ISNGI 2017
11th – 13th September 2017
One Great George Street, London
www.isngi.org

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Foreword

Development of next generation infrastructure is at a tipping point. Far greater investment is needed in an increasingly complex context so the challenges are significant. The ISNGI vision is to ensure the best minds from industry, government and academia collectively inform strategies to meet these challenges and ensure long-term prosperity. Implementing these strategies systemically is key to future success.

This year’s symposia marks a significant step in the recognition of the importance of next generation infrastructure; infrastructure modernisation is a pressing problem for most developed countries and is critical to developing countries. Taking a collaborative and coordinated approach to research adds value to the body of knowledge and enables better learning outcomes for the future. These transfer to industry and hence strengthen the economy.

The UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC), a major UK research programme launched this year, is co-sponsor of ISNGI 2017. UKCRIC is central to the UK’s infrastructure and cities research agenda but its collaborative aims and objectives – to understand how to make the system of systems that constitutes the nation’s infrastructure more resilient to extreme events and more adaptable to changing circumstances, and provide services that are more affordable, accessible and usable to the whole population – have international reach.

Challenges are plentiful. Inadequate infrastructure costs the UK £2M a day, and extreme events, such as flash flooding, can cost hundreds of millions more. Understanding how to mitigate the effects of future extreme events will be very valuable. Existing research and thinking around infrastructure, cities, and planning is fragmented and under-resourced and, in order to plan effectively for the future, a coherent research programme to de-risk, help prioritise and provide evidence for investment, is required. A system-of-systems view of infrastructure is needed, but persuading governments and planners to think in an integrated way remains a challenge.

ISNGI 2017 aims to tackle these issues through a range of contributions from leading academics, industry leaders and government representatives. Both ISNGI and UKCRIC draw on world-leading and transdisciplinary expertise to provide an integrated and systemic view on how infrastructure can be modernised and improved for the world at large. I look forward to meeting you at ISNGI to help shape the future of infrastructure to improve the quality of life for generations to come.

Professor Brian Collins, CB, FREng
Chair Academic Committee, ISNGI 2017
Professor of Engineering Policy, University College London
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* please note that the abstracts for the contributed talks have been taken from early submissions from the authors and these may be updated in the final version of the papers available in the conference proceedings following ISNGI.
## Agenda

### Monday 11th September

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<td>The Rotunda</td>
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<td>09.00</td>
<td>Introduction and welcome</td>
<td>Thomas Telford Theatre</td>
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<tr>
<td>09.10</td>
<td>Opening address: UKCRIC: a transformational global opportunity for collaboration on infrastructure research</td>
<td>Thomas Telford Theatre</td>
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<tr>
<td>Professor Brian Collins CB, FREng, Convenor of UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC), UCL, UK</td>
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<tr>
<td>09.30</td>
<td>ICE’s role in engineering a digital future</td>
<td>Thomas Telford Theatre</td>
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<td>Professor Tim Broyd FREng, Professor of Built Environment Foresight and President of the Institution of Civil Engineers</td>
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<td>10.10</td>
<td>Measuring the value added of infrastructure for society</td>
<td>Thomas Telford Theatre</td>
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<td>Dr Aernout van der Bend, Managing Director, Next Generation Infrastructures</td>
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<td>10.50</td>
<td>Coffee Break</td>
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<tr>
<td><strong>Delivery of infrastructure systems and services</strong></td>
<td><strong>Learning frameworks for infrastructure provision</strong></td>
<td><strong>Next Generation Infrastructure Interdependencies: An economic deterministic model of transport interdependencies in the United Kingdom</strong></td>
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<td><strong>Professor Jim Hall FREng, University of Oxford and UKCRIC, UK (Chair)</strong></td>
<td><strong>Professor Colin Taylor CEng FICE</strong></td>
<td><strong>Nikolaos Kalyviotis</strong></td>
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<td><strong>Professor Chris Barrett, Virginia Tech, USA</strong></td>
<td><strong>Next generation doctoral training at the University of Cambridge for future infrastructure and built environment</strong></td>
<td><strong>Infrastructure System of Systems Integrity</strong></td>
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<td><strong>Professor Pascal Perez, University of Wollongong, Australia</strong></td>
<td><strong>Dr Niamh Gibbons</strong></td>
<td><strong>Dr Ricardo Peculis</strong></td>
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<td><strong>Professor Wijnand Veeneman, Delft University of Technology, The Netherlands</strong></td>
<td><strong>Prosperity in a Rocking Boat</strong></td>
<td><strong>Navigating complexity for next generation infrastructure decision-making: integrating governance and modelling analysis</strong></td>
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<td><strong>Dr David Warburton, Auckland Transport, New Zealand</strong></td>
<td><strong>Dr Peter Dudley</strong></td>
<td><strong>Dr Katherine Lovell</strong></td>
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<td>12.10</td>
<td>Lunch</td>
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### PARALLEL SESSION 2

**13.10** The role of smart infrastructure and construction for next generation cities
**Professor Lord Robert Mair CBE FREng FICE FRS,**
Sir Kirby Laing Professor of Civil Engineering, University of Cambridge, UK

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<td>Systems thinking to transform infrastructure services</td>
<td>The individual as the key-stakeholder of Next Generation Infrastructure projects: Defining the social value of transport infrastructure in the UK</td>
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<td>Professor Cynthia Mitchell, UTS, Sydney, Australia</td>
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<td>Anne O’Neil, PE CSEP Systems Engineering Strategist and Catalyst, USA</td>
<td>Engineering Comes Home: co-designing nexus infrastructure from the bottom-up</td>
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<td>Dr Ajith Parlikad, University of Cambridge, UK</td>
<td>Dr Sarah Bell</td>
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**15.00** Coffee Break

**15.20** The Next Generation must be Net-Positive
**Professor Cynthia Mitchell,**
Deputy Director, Institute for Sustainable Futures, UTS, Sydney

**16.00** Smart City: the Good, the Bad and the Ugly
**Professor Pascal Perez,** Director, SMART Infrastructure Facility, University of Wollongong, Australia

**16.40** Active and Smart Infrastructure: Can they Co-Exist?
**Professor Robert Cervero,** Director of the University of California Transportation Center (UCTC), USA

**17.20** UKCRIC research facilities: an overview and update
**Professor David Richards,** University of Southampton and UKCRIC, UK

**17.40** Poster Session and Wine Reception CLOSE at 19.30

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**Tuesday 12th September**

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<td>Registration</td>
<td>The Rotunda</td>
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<tr>
<td>09.00</td>
<td>The role of the NIC and how it is affecting the infrastructure policy landscape, in the UK and globally</td>
<td>Thomas Telford Theatre</td>
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<td>Sir John Armitt CBE FREng FICE, Deputy Chairman, National Infrastructure Commission</td>
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<td>09.50</td>
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<td>Governance of infrastructure systems and services</td>
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<td>Cees Brandsen, Managing Director, Rijkswaterstaat, The Netherlands</td>
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<td>Hon. Wayne Swan MP, Former Treasurer and Deputy Prime Minister of Australia; Member of the Australian House of Representatives, Australia</td>
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<td>Co-creating ‘responsive’ infrastructure: a case for systems capacity building</td>
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<td>Anne O’Neil PE CSEP Systems Engineering Strategist and Catalyst, USA (Chair)</td>
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<td>Dr Corina Kwami, UCL, UK</td>
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<td>Professor Nick Tyler CB FREng, UCL, UK</td>
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<td></td>
<td>A decision support system to proactively managing subsurface utilities</td>
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<td>Professor Barry Clarke</td>
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<td>Assessing the Underworld – Understanding the Context for Engineering the Next Generation Infrastructure</td>
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<td>Designing urban deep basements in South East England for future ground movement: Progress and opportunities for experimental simulation of long-term heave</td>
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<td>Contributed Talks 3b</td>
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<td>Next generation offshore infrastructure</td>
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<td>Professor Susan Gourvenec</td>
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<td>Vulnerability of Maritime Infrastructure: A Network Science Approach</td>
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<td>Dr Jitendra Agarwal</td>
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<td>Next Generation Infrastructure: Smart Biomimetic Construction Materials</td>
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<td>Professor Abir Al-Tabbaa</td>
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<td>11.10</td>
<td>Moving from BIM to a Digital Economy in infrastructure and city programmes</td>
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<td></td>
<td>Dr Mark Bew MBE, Chairman at PCSG, Chairman at BIM Task Group</td>
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<td>11.50</td>
<td>Lessons from the shop floor: Delivering better and more infrastructure</td>
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<td>Isabel Dedring, Global Transport Leader, Arup, UK</td>
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<td>The challenge of responsive infrastructure provision</td>
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<td>Cees Brandsen, Managing Director, Rijkswaterstaat, The Netherlands</td>
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<td>Experience of transport strategy and programme execution in a rapidly growing city</td>
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<td>Dr David Warburton, Chief Executive, Auckland Transport, New Zealand</td>
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<td>Smarter Towns, Better Living – Developing Smart Urban Habitats</td>
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<td>Er. Dr. Johnny Wong, Group Director, Building &amp; Research Institute,</td>
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<td>Housing &amp; Development Board, Singapore</td>
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<td>Cities and Urban Systems</td>
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<td></td>
<td>Professor Chris Rogers, University of Birmingham and UKCRIC, UK (Chair)</td>
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<td>Julie Alexander, Siemens, UK</td>
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<td>Professor Robert Cervero, University of California Transportation Centre, USA</td>
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<td>Keith Clark CBE, Tidal Lagoon Power, UK</td>
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<td>Impact of the Internet of Things on Infrastructure Asset Management</td>
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<td>Professor Mark de Bruijne, TU Delft, The Netherlands</td>
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<td>Esther Hardi, Alliander, The Netherlands</td>
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<td>Giel Jürgens, Port of Rotterdam, The Netherlands</td>
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<td>Annemarie Verbeek-Kalshoven, Vitens, The Netherlands</td>
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<td>Wim Verheul, ProRail, The Netherlands</td>
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<td>16.50</td>
<td>UK Research and Innovation and Next Generation Infrastructure</td>
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<td>Sir Mark Walport FRS FMedSci, Government Chief Scientific Advisor</td>
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<td>17.30</td>
<td>DAY CLOSE</td>
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<td>After dinner speech: Planning infrastructure in big cities: London’s example</td>
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<td>Jules Pipe, Deputy Mayor for Planning, Regeneration and Skills, Greater London Authority</td>
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<td>Land use, worker heterogeneity and welfare benefits of public goods</td>
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<td><strong>Professor Coen Teulings, Montague-Burton Professor of Labour</strong></td>
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<td><strong>Economics University of Cambridge</strong></td>
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<td><strong>Professor Phil Purnell, University of Leeds and UKCRIC, UK (Chair)</strong></td>
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<td><strong>Tom Bousfield, National Infrastructure Commission, UK</strong></td>
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<td><strong>Ann Pettifor, PRIME, UK</strong></td>
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<td>Governance tools for adaptive infrastructure: lessons from Medellin,</td>
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<td>Colombia, Dr Corina Kwami</td>
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<td>Towards the Development of an Energy City Systems Conceptual Framework</td>
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<td>Realising the circular economy in wastewater infrastructure - the role</td>
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<td>of governance Dr Heather Smith</td>
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<td>Solid Waste Infrastructure Modelling Software (SWIMS); determining</td>
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<td>future waste arisings and waste treatment infrastructure needs within</td>
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<td>a system of systems model to act as a decision support tool Dr Keiron</td>
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<td>A systemic, purposeful, performance-led and outcome oriented approach</td>
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<td>to infrastructure need assessment Dr Tom Dolan</td>
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<td>A systems thinking approach to the development of alternative</td>
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<td>infrastructure business models Dr Christopher Bouch</td>
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<td>Planning pathways to climate-ready mobility infrastructure Dr Andrew</td>
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<td>A Storm Cometh: Can we better protect infrastructure from the impacts</td>
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<td>of approaching storms using rational assessment frameworks? Dr Sarah</td>
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<td>Designing a road traffic model for the cross-sectoral analysis of</td>
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<td>future national infrastructure Dr Milan Lovric</td>
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<td>Digital underpinnings for smart cities: challenges and</td>
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<td><strong>Professor Nick Jennings, CBE, FREng</strong></td>
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<td><strong>Vice Provost (Research), Imperial College London</strong></td>
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<td>Intelligent brokerage in the UK Water sector: A collaborative approach to supply chain innovation Andrew Hale</td>
<td>Mapping out the landscape of long-term national infrastructure demands for the U.K.'s National Infrastructure Assessment Dr Matt Ives</td>
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<td>Dr. Jennifer Schooling, University of Cambridge and UKCRIC, UK (Chair)</td>
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15.30 PARALLEL SESSION 7

