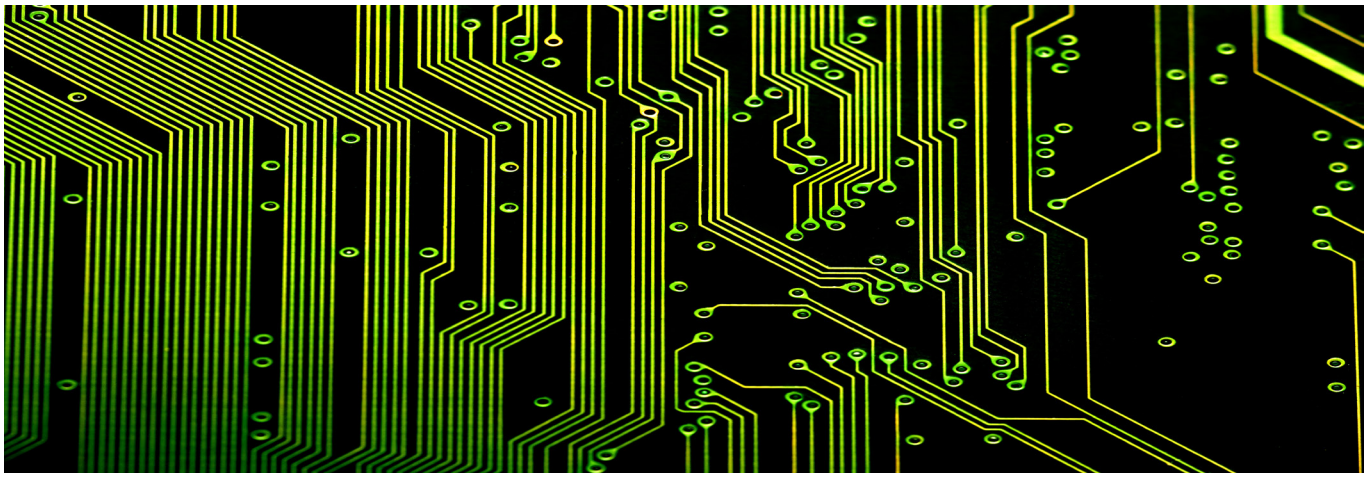
Centre for the Evaluation of Complexity Across the Nexus

Note No. 3
Autumn 2016

Agent-Based Modelling for Evaluation

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



Agent-based modelling is a powerful tool for understanding the behaviour of complex systems. It is capable of generating a deep qualitative and quantitative understanding of the interactions of man-made (engineered or technical), socio-economic (human) and natural (environmental) systems. Its ability to represent real-world processes, diversity, behaviours and outcomes at different scales means it can deliver meaningful insights where many other methods cannot. It is not, however, suitable for every situation. It requires expert modellers and facilitators to implement and can be costly. For many simple systems more traditional methods are likely to work just as well. Moreover, the results can be complex and difficult to communicate. However, as the complexity of the outputs arises directly from the complexity of the real world – of the human behaviours and natural systems represented by the modelling – this is a challenge that must be faced. CECAN will be working to raise the profile of agent-based modelling, develop guidance on its application to evaluation, and promulgate good practice.

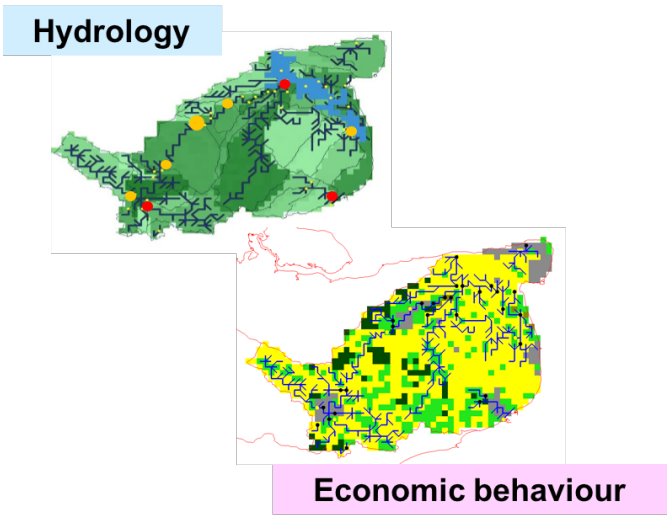
What is agent-based modelling?

Agent-based models seek to demonstrate the emergent behaviour and properties of systems by modelling the behaviours of the many individual actors that make up the system, the agents, and the interactions between them. Agents can be people, companies, projects, assets, vehicles, cities, animals, etc.

