Numeracy Nugget #5: Influence Factors Diagrams – How to Understand and Communicate Complex Issues

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Almost all of us consider ourselves above average in the ability to think clearly, or more precisely, to be able to think critically. We spend our days effortlessly second guessing and pointing out the obvious foibles and missed opportunities that others, ranging from Congress to the local dog catcher, commit and cause us suffering. The right answers seem to come to us effortlessly. The only time that a doubt fleetingly darkens our brow is when someone in our presence disagrees with our conclusions or beliefs. But we quickly dispense with the annoyance by either telling the interloper that the contending view is only their opinion with the implication that it should be weighted equally with about one hundred million other such varying opinions. Most of us are fully armored to repel any inconvenient facts.

In 1979 Herbert Simon - economist, deep intellect, and keen observer of life – was awarded the Nobel prize in economics for having demonstrated that reality is far from this common brand of self assessment. He introduced the world to the "principle of bounded rationality" and described the limits of human decision-making abilities with

> *The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problem whose solution is required for objectively rational behavior in the real world or even for a reasonable approximation to such objective rationality.*

Yet the only people who seem to appreciate this built-in human limitation come from the technical fields. They have gone to great lengths to develop a large collection of tools that augments their meager mental machinery. The response of the typical layman is 'if I can't understand it in 30 seconds, it must not be important', or worse 'damn rationality, my vote still counts as much as yours!'

But it doesn't have to be that way. There now exist straightforward methods from the various fields of systems technology that can greatly assist many people to (better) understand complex situations and the decisions connected with them. These methods may be used individually or in groups to formulate and communicate problems and situations ranging from a family's healthcare decisions to addressing a town's growth management concerns.

Learning new stuff is hard, and successful learners need to be motivated. Those who feel that the above view of how we approach critical thinking is a little brutal and too broadly applied need only attend any grass roots public gathering having to do with community affairs. Many of these meetings, especially those sponsored by some special interest group or local government body, include the presentation of much information and data that is news to a good fraction of the attendees. As people take their turn at the microphone seldom if ever does one hear the words, 'Well, I'll be damned! I didn't know *that* and I have to admit that it puts things into a new light. I'll have to go and puzzle on the matter and see if my long-held position can still stand up.'

What almost always happens at these gatherings is that over half the people don't know what the topic of discussion is and could not stay on it if it were pasted to their foreheads. All they focus on is that in a participative democracy they have a right to be heard regardless of what comes out of their mouth. And, of course, they are right. But then the rest of the folks have to sort through the debris of such diverse offerings for bits of relevance to the topic at hand.

One of the most illuminating ways for showing the relationship of the various factors that impact an issue is to draw a picture of it. A picture consisting of bubbles interconnected with some arrows showing the direction of what influences what. The bubbles represent relevant and labeled factors to which some notion of amount, intensity, or level can be attached indicating that such level can be influenced to go up and down. The picture we develop can be called an 'Influence Factors Diagram' and is really a causal model of what interests us. Most such IFDs include paths following the arrows that make complete loops. These show the feedbacks – the so-called virtuous (balancing) and vicious (reinforcing) cycles - that characterize the real world. But once drawn and displayed to a group gathered to discuss an issue, the IFD serves as a focus point to keep everyone on the topic and connected to the important parts of the problem. We'll summarize some of the benefits of using such IFDs later after learning how they work and how to draw them.