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16.40 Delivering the ‘modelled world’ of infrastructure
Professor Jim Hall FREng, Director, Environmental Change Institute, University of Oxford and UKCRIC, UK

17.10 UKCRIC; joining the dots in infrastructure and cities research
Professor William Powrie FREng, Dean of the Faculty and Engineering and the Environment, University of Southampton and UKCRIC, UK

17.40 EVENT CLOSE
Speakers’ Biographies & Abstracts

Panel Session 4a: Cities and Urban Systems

**Biography:** Julie is a Director for Urban Development and leads on the Smart Cities sector. With her global remit working with cities around the world, she is responsible for engaging with cities to showcase the role of infrastructure and integrated technological solutions in urban development. Her recent book Smart Cities: Cities in the Digital Age, illustrates the importance of digitalization in the field of critical infrastructure. Her latest research on The Business Case for Smart Cities: Infrastructure Investment has drawn global attention with its unique methodology for business case development for cities. Particular areas of specialism include the financing and funding of urban infrastructure through the use of innovative mechanisms and value capture. On this topic, Julie recently co-authored the report – ‘Investor Ready Cities’ in conjunction with PwC and BLP Law. Julie also specialises in urban masterplanning, and digital enablement. Julie is a member of the Smart London Board, Institute for Future Cities Board and Urban Living Partnership Advisory Board.

**Julie Alexander**
Global Director, Urban Development and Smart Cities Lead, Siemens Global Centre of Competence for Cities

Panel Session 3a: Governance of infrastructure systems and services

**KEYNOTE:** The role of the NIC and how it is affecting the infrastructure policy landscape, in the UK and globally

**Abstract:** Physical infrastructure is recognised by Governments around the world as being a central plank of economic growth. However, in a democratic society it can take many years to plan and deliver and has a useful life of up to 100 years. It is also expensive and can carry significant capital and revenue risks whether to Government or private investors.

Set against most Governments short term agendas the planning and delivery of infrastructure therefore presents a considerable challenge. In recent years the need to address this challenge in a structured way has been recognised by various countries and in the UK resulted in the establishment of the National Infrastructure Commission (NIC) in 2015. The Commission has been established as an Independent Government Agency taking its direction from the Chancellor of the Exchequer.

Its role is to identify the infrastructure needs of the UK over a 30 year horizon so that the UK can be economically competitive whilst sustaining a high quality of life in an environmentally sustainable manner. It has to make its recommendations within a fiscal remit set by the Government.

It is required to produce its long-term recommendations once in each Parliament and report on the progress being made by Government against those recommendations on an annual basis. The Commission also produces shorter-term assessments for Government on particular infrastructure challenges.

The talk will describe the background, nature and work to date of the NIC. Its modus operandi, the drivers, criteria and modules which are used to create its outputs. It will also touch on the approach taken by other countries, similarities and differences.

**Biography:** Sir John Armitt is Chairman of the National Express Group, the City & Guilds Group, Deputy Chairman of the Berkeley Group and Deputy Chairman of the National Infrastructure Commission. Sir John is also on the Board of Expo 2020.

In September 2013 Sir John published an independent review on long term infrastructure planning in the UK. The recommendations in the Armitt Review received widespread support and in large part have now been adopted by the current government, resulting in the National Infrastructure Commission.

**Sir John Armitt**
CBE, FREng, FICE
Deputy Chairman, National Infrastructure Commission

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After leaving John Laing plc in 1993, where Sir John had been Chairman of Laing’s International and Civil Engineering divisions, he became Chief Executive of Union Railways. In 1997 he became Chief Executive of Costain, a position he held until 2001. Sir John was Chief Executive of Railtrack plc from 2001-2002, Chief Executive of Network Rail from 2002-2007, Chairman of the Olympic Delivery Authority from 2007-2014, Chairman of the Engineering and Physical Sciences Research Council from 2007-2012, and a member of the Airports Commission from 2012-2015, and a member of the Board of Transport for London from 2012-2016.

**Panel Session 7: Future research and innovation agendas for next generation infrastructure systems**

**Biography:** Roger joined the Thames Tideway Tunnel project in February 2012 as Head of Asset Delivery in the Thames Water Client team and transferred to Tideway, as Asset Management Director in September 2014. Roger is a Fellow of the Institution of Civil Engineers and has held board level positions in both contracting businesses and engineering and planning consultancies prior to joining the project. The first 20 years of his career was in the geotechnical contracting sector (mining, piling and ground engineering) in the UK and overseas before moving into transportation consultancy (highways, rail, aviation) for organisations such as Crossrail, Network Rail, TfL, Highways Agency and Department for Transport. Roger’s Asset Management Team at Tideway is responsible for integrated assurance, technical oversight of project delivery (including design assurance, compliance with planning permission, innovation, environmental sustainability, skills and employment) and the operational integration of the completed Thames Tideway Tunnel asset into the existing London sewer network.

**Panel Session 1: Delivery of infrastructure systems and services**

**Biography:** Chris Barrett received a Ph.D. in Bioinformation Systems in 1985 and an MS in Engineering Science in 1983 from the California Institute of Technology. Prior to joining Biocomplexity Institute of Virginia Tech, he lead a research group at the Naval Air Development Center focused on the integration of machine and human intelligence in naval aircraft and later was leader of the Basic and Applied Simulation Science Group at the Los Alamos National Laboratory (LANL). At LANL Barrett built up a research group active in theoretical and applied research in complex systems, particularly those related to biological and social computation, interdependent societal infrastructures, computational epidemiology and synthetic information systems. The computational work is grounded in a basic research program in mathematics, theoretical computer science and the basic science of HPC-enabled representation of very large systems in great detail. After retiring from LANL he established the Network Dynamics and Simulation Laboratory at Biocomplexity Institute. At Biocomplexity Institute he has extended the scope of informatics research in biosocial complex systems.

Professor Barrett has scientific experience in simulation, synthetic information systems, computational social and psychological science, scientific computation, algorithm theory and development, network science, system science and control, artificial intelligence, biosystems analysis, decision science, cognitive science. His research is largely devoted to the development and use of large-scale, high performance synthetic information systems. Dr. Barrett has received Distinguished Service Awards from the US Navy, Los Alamos National Laboratory, the Alliance for Transportation Research, the Royal Institute of Technology in Stockholm, was named a Jubileum Professor of Computer Science at Göteborg University in Sweden.

In 2014, Professor Barrett was named Executive Director of the Biocomplexity Institute at Virginia Tech.
Panel Session 2: Systems thinking to transform infrastructure services

**Biography:** John is a partner in Beckford Consulting, Visiting Professor in the Department of Civil, Environmental and Geomatic Engineering at University College London and in the Centre for Information Management at Loughborough University and a Non-Executive Director of Fusion21 Limited (a social enterprise). He holds a PhD in Management Systems and Sciences from The University of Hull, is a Fellow of the Cybernetics Society, a Member of The Institute of Management Services, a Fellow of the Royal Society for the Arts and a Fellow of the Institute of Engineering and Technology. John is author of The Intelligent Organisation (Routledge, 2016) and Quality (Routledge, 4th Edition, 2017) and numerous papers and articles. Consulting activity covers public, private and third sector organisations and both manufacturing and services. Since 2009 John has been at the heart of the application of systems ideas to the challenge of national infrastructure.

Panel Session 6: Digital Transformation

**KEYNOTE:** Moving from BIM to a Digital Economy in infrastructure and city programmes

**Abstract:** The DBB programme seeks to enable the Government to achieve the following strategic objectives:

- **Reduce the total expenditure associated with the built environment:** Information-enabled transformation will enable optimisation across the built environment lifecycle, resulting in reduced whole-life costs. For example, information that can enable changes in maintenance and energy use or enable advanced manufacturing techniques to drive down costs.
- **Maximise the return on investment in the built environment:** Enable trusted data-driven decision-making through integrated strategic financial investment planning to promote transparency, cost certainty and provide confidence that every pound invested will be maximised through delivering the right assets.
- **Increase availability, capacity and performance of the existing built environment:** The majority of infrastructure planned to be available in 2050 is already in existence. This programme will define a commercial and information framework to accelerate the development and application of new disruptive technologies to increase performance and get the most value out of the existing built environment. For example, acceleration of connected and autonomous vehicles, UBER services or built environment 3D printing.
- **Drive growth in the UK’s information economy:** New technologies, skill sets and high-paid employment opportunities which drive growth and create valuable export opportunities. For example, through the formation of data scientists using advanced artificial intelligence algorithms, robotics systems, big data analytics.

Mark will describe how these objectives are being evaluated and developed to ensure the UK maintains its position as a global leader in digitisation and delivery of services.

**Biography:** Mark chairs the UK Government Digital Built Britain programme, which is charged with delivering BIM Level 2 into the UK Public Sector Construction Sector by 2016 and Level 3 by 2025. He is also Chairman PCSG Ltd which is an organisation focused on delivering technology, process and associated sustainability services to the construction and built environment sector. Clients value Mark’s forthright approach to business. He possesses strong business acumen and has gained considerable experience serving on two UK construction sector company executive boards, authoring many published papers and presenting at major conferences in the UK, Europe, the Middle East and the United States.

Mark was awarded the MBE for services to construction in January 2012.
Panel Session 5: Funding and Finance for Infrastructure

Biography: Tom is an Economic Adviser at the National Infrastructure Commission. He is currently working on new and innovative ways to fund infrastructure through land value capture and road pricing. He has previously worked on waste policy and infrastructure financing.

