Centre for the Evaluation of Complexity Across the Nexus

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Dependency Models

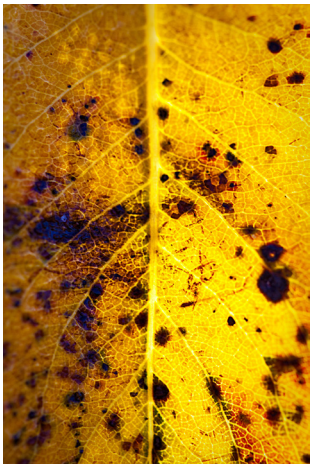
A CECAN Evaluation and Policy Practice Note for policy analysts and evaluators

Dependency modelling is a large family of different approaches used to explore, describe and predict how different entities affect and inter-depend on one another. Typically, it is a quantitative approach, although it can also be qualitative. Two well-known quantitative approaches are Bayesian Networks and Bayesian Decision Analysis; Fuzzy Cognitive Mapping (FCM) is one of the better known qualitative approaches. Dependency models provide an excellent graphical description of a complex network of systems (e.g. cross-sector decision making). They can be especially powerful in understanding not only what worked or did not work, but also what might be done differently. In turn, they can be tremendously helpful to those involved in complex policy intervention and evaluation-related decision making. Indeed, the process of developing a dependency model is itself a way of bringing together different participants within a complex system, which can have a long lasting benefits in creating a new kind of collaborative environment.

What are the main elements?

Dependency models tend to share a number of generic characteristics, namely, they:

- Provide an excellent way of exploring interdependencies between items (e.g. variables, objects, organisations, events, processes, etc.);
- Help to describe the interactions of a complex system to help decision making within that system;
- Use graphical techniques which are accessible to non-experts as a way of representing the different parts of a system and how they relate together;
- Provide a useful way of examining and quantifying areas of risk and uncertainty within a large system;
- Enable multi-user participation (e.g. different experts, users, policy makers);
- Have huge potential to be applied to policy evaluation, although this is an area that is only just beginning to emerge.



What are the main strengths?

Highly participative. The process of building a model is as important as the results: it brings people together.

Very graphic. Different users come together to build, draw and construct the way the dynamics, processes and structures all interact together.

Makes the invisible visible. The models can reveal where, when and how different units interact, which is especially valuable in large networks where it is difficult or impossible to see other parts of the system.

Quick and cheap. Sometimes, constructing the graphical model may be all that is required, which is a very inexpensive and efficient way of evaluating any system.

Can be used for very complex, high dimensional systems. This can be important where evaluations may be spatially complex or involve many stakeholders.

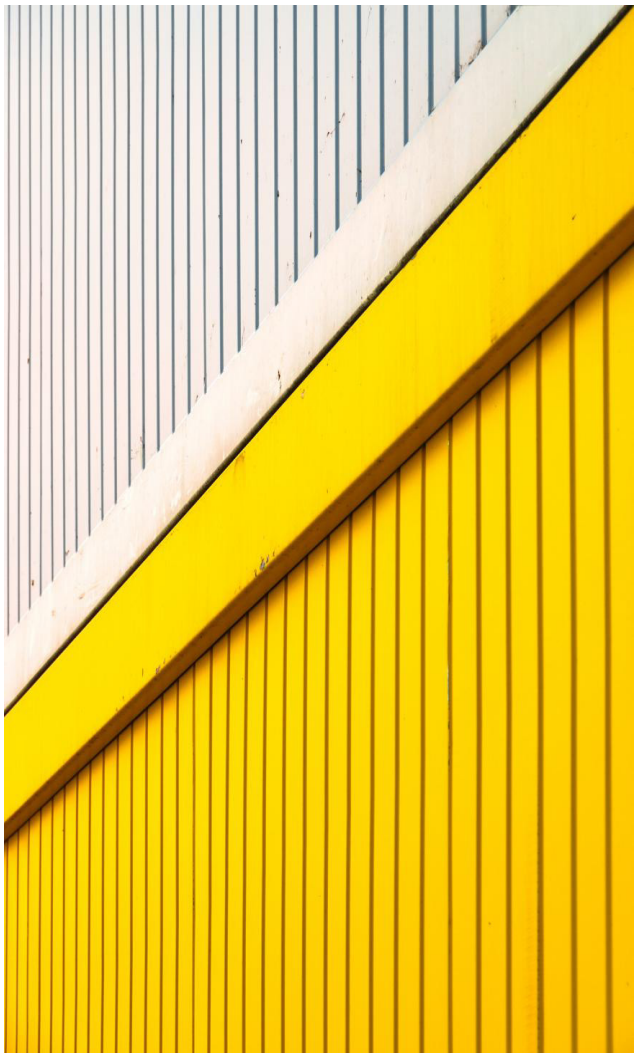
Updatable. Models can be adapted in real time as new data or measures become available.

Experimental. Scenarios are played out to better understand how the system works.

Structures thinking around difficult problems. Building a model can be a powerful way of re-describing, reformulating and re-evaluating complex policy issues.