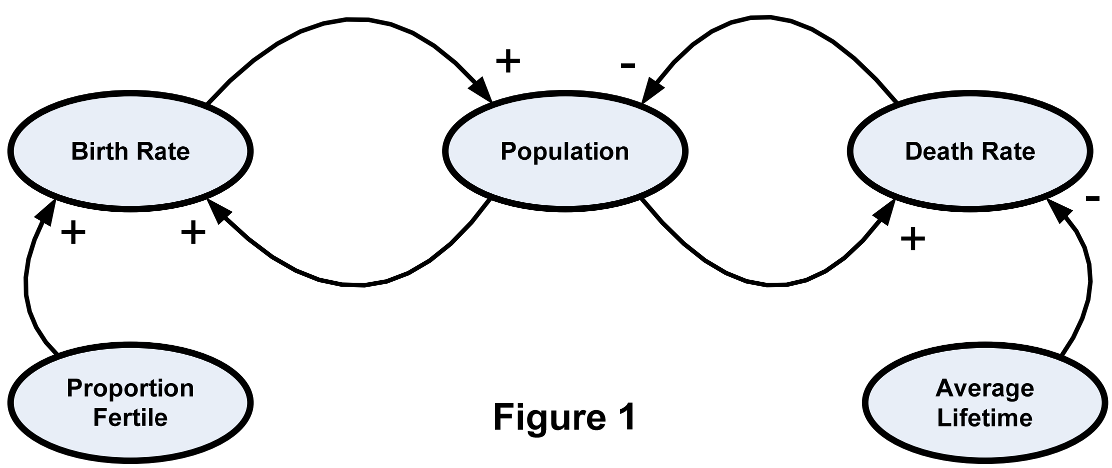

Figure 1

Let's start with a simple example from Sterman (2000)[1] that gets the idea across. In Figure 1 we consider the elementary dynamics of a population. The diagram consists of two cycles – one virtuous (balancing) and one vicious (reinforcing) - each is affected by an outside influence. Notice the little plus/minus signs by the arrowheads pointing to the influenced factor. These are called link polarities. A plus sign means that the influenced factor goes up/down as the influencing factor (at the arrow's tail) goes up/down. As you might guess, a minus sign denotes the opposite effect in which the influenced factor goes up/down as the influencing factor goes down/up. In the left (birth) loop we note that increasing the birthrate will increase the population. On the other hand, in the right (death) loop we see that an increasing death rate will reduce the population level and vice versa as indicated by the minus sign by the arrowhead from death rate to population. The careful reader at this point will have noticed that these plus/minus influence direction indicators really should include the proviso 'with the other influencing factors remaining unchanged' in the above meaning of the plus/minus signs.

It should now be clear how an IFD can capture and quickly communicate the dynamics of a real world situation comprised of interlinked causal factors. Before we finish this brief introduction, a word about those all important vicious and virtuous cycles is in order. Follow the arrows around any closed path or loop in an IFD, count the number of *minus* signs encountered. If this number is odd, you have identified a virtuous or balancing cycle. With zero or an even number of minus signs the cycle is vicious since the influences all reinforce each other around the feedback loop that can lead to a potential runaway situation. This is another of the many complex behaviors that IFDs quickly and clearly highlight when used to study and communicate practical issues in a group setting.

I will close this Nugget by leaving you to study a more realistic IFD from Sterman (see Figure 2 below). This IFD can be used as a tool to think about and discuss the impacts of road traffic in a community. Here we have omitted the bubble boundaries for the factors. This important IFD demonstrates how "reduced travel time and an expanded highway network increase the size of the region accessible from the center, which expands the population and leads to still more traffic." Everyone is aware of this historic effect in big cities such as Los Angeles, and yet too few are aware that it impacts smaller communities in the same way. We will dissect this IFD in a future Nugget, but with what you have learned here you should have little difficulty in going through the traffic IFD below.

Without such a more complete picture of the issue in mind, it is clear why most people will focus on a small part of the problem while passionately arguing the interrelation of two or three factors and taking into consideration no feedbacks at all. The absence of such common understanding goes a long way to underpin the comedy and/or farce of most 'workshops' where the community is invited to gather and provide input to the powers that be. It was ever thus, but it doesn't have to be.

[1] I strongly recommend studying *Business Dynamics – Systems Thinking and Modeling for a Complex World* by John Sterman of MIT. It is well written for the non-technical, intelligent reader who is involved with real world issues and planning. Using lots of figures and actual case studies, the book gently opens up vast new horizons in critical thinking and with the least possible pain endows skills to understand/solve complex problems in policy and planning.