Panel Session 3a: Governance of infrastructure systems and services

KEYNOTE: The challenge of responsive infrastructure provision
Abstract: Infrastructure providers are well aware of the increasing intensity of interaction, interconnection and interdependency between their systems. In major infrastructure hubs, especially cities, they are more and more often competing for space and causing hindrance for residents and users of infrastructure. Coordination and cooperation are needed to reduce costs and hindrance but also to grasp cross sector opportunities for better performance. Infrastructure providers in the Netherlands have taken the initiative to establish a joint knowledge platform for exchange of best practices across infrastructure sectors and joint knowledge development for the future provision of infrastructure, thus creating a basis for the coordination that is missing in the current system. Through this platform they aspire to be more responsive to each other’s needs as well as to create better responsiveness to emerging societal needs.

Biography: Cees Brandsen is Managing Director of the Rijkswaterstaat national unit for Water Management, Traffic, and the Environment, and member of the Executive Board of Rijkswaterstaat responsible for knowledge and quality of the infrastructure. Cees Brandsen started in 1980 at an engineering consultancy firm where he held several positions. In 1996 Cees joined Øresondskonsortiet in Copenhagen and was responsible for the project management of the tunnel part of the Øresund Link, the tunnel and bridge connecting Denmark and Sweden. Later, Cees Brandsen worked at the north-south metro connection in Amsterdam and the new train connection between the Port of Rotterdam and Germany. In 2002, Cees Brandsen became member of the management board of a large construction company in the Netherlands.

Cees Brandsen joined Rijkswaterstaat in 2006, first as director of Projects, and from 2008 to 2017 as Managing Director of the national unit Major Projects and Maintenance. In this capacity, he was responsible for the technical expertise, procurement and contract management, and project management of Rijkswaterstaat’s major construction projects.

Since 2017, Cees Brandsen is responsible for translating policy decision, knowledge and innovation to the executive tasks of Rijkswaterstaat, and vice versa. In making sure that the executive tasks of Rijkswaterstaat can be done now and in the future in the best way possible, Rijkswaterstaat collaborates closely with knowledge institutes and private parties.

Cees Brandsen graduated in Civil Engineering at the HU University of Applied Sciences in Utrecht.

Panel Session 3b: Governance of infrastructure systems and services

KEYNOTE: ICE’s role in engineering a digital future
Abstract: ICE is a charitable membership body with over 90,000 members spread across more than 150 countries. It has a proven ability to convene genuinely independent, impartial and authoritative industry groups from across the whole spectrum of
ICE believes there is an opportunity for the UK to establish itself as a world leader in digital delivery and smart infrastructure, while ensuring the productivity and resilience of our current networks. To achieve this, there needs to be a transformation in the way engineers think about our infrastructure and our professional practices, so that the industry can lead the way in innovative, disruptive change and find new ways of adding value.

This presentation will draw on the need to ensure that engineers’ skills and competencies are attuned to the current needs of the market, as well as outline ICE’s expertise in offering policy, technical and commercial advice on the changes required to allow maximum benefit from use of new technologies. Examples will include the BIM Action Group, ICE’s State of the Nation: Digital Transformation report and the ICE Thinks thought leadership programme, all of which seek to demonstrate how both industry and Government can make the most of existing levers to drive and embed digital transformation across infrastructure sectors.

**Biography:** Tim is Professor of Built Environment Foresight as well as Honorary Professor of Civil Engineering at University College London. He has spent most of his career developing and deploying innovative approaches to solve industrial problems, and has been corporate director of technology, innovation and sustainability at global engineering consultancies as well as a period running the civil engineering research company CIRIA. Tim’s major current interests include digital engineering, infrastructure resilience and decision taking in a world of increasing uncertainty. Both a Fellow of the Royal Academy of Engineering and the ICE, Tim is greatly respected in the industry. He is currently a Vice Chairman of the Construction Industry Council and a Director of both BuildingSmart (UK) Ltd and CEEQUAL Limited.

Tim became Vice President of the Institution of Civil Engineers in 2011, with particular responsibility for Public Voice and Policy. He is now President for 2016/7.
public health benefits. Yet autonomous, connected vehicles and other smart technologies are poised to promote increased automobility, stretching out cityscapes and in doing, making it more difficult to walk and cycle. This talk draws upon international research on factors influencing active mobility and suggests pathways for increasing non-motorized transport in an era of autonomous technologies, e-commerce, and other potentially disruptive technological advances and mega-trends.

Economic development benefits of active mobility are reviewed in the talk, particularly in terms of land price appreciation and creative-class employment. How network design, low-stressed pathways, land-use mixes, natural habitats, urban amenities, and public policies individually and collectively influence bicycle commuting is also examined, drawing on recent research on experiences across 36 medium-sized cities and towns in the UK. Active transport, it is noted, can play a particularly important role as a first- and last-mile connectivity bridge to public transport. While ICT, autonomous technologies and e-commerce could promote more car-centric urbanism and work in other ways to discourage active mobility, this can be tempered through thoughtful and pro-active public policies, including lane and land reassignments, smart autonomous public-transport investments, and smart pricing, including for parking.

Biography: Robert Cervero is Professor Emeritus of City and Regional Planning at the University of California, Berkeley and Director of the University of California Transportation Center (UCTC). Professor Cervero’s research examines the nexus between urban transportation and land-use systems. Professor Cervero chairs the International Association of Urban Environments and serves on the Advisory Board of the World Economic Forum’s Future of Urban Development Initiative and the American Planning Association’s Emerging Issues Task Force. He was a contributing author to the recent IPCC (International Panel on Climate Change) Fifth Assessment and UN-Habitat’s Global Report on Sustainable Mobility. In 2013 he was ranked among the top 100 City Innovators Worldwide by UMB’s Futures Cities. In a recent review of scholarly work by more than 900 urban planning professors in North America, he ranked number five in terms of Google Scholars citations and 2nd in terms of the H-Index factor.

The June 2016 issue of Planning magazine called him “the world’s top expert on transit-oriented development” and credited him as the “pioneer” of the now-ubiquitous “D” variables for explaining travel behavior.

Professor Brian Collins
CB, FREng
University College London
Director, International Centre for Infrastructure Futures
UKCRIC

Panel Session 3a: Governance of infrastructure systems and services

OPENING ADDRESS: UKCRIC: a transformational global opportunity for collaboration on infrastructure research

Abstract: The vision of UKCRIC is to provide leadership, support and coordination for the development and growth of a coherent, world class, UK based infrastructure research community. This will engage academia, industry and citizens in a joint venture that drives innovation and value creation. An uplift in investment in capital equipment and facilities is already underway. This will underpin transformative research across all disciplines and sectors and for all stakeholders for decades to come. This talk will describe the current status of this initiative, what is planned to happen in the near future and how potential partners can engage in a once in a lifetime opportunity to carry out research that will transform how we live in nations and cities in the UK and across the world.

Biography: Professor Collins took up the position of Director of the Centre of Engineering Policy at University College London (UCL) in August 2011. In this role he participates in and supports an international network of academics interested and active in research in infrastructure engineering and modernisation.

Prior to joining UCL, he was the Department for Transport’s (DfT) Chief Scientific Adviser (CSA) and CSA for the Department for Business Innovation and Skills (BIS). Brian chairs an Engineering and Interdependency Expert Group for Infrastructure UK, led by Lord James Sassoon, Commercial Secretary
in Her Majesty’s Treasury and was appointed as a visiting Professor to the SMART Infrastructure Facility in 2011.

Professor Collins is an elected Fellow of the Royal Academy of Engineering and was conferred the honour by Her Majesty the Queen of election to Companion of the Bath in the 2011 New Years Honours List.

Isabel Dedring
Global Transport Leader
Arup

KEYNOTE: Lessons from the shop floor: Delivering better and more infrastructure

Abstract: The gap between the list of infrastructure projects we would like to see happen and those that are funded and delivered is huge, and shows little sign of reducing. This is in part because of continued growth in demand for infrastructure, but also due to a lack of new solutions to this long-standing problem. What new ways of working can we develop to bridge these gaps, and what lessons are there from projects around the world in this area? What role can city institutions play in tackling this challenge?
Isabel Dedring is the Global Transport Leader at Arup where she is responsible for driving the development of the firm’s business across the transport sector.

Biography: Isabel joined Arup in March 2016 from London’s City Hall, where she was Deputy Mayor for Transport and Deputy Chair of Transport for London. In this capacity she was responsible for setting policy and ensuring delivery across the Mayor’s transport portfolio. Key projects she initiated and delivered included the Tube Reliability Programme which led to a 40% reduction in Tube delays; the £300m Growth Fund to fund transport infrastructure to unlock new house building; the Mayor’s new £1b cycling infrastructure programme; and London’s first-ever roads strategy and the associated £4b implementation programme.

Prior to her transport role, Isabel was the Mayor’s Environment Advisor, responsible for delivering large-scale building retrofit programmes, parks and trees programmes and the £100m London Green Fund, among other initiatives.

Previous roles include running the policy team at Transport for London and 4 years as a management consultant at McKinsey. Isabel is a qualified US lawyer.

Mark Enzer
Chief Technical Officer
Mott MacDonald

Panel Session 6: Digital Transformation

Biography: Mark is Mott MacDonald’s Chief Technical Officer. In this role, Mark is accountable to the Group Board for technical excellence globally, which he drives via Mott MacDonald’s internal professional networks. Mark is a keen champion of innovation in the context of collaborative delivery models and he is particularly interested in transformational change in infrastructure engineering, including the application of digital transformation, Smart Infrastructure, low-carbon sustainable solutions, product-based delivery, BIM and design for manufacture and assembly (DfMA).

Mark is the leader of the Digital Transformation workstream as part of “Project 13″ for the Infrastructure Client Group, which represents the UK’s major infrastructure client organisations.

Professor Jim Hall, FREng
University of Oxford
Director, Environmental Change Institute, University of Oxford
UKCRIC

Panel Session 1: Delivery of infrastructure systems and services

KEYNOTE: Delivering the ‘modelled world’ of infrastructure

Abstract: Computer modelling has long been a
central aspect of infrastructure planning and design. Energy systems optimisation models, transport planning models, flood risk analysis models and water resource systems models are indispensable tools. Nonetheless, until recently these approaches (i) tended to be based on different conceptual framings and scenario assumptions and (ii) represented the interdependencies between infrastructure sectors in simple and static ways, if at all.

This has all begun to change with the development of system-of-systems modelling methodologies that seek to provide a consistent platform for national infrastructure assessment. A unique capability of this type has been developed in the UK, which is the NISMOD national infrastructure systems model developed over the last six years by the Infrastructure Transitions Research Consortium and now being used by the National Infrastructure Commission for the National Infrastructure Assessment, after previous use for the National Needs Assessment and by Infrastructure UK.

Looking ahead, the recently funded Data and Analytics Facility for National Infrastructure (DAFNI), which is one of the major UKCRIC investments, will provide a secure national repository for the NISMOD-DB National Infrastructure Database and an e-science platform with accompanying visualisation facilities, which can be utilised for a wide range of different analytical and simulation tasks. DAFNI will be accessible to academics, businesses and government department and agencies. By crowding in data and modelling capabilities, DAFNI will become a hub of global importance for infrastructure systems analytics. This talk will look ahead to some of the new opportunities that DAFNI will present: scalable computing that will enable analysis and optimisation of risks, resilience and investment plans at a national scale; and the assimilation of new data sources to achieve multi-scale simulation and real-time data assimilation.