Agent-based modelling differs from many classical modelling approaches in that:
No attempt is made to impose the behaviour of the system directly; the global behaviour emerges as a result of interactions of many individual behaviours.
There is no assumption of equilibrium; the system is modelled as dynamic and adaptive.
Models can simulate many of the features observed in complex systems in real life, for example:

- Self-organisation
- Inertia
- Feedbacks and nonlinearities
- Tipping points.

Example: Application of agent-based modelling to Water Abstraction Reform



The abstraction of water from rivers and aquifers is controlled by a licensing regime established in the 1960s. The Government wished to reform the system to one that provides better incentives for abstractors to manage water efficiently and work together to make best use of water.

Assessing the costs, risks and benefits of the different ways of reforming the system is very complex. It needs to take into account:

- The interactions between a complex natural system and abstractors (including the public water supply, power producers, farmers, and industry)
- That economic, social and climate conditions will change in ways that we cannot predict, and
- The complex way that the new measures will influence individual abstractor behaviours on a day by day, year by year basis.

Agent-based modelling was ideally suited to explore how the existing and proposed reforms might operate. A multi-disciplinary team worked with a wide range of experts and stakeholders to develop an agent-based economic behavioural model integrated with catchment hydrological models on a daily time-step basis. This was used to explore how the reforms would work in practice. It exposed many unanticipated and often unwelcome effects, and so enabled the design of the reforms to be optimised.

Why use agent-based modelling for policy evaluation?

Policy interventions are generally designed to act on individual, business or household behaviours, rather than at the system level, Agent-based modelling allows these mechanisms to be fully represented. This and the ability to represent real world behaviours, using disciplines such as behavioural economics, means that agent-based modelling is ideally suited to policy applications.

Building an agent-based model:

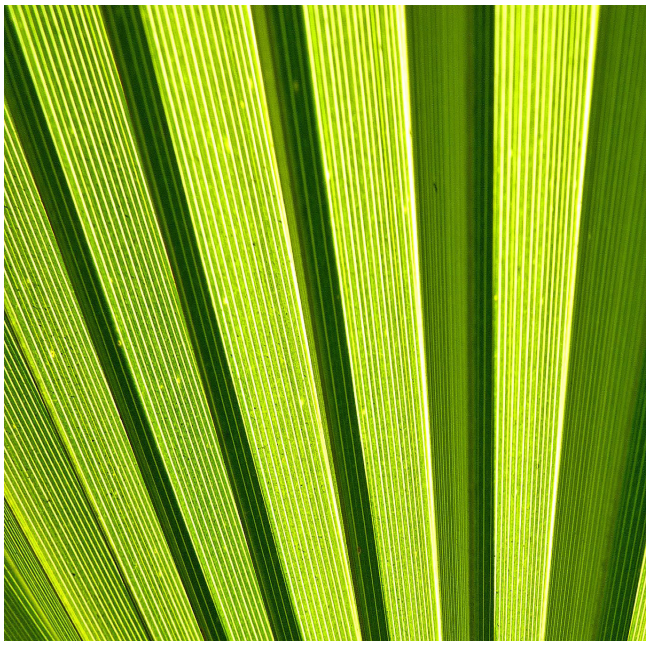
- Generates a deep qualitative and quantitative understanding of the domain being modelled.
- Is particularly well suited to the evaluation of nexus policy interventions where:
  - Interactions between multiple complex systems must be considered,
  - Benefits are anticipated over the longer term, and
  - The impact of the policy is expected to be difficult to disentangle from the effects of other factors driving outcomes.
- Could help to:
  - Generate and test detailed hypotheses of causation – i.e. how a policy intervention is expected to lead to outcomes,
  - Establish early warning indicators that a policy is unlikely to deliver the outcomes anticipated,
  - Identify the kinds of data that should be collected to support evaluation, and
  - Generate virtual or artificial counterfactuals to show what might have happened had a policy not been implemented.

Example of a modelled counterfactual

Highways England used a modelling approach to determine why targets for journey time reliability were not being achieved.

Rather than try to calculate a 'correction' to current measured performance to take out the effects of factors such as changes in traffic flow and proportion of HGVs since the reference year, the model was used to 're-base' the target, i.e. show what the target would have been if traffic flow and mix had been the same in the reference year as they were at the time of modelling.

This demonstrated that the agency had made progress, but this had been negated by traffic growth.



How can value be optimised?

