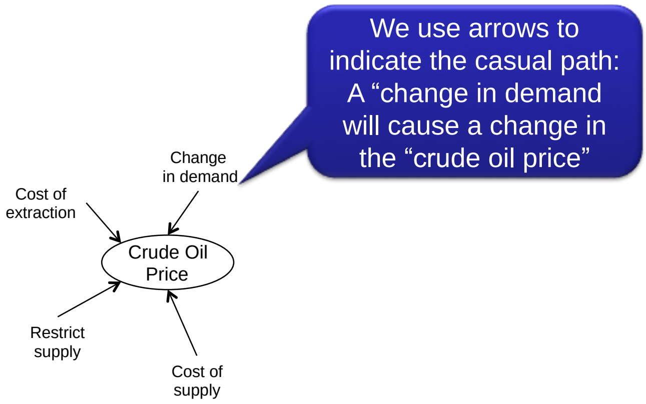

Figure 3: The primary factors contributing to a change in the "Crude oil price"

It can also help to grow understanding by treating the focal parameter as a cause itself as shown in Figure 4.

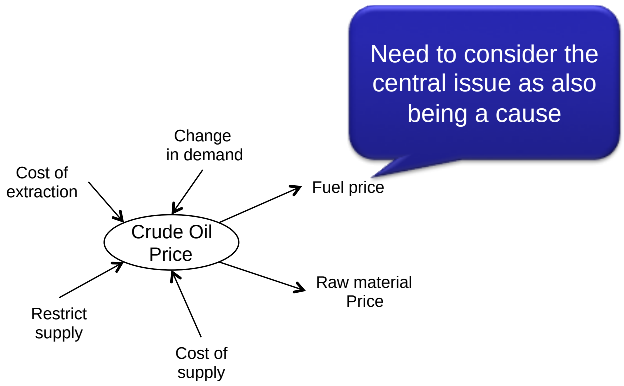

Figure 4: "Crude oil price" as a cause

Once we have exhausted the primary level causes and effects, each is taken in turn and for each cause look for their causes to develop an understanding of causal chains in terms of the primary, secondary and tertiary drivers and their contributors. Again the Spray Diagram is source of information and ideas. For example, what are the causes of a "change in demand"? Figure 5 shows a possible outcome.

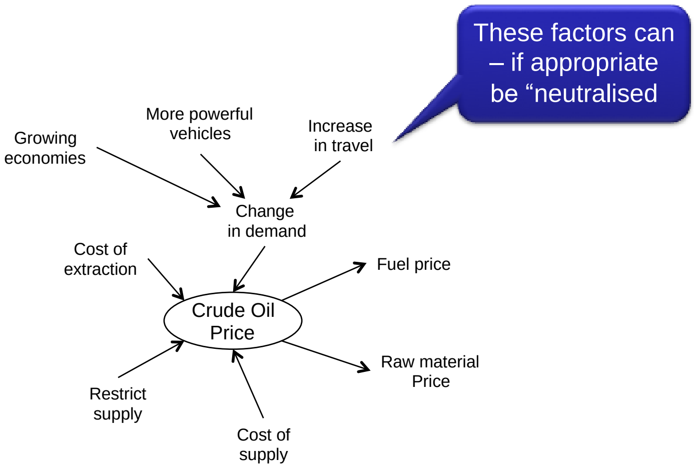

Figure 5: Secondary factors contributing to a "Change in demand"

Note that in Figure 5, several of the secondary factors specify a change of direction. It is possible, and desirable, to neutralise these as shown in Figure 6. In this case, the act of neutrialisation leads to the uncovering of more contributory factors as shown.