**Biography:**
Professor Jim Hall FREng is Director of the Environmental Change Institute in the University of Oxford, where he is Professor of Climate and Environmental Risks in the School of Geography and the Environment, a Senior Research Fellow in the Department of Engineering Science and fellow of Linacre College. His research focuses upon management of climate-related risks in infrastructure systems, in particular relating to various dimensions of water security, including flooding and water scarcity. Jim Hall is a member of the UK independent Committee on Climate Change Adaptation. In 2010 Jim was elected as a Fellow of the Royal Academy of Engineering “for his contribution to the development of methods for flood risk analysis, which underpin approaches for flood risk management in the UK and internationally.” He sits on the Public Voice Committee of the Institution of Civil Engineers and was a member of the panel conducting the Institution of Civil Engineer’s 2014 State of the Nation Infrastructure assessment and the Executive Group for the National Needs Assessment – A Vision for UK Infrastructure. Until 2015 Jim Hall was co-chair of the Global Water Partnership / OECD Task Force on the Economics of Water Security and Sustainable Growth. He advises the World Bank on water security and is editor of the AGU journal Water Resources Research. Jim leads the UK Infrastructure Transitions Research Consortium, which has developed the world’s first national infrastructure simulation models for appraisal of national infrastructure investment and risks. His book “The Future of National Infrastructure: A System of Systems Approach” was published by Cambridge University Press in 2016. He sits on the Expert Advisory Group for the National Infrastructure Commission and Chairs the DAFNI Data and Analytics Facility for National Infrastructure.

**Panel Session 4a: Cities and Urban Systems**

**Biography:**
Terry Hill is a Trustee of the Arup Group owning Trusts, a non-executive Director of Crossrail Ltd, Chairman of the Transport Systems Catapult innovation centre, and Chair of the Independent Transport Commission. Terry was President of the International Organisation for Standardisation (ISO) for two years, 2013 -2014, and also a founder member of the UK Advisory Council, and led its Infrastructure Cost Review.
A civil engineer and economist, Terry Hill has led many infrastructure investments and has a proven record of achievement in innovative transport, highways, metro and high speed rail. Terry was previously Chair of the £1bn turnover, 11,000 staff Arup Group Ltd and its owning Trusts from 2004 – 2013 and before that led its global Transport Market and Infrastructure Division, where his role centred on consulting, infrastructure and managing major projects. He now chairs The Ove Arup Foundation.

Originally from Manchester, Terry Hill lives in the UK near London, is married and has three sons.

Panel Session 4b: Impact of the Internet of Things on Infrastructure Asset Management

**Biography:** Esther Hardi is a strategist and innovation manager with Alliander, the largest regional infrastructure provider for electricity, gas and heat in the Netherlands. For 20 years she has been working in the energy business in the field of competitive strategy, innovation and business development. She has been a pioneer in biogas injection in the Dutch gas grid and is actively involved in renewable sustainable energy supply. She supervises a number of major systems integration pilot projects, such as Power2gas, EBay for Energy, and Heat systems 2.0 in neighbourhoods. She co-chairs ETIPS NET - the European Technology and Innovation Platform “Smart Networks for Energy Transition” which aims to ensure that all energy customers and market actors can rely on optimally integrated networks, systems and markets. Esther holds an MSc in applied mathematics (TU Delft) and is currently affiliated with TU Delft as a PhD research fellow. Prior to her career in Alliander, she worked for Schlumberger Offshore and Nuon (now Vattenfall).

**Professor Nick Jennings, CB, FREng**

Vice Provost (Research)
Imperial College London

**KEYNOTE: Digital underpinnings for smart cities: challenges and opportunities**

**Abstract:** This talk will explore the digital infrastructure that is needed to underpin smart cities. It will highlight the potential that connected services can provide to citizens, in terms of timely and accurate information and how such information can be used to develop personalised services. The talk will also explore the cyber security challenges faced by such digitally-enabled cities -- from the denial of access to such services, to the possibilities of wide spread harm and disorder.

**Biography:** Professor Nick Jennings, CB, FREng, is responsible for promoting, supporting and facilitating Imperial College London’s research performance and for leading on the delivery of the Research Strategy. He also holds a chair in Artificial Intelligence in the Departments of Computing and Electrical and Electronic Engineering. Before joining Imperial College London, Professor Jennings was Regius Professor of Computer Science at the University of Southampton and the UK Government’s Chief Scientific Advisor for National Security. Professor Jennings is an internationally-recognized authority in the areas of artificial intelligence, autonomous systems, cybersecurity and agent-based computing.

**Giel Jurgens**

Asset Owner
Port of Rotterdam

Panel Session 4b: Impact of the Internet of Things on Infrastructure Asset Management

**Biography:** Giel Jurgens is, on behalf of the COO, the Asset Owner of the Port of Rotterdam. Giel has over 20 years of experience in Maintenance Management.
and Asset Management. Port of Rotterdam is the ‘landlord’ of a port and industrial cluster of 12,500 hectares and the first port in the world that was ISO 55001 certified for its asset management. Port of Rotterdam manages a wide variety of assets, with the main part of the asset base being port related infrastructure.

Giel Jurgens is closely involved in several roles in the Next Generation Infrastructures programme, a cross-sector alliance of Dutch infrastructure providers.

**Panel Session 3b: Co-creating ‘responsive’ infrastructure: a case for systems capacity building**

**Biography:** Corina Kwami is a doctoral researcher interested infrastructure, innovation and technology for cities in emerging markets. She is currently working on a study of governance in the water sector in Medellin, Colombia with a utilities’ provider based in Medellin, Colombia.

Previous work has included consultancies for the United Nations with direct international experience in cities in Europe, the Middle East and Africa. She has worked with UN agencies such as WHO, International Labor Organization, partner agencies such as UNICEF, UNFPA and UNHCR, development partners such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Belgian Development Cooperation (BTC) and through partnerships with the Bill & Melinda Gates Foundation, Mastercard Foundation and Ferrero Chocolate. The role of smart infrastructure and construction for next generation cities.

**Panel Session 6: Digital Transformation**

**Biography:** Dr Stephen Lorimer is the Smart London Strategy and Delivery Officer at the Greater London Authority. He develops the Mayor of London’s policies and programmes in smart cities and the strategic transformation of city services using digital technologies.

He is the programme manager for the forthcoming London Office of Technology and Innovation, a new vehicle for digital collaboration between the GLA, London Councils and the London Boroughs. It will establish new digital governance for London, promote common standards, and foster open innovation. He was the lead developer of The Future of Smart, a review of how smart city technologies engage Londoners and enable good growth when the city works with innovators. He was a co-author of Digital Master Planning, An Emerging Strategic Practice in Global Cities, a study of how cities around the world plan for amplification of existing investments in infrastructure, improved government services, and economic development through sustained, incremental innovation in digital technology.

Before working for the Mayor of London, he worked in consultancy and academia. He managed the Sustainable Society Network for the RCUK Digital Economy Programme, commissioning studies in how technology solves societal challenges. His doctoral and post-doctoral work on big data, energy, and city life spanned the architecture, planning, spatial analysis, and transport studies centres at UCL. His work as a consultant to local authorities in the UK, France, and Ireland ranged from urban design in masterplans to policy work for housing and conservation standards and design.
KEYNOTE; The role of smart infrastructure and construction for next generation cities

Abstract: The engineering, management, maintenance and upgrading of infrastructure requires fresh thinking to minimise use of materials, energy and labour whilst still ensuring resilience. This can only be achieved by a full understanding of its performance, both during its construction and throughout its design life, through the application of innovative sensor technologies and other emerging technologies. It can benefit enormously from being ‘smart’, which involves the innovative use of emerging technologies in sensor and data management. If future cities are to be well-led and well-managed, they must have high-quality infrastructure, so that they can provide the best services, quality of life, economies and jobs. Important city infrastructure comprises such items as tunnels, bridges, roads, railways, buildings and utilities; its quality and performance is essential for supporting economic growth and productivity. High quality city infrastructure attracts globally-mobile businesses and promotes social well-being.

There is a compelling case for using sensing and data analysis to enable smarter, proactive asset management decision-making for city infrastructure. Being proactive, not reactive, enables maintenance, inspection and refurbishment programmes for city infrastructure assets to be developed, focusing on condition and preventive maintenance. It is essential to capture and analyse the right data at the right time for city asset management decisions to be effective. The Cambridge Centre for Smart Infrastructure and Construction (CSIC), funded by EPSRC, Innovate UK and industry, aims to transform the future of city infrastructure. Its role is to advance research in smart infrastructure and create impact in the infrastructure and construction industry. CSIC is developing cutting edge sensing and data analysis models, which will provide a powerful platform for providing data to enable smarter and proactive asset decisions, both during construction of new city assets and for existing city infrastructure.

The presentation will describe how CSIC is collaborating with industry to commercialise independent, world-leading research and drive technology-led business growth using novel technologies such as fibre optics, wireless sensor networks, low power sensors based on micro electro mechanical systems (MEMS), computer vision and energy harvesting. Examples of recent applications will be presented, showing how these new technologies have the potential to revolutionise the construction and management of infrastructure. Such opportunities can lead to considerably enhanced efficiencies, economies, resilience and adaptability, benefitting not just the construction industry but society served by its infrastructure.

Biography: Robert Mair is the Sir Kirby Laing Professor of Civil Engineering at Cambridge University and until recently was Head of Civil Engineering at Cambridge. He was Master of Jesus College 2001-2011 and Senior Vice-President of the Royal Academy of Engineering 2008-2011. Before he was appointed to a Professorship at Cambridge in 1998 he worked in industry for 27 years, joining Scott Wilson Kirkpatrick after graduating from Cambridge; he worked in Hong Kong in the early 1970s. In 1983 he became a founding Director of the Geotechnical Consulting Group, an international consulting company based in London and is currently a Senior Partner. He is also Engineering Adviser to the Laing O’Rourke Group.

His research group at Cambridge specialises in the geotechnics of tunnelling and underground construction. He has advised on numerous tunnelling and major civil engineering projects in the UK and worldwide. He has been closely involved with many London Underground projects, as well as Crossrail for which he has been a member of its Engineering Expert Panel. He is Chairman of the Science Advisory Council of the Department of Transport. He also leads the Centre on Smart Infrastructure and Construction (CSIC) at Cambridge, involving the innovative use of the latest sensor technologies to monitor the performance of civil engineering infrastructure. He chaired the Royal Society/Royal Academy of Engineering Report on Shale Gas for the Government, published in 2012.
He was elected a Fellow of the Royal Academy of Engineering in 1992 and of the Royal Society in 2007. He was recently appointed an independent crossbencher in the House of Lords and is a member of their Select Committee on Science and Technology.

Panel Session 7: Future research and innovation agendas for next generation infrastructure systems

Biography: Until recently, Professor Masterton was Vice-President of Jacobs Engineering. He is a past president of the Institution of Civil Engineers, past president of the Institution of Engineers and Shipbuilders in Scotland, former chairman of the Construction Industry Council, former Vice Chairman of the Royal Commission on the Ancient and Historical Monuments of Scotland, and founder and current Chairman of the Scottish Engineering Hall of Fame. Professor Masterton was the UK Government’s project representative on the £15bn Crossrail development in London – Europe’s largest construction project to date. Recently, he was appointed a member of the Independent Assurance Panel for the HS2 high-speed rail link.