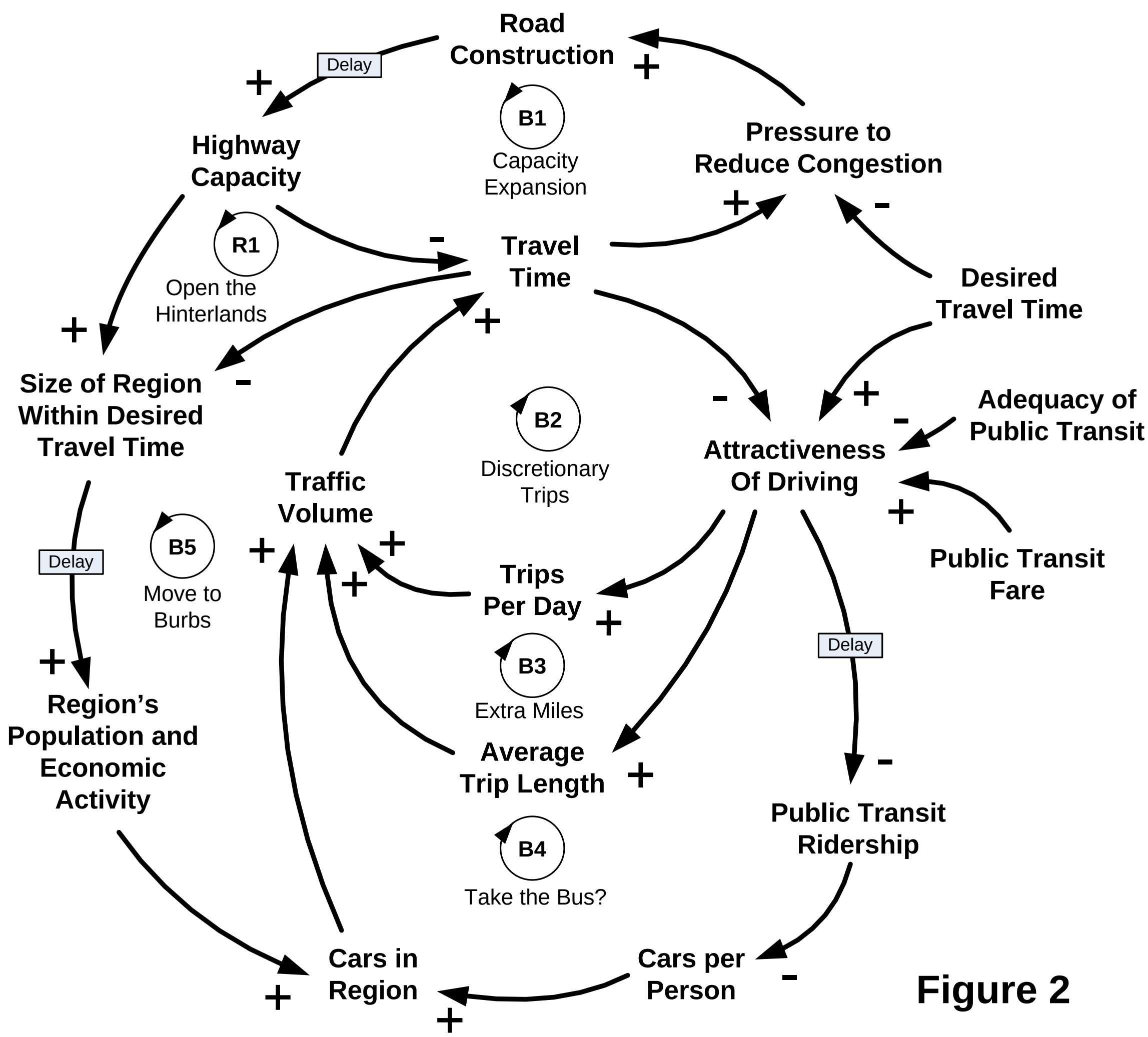
Road
Construction
Delay
Highway
Capacity
B1
Capacity
Expansion
Pressure to
Reduce Congestion
R1
Open the
Hinterlands
Travel
Time
Desired
Travel Time
Size of Region
Within Desired
Travel Time
B2
Discretionary
Trips
Attractiveness
Of Driving
Adequacy of
Public Transit
Traffic
Volume
Delay
B5
Move to
Burbs
Trips
Per Day
Public Transit
Fare
B3
Extra Miles
Delay
Region's
Population and
Economic
Activity
Average
Trip Length
Public Transit
Ridership
B4
Take the Bus?
Cars in
Region
Cars per
Person