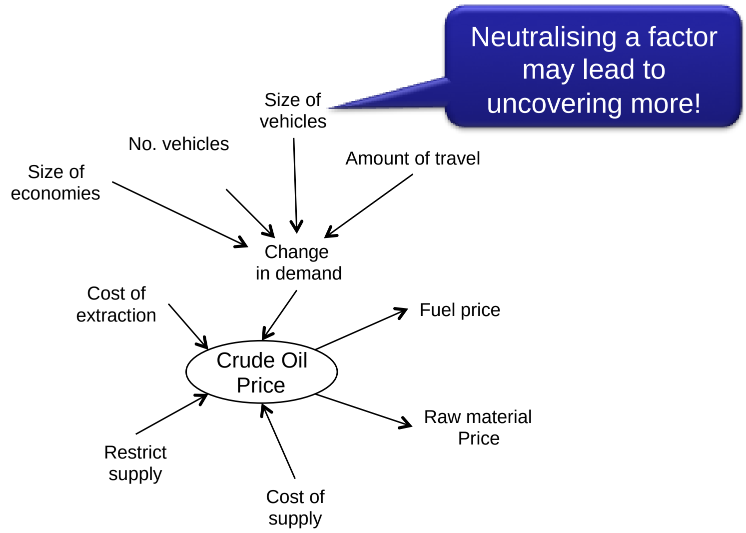

Figure 6: Neutralisation of Contributory Factors

In looking for the generation of secondary contributions, it is also worthwhile considering secondary effects as shown in Figure 7.

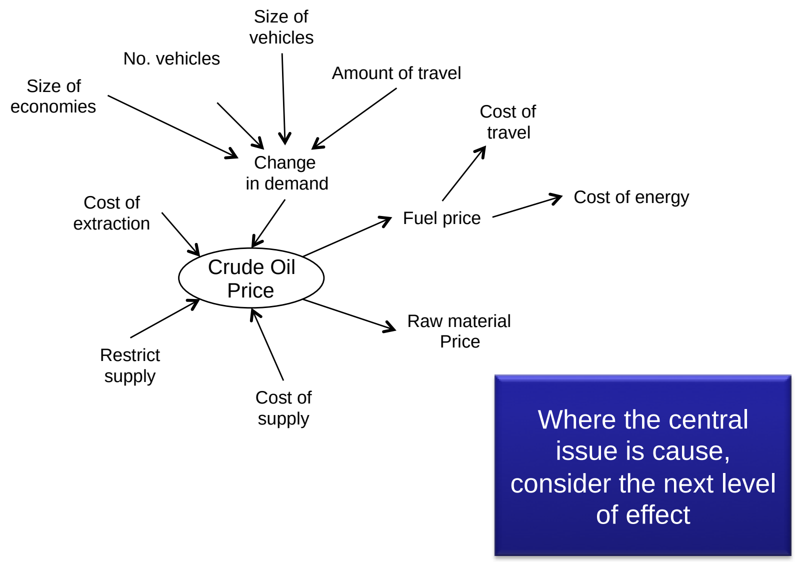

Figure 7: Generation of Secondary Effects

What makes a Multiple Cause Diagram more powerful than Cause and Effect Diagrams is the ability to capture non-linear causal chains. Whereas Cause and Effect Diagrams can only capture A causes B causes C, Multiple cause diagrams can capture much more complex and subtle causal relationships. Figure 8 shows another iteration of the “Crude oil price” model.

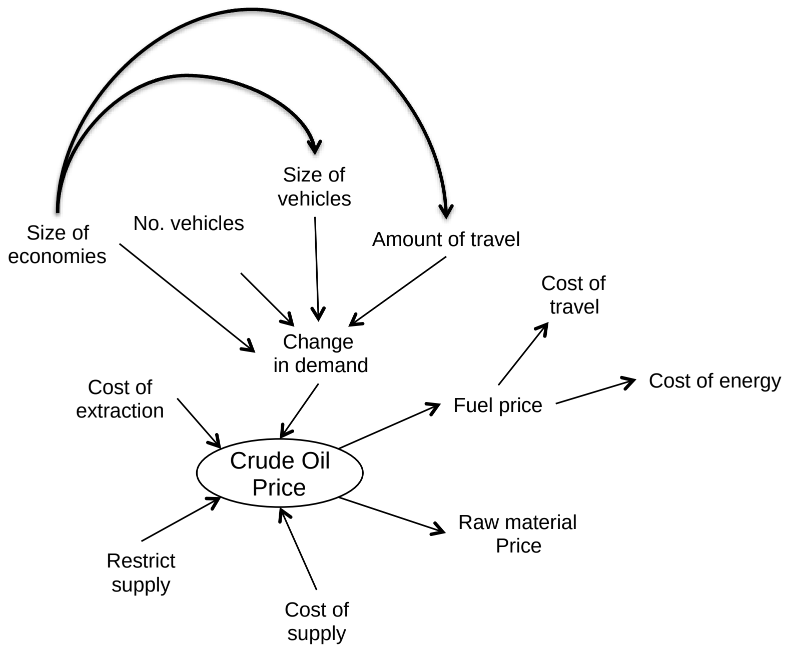

Figure 8: Capture of Causal loops

Although not complete, Figure 8 shows how it is possible to capture complex relationships between the various factors. How the "Size of economies" affects other factors such as "Size of vehicles" and "Amount of travel", all of which then affect the "Change in demand". Such models can be further refined by capturing the very nature of the causality as:

- Reinforcing Behaviour: a +ve change in the current component will cause a +ve change in the following component
- Balancing Behaviour: a +ve change in the current component will cause a -ve change in the following component.

For example an increase in the demand for oil will cause a crude oil price rise: reinforcing feedback is present. Whereas a restriction in supply will also cause the crude oil price to rise. In this case the relationship is of balancing feedback. This ability to show on the diagrams the direction of change makes Multiple Cause Diagrams a very powerful Systems Thinking tool. The incomplete example given in Figure 8 is technically an unsigned Multiple Cause Diagram, while that show in Figure 1 is an example of a signed Multiple Cause Diagram. Figure 1 is also known as a Causal Loop Diagram, since it is possible to identify complete reinforcing or balancing loops within systems.

The generation of a signed Multiple Cause Diagram often requires careful consideration of the factors or parameters in the model. These need to be defined in a way such that their increase or decrease leads to a clear understanding. A classic example comes the work of Keynes and the world's economies where he developed a very simple yet powerful model. This is repeated in Figure 9.

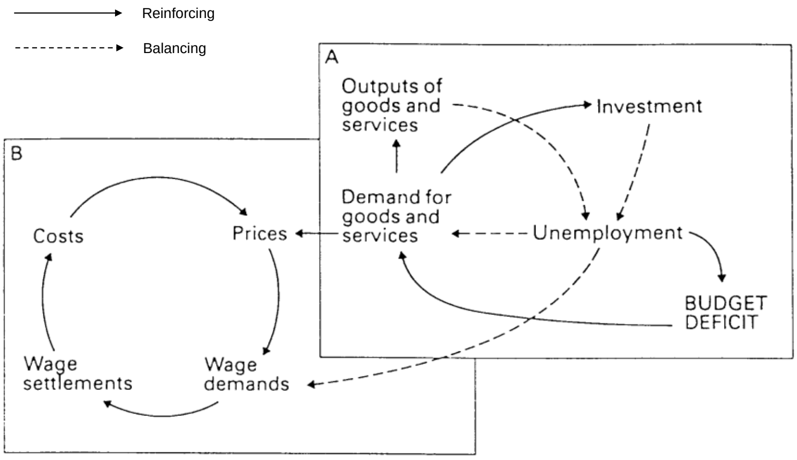

Figure 9: Keynes' economic model

In Figure 9 we can see with sub-system B a classic reinforcing or positive feedback loop that models wage driven inflation. Sub-system A on the other hand has several balancing loops that in turn impact upon the inflation spiral. It was this understanding of non-linear causality that allowed Keynes to propose the necessity of Governments to interfere with an economy through investment in infrastructure projects.

Humans often fail to understand system behaviour because they look for linear cause and effect.

Direct Approach to Constructing a Multiple Cause Diagram

The direct approach to constructing a Multiple Cause Diagram does not bother with the initial generation of ideas, but attempts to develop model through successive iterations. To a large extent it is no different to the second step of the indirect approach the various elements that will make up the diagram are identified *ab initio*. What is important to note is that it can take several iterations to arrive at a satisfactory diagram, especially if there is insufficient knowledge in the team or individual. Notwithstanding this, many people prefer the direct approach since it appears wasteful to generate information and ideas via a Spray Diagram (and other means) only not use it in subsequent Multiple Cause Diagram.

Figure 10 shows the starting point for a direct Multiple Cause Diagram for "House Price". This could have been done for "House Price Increase" but it was decided to start with a neutral focus. The question was then asked:

> What directly affects house price?

As potential cause parameters were generated they were tested. That is, will a change in this parameter lead directly to a change in house price? It is important when doing a direct Multiple Cause Diagram to be clear on the full meaning of the captured parameters. For instance in this case by house it was decide to be broader than just the actual asking price but to look at all potential costs involved in purchasing a new home. Hence Figure 10 includes items such as the "conveyancing cost", "estate agents fees" etc.

