

Maths and Public Policy for Cities and Infrastructure

Wednesday 11th March 2015 – Church House Conference Centre, London

Summary Note

Jane Leeks, Knowledge Transfer Manager of the Turing Gateway to Mathematics (TGM) welcomed delegates and provided a short introduction to the event. The TGM is delivering a programme of work and associated events on behalf of the Engineering and Physical Sciences Research Council (EPSRC), which are bringing together mathematical sciences researchers and policy makers to explore modelling and problem solving. The TGM is an impact acceleration initiative of the Isaac Newton Institute (INI) based at the University of Cambridge. It acts as a vehicle for knowledge transfer between the mathematical sciences and potential users of mathematics, such as industry and other academic disciplines in the UK as well as internationally.

A launch event took place in December which was attended by delegates from across Government departments, academic institutions, learned societies and other public sector organisations. This had been followed by 2 events - this one on Cities and Infrastructure and one later in March on Health and Society.

Brian Collins, Professor of Engineering Policy at University College London welcomed delegates and provided an introduction to the event.

Frank Kelly, Professor of the Mathematics of Systems at the University of Cambridge introduced the speakers of the morning session.

Presentations - copies of the slides used during the event can be seen at www.turing-gateway.cam.ac.uk

Philippa Hemmings, Theme Leader Mathematical Sciences (EPSRC)

Philippa highlighted that this was the second of three events bringing mathematicians and policy makers together. EPSRC has a particular interest in mathematics and encouraging its application as widely as possible. This event aimed to provide insight into the policy context and some of the challenges, discuss how the mathematical sciences can contribute and help to build links between the academic and policy communities.

Alan Wilson Professor of Urban and Regional Systems (University College London)

Alan spoke about the Government Office for Science Foresight project that is looking at the opportunities and challenges facing UK cities over the next 50 years. This covers 6 themes and explores the interdependencies in city and regional systems. As part of the project, visits to 19 cities have taken place, to develop the evidence base and identify how science and maths can play a role in shaping a long term urban future. Scenarios and models for the future have been developed which highlighted top priorities - including the scale of social disparities in cities. These scenarios will allow policy makers to explore critical policy options for city development.

Alan highlighted the links in a city sub system and the role that infrastructure plays. He illustrated this with a number of examples - one related to retail modelling, where analysis of flows into a particular retail centre were modelled to help calculate revenue. He also suggested that it is possible to draw inspiration from meteorologists who predict the paths that hurricanes will take by defining a "possibility cone". There are many diverging possible paths for the hurricane - can we build a possibility cone for urban systems? Alan concluded by questioning where models are well developed, whether these can be applied to other sectors - such as retail, education or health?

Eddie Wilson, Professor of Intelligent Transport Systems (University of Bristol)

Eddie spoke about transport applications and transport modelling, which he illustrated with an explanation about phantom traffic jams. A video illustrating the impacts of differences in driving behaviour wasn't able to be shown, but is available from the [TGM website](#). When trying to drive at the same speed, small differences in



speed and distances between cars, can cause cars to bunch up, which leads to a traffic jam, that has come about through no obvious obstruction in the road.

Another example related to MOT's, where results have been stored digitally and published online since 2010. The intention was that people could study the reliability of makes and models of cars, but there were unintended consequences. The certificate includes the mileage of that car, which could be used to measure the total mileage across the UK (with related links to carbon reduction etc.). Two graphs were shown, that compared mileage distribution of new cars in West London and Kirkcaldy, with that of old cars. One conclusion could be that people drive old cars more in rural areas, but other factors could be at play - in households where there are 2 vehicles, people may choose to drive the older car in preference to the newer one. This prompts more analysis and questions. Eddie reiterated the need for mathematicians to get involved in problems that are faced by stakeholders and the need for exploring models around uncertainty quantification.

Kulveer Ranger, Strategic Advisor (Cities & Transport)

Kulveer spoke about the challenge of managing transport in a city such as London, where there are 25 million journeys a day, 10 million by car. The public are hugely influential on politicians and policy makers - this is a healthy tension, but needs to be managed to help make informed decisions. Kulveer illustrated this with an example related to a minor traffic incident, such as a flat tyre on a car that would cause grid lock within 5/10 minutes at particular areas, such as Parliament Square. When considering the desire for pedestrianising an area, the impact on traffic flow needs to be taken into account, as well as the need to ensure safety when considering a shared space, for example Exhibition Road, where you want to encourage greater movement with increased safety.

