A Model for Evaluation of Transformation to a Green Energy Future

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I just got back from the IDEAS global assembly, which carried the theme: Evaluation for Transformative Change: Bringing experiences of the Global South to the Global North. I was struck by the considerable effort, and little satisfaction, that came from efforts to develop a theory of change (TOC) to assess progress toward transformation.

Between the formal sessions and my informal conversations, I think I know why the effort/success ratio has been disappointing. The essential difficulty is that while everyone acknowledges that transformation involves complex systems, they have not captured the ways in which complexity is involved.

This document is my effort to articulate a TOC for transformation that incorporates my understanding of complexity. I'm focusing on transformation to the use of non-carbon-based energy sources, but the kind of TOC I'm advocating is also applicable to other transformations.

How do I think about complexity?

My perspective is based on what I have been advocating for a long time. Ignore "complex systems" and focus on the behaviors of complex systems, i.e. on what complex systems do. Why do I think this? One reason is that I don't know what a complex system is, and none of the gazillion definitions that I have run into are useful. Another reason is that I don't know how to apply the notion of a "complex system" to making practical decisions about models, metrics, and methodologies. The behaviors of a complex system though? Those are things I can do something about. (Complex systems or complex behavior?)

Lest you think that I am a voice in the wilderness when it comes to applying technical understanding of complexity to sustainability, take a look at the School for Environment and Sustainability at the University of Michigan. I'm sure there are other such programs, but I happen to know about this one. I think our field would do well to establish some informal, rich communication with that research community.

Defining transformation – a complexity-based explanation

In a colloquial sense, transformation is the "new normal". It's how things are, and how they are likely to remain, for the foreseeable future.

In more techie complexity terms, a "new normal" can be seen as an "attractor" within which the values for a phenomenon can be found. It's an equilibrium condition, which means that if the condition is perturbed, it will settle down into some value within the attractor's borders. Examples of attractors include kids in a playground, watersheds, population densities in urban areas, and choices among competing technologies. (Why might it be useful to think of programs and their outcomes in terms of attractors?)

Defining transformation – a green energy-based explanation

With respect to green energy, the relevant question is: How much use of green technology is needed to make it the default choice for the foreseeable future? (PS, I'm using the term "green" to avoid arguments about the role of nuclear power in reducing reliance on carbon.)

I have no idea what the answer is to this question, but if transformation is to be evaluated, a consensus needs to be reached. Some of the consensus might be based on empirical research. For instance, adoption curves for similar technologies might be consulted. So too might be models of climate behavior. The greater the reliance on past empirical research the better, but between what has not been researched, and disagreements about the interpretation of research that does exist, a great deal of consensus building is inevitable.

Whatever definition is agreed to, it needs to be a construction along the following lines: "We know that transformation has happened if in place X, 80% of energy use comes from green sources, and has remained at about that level for five years." I like this form because it includes six elements that speak to my naïve understanding of energy transformation.

- Geographic range: I may not believe there is a new normal if my small town of Ann Arbor reached a particular level of energy source use, but I may believe in a new normal if all the mid-Western states reached that level. Or, I might compromise with myself and believe there is a new state of affairs if the change only included the entire state of Michigan.

- Level of energy use: "Eighty percent" is a level of energy use that would be truly different from the old way of doing things. It's a number that could only come about from a profound change in energy sources and their supporting constituents. It is a number that would make a significant dent in efforts to mitigate climate change.

- Time: "Five years" acknowledges that an indicator of profound change requires assurance that the construct it reflects will endure over time.

- Imprecision: The definition acknowledges the state of my meager knowledge by using the phrase: "*about*" 80%.

- Measurement: Everything in the definition can be measured.

What if the definition turned out to be wrong? What if our definition of the new normal danced about more than we would wish? Or in techie terms, what if small perturbations were enough to change the equilibrium state? What if attaining that level of energy use was not enough to reduce the atmospheres' carbon content?

Getting the definition wrong would be OK from the point of view of evaluation. After all, that definition of transformation came from a program theory that was articulated by stakeholders. If they were wrong, that would be fine as long as evaluators could report on it accurately and provide guidance as to how to do better. Is it possible to provide that guidance? Yes. But. Read on.

What does complexity tell us about the difference between *whether* there is transformation and *why* there is transformation

Knowing *if* a condition obtains is quite different from knowing *why* a condition obtains. It's the difference between prediction and explanation.

The definition of transformation that I gave above says nothing about how transformation came about. What changes were needed in the myriad factors that may be at play – functionality of available technology, energy cost, technological innovation, regulation at local, national and international domains, culture, perceptions of risk, context of international cooperation, geopolitical strategies of various nation states, and who knows what else that I can't think of right now?