The new Professor brings more than 35 years of industry experience and leadership of major infrastructure design, construction and commissioning to his new post.

The concept of restorative, regenerative, net positive outcomes is well established in some product design processes, and increasingly represented at building/precinct scale. It is now time to begin in earnest the journey towards net positive infrastructure. This journey will require not only new tools but also new perspectives and dispositions for the wielders of those tools.

Accordingly, in this talk, I will share insights from three resonant domains of recent work. First, in the water sector, applying the 3 Horizons futuring tool with Hunter Water, a major water utility in Australia, to chart a qualitatively different path forwards. Second, in the field of learning, sharing new insights into the process of worldview transformation. Third, demonstrating practical frameworks for implementing the necessary transdisciplinary approaches required to orchestrate change at this scale.

Biography: Professor Cynthia Mitchell is a leading researcher and thinker with broad experience in future-oriented city and water planning, policy and assessment. She brings together insights from different disciplines to improve water supply and sanitation systems in developed and developing countries.

Prof. Mitchell uses systems thinking to analyse how the parts of these systems interrelate over time within the context of larger systems, and she uses transformational learning to facilitate the changes in beliefs and behaviours needed for systemic change. In developing countries, her research focuses on moving away from preconceived ideas to find what
existing or new technologies and more importantly, institutional/financial/economic arrangements, will deliver the desired outcomes in both the short and long term.

Prof. Mitchell provides high-level advice to State government ministers as a member of the Independent Water Advisory Panel in NSW that provides strategic and technical advice on urban water planning for the lower Hunter and greater Sydney and the Independent Review Panel which provides advice on the water security program for South East Queensland (SEQ). She is Deputy Chair of the SEQ IRP reporting to their Board. She is Chairperson of Foodswell, a charitable organization offering programs to enable Indigenous and non-Indigenous people to work together to better access sustainable, regular, healthy food now and in the future.

Prof. Mitchell is widely respected within Australia and internationally and her research has won many awards from industry, government and academia. Prof. Mitchell was elected a Fellow of the Australian Academy of Technology and Engineering (ATSE) in 2012 and she received an Honorary Doctorate from Chalmers University in Sweden in 2007 for her interdisciplinary work for the environment. She holds a Diploma of Business (Governance) and was nominated as one of the Australian Financial Review’s 100 ‘Women of Influence’ in 2015 for her contributions to public policy.

Panel Session 5: Funding and Finance for Infrastructure

KEYNOTE: Infrastructure research and the UK funding landscape

Abstract: The UK’s infrastructure is a complex, interlinked ‘system of systems’. However, the resilience of our current system is being challenged by a scarcity of resources, together with ageing utilities and a rising population. In order to meet these challenges the UK will require innovative research coupled with major public and private sector investment.

Infrastructure is not just concerned with visible structures like roads and railways; it has many layers, including communications networks, energy production, storage and transmission, to name just a few. Each system has its own role to play, but they are highly interdependent. Understanding the relationships between these components is a key challenge for those involved with the national infrastructure – be they researchers, planners or Government representatives.

Developing new infrastructure presents opportunities for domestic growth and job creation, but it also gives the UK the chance to demonstrate its innovative thinking, leadership and skills with the potential to expand into global markets. All this is set against a backdrop of a rising R&D budget and the Government’s new Industrial Strategy. This was announced by the Prime Minister in November last year, during her first speech to the CBI Annual Conference. In this, she outlined the Government’s plans, with investment in science, research and innovation, and upgrading infrastructure, being two of the ten “pillars” on which this new Industrial Strategy is being built.

As one of the nine partners that will form UKRI, EPSRC has an extensive remit that covers the many components of infrastructure, supporting nearly 400 projects worth more than £400 million. These projects include both fundamental research and activities targeted at shorter term outcomes. The portfolio includes EPSRC’s flagship investment in infrastructure research, The UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC), which is connecting multiple communities of researchers to develop an integrated view of infrastructure needs, development and delivery. The research undertaken by UKCRIC will help us to understand how we can make the nation’s infrastructure more resilient to extreme events, more adaptable to changing circumstances, and how it can provide services that are more affordable, accessible and useable for the whole population.

This session will showcase some of the leading research that EPSRC has supported in this area, looking at how these projects are helping to deliver real impact and resilience for the nation.
Biography: Philip Nelson served from 2005-2013 as Pro Vice-Chancellor of the University of Southampton, with particular responsibility for Research and Enterprise. He previously served as Director of the University’s Institute of Sound and Vibration Research and as Director of the Roll-Royce University Technology Centre in Gas Turbine Noise. He holds the post of Professor of Acoustics and has personal research interests in the fields of acoustics, vibrations, signal processing, control systems and fluid dynamics.

Professor Nelson is a Chartered Engineer and is a Fellow of the Royal Academy of Engineering, the Institution of Mechanical Engineers, the Institute of Acoustics, and the Acoustical Society of America. He is the recipient of both the Tyndall and Rayleigh Medals of the Institute of Acoustics, and served as President of the International Commission for Acoustics from 2004-2007. He also served as the Chair of the Sub-Panel for General Engineering in REF 2014. He is the author or co-author of 2 books, over 120 papers in refereed journals, 30 granted patents, and over 200 other technical publications.

Professor Nelson has had a long association with EPSRC, most recently serving as a member of the Council’s Strategic Advisory Network since 2010.

Anne O’Neil PE CSEP
Systems Engineering Catalyst & Strategist
Anne O’Neil Consultants LLC

Panel Session 2: Systems thinking to transform infrastructure services
Panel Session 3b: Co-creating ‘responsive’ infrastructure: a case for systems capacity building

Biography: Former founding Chief Systems Engineer for MTA NYCT, Anne O’Neil serves as a committed catalyst for building systems capability among infrastructure sectors.

Founder of Anne O’Neil Consultants LLC, Anne advises organizations seeking to adopt systems practices and apply systems engineering (SE) capability to achieve and improve business outcomes. She counsels the increasingly diverse range of industries facing complexity and integration challenges from automotive and ground transportation to buildings and healthcare. She supports businesses across a spectrum of maturity levels – from assessing where applying systems expertise offers the strongest business benefit, to acquiring or enhancing an internal systems capability.

From 2005-2013 as the founding Chief Systems Engineer for MTA New York City Transit (NYCT), Anne established and integrated SE capability to improve the agency’s capital project delivery. This required developing systems engineering discipline expertise and modifying the agency’s business process and program development approach. It also necessitated effecting change and building systems awareness at an industry level – among peer transit properties, consultants, contractors and systems suppliers.

A former INCOSE, International Council on Systems Engineering, Board member, Anne currently serves as INCOSE Industry Outreach Ambassador. She has long served as a systems champion within the transportation industry, raising SE awareness. She evolved the INCOSE Transportation Working Group into an international forum for industry exchange, serving 6 years as co-chair. Concurrently, she founded and chaired (2008-2012) the Systems Engineering Committee for APTA, American Public Transportation Association. In recognition of Anne’s extensive outreach efforts within both the SE community and transportation industry, she was awarded the 2011 INCOSE Founders Award.

Dr. Ajith Parlikad
Senior Lecturer in Industrial Systems
University of Cambridge

Panel Session 2: Systems thinking to transform infrastructure services

Ajith Kumar Parlikad is a University Senior Lecturer at Cambridge University Engineering Department. He is based at the Institute for Manufacturing, where he is the Head of the Asset Management research group. He is also the MET IIB course director.
Ajith leads research activities on engineering asset management and maintenance. His particular focus is examining how asset information can be used to improve asset performance through effective decision-making. He actively engages with industry through research and consulting projects. He is also a member of the steering committee of the IFAC Working Group on “Advanced Maintenance Engineering, Services and Technology”.

Ajith joined Cambridge University to read for his PhD degree, which he successfully completed in August 2006. For his PhD, he developed a methodology for quantifying the benefits of improving product information availability and quality on the effectiveness of product recovery processes.

Panel Session 1: Delivery of infrastructure systems and services

KEYNOTE: Smart City: the Good, the Bad and the Ugly

Abstract: While there is a broad consensus to define and describe the Internet of Things (IoT), the concept of ‘smart city’ seems to suffer from the dual nature of its foundation, partly drawn from New Urbanism principles and partly fed by a technology-focused agenda hailed by corporations like IBM and CISCO. As a result, smart cities progressively emerge through a confusing process whereby rapid technology deployment pre-empts robust needs analyses, a largely liveability-focused narrative is contradicted by dominantly productivity-oriented applications, and short-term commercial interests jeopardise the long term interoperability of enabling technologies and services. As a result, residents, local businesses and local authorities feel pressured to embrace the smart city revolution while being utterly confused about its immediate benefits and long-term achievements. However, a growing number of initiatives around the world try to reconcile people’s needs and aspirations with technological deployment. These examples of smart cities from the bottom-up need to be encouraged and generalised in order to foster the appropriation of the concept and adoption of its solutions by urban dwellers. Failing to do so, the revolution might be short lived and smart cities only remembered as ‘fad cities’.

Biography: Prof Pascal Perez is a specialist of integrative infrastructure modelling, using various computer simulation technologies to explore complex interactions between social and technological components of infrastructure systems. He has a 30-year experience in complex system modelling, first in France, then at the Australian National University and CSIRO. Pascal joined the University of Wollongong in 2011 where he is now the Director of the SMART Infrastructure Facility. He is a Fellow of the Royal Society of NSW and of the Modelling and Simulation Society of Australia and New Zealand (MSSANZ). He is currently standing on the ministerial committee for Infrastructure Data Collection and Dissemination Strategy, set up by minister Paul Fletcher MP, and on the National Academic Committee of the Australian Urban Research Infrastructure Network (AURIN). Professor Perez has published 149 refereed papers and book chapters. In 2006, he co-edited with his colleague David Batten the book ‘Complex Science for a Complex World’ (ANU E Press).

Panel Session 5: Funding and Finance for Infrastructure

Biography: Ann Pettifor’s work and writing has concentrated on the international financial architecture, the sovereign debts of the poorest countries, and the rise in sovereign, corporate and private debt in OECD economies. Her latest book, Just Money: how society can break the despotic power of finance was published by Commonwealth in 2014. She is well known for her leadership of an organisation Jubilee 2000, that placed the debts of the poorest countries on the global political
agenda, and brought about both substantial debt cancellation, and radical policy changes, at national and international levels. In 2003 she edited the new economics foundation’s ‘The Real World Economic Outlook’ (Palgrave) with a prescient sub-title: ‘the legacy of globalisation: debt and deflation’. In 2006 Palgrave published her book: “The coming first world debt crisis”. In 2008 she co-authored “The Green New Deal” and in 2010 co-authored an essay with Professor Victoria Chick: “The economic consequences of Mr. Osborne.”

**Jules Pipe**

Deputy Mayor for Planning, Regeneration and Skills
Greater London Authority

**After dinner speech: Planning infrastructure in big cities: London’s example**

**Biography:** Jules Pipe is the Deputy Mayor for Planning, Regeneration and Skills. He is working on key priorities for the Mayor, including: major regeneration projects across the capital, providing young people and adults with the skills they need, ensuring London’s infrastructure needs are delivered to benefit all Londoners, and leading on revising the London Plan.