Kulveer concluded by highlighting the role of a "Smart City" - one which is connected and makes efficient use of resources. The Digital City Exchange is a cross-faculty research programme between Imperial College Business School and the Faculty of Engineering which has been funded by Research Councils UK. It has helped analyse the role of digital data versus conventional data, as well as the provision of smart-city services and development of business models.

Miles Elsdon, Chief Scientist and Acting Chief Scientific Advisor, (Department for Transport)

Miles began by highlighting the value of having mathematicians in Government, as they are able to bring a different way of thinking.

The National Transport Model underpins a lot of the decisions made in the Department and provides a systematic means of comparing the consequences of alternative transport policies, against a range of background scenarios which take into account the major factors affecting future patterns of travel. Policy makers responsible for this model are keen to engage with academics, as there are a number of uncertainties in relation to the input to the model. One example of operational research, related to carrying out an audit of road signs, where people were sent out to count them, which was expensive and not an effective use of time. This has been replaced by using the existing record of signs and using operational research tools to model the quantity.

Miles identified a number of challenges, such as demographics, climate change, extreme weather events as well as big data, open data and the internet of things. But these provide opportunities too, for demand forecasting, energy efficiency, hybrid vehicles etc. He indicated the value of collaboration, in mathematics as well as the social sciences, for example between DfT and the Met Office, in relation to a volcanic eruption in 2010, that has helped develop stronger models. Miles concluded by highlighting the value of engagement - how to communicate better and identify clear ways for policy makers to be equipped to understand the complexities that are needed to make informed decisions.

Charles Kennel, Director Emeritus & Vice-Chancellor, (Scripps Institution of Oceanography)

Charles introduced the speakers of the afternoon session and provided an introductory talk related to adaptation to climate change. As we are experiencing new challenges, past experience will be decreasingly reliable. There is a capacity problem for both adaptation and mitigation - the number of people that decisions



have to reach is vastly increasing. In relation to the impacts of climate change on humans, there is greater complexity for adaptation than mitigation, because there is no central actor that can conceive all that is ahead.

Charles highlighted that a challenge is that even if we stopped emitting carbon tomorrow, there would still be climate change for one thousand years, so the knowledge that we generate today has to keep in active use for one thousand years. There is an issue of timeliness - communities who are at risk may not want to wait for knowledge to be transferred down to the local level. A management process is needed - some sort of architecture that collects knowledge at the national, regional and local level. Charles concluded by highlighting the need to disseminate assessments of best practices in adapting to climate change.

David Mackay, Regius Professor of Engineering (University of Cambridge)

David began by reflecting on his role as Chief Scientific Advisor at DECC, where one challenge related to the number of objectives that had to be delivered against, in a way that saved public money. Some objectives were in conflict with others - obviously reducing carbon emissions is in tension with maintaining secure energy supplies; less obviously, national renewable targets may be in tension with the goals of saving energy and reducing carbon emissions. Additionally, European Law had to be adhered to, so consideration was needed on the impact of European State Aids rules and the Habitats Directive.

David illustrated his talk with the [2050 calculator](#), a web based tool that allows users to experiment on how to meet the UK emissions targets. This can be used as a basis for making suggestions on policy and it has had a direct impact on DECC policy that is being developed. He also spoke about feed in tariffs, that were based on an Excel model with incorrect assumptions, highlighting the need to acknowledge uncertainties with an ability to modify parameters and incorporate inference. David concluded by highlighting probabilistic programming, an approach to analysis in which uncertain parameters are automatically inferred from data. He proposed a project to develop an open source modelling tool, that suits real analysts in Whitehall and creates the right environment for rapid development of tools to support decision makers.