The previous paragraph implies that we can build an unambiguous model. If only we were smart enough, if only we could conduct the right research, then we would know what the relevant variables were, and how they related to each other. And if we knew that, we could build a model that we could use to assess progress toward transformation.

Complexity tells us that we cannot build such a model. Or at least, that we cannot do it in the comfortable ways in which we usually think about explanation and causality. Three characteristics of complexity are at play – attractors, sensitive dependence, and emergence.

Attractors

See above.

Sensitive dependence

The cleanest explanation of "sensitive dependence" that I can find comes from Wikipedia: "Sensitivity to initial conditions means that each point in a chaotic system is arbitrarily closely approximated by other points with significantly different future paths, or trajectories. Thus, an arbitrarily small change, or perturbation, of the current trajectory may lead to significantly different future behavior. (For now, I am going to ignore the question of what a "chaotic system" is and focus the "small change" aspect of the definition. For anyone who wants to get into the gory details, I recommend either that Wikipedia article, or Chaos, an entry in the Stanford Encyclopedia of Philosophy.)

For us evaluators, sensitive dependence means that if we posit a TOC, we must accept the possibility that the trajectory of change through the our model may change radically because of a small change in any single element, or group of elements. The existence of sensitive dependence is not guaranteed. It is quite possible that the trajectory we identify in our TOC may be stable. But sensitive dependence appears in a great deal of complexity-based modeling. We must take the possibility seriously.

Emergence

Here too I will rely on my favorite font of all wisdom, Wikipedia. "In philosophy, systems theory, science, and art, emergence occurs when an entity is observed to have properties its parts do not have on their own. These properties or behaviors emerge only when the parts interact in a wider whole."

Think of two cases – a cylinder in the engine of a car, and the vitality of urban life under particular conditions of population density. Both cars and urban vitality are more than the sum of their parts. The difference between the two is the uniqueness of the parts. The unique characteristics of a cylinder endure. I can always identify the part called the "cylinder" and I will always know how it contributes to the operation of the car.

Not so with the vitality of urban life. No matter how much I knew about each person in the city, or that person's income, or the number of businesses and cultural institutions in the city, or the quality of public transportation, I could never pull these apart in an unambiguous model that explained how all these factors combined to produce "urban vitality".

What can be predicted?

I overstated the case and left the impression that models cannot be predictive. That's not quite true. The unpredictability of models driven by sensitive dependence increases with the number of elements in the model and the time between change in one element and the others it is connected to. (This is not quite true but getting into the whys and wherefores will take me far afield, and my brash overly simplified assertion is good enough for present purposes.)

For now, let's accept the assertion that the more elaborate the model, the less likely it is to produce outcomes that predict real world behavior. That means that if the model is restricted enough, it might produce predictable outcomes. So, if we focus on a small part of an elaborate model, we might be able to trust its predictions. See the picture for an

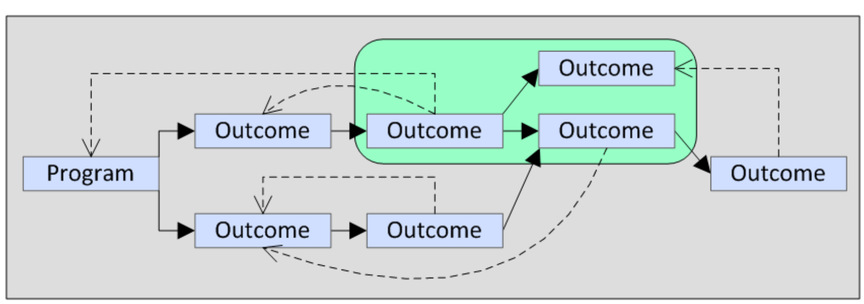

illustration of what I mean. The green rectangle can be made bigger or smaller. The fewer relationships it covers, the greater the certainty that there will cover unambiguous relationships among its elements. Also, the rectangle can be moved over the model. Or put another way, the model may be incorrect globally, but everywhere correct locally. (I pulled the picture from the slides I use in my complexity workshop.)

Applying complex behaviors to understanding transformation

In this section I'll discuss how the concepts of "attractors", "sensitive dependence" and "emergence" combine to illuminate our understanding of transformation. In the following section I'll show how these concepts work themselves into practical decisions about doing evaluation .

Emergence

Because of emergence, we cannot understand transformation by specifying a collection of individual variables set to particular levels. We may know which variables are important, but we can only explain transformation as an emergent property of these variables. Transformation is like urban vitality. It is not like a cylinder in an internal combustion engine.