Jules has unrivalled knowledge of London government, becoming the first directly elected mayor of Hackney in 2002 and serving as Chair of London Councils from June 2010 to July 2016.

**Panel Session 7: Future research and innovation agendas for next generation infrastructure systems**

**Professor William Powrie FREng**

Professor of Geotechnical Engineering and Dean of the Faculty of Engineering and the Environment, University of Southampton, UKCRIC

**KEYNOTE: UKCRIC; joining the dots in infrastructure and cities research**

**Abstract:** UKCRIC, the UK Collaboratorium for Research in Infrastructure and Cities, is a new collaboration between thirteen of the UK’s leading universities in civil and construction engineering. It is distinctive in not having a single centre – rather, each partner institution leads on a particular theme and contributes to others. UKCRIC comprises three strands – living laboratories, data and simulation, and facilities. This presentation will focus on the UKCRIC organisation and governance, and the promotion of collaboration in research and use of facilities. UKCRIC’s proposed organisational and governance structures together with steps being taken to encourage and facilitate collaboration will be described, and exemplar collaborative case studies will be presented.

**Biography:** Professor William Powrie’s main technical areas of interest are geotechnical transport infrastructure, and sustainable waste and resource management – in both cases underpinned by an understanding of fundamental soil behaviour. He was elected a Fellow of the Royal Academy of Engineering in 2009 in recognition of his work in these areas. He is a co-author of the recently-updated CIRIA guides to groundwater control (C750) and embedded retaining walls (C760). He played a key role in establishing the Rail Research UK Association, and leads the UK Rail Research and Innovation Network (UKRRIN) Infrastructure Hub and an EPSRC Programme Grant on railway track systems. He is also Geotechnical Consultant to the internationally-leading groundwater control company, WJ Groundwater Ltd.

**Panel Session 5: Funding and Finance for Infrastructure**

**Biography:** Phil Purnell is Professor of Materials and Structures in the School of Civil Engineering, University of Leeds (UoL). Prof. Purnell is a previous
Professor David Richards
UKCRIC Capital Investment Programme, Associate Dean (Infrastructure), Faculty of Engineering and the Environment, University of Southampton, UKCRIC

KEYNOTE: UKCRIC research facilities: an overview and update
Abstract: UKCRIC, the UK Collaboratorium for Research in Infrastructure and Cities is a new collaboration between thirteen of the UK’s leading universities in civil and construction engineering. This presentation will provide a brief overview of the main laboratory facilities and highlight the progress in their design and construction.

UKCRIC research facilities: an overview and update
UK Collaboratorium for Research on Infrastructure and Cities - UKCRIC comprises an initial and non-exclusive group of 14 universities coming together to conduct world-leading research through a network of experimental facilities and urban laboratories. The Engineering and Physical Sciences Research Council (EPSRC) has supported the establishment of UKCRIC with an investment of £125 million, and in total more than £216.6 million is being invested by EPSRC and university partner organisations to create state-of-the-art new research facilities to inform and support the upgrade of the nation’s infrastructure. A brief overview of the progress in the design and development of these facilities will be made.

Biography: David’s main technical areas of interest are associated with infrastructure relate to field based studies assessing resilient foundation performance associated with the UK’s high voltage distribution structures, propped retaining structures, overhead line rail electrification foundations and performance of screw piles for use on deep sea wind turbine foundations.

Panel Session 6: Digital Transformation

Biography: Dr. Rick Robinson is Director of Technology for Amey, one of the UK’s largest providers of public and regulated services and infrastructure. In this role, Rick is responsible for driving advances in digital technology into public services and infrastructure that are used by about 1 in 4 people in the UK every day. Previously, Rick was Executive Architect for Smarter Cities for IBM. Rick collaborates with a network of technology entrepreneurs, Universities and social institutions to explore innovations in digital technology, and has advised the UK Government and United Nations on their impact on infrastructure, communities and society. Rick is a Fellow of the British Computer Society, a Fellow of the RSA, a member of the Academy of Urbanism, a member of the Board of Innovation Birmingham and Birmingham Science City Alliance. He founded and chairs the Birmingham Smart City Alliance. Rick writes about his work at http://theurbantechnologist.com/
Panel Session 4a: Cities and Urban Systems

Biography: Chris Rogers spent three years in the civil engineering industry before returning to academia to research pipeline soil-structure interaction. He lectured at Nottingham and Loughborough Universities before taking up his current position at the University of Birmingham in 1998. His research portfolio is dominated by two primary, necessarily interrelated, themes of infrastructure engineering and urban sustainability, resilience and liveability.

Building on prior research into trenchless technology, buried pipes, soil stabilization and road foundations, since 2004 he has led the multi-university EPSRC Mapping the Underworld (MTU) research initiative. MTU addresses the complex challenge of locating and mapping pipelines and cables buried beneath the streets, and has recently expanded into the use of shallow-surface geophysics to assess the condition of road structures, buried pipelines and cables, and the ground that supports them both (Assessing the Underworld). In iBUILD, he is working with engineers and economists to explore alternative business models emerging from considerations of infrastructure interdependencies.

With a focus on underground space use and utility service provision to future cities more generally, he led the multi-disciplinary Urban Futures consortium (part of EPSRC’s Sustainable Urban Environments programme) and leads the Liveable Cities Programme Grant, both exploring the performance of future cities in relation to citizen and planetary wellbeing. He is the engineering lead for Urban Living Birmingham, one of five Urban Living Partnership pilot studies exploring the challenges posed by UK cities, and is applying his futures analyses to address the problems faced by shrinking cities in the EU 3SRECIPE programme.

He is the academic lead of the UKCRIC’s £27.6m National Buried Infrastructure Facility, which is currently under construction, and leads the PLEXUS – the first research collaboration linking UKCRIC’s new experimental laboratories.

He chairs the ICE’s Research, Development & Innovation towards Engineering Excellence Panel and Futures Group, and was a member of the Lead Expert Group of the UK Government Foresight Future of Cities project.

Panel Session 6: Digital Transformations

Biography: Dr Jennifer Schooling was appointed Director of the Cambridge Centre for Smart Infrastructure and Construction (CSIC) in 2013. Dr Schooling has secured £7.6M in grant funding from EPSRC and Innovate UK for the Centre, including an additional five years’ core funding awarded to enable the Centre to expand its valuable work. She is founding Co-Editor-in-Chief of the Smart Infrastructure and Construction Proceedings journal (ICE) and a member of PAS185 smart cities security standard steering group and the UKCRIC standing committee. She has also recently served as a member of ICE’s State of the Nation 2017 ‘Digital Transformation’ Steering Group, the Tideway Innovation Forum and Tideway Academic Advisory Group. Prior to joining the Centre, Dr Schooling worked for Arup, leading the firm’s Research Business. She also worked with the Modern Built Environment Knowledge Transfer Network leading on the development of the agenda for the emerging Future Cities Catapult. Before joining Arup, Dr Schooling worked for Edwards Vacuum (then BOC Edwards) as a manager for New Product Introductions.
Panel Session 4a: Cities and Urban Systems

Biography: Jeremy Skinner is head of economic growth policy at the Greater London Authority. His team advises the Mayor on policies, programmes and projects to support both higher rates of growth in the capital and greater opportunities for Londoners. He leads the team that produced the London Infrastructure Plan to 2050, the original SMART London plan, and both the 2013 and 2017 reports of the London Finance Commission, which recommended devolution of taxes to the capital. His earlier work at the GLA included establishing London and Partners Ltd and MedCity Ltd and leading the successful campaign for Crossrail 1. He has previously worked at HM Treasury, PA Consulting Group and trained as a CIPFA accountant with the Audit Commission. He studied History at Gonville and Caius College, Cambridge University.

Jeremy Skinner
Head of Economic Growth Policy
Greater London Authority

Panel Session 3a: Governance of infrastructure systems and services

Biography: Wayne Swan served as the Treasurer of Australia for nearly six years, including three years as Deputy Prime Minister. He was one of the longest serving finance ministers in the G20 and was recognised as one of its leading contributors, drawing on his unique experience overseeing Australia’s economic outperformance among the developed world.

Hon. Wayne Swan MP
Former Federal Treasurer and Deputy Prime Minister, Australia
Member of the Australian House of Representatives, Australia

Panel Session 2: Systems thinking to transform infrastructure services

Biography: Prof Colin Taylor CEng FICE is Professor of Earthquake Engineering in the Department of Civil Engineering at the University of Bristol. He has

Mr Swan was awarded Euromoney Finance Minister of the Year in 2011 for his ‘careful stewardship of Australia’s finances and economic performance’ during the global financial crisis. He was only the second Australian to receive this accolade and the first for almost 30 years. His focus as Treasurer was on strong, secure economic growth, job creation, and maximising the opportunities for Australia in the Asian Century. He was instrumental in the publication of the Asian Century White Paper – a blue print for Australia’s engagement in the region.

He is the author of The Good Fight: Six Years, two prime ministers and staring down the Great Recession (2014). More recently, Mr Swan co-authored a report on Inclusive Prosperity, commissioned by the Center for American Progress. In 2015, he attended the UN General Assembly as a member of the Australian delegation. During this time, Mr Swan was a Senior Fellow at Yale University’s Institute for Global Affairs, heading a series of seminars on political and economic reform in the 21st century with a focus on contemporary Australian experiences.

He also published a report on Financing for Development for the United Nations Social and Economic Commission in the Asia Pacific (UN-ESCAP) and chairs their Eminent Expert Group (EEG) on Tax Policy and Public Expenditure Management for Sustainable Development.

Mr Swan was re-elected for the eighth time in the July 2016 Federal Election as the Federal Member for Lilley in the Australian House of Representatives.

Professor Colin Taylor
CEng FICE
Professor of Earthquake Engineering
University of Bristol
UKCRIC
a particular interest in the performance of complex infrastructure systems when subjected to natural hazards. His work has spanned across all kinds of infrastructure systems, including dams, long span bridges, utility networks, transportation and nuclear facilities, integrating theory, analysis, and advanced laboratory and prototype experimentation. His team recently won the Showcase Award of the Institution of Civil Engineers SW Region for its innovative experimental programme for EDF that is investigating the seismic performance of the ageing graphite cores of the UK Advanced Gas-cooled Reactor (AGR) nuclear power station fleet. Other ongoing work is exploring how infrastructure services influence customer and societal behaviours; a project with the UK payments infrastructure provider, Bacs, is generating new insights into customer learning and choices, and how these influence well functioning markets and the architecture of the infrastructures that service them. Colin is the Principal Investigator for the £13.9m UKCRIC investments at Bristol, which include the National Soil-Foundation-Structure Interaction facility and the UKCRIC Bristol Infrastructure Collaboratory that is developing the city as a holistic infrastructure laboratory.