Chris Dent, Senior Lecturer in Energy Systems Modelling (University of Durham)

Chris spoke about uncertainty and variability in flows of renewable energy. Increasing uncertainty and complexity in energy systems inevitably means that new mathematical, statistical and control approaches will be needed, and much of this work is within the professional domain of mathematical sciences rather than the skills set of the engineering application community. For example, careful statistical modelling of available renewable output and consequent decision analysis are required for analysing short term balancing, planning timescale generation adequacy, and network planning. There are also broader issues of how to take systematic capital planning decisions and design markets under severe uncertainty about future system backgrounds. Also, how to control smartgrids in which the number of active demands is much greater than in present day systems and hence incumbent centralised optimisation approaches become intractable.

Chris highlighted that there is a strong community of mathematicians involved in energy research in the UK. He struggled to think of other countries where there is a collection of projects on energy that are well linked to each other and industry - this provides good opportunities for future collaboration and for building a world-leading UK activity. He concluded with the consideration of how to integrate this community into the mainstream of the Research Councils Energy Programme and how to bring the right people, with the right skills, together for academic research and industrial development.

Alec Waterhouse, Head of Modelling, Central Modelling Team (Department of Energy and Climate Change)

As had been highlighted by David's talk, modelling and using mathematics is at the heart of what DECC does, for example setting the UK's carbon budgets and assessing the impact of policies on emissions, energy markets, households, businesses and the wider economy. Modelling objectives need to be effective, efficient, accessible, coherent and coordinated. Policy makers need to understand how these interact with the rest of the world and other agencies, such as the Met Office. DECC's energy model makes use of hard analytical techniques - (forecasting, simulation) as well as soft problem structuring (systems thinking, decision making).



Alec spoke about the National Household Model which will soon be available as open source. It's a model of how household's energy would work - modelling of energy use that is data driven. It takes into account effects of issues such as energy demand, installation of energy efficiency measures, consumer choice and fuel prices over time. However, people aren't rational - there is a need to understand the choices people make. Another challenge is pace - the speed at which models are developed and the tension between how much is spent on models as opposed to using them. Alec concluded by reflecting on the need for knowledge management and how to maintain continuity of knowledge.

Discussion Sessions

Over the day there was time for discussion and the key points that were raised are briefly outlined below.

- Opportunities that could be explored included exploiting existing knowledge and networks, use of open data and engagement with study groups, internships etc.
- Challenges that were discussed included quantifying and communicating uncertainty, the impact of human behaviour on modelling, how to manage conflicting interests (transport vs. economics vs. environment) and the need for mathematicians to have flexibility to face real world problems.

One key theme related to the relationship between policy makers and those involved in academic research and mathematical modelling. A number of points were highlighted:

- Communication, engagement and collaboration - discussion with as wide a group of people as possible and the value of developing and sharing exemplars.
- Skills, knowledge and technology transfer- analysts in arms length bodies have lots of relevant skills and there is a risk of losing these skills when these organisations have been privatised. How to overcome this?
- Role of mathematical modelling vs. expert opinion (value of incorporating emotional content and context), as assumptions can be inherently emotional or political.
- Quantifying and modelling uncertainty - decision makers don't handle uncertainty well.

Conclusion

Brian Collins brought the event to a close. He encouraged all who had attended to consider how their disciplines interact with policy makers as well as the policy making process and to develop opportunities for engagement. He highlighted that the pace of change is becoming more complicated - increased scale, disproportionate change between disciplines, as well as migration changing the way that we live. Mathematics can be seen as an enabler, as it provides insight as well as the opportunity for academics to work more closely with those developing policy.

Philippa Hemmings reiterated thanks for attending the event and concluded by outlining that feedback from this and the subsequent health and society workshop would be analysed and taken into account in any next steps to be taken forward.

Post Event

Verbal feedback on the day was positive and a number of emails and twitter messages from delegates were exchanged post-event which highlighted the value of attending. Analysis of the feedback forms indicated that the event offered a good insight into how Government departments are implementing mathematical techniques to assist with policy decisions. It helped to highlight the opportunities for the use of new techniques and models. The presentations were well received by academics and policy makers, with participants actively engaging in the discussion and networking sessions, which will help build links between academics and those from policy areas. The calibre of speakers was felt to be high, with attendees highlighting that the talks contained engaging, informative and interesting material. Post event material was sent to those who had been unable to attend and this was felt to be useful.