Figure 2

Solution to the NN4 Problem: We first repeat this short problem. It is equally likely that a canvas sack contains either a red ball or a blue ball. Into this sack is dropped a red ball so that it now contains two balls. Later a random draw from the sack yields a red ball. What is the probability that the sack now contains one red ball?

This problem was first posed by Lewis Carroll, the mathematician who wrote *Alice in Wonderland*. The answer is 2/3 = 0.667. You get the answer by one of several methods. Here we describe the probabilistic contingency tree, a simple and powerful approach that comes in handy for structuring all kinds of problems in critical thinking. We can envision this branching tree in our minds in the context of three balls labeled R1, B, and R2.

This contingency tree starts at its root node with the random placement of either R1 or B into the sack. Two branches grow out of the root each of which has a probability 0.5 of happening. Let's follow the one in which B winds up first in the sack.

Then R2 gets dropped into the sack that now has in it a red and a blue ball. So far the probability of this state of affairs is just the original 0.5 since R2 gets added in any case. Now at random a ball is withdrawn that can be either blue (B) or red (R2). Each of these two branches again has a probability of 0.5 of happening. So if B is withdrawn, R2 (red) remains in the sack and the total probability of getting to this end point, or leaf in the contingency tree, is by multiplying the probabilities along the path, 0.5 x 0.5 = 0.25. But if R2 is withdrawn, B (blue) remains in the sack and that again yields another leaf with probability 0.25 of happening.

Now let's go back to the root and consider the branch where R1 is randomly placed into the sack with probability 0.5. When we then drop in R2 there will be two red balls in the sack. Drawing a ball at random yields either R1 or R2 with the other red ball remaining in the sack. Each of these leaves has a probability of 0.5 x 0.5 = 0.25 of coming true. So now we have a contingency tree that ends in four leaves each with probability 0.25 of occurring. But the problem statement requires us to consider ONLY the contingencies or results in which a red ball (R1 or R2) remains in the sack. From the above exposition there are three of these, each occurring with probability 0.25. But only two of these three include the observed event that a red ball (R1 or R2) was drawn. Each of these events also had a probability of 0.25 of happening. So the answer is simply the sum of the successful event (red ball drawn, red ball in sack) probabilities divided by the sum of the qualifying contingency or conditional (red ball left in sack) probabilities. The simple calculation is (0.25 + 0.25)/(0.25 + 0.25 + 0.25) = 2/3. Note that if tracing out the four branches ending in the described leaves would yield probability values different from the ones given here, you would still follow the same procedure of adding up the numerator and denominator as we have done and then divide to get the correct answer. This is a powerful and general approach to solving a large class of complex problems involving uncertain outcomes and also is a general paradigm for good thinking.

If all this has left you shaking your head, please go over the solution again and draw it out if necessary. Here is not just a silly little problem that is relevant only to solvers of arcane puzzles. Carroll posed it because it illustrates how to deal with the likelihood of conditional events that are contingent on certain factors which don't occur in every outcome. In this class are community problems such as air quality, growth, traffic congestion, affordable housing, etc. all dealing with contingency trees that end in uncertain outcomes the likelihoods of which should shape policy.

If we can't understand, let alone handle, such everyday complexities, then our only alternative is to let good intentions buttressed by fervent emotions be our guide. The road to hell is always prepared to accept such paving materials.

NN5 Problem: Three contestants are blindfolded. A white piece of paper is pasted on each contestant's forehead. They are told 1) that they each have a white or black paper on their forehead, 2) that not all the pasted pieces of paper are black, and 3) that the first one to correctly deduce the color of their paper will win the prize. The blindfolds are removed simultaneously and after a second or so all three contestants announce 'White!' at the same time. Why?