KEYNOTE: Land use, worker heterogeneity and welfare benefits of public goods

Abstract: Two sorting issues play an important role in the valuation of local public goods. First, availability of public goods leads to higher population densities. Second, population groups may differ in their valuation of public goods and they will sort accordingly. Both processes lead to a more efficient use of local public goods. We develop methods to estimate a spatial general equilibrium model that accounts for both effects. The model is estimated using data on transport infrastructure, commuting behaviour, land use and land rents for some 3000 ZIP-codes in the Netherlands and for three levels of education. Welfare benefits of investments in public transport infrastructure are shown to differ sharply by workers’ educational attainment, which is critical for the cost-benefit analysis of infrastructure projects.

Biography: Coen Teulings (1958) studied Economics at the University of Amsterdam and graduated in 1990. He is currently Professor of Economics at the University of Cambridge and part-time Professor of Economics at the University of Amsterdam. He has published many articles mainly in the field of labour economics (minimum wages, returns to education and income inequality, job search, marriage market and the city). He was previously director of CPB (Netherlands Bureau of Economics), director of SEO Economic Research, Professor of Economics at the Erasmus University Rotterdam and director of the Tinbergen Institute.

Panel Session 3b: Co-creating ‘responsive’ infrastructure: a case for systems capacity building

Biography: Professor Nick Tyler CBE FREng is the Chadwick Professor of Civil Engineering at UCL. He invented, and runs, the UCL Pedestrian Accessibility Movement & Environment Laboratory, which is a life-scale environmental space, to conduct his multi-scalar research into the environment’s interactions with people. The UK Government has funded an expansion of this laboratory as part of its UK Co-Laboratorium for Research on Infrastructure and Cities, to include more multisensorial capability. He is working extensively with bodies such as Transport for London, national and local governments, and civil society in the UK, EU, Latin America, Japan and China to help create an adaptive and sustainable urban realm which is responsive to people and their needs. He led the transformation of the Civil Engineering degree programmes at UCL and is a Trustee of Engineers Without Borders UK.
KEYNOTE: Measuring the value added of infrastructure for society

Abstract: Aernout van der Bend, Managing Director, Next Generation Infrastructures, The Netherlands

There is no question that the provision of infrastructure systems and services creates tremendous value for society. However, the value created by infrastructure is not so easily measured, especially not in the social and environmental dimensions. While the question of how to measure the economic value added of infrastructure may seem simple in comparison with the social and environmental value, quite a few obstacles are to be cleared on the way to finding a meaningful answer. First of all there is the non-trivial question of how to define infrastructure, as a network of cables or pipelines as such is not providing us any service. Other obstacles are created by e.g., the unbundling of infrastructure value chains, by multiple use or functionalities of infrastructure assets, and by the statistical classification of economic activities. The presentation will go into the methodological hurdles of measuring the macroeconomic value added of infrastructure for the Netherlands and how we solved them in an experimental study with the Netherlands Central Bureau of Statistics.

Biography: Aernout van der Bend is the General Director of Next Generation Infrastructures, the cross-sector alliance of Dutch infrastructure providers. He has worked in both the public and private sector and at his best operates on the edge of them. He has previously led the Traffic Corporation (Verkeersonderneming) in Rotterdam, which received wide acclaim for its successes in changing mobility behavior. Aernout holds a PhD in public administration and has ample work experience in the fields of infrastructure policy making and delivery of infrastructure projects.

Panel Session 1: Delivery of infrastructure systems and services

Biography: Wijnand Veeneman is scientific director of the Next Generation Infrastructures, the cross-sector alliance of Dutch infrastructure providers. He is also associate professor at Delft University of Technology researching and teaching about governance and management of infrastructures with a focus on dealing with complexity. He is an international expert on governance in public transport. On those topics he also teaches in existing programs at Shell and Politecnico de Milano. Wijnand his current research interests include the implementation of data platforms in existing governance structures and processes for transport and mobility, and dealing with organisational conflict and trust in mobility and infrastructures. Wijnand advises both national and regional governments on their governance designs in infrastructures. He is the Chair of the Advisory Council of the Dutch School of Government

Panel Session 4b: Impact of the Internet of Things on Infrastructure Asset Management

Biography: Annemarie Verbeek-Kalshoven MSc (1976) started her career in marketing-communications. Along the way she gained more and more interest in the way organizations deliver their (brand)promise and she specialised in organizational development and change management. In 2009 she started as a programma manager at Vitens and facilitated the board and management on the organizational and cultural change at Vitens. Since 2015 she is responsible for Strategy & Programmes Asset Management.

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Panel Session 4b: Impact of the Internet of Things on Infrastructure Asset Management

Biography: In 1996, I graduated at the Delft University of Technology as a Master of Science in Industrial Design Engineering. I started my career in research, development and design of systems for traffic, rail, parking and public transport on a functional level and with customer focus at Volker Rail / Vialis Traffic & Mobility. The last years my focus has been broadened to business development and new technologies for information systems and services. Since 2008 I have been working at ProRail Business Development / Innovation on new information services and infrastructure solutions for train operators, passengers, ProRail Assetmanagement and Operations. My approach in being succesfull is understanding technological opportunities and risks and finding solutions to be combined with operational/legacy systems to serve running and new processes.

Being responsible for IoT within the ProRail Datalab, I am testing a broad range of Internet of Things sensors, networks and data solutions since 2016, for both Assetmanagement and Logistics. My focus is understanding the performance of IoT, measuring models for sensors, user aspects and the merge with Big Data analytics.

Wim Verheul
Innovation Programme Manager
ProRail

KEYNOTE: UK Research and Innovation and Next Generation Infrastructure

Abstract: The world is changing. Population growth, changing demographics and environmental change are creating challenges for UK and global infrastructure that will require increasingly interdisciplinary and integrated solutions. The world of business and research is also changing. Developments in areas such as artificial intelligence, big data and smart infrastructure are driving enormous progress and new opportunities, as well as challenges of their own.

With city authorities increasingly taking a more integrated approach to urban infrastructure systems, there are opportunities for improvements in coordination, coverage, scale of delivery and resilience of infrastructure solutions. Our current system could be strengthened by taking a systems view of infrastructure as a whole, to align targets and budget planning, convene stakeholders and strengthen citizen engagement.

To meet these challenges, we need a system that is fit for the future as well as the past. UK Research and Innovation is bringing together the seven Research Councils, Innovate UK and a new organisation, Research England to encourage cutting-edge researchers and innovators to create and drive integrated programmes of work that solve the big challenges of science and society. A key role for UK Research and Innovation will be to sustain and develop the interdisciplinary research and innovation needed to meet the infrastructure needs of the future.

This is an opportunity to hear the vision for UK Research and Innovation and how it can contribute to meeting the infrastructure challenges of a changing world.

Biography: Recently appointed Chief Executive Designate of UKRI, Sir Mark Walport has been a champion for science, engineering and technology in his role as Government Chief Scientific Adviser, Head of the Government Office for Science and Co-Chair of the Prime Minister’s Council for Science and Technology.

As former Director of the Wellcome Trust, Sir Mark has experience running a large scale research organisation and global charitable foundation. A distinguished scientist in his own right, Sir Mark was also Professor of Medicine and Head of the Division of Medicine at Imperial College London.

Sir Mark Walport
FRS FMedSci
Government Chief Scientific Advisor
Previous career highlights for Sir Mark include being a member of the India UK CEO Forum and the UK India Round Table, a member of the advisory board of Infrastructure UK and a non-executive member of the Office for Strategic Coordination of Health Research. Before becoming GCSA, he conducted independent reviews for the UK Government on the use and sharing of personal information in the public and private sectors: ‘Data Sharing Review’ (2009); and secondary education: ‘Science and Mathematics: Secondary Education for the 21st Century’ (2010). He received a knighthood in the 2009 New Year Honours List for services to medical research and was elected as Fellow of The Royal Society in 2011.

**Panel Session 1: Delivery of infrastructure systems and services**

**KEYNOTE: Experience of transport strategy and programme execution in a rapidly growing city**

**Abstract:** Delivering transport infrastructure, particularly in a rapidly growing city and at a time of accelerating technological changes, requires a holistic approach that is both efficient in execution and flexible in its application and assimilation into existing networks.

Clarification of the city vision and primary drivers is a pre-requisite to assessing asset requirements and associated funding demands. The ability to meet longer term work programmes, with identifiable project milestones, allows assessment of risk and appropriate allocation of mitigating measures through funding, procurement, contract management and commissioning.

Ultimately, any programme will need both refinement as the work progresses and vigorous review / monitoring to ensure that deliverables are achieved and learnings from the projects imbedded into future work frameworks.

The paper highlights the key requirements for efficient infrastructure delivery and provides working examples of its application in Auckland.

**Biography:** David has been Chief Executive of Auckland Transport since its establishment in November 2010. Prior to this he was Chief Executive of professional services business CPG, a subsidiary of Downer EDI. David has held a number of roles as Chief Executive / Director in a range of businesses including the energy, packaging, processing and farming sectors.

David has a doctorate in environmental engineering and is a Fellow of the Institute of Professional Engineers, New Zealand. Having started his professional career at Universities including roles as an Associate Professor at the University of Illinois and Senior Lecturer at Massey University he comes with a breadth of academic, commercial and local government experience.

**Panel Session 7: Future research and innovation agendas for next generation infrastructure systems**

**Biography:** Clare is Global Practice Leader for Cities with global engineering, management and development consultancy Mott MacDonald. Her role involves using systemic engineering at both building and city scale to facilitate the accommodation of more people in urban areas whilst consuming fewer resources, improving resilience and achieving enhanced quality of life. She brings a practical understanding of construction and development drivers and processes at both macro and micro level. Combining this with engagement in policy she is able to bring insight into the technical, political, financial and behavioural aspects of sustainable development. Her role is to help stakeholders understand the influences of future disrupters (such as climate change or Big Data) and then apply ingenuity, innovation and connected thinking to find integrated solutions and resilient outcomes.

**Biography:** David Warburton is the Chief Executive of Auckland Transport, New Zealand. Prior to this, he was Chief Executive of professional services business CPG, a subsidiary of Downer EDI. He has held a number of roles as Chief Executive / Director in a range of businesses including the energy, packaging, processing and farming sectors. David has a doctorate in environmental engineering and is a Fellow of the Institute of Professional Engineers, New Zealand. Having started his professional career at Universities including roles as an Associate Professor at the University of Illinois and Senior Lecturer at Massey University he comes with a breadth of academic, commercial and local government experience.

**Biography:** Clare Wildfire is the Global Practice Leader for Cities with global engineering, management and development consultancy Mott MacDonald. Her role involves using systemic engineering at both building and city scale to facilitate the accommodation of more people in urban areas whilst consuming fewer resources, improving resilience and achieving enhanced quality of life. She brings a practical understanding of construction and development drivers and processes at both macro and micro level. Combining this with engagement in policy she is able to bring insight into the technical, political, financial and behavioural aspects of sustainable development. Her role is to help stakeholders understand the influences of future disrupters (such as climate change or Big Data) and then apply ingenuity, innovation and connected thinking to find integrated solutions and resilient outcomes.
KEYNOTE: Smarter Towns, Better Living – Developing Smart Urban Habitats

Abstract: Urban infrastructure is vital to the growth of cities – enhancing living environment for citizens, and supporting economic activities. Cities today face many challenges, hence critical for cities to ensure the adequacy, sustainability, and resilience of its urban infrastructure, especially for cities where their urban population increases at a much faster rate than what they can support.