User-led. The models ultimately inform users where the potentially most effective places are for them to intervene for system management.

Ethical. For policy evaluation, experimenting with simulated scenario-building can often be the only way to ethically explore particular interventions.



What are the main weaknesses?

Can simplify to the point of error. Models necessarily simplify; caution is therefore needed when interpreting them.

Liability. Models often show where joint ownership of problems and solutions may lie. Financial and legal issues need to be collaboratively negotiated to manage issues where joint liability may be necessary to implement.

May need several iterations. A model of an extremely complex system may need to be iteratively re-built to improve strategic decision making.

Subjective. Probabilities that an event is likely to happen because of one or more others are subjectively defined through conversation, although this can be supplemented by empirical evidence.

Training. Model developers need to be trained to get the probabilities working properly.

Uncertainty. Dependency models explicitly display uncertainties; they rarely offer one-answer solutions to problems.

How have dependency models been used? Examples from Food Security

Food security - access to sufficient safe, nutritious food for active and healthy lives, is enormously important for individuals and a key responsibility of national and international governments. Food security is:

Determined by a huge range of factors over many scales ranging from global climate and water to individuals' food choices and waste behaviours. Food security policy decision-makers need to take account of these factors and their interdependencies using available data and experts judgements.

Defined by the UK's Department for Environment, Food and Rural Affairs (DEFRA) as `consumers having access at all times to sufficient, safe and nutritious food for an active and healthy life at affordable prices' (Defra 2008).

Characterised by a food supply that is reliable and resilient to shocks and crises and produced in an environmentally sustainable way to avoid longer-term problems. In addition to availability, there must also be access, affordability and awareness for individual consumers (Kneafsey et al. 2013).

Dependent upon a complex system of environmental, economic and social factors which makes it challenging to foresee the consequences of decision-making on all the disparate elements of this system. A system that is able to reconcile the often conflicting goals of resilience, sustainability and competitiveness and that is able to meet and manage consumer expectations will become the new imperative (Amber-Edwards et al. 2009).

Although the application of dependency models in evaluating food security policy is novel, two approaches can be particularly powerful.

Dynamic Bayesian Networks have been used to capture the dependencies between quantitative variables in the food security system and combine data with expert opinion in a rigorous fashion as they develop over time. Barons et al (2014), for example, use Dynamic Bayesian Networks for decision support; the mapping of the networks that contribute to decision making are explored as a way to connect, in a principled manner, the key local and international factors influencing the UK supply and price of sugar, to evaluate the effects of various shocks to the system and to uncover the consequent levels of UK food poverty.

Fuzzy Cognitive Mapping (FCM) - an alternative dependency modelling approach - has also been used to bring out the importance of qualitative knowledge of diverse expert stakeholders. Penn et al. (2013; 2016), for example, use FCM to explore the interdependencies between the important parts of a regional bio-based economy, including the agricultural element. Co-creating a qualitative cognitive map of interacting factors affecting the economy allowed different stakeholders to understand each other's decision making processes, thus enhancing effective communication and collaboration. Network analysis of the qualitative model suggested influential or vulnerable system components which could be used as policy or management levers or which posed potential threats. This analysis, combined with stakeholders' inputs on their own differing abilities to influence different system components, suggested management strategies which could exploit system structure effectively and be the most achievable for specific stakeholder groups or collaborative consortia.

How might dependency models be developed?

There is a great deal of scope to extend existing approaches to dependency modelling in the following main ways:

- So far, qualitative and quantitative dependency modelling approaches tend to sit separately, but both approaches could benefit from each other if brought together.
- A mixed methods approach could help to speak to audiences that currently struggle to interact because of the different methodological cultures.
- Dependency modelling can theoretically cope with very different kinds of data (e.g. big or small un/structured data), but this needs to be put into further practice.
- Models tend to focus on *which* components constitute a system and *how* they interact together. But they can also be used to explore *where* and *when* parts of the system become stuck, go (too) fast or slow relative to other parts of the system, which could benefit understanding about *when* and *where* to intervene in (different parts of) a system;
- Dependency models are typically used to help decision making. They have yet to be widely used in evaluation and policy designs.
- Because models are built and can be updated over time, there is scope to use them to both *design* and *evaluate* policy at the same time.

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cecan
Centre for the Evaluation of Complexity Across the Nexus

www.cecan.ac.uk / cecan@surrey.ac.uk / +44 (0) 1483 682769

The Centre for the Evaluation of Complexity Across the Nexus (CECAN) is a £3m national research centre hosted by the University of Surrey, bringing together experts to address some of the greatest issues in policy making and evaluation.

This Evaluation Policy and Practice Note was written by Dr Emma Uprichard, University of Warwick e.uprichard@warwick.ac.uk and Dr Alexandra Penn, University of Surrey a.penn@surrey.ac.uk. With valued contributions and comments from Martine Barons, Anne Liddon, David Byrne, Barbara Befani, Helen Wilkinson and James Q. Smith.

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