Sensitive dependence

Because of sensitive dependence, we cannot specify a precise pathway through which the relevant components of transformation relate to each other to yield a state of transformation. We cannot even determine whether all the factors are always required. And, it is entirely possible that each time transformation occurs, it does so via a different combination of its constituent parts.

Attractors

My discussion of emergence and sensitive dependence may lead to the depressing conclusion that it's all random, that prediction is impossible, and that one can never engage in rational planning in furtherance of bringing about transformation. But hope exists.

It is entirely possible that complex behaviors generate outcomes that can be defined within an attractor space. It may be impossible to predict where in that attractor space a system will end up, but it may be possible to identify the shape and boundaries of the space. This is the reason why the word "about" showed up in my definition. It's not for lack of precise measurement. It's an acknowledgement that whatever "transformation" is, it exists somewhere within that space.

Evaluating progress toward transformation

Considering everything I just said, what's the best we can do in measuring progress toward transformation?

Use a TOC that recognizes complexity

Develop a TOC that recognizes that successful outcomes in transformation efforts may appear in different guises. For instance, the definition I gave earlier for level of energy use specifies that "80% of energy use comes from green sources." In addition to uncertainty as to the percentage, this definition provides no specificity as to which technologies will be used, or which sectors of society will change the most, or what other societal changes may attend the transformation.

My definition also specifies that a state of "transformation" requires a five-year timeframe. Why is the extended time important? Because we know that relationships among the factors driving transformation are subject to sensitive dependence. We want to be sure that however those interactions dance, they keep resulting in the new normal (AKA attractor) we desire. (In addition to sensitive dependence among variables we know about, there are also a large number of very low probability events that we cannot foresee, that are powerful enough to knock our system out or equilibrium. But dealing with this issue is for another time.)

If we believe that transformation is an emergent property, then we must acknowledge that our TOC cannot measure "progress toward transformation" as we might measure things like "progress to universal literacy", or "market penetration of solar panel technology". But we can still do evaluation that will give us a sense of whether we are advancing the cause of energy transformation.

Measure each individual factor

We can measure change in each of the factors that we know are related to transformation. As an example, we may not know how cultural values contribute to the emergence of transformation, but we know that culture matters. Similarly, with each of the other relevant factors. Of course, the quality of these measures will vary, but as with any research, all we can do is the best we can. How do we know if the factor we are measuring plays some role in bringing about transformation? We know because we took the effort to carefully determine what should be in our TOC.

Change in multiple relevant factors

Once we determine how much change has taken place in each element in our TOC, we can think of how many of the elements of that model have changed. We might not believe in all the precise relationships in our TOC, but we do believe that if a lot happens, it's more likely that transformation will take place. Imagine that after all our literature reviews, theory building, and consensus efforts, we identified ten factors that were important for bringing about transformation. I'd feel a lot better if efforts at transformation brought about a lot of change in eight of them, and not so good if all we got was a little change in two.

Focus on parts of the model

There are certain to be regions within the model that might be worth scrutinizing for stable relationships. For instance, one might expect a correlation between the penetration of a technology in a population and the attitude of potential adopters about the value of the technology. The model as a whole may not predict, but it's still worth knowing whether subsets of the model can be trusted.

Computer-based Modeling

Both agent-based and system dynamic-based modeling can enlighten our understanding of transformation. Modeling cannot predict with any accuracy. It's not that we don't know enough to get accurate prediction, it's that it's impossible. So if modeling won't help us predict, what's it good for? Many things.

- Modeling can give us a sense of the "performance envelop" of the system we are working with. (Or in complexity terms, it can tell us if there is an attractor.)

- Modeling can be used as part of a group process to capture diverse opinion. It's fun to do that. It makes for delicious arguments.

- Modeling can help us test our assumptions before a real-world research effort is launched. It's cheap to tweak a model.

- It may be difficult and expensive to alter a research effort in midstream, but it's not impossible, and it can be practical. Decisions about whether, and how to make those changes can come from a process of regularly feeding the most currently available empirical data into the model and considering the implications of the model's output for the research design and data collection. For a peek at how this can be done, see: *Integrating Agent Based Modeling Traditional Evaluation* (Part 1 7 minutes, part 2 20 minutes, part 3 20 minutes.)

Cross site comparison

Imagine an effort at transformation in seven different places. (I leave it to you to define the boundaries of a "place".) In each place there is:

- a measure of transformation,
- data on all the factors in the TOC,
- time series of change in each factor,
- a computer-based version of the TOC, and
- a complexity-aware program theory that is driving change efforts.

With all that data embedded in a multi-comparative case study design, I'd be a happy person.