Greatest value is gained from agent-based modelling where it is:

used at each stage of the policy cycle, and
developed using participatory approaches.

Agent-based modelling is a very powerful way of exploring and generating understanding about a system at any stage of the **policy cycle.** For example:

- Models developed to improve understanding of a system, and assess and appraise reforms, can then be used to define monitoring and evaluation frameworks, and support the evaluation itself.
- Elements of the modelling work could also be used by the systems and processes that support the implementation and operation of the policies. In the Water Abstraction example, the modelling work done to match abstractors who want to trade would be a good basis for systems that actually match abstractors in reality.

Participative modelling is an interactive process that involves, at every stage of model development: the client, policy domain experts, system domain experts, policy implementers and enforcers, stakeholder representatives and stakeholders that are affected by the policies under examination. This approach:

- Ensures representation of agents, processes and behaviours captured in the model reflect real-world experiences and a wide range of perspectives.
- Helps validate the model as model assumptions and interim outputs, such as patterns of behaviour observed in the model, can be reflected back to the group.
- Helps build understanding of the approach and a deep and shared understanding of the system under examination.
- Generates confidence in, and champions for, the results.

Participative development of agent-based models, however, introduce new challenges:

- Agent-based models can capture detailed processes and behaviours in a way that looks very realistic – this can lead to pressure from stakeholders and experts to try to reproduce the real world in the model in more detail than is necessary or practical.
- Modellers and clients alike need to show discipline and to focus on identifying and modelling those aspects of the system necessary to produce reliable conclusions.

Why is agent-based modelling not more widely used?

Policy analysts and evaluation practitioners could make greater use of this technique.
Barriers have been that:

- They lack familiarity with what in this context is a relatively new technique.
- It requires expert modellers and facilitators to apply – to capture the system in sufficient detail to make the results meaningful, while keeping the modelling tractable.
- It can be, though is not always, expensive; with public spending under pressure it may seem an indulgence. (Although failing policy or failing policy evaluation is more expensive.)

Also, the results can be complex and difficult to understand and communicate. For example it can be difficult to isolate what is driving the results. However, as the complexity of the outputs arises directly from the complexity of the real world, of the human behaviours and the interactions between the human and natural systems captured by the modelling, this is a challenge that must be faced by policy makers and analysts.

What will CECAN be doing?

CECAN will be working with policy analysts and decision-makers to address these challenges by:

- Raising awareness of complexity and complexity methods.
- Raising awareness of agent-based modelling.
- Developing clear guidance on:
  - -the different approaches to agent-based modelling and their various strengths and weaknesses
  - -how to procure agent-based modelling
  - -managing implementation to control costs and deliver policy relevant outcomes
  - -data considerations – different approaches to populating models (agent-based models can work very effectively without detailed data) and managing e.g. data security issues
  - -making sense of agent-based model outputs.
- Ensuring complexity is handled appropriately in key processes, such as Impact Assessment and Post Implementation Review, and in government publications, such as the Magenta and Green Books.

References and further information

Brian Heath, Raymond Hill and Frank Ciarallo (2009), A Survey of Agent-Based Modeling Practices (January 1998 to July 2008), *Journal of Artificial Societies and Social Simulation 12* (4) 9 [online] http://jasss.soc.surrey.ac.uk/12/4/9.html
Catherine S.E. Bale, Liz Varga, Timothy J. Foxon, Energy and complexity: New ways forward, *Applied Energy 138* (2015) 150–159
Gilbert, N. (2008). *Agent-based models.* Thousand Oaks, CA: SAGE
Janssen, M. A., and E. Ostrom. 2006. Empirically based, agent-based models. *Ecology and Society 11*(2): 37. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art37/
Mac Namee, B. (2009) Agent Based Modeling in Computer Graphics and Games. In R.A.Meyers (ed.) *Encyclopedia of Complexity and System Science,* Springer
Risk Solutions, The Impact of Water Abstraction Reform - Final Report, 2015
Risk Solutions, Cost Benefit Analysis of Foot and Mouth Disease Controls, 2005
Risk Solutions, Virtual motorways to manage real-life jams

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 note was written by Helen Wilkinson, with contributions and comments from Nigel Gilbert, Liz Varga, Corinna Elsenbroich, Henry Leveson-Gower (Defra), Jonathan Dennis (Environment Agency) and the CECAN team. It draws on policy directed agent-based modelling carried out by Risk Solutions and funded by Defra and the Technology Transfer Board – now InnovateUK – as well as research work by Cranfield University and the University of Surrey.