[Burge Hughes Walsh logo]

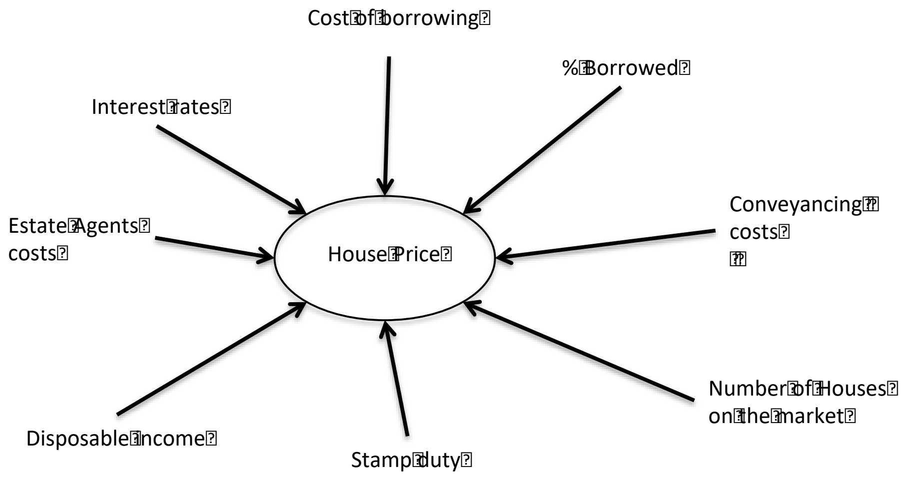

Figure 10: Focus and first pass causes

It is important to recognise, even at this early stage of constructing a Multiple Cause Diagram that it is going to be iterative and attempting to be complete at this stage can be counterproductive. The fact we may have missed a causal factor, or captured one that is not a direct cause will be corrected on successive iterations. Moreover, wherever possible it is worthwhile seeking some form of validation usually via review.

Having completed the first pass diagram, each of the first-order causal factors should be investigated to identify and capture their causes. At this stage we should also look for multiple causal paths. That is where one causal factor contributes to two or more causal factors. Figure 11 shows the House Price diagram following the inclusion of second order causal factors. It is at this point in constructing a Multiple Cause Diagram that we start to identify and capture the multiple cause paths that typical of real-world situations. For example there is an arrow between “interest rates” and Estate Agent Costs”. The implication here that Estate Agents may vary their fees when mortgage providers vary their interest rates. This may not be a very strong link, but it could apply. The diagram also has the causal element “Competitor rate” which points an arrow towards “interest rates”. The thought process captured here is that mortgage providers will adjust their interest rates relative to their competitors rates. There is also an arrow from “Competitor rate” to “%Borrowed”. Captured here is the thought that what the competition does may affect what % of the house asking price a particular mortgage provider will offer.