Growth of cities can only be successful if the urban infrastructure is carefully planned, developed and maintained. This includes looking at the reliability and ease of expansion of its existing urban infrastructure, and the provision of new infrastructure to allow for new services and growth. Technological advancements in the areas of Information and Communication Technology (ICT) can help facilitate the development of ‘next generation cities’ – where sensors, IoT and communication networks are used to provide better services to citizens.

Faced with challenges such as rapid urbanisation and severe land constraints, Singapore as a nation has come a long way in providing highly compact yet very liveable towns for its citizens. The Housing & Development Board (HDB), Singapore’s public housing authority, has been providing affordable housing for the entire nation over the past 50 years. Today, more than 1 million flats have been developed in 23 towns and 3 estates across the island, housing more than 80% of Singapore’s resident population, and with 90% of the residents proudly owning their flats.

What started out as a need to quickly house the growing population in basic and decent homes, has evolved into a highly successful public housing model that offers modern quality homes for many. To enhance the living experience for residents in its towns, HDB continuously strives to develop ‘Homes that are of high quality and value’; ‘Towns that are vibrant and sustainable’; and ‘Communities that are active and cohesive’. Wanting to drive greater excellence for its sustainability efforts, and with Singapore positioning itself as a Smart Nation, HDB took the lead in mapping out the Smart Urban Habitat efforts for its towns and bringing in all relevant stakeholders from the government agencies and private sector to work out a Smart Urban Habitat Masterplan and Framework.

HDB’s Smart Town Framework essentially comprises two layers: (1) the development of the applications and services layer in the domains of Smart Planning, Smart Estate, Smart Environment, Smart Living, and Smart Community; and the (2) provision of an enabling infrastructure layer – comprising sensors, communication systems and a data hub.

The development of the enabling infrastructure, centralised Smart Hub, provision of innovative Smart urban solutions for residents, and test-bedding of new Smart ideas in identified Living Laboratories in HDB towns, are but some examples of exciting works carried out by HDB for the past few years. These initiatives have also facilitated the collection of data in towns to allow for Big Data analytics linked to provision of better municipal services and promotion of greater community engagements in towns. With advancement in technology areas such as Artificial Intelligence, there are opportunities to look at cognitive maintenance and thus continue moving towards the concept of developing ‘estates that learn’.

Biography: As the Group Director of Building & Research Institute (BRI), a research set-up under the Housing & Development Board (HDB) of Singapore, Dr Wong is responsible for leading HDB’s efforts in spearheading new innovative, cost effective solutions and technologies to create a better living environment and achieve greater sustainability.

Dr Wong has been involved in many research studies on areas relating to building materials, acoustics, prefabrication technology, urban solutions and systems, construction technology and environmental sustainability. He is also responsible for promoting smart and sustainable development initiatives in HDB buildings and estates. Some of the initiatives which he spearheaded included the development of green roof tray system, HDB Smart Town framework, deployment of solar energy systems in public housing and connection systems for precast application and complex urban systems modelling. Dr Wong is
driving the holistic and comprehensive sustainable development framework to guide the development of Punggol Eco-Town. In driving Singapore’s Smart Nation agenda, HDB is championing the Smart Urban Habitat Domain and Dr Wong co-chairs an inter-agency working committee to spearhead the Smart town efforts, which aims to leverage smart technologies to make towns and estates more liveable, efficient, safe and sustainable.

Dr Wong graduated with a first class honours degree in Bachelor of Engineering in 1993 from the University of Sheffield, United Kingdom and obtained a Ph.D in Civil & Structural Engineering from the same University in 1997. With notable contributions to his field of work as a Professional Engineer, Dr Wong has been conferred several awards including the Henry-Boot Award, Laverick-Webster-Hewitt Award, the Institute of Civil Engineers Award and Public Administration Medal (Silver) for his contributions to the Public Sector. He and his team have been conferred several awards, including the Institution of Structural Engineers (IStructE) Singapore Structural Award, ASEAN Federation of Engineering Organisations (AFEO) ASEAN Outstanding Engineering Achievement Award and Energy Globe Award in 2016. Dr Wong is also a Board member of the Singapore Green Building Council and represents HDB in the Green Mark Advisory Committee.
for Infrastructure Futures (ICIF) project, funded by the UK Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC). The paper will discuss notions of ‘Resilient Agency’, ‘Learning Journey’ and ‘Learning Power’, arising from fundamental research in education and resilience, and will map these onto the typical learning journeys that infrastructure actors implicitly create and navigate. Such considerations strengthen the argument that infrastructure provision should focus on the services that the infrastructure provides. They also provide a new perspective on infrastructure business models as learning and action frameworks.

The discussion will be illustrated by reference to examples drawn from the nuclear industry, the Clifton Suspension Bridge, and the UK payments digital infrastructure. The paper will also relate the discussion to the potential impacts of Artificial Intelligence in future infrastructure provision and will explore how future infrastructure standards might be recast as learning frameworks to take advantage of AI, machine learning, and data intensive information and learning.

Next generation doctoral training at the University of Cambridge for future infrastructure and built environment

Niamh Gibbons, Janet M Lees Mail, Abir Al-Tabbaa
University of Cambridge

Urbanisation, population growth, scarcity of resources, climatic change, rapid technological development, and the globalisation of both construction and engineering design are driving the pace of change within the construction industry. There is a clear need for engineering education to evolve alongside these changes. At a doctoral level specifically, there is a need to provide training that reflects both modern research practice, facilitating multi-disciplinary and industry collaborations, and the need for industry leadership in order to drive innovation and entrepreneurship. The EPSRC Centre for Doctoral Training in Future Infrastructure and Built Environment at the Department of Engineering at the University of Cambridge was established with the aim
Prosperity in a Rocking Boat

Peter Dudley, Dudley Consulting

The title of this paper is a paraphrase of the title of Geoffrey Vickers’ 1970 book, Freedom in a Rocking Boat and it is sad to reflect that, in many ways, its content revisits many of the issues raised by Vickers some forty seven years ago. The need to understand both our technological capabilities and our human and societal goals was key to much of his argument. In particular not being drawn into behaviours that were driven by the functioning of what he termed “self-exciting systems” — systems that followed internal logics which encouraged behaviours that, whilst perfectly consistent with (indeed encouraged by) these internal logics, were damaging to wider human or social interests.
The paper introduces a model designed to integrate the activities of what is argued are three primary communities (Policy Making, Delivery, and Research) in the provision of Next Generation Infrastructure (NGI) in relation to their performance in servicing (or, perhaps, exploiting) a fourth – the consumer community (consumer here being defined as any and all those individuals and groups of individuals that draw on infrastructure and infrastructure services provision).

Drawing on the work of W. Ross Ashby, particularly the developed “ultrastable system”, the key arguments are that: a) whilst the first three of these communities will have (legitimately) differing internal models of operation, success and, possibly, different ‘languages’ for expressing them, their normal, day-to-day functioning will, of necessity, impact the others, thereby affecting their experienced performance context; b) that any consensus these communities may reach will define the context for infrastructure delivery; and, c) that whatever these internal differences may be, the final measure of their success both individually and in combination should only be assessed in relation to the extent that they satisfy the needs of the fourth (i.e., the consumer) community. Proceeding by introducing a model of an intelligent network suggested as the necessary informational/technological substrate of infrastructure delivery; and then, a model of ‘co-regulation’ which it is suggested, is both general in application and provides a structure for what might be termed coherent control. The intention is to demonstrate the possibility of integrating the operation of these groups into a coherent whole capable of identifying, influencing and acting upon emergent changes in the infrastructure requirements, development and provision arenas.

In concluding a number of suggestions for future activity are given.

Contributed Talks 1b

Next Generation Infrastructure Interdependencies: An economic deterministic model of transport interdependencies in the United Kingdom

Nikolaos Kalyviotis University of Birmingham & University of Illinois Urbana-Champaign
Chris D.F. Rogers University of Birmingham
Miles R. Tight University of Birmingham
Geoffrey J.D. Hewings University of Illinois Urbana-Champaign
Hemanta Doloi University of Melbourne

The role of infrastructure interdependencies is challenging due to the complexity and dynamic environment of all infrastructures and vital for critical infrastructure systems. There is an ongoing debate about the value of the benefits of the five national infrastructure sectors (energy, water, transport, waste and communication) in the UK and how they interact in terms of social, economic and environmental wellbeing. This study focuses only on one of the three aforementioned values, the economic value. The hypothesis tested is whether the transport sector is economically complemented by the energy, water and waste sectors and economically substituted by the communication sector. The authors use the process analysis “networks and cohorts”, an analysis that uses tables, diagrams, models and networks of interactions along with organizational linkages. Of interest for this study in particular is the grand total of all revenues (capital value) which create incomes into other sectors and creates dependencies. This, by definition, is the Gross Value Added. The last five symmetric (product by product) Input-Output tables of gross value added are used: 2010, 2005, 1995, 1990 and 1984.

2 https://research.ncl.ac.uk/ibuild/ (2015)
3 Hill, M.R. Archival Strategies and techniques (Qualitative research methods series 31) (Sage, 1993).
The theory underpinning the hypothesis was verified and one mathematical equation was developed based on the historical data of the gross value added by the other critical sectors to transport:

\[ Y_p = 0.32 \cdot X_{v1} + 2.99 \cdot X_{v2} - 0.35 \cdot X_{v3} + 5.27 \cdot X_{v4} + 125.74 \]

(where \( X_{v1} \): value created from Energy to Transport,
\( X_{v2} \): value created from Waste to Transport,
\( X_{v3} \): value created from Communication to Transport &
\( X_{v4} \): value created from Water to Transport;
when \( X_{v1} \in [506; 1765] \), \( X_{v2} \in [0; 380] \),
\( X_{v3} \in [411; 1628] \) and \( X_{v4} \in [43; 82] \)

**Infrastructure System of Systems Integrity**

Ricardo Peculis* and Farid Shirvani
SMART Infrastructure Facility, Faculty of Engineering and Information Sciences, University of Wollongong, NSW 2522, Australia
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Infrastructure systems typically consist of technical structures comprising of physical and operational components of interrelated constituent systems forming what is now known as system of systems (SOS). The complexity and uncertainty of unforeseen events that are inherent characteristic of infrastructure systems makes it impossible to predict undesirable emergent behaviours that could push the operation of such systems away from their intended purposes. Infrastructure systems present numerous challenges throughout their lifecycles. This paper addresses one of these challenges that is presented during operation, when managers need to report ‘how well’ the system is performing and find ways to address the consequences of unexpected events that often degrade the intended performance. This paper adopts a definition of system integrity (SI) to assess the SI for each constituent system and then combines them into the overall SI for the SoS. The proposed method is based on the on-going performance, safety and resilience of the constituent systems and applies the Analytic Hierarchy Process (AHP) to create a quantitative value derived from experience-based qualitative assessment. In this method, firstly the key indicators (KI) for each of the agreed assessment criteria for performance, safety and resilience are defined and individually assessed. Then the KIs for each of the three criteria are weighted relatively to each other to obtain the overall assessment for performance, safety and resilience for each individual system. These three criteria are also compared and weighted to determine their level of contribution to the SI for the system which is then calculated. The method is then expanded to assess SI for SoS and applied into a hypothetical urban transport system for