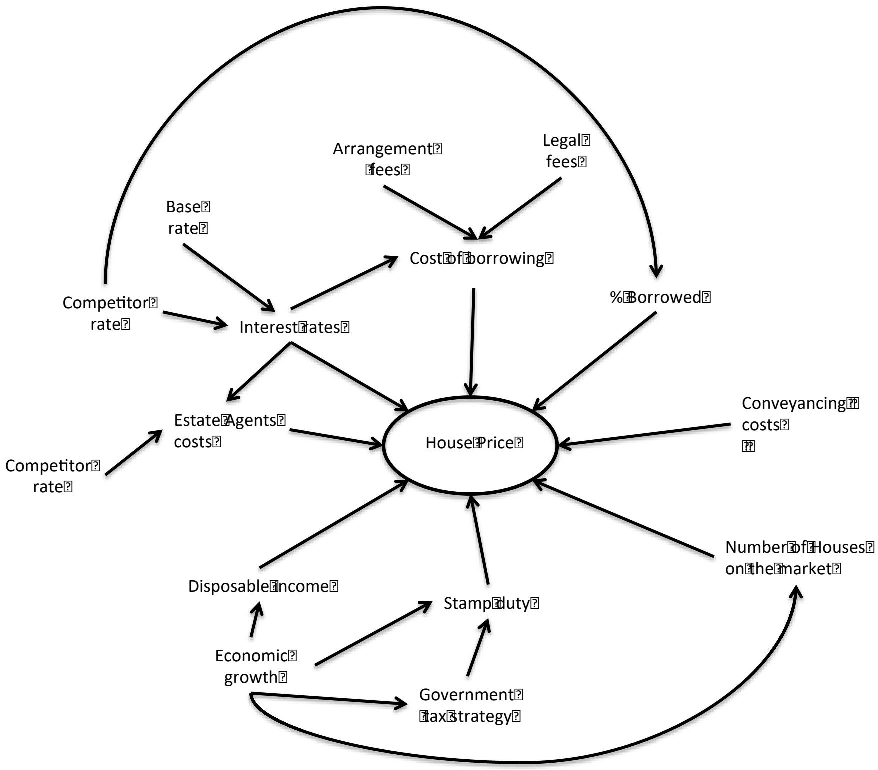

Figure 11: Second pass causes

Obviously, following the second pass cause identification and capture, the third pass begins. However, as we move further away from the focus of the diagram the less linear the cause and effect chains become. Identifying and capturing these multiple causes is the name of game.

What Goes Wrong: The limitations of Multiple Cause Diagrams

Multiple Cause Diagrams, especially signed versions, is simple but incredibly powerful way of representing complex causal chains that lead to situations of interest. It does however have limitations and can be difficult to construct. Given below, are some of the issues with its use are together with advice on avoiding, and recovering from, the problem

- Individuals dominating the grouping resulting in their personal view being captured as representative of the whole group. If the group is hierarchical consider using a facilitator or limit the number people involved in the grouping.
- Not recognising that iteration is part of the process and rushing to finish resulting in an incomplete and overly linear diagram. Consider:
    - “parking” the diagram and reviewing at a later date

  - spending time to "test" the casual chains. A very useful technique here is the "5-Whys". 5-Whys is a technique where the question "why?" is repeated asked of the previous answer. The technique was originally developed by the Toyota Motor Corporation to explore the cause-and-effect relationships underlying a particular problem. The goal of the technique is to determine the root cause of a problem. Experience shows that the identification of the root cause occurs after 5 repetitions of "why?"
  - reviewing the diagram with another group of "experts".
- Don't spend the time:
  - Exploring and testing views of causality
  - Neutralising elements.

  Explain time allocation at the beginning of the session and allocate sufficient time for testing out the resultant diagram.

Success Criteria

The following represents a set of criteria that have been found to be useful when constructing a Multiple Cause Diagram.

- Team size between five and eight.
- Team constitution has expertise and experience in a wide range of solution technologies.
- Use an experienced independent facilitator.
- Do review the first draft of the Multiple Cause Diagram to test the "logic" of the causal chains (5-Whys).
- Take time to neutralise elements – especially if the aim is a signed Multiple Cause Diagram.
- Plan for one-half to one-day's effort.

Illustrative Example

The following shows a real example of a Multiple Cause Diagram. Early in her primary school career my daughter was diagnosed with dyslexia and dyscalculia. To some extent the diagnosis was a relief because it explained her mounting difficulties with mathematics, especially the “times-table”. But as a dyslexic myself, I have unpleasant recollections of my early schooling in consequence. I also recognised that the problem is not simple and has multiple interacting facets that my wife and I as parents needed to be aware and ways in which we could support her. To this end I constructed the Multiple Cause Diagram shown in Figure 12.

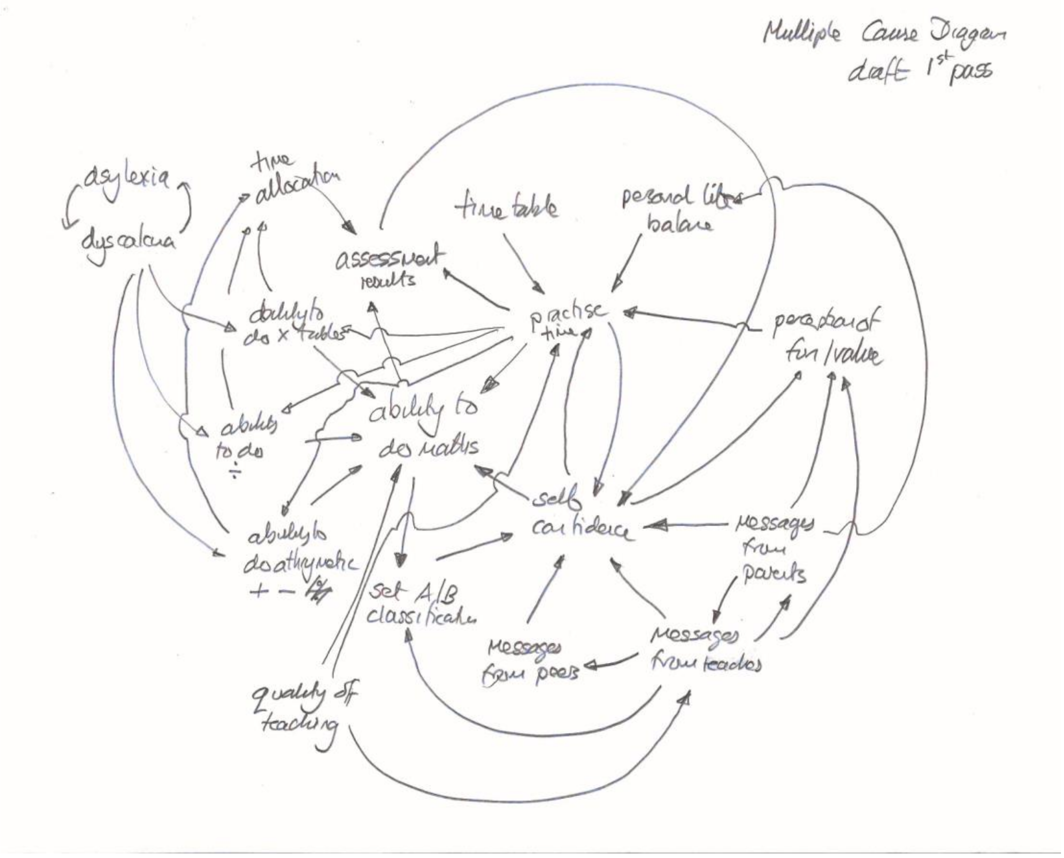

Figure 12: Example Multiple Cause Diagram for Dyslexia/Dyscalculia

In constructing Figure 12, my initial view was to use “Dyslexia/ Dyscalculia” as the focal point. However, on reflection my concern was really about helping my daughter improve her “ability to do maths” and thereby this was selected a starting point. I then thought about the factors that could affect this, drawing upon my own experience, logic and her personal circumstance. This identified a number of factors including:

Practise time
Ability to do x-tables
Ability to do division
Ability to do + -
Quality of teaching
Self-confidence

I also decided to treat “ability to do maths” as a cause and identify consequent effects:

Set A/B classification
Assessment results

I included these because I recognised that “self-confidence” played an important role. Primarily from my own experience but also the behaviour of my daughter. The Diagram started to get interesting when the second and tertiary factors where added and the causal chains began to appear.

Figure 12 is not complete, but it is useful! As parents, several things emerged that we had not considered. Firstly how important it is for us to communicate with our daughter’s teachers. To understand the approaches and messages they were giving so we could support and reinforce them. Also the “perception of fun/value” is something we as parents can contribute to. We constantly strive to find real world applications of mathematics to make it “real” and relevant. Another key factor we identified is “practise time”. Some people are mathematically gifted, most are not but it is a skill that can be improved through practise. What became clear is our need to help her plan her time.

In summary, Figure 12, has helped us understand a real complex situation.

Bibliography

Actually none – The Open University has a very good website that includes descriptions of Multiple Cause Diagrams and examples. The other source for which there are books (or references in books) are Causal Loop Diagrams. These are effectively signed Multiple Cause Diagrams and the references include:

Anderson V. and Johnson L. Systems Thinking Basics, 1997, Pegasus Communications, ISBN 1-883823-12-9

Not a bad book at all – easy to read and not too long. The focus is on analysis using causal loops and feedback.

Sterman J.D. Business Dynamics: Systems Thinking and Modelling for a Complex World, 2000, McGraw-Hill, ISBN 978-0-07-231135-8

If you really want to get into modelling business systems then this is the book. It's good, but heavy going.

References

[1] Burge S. "Spray Diagram" www.burgehugheswalsh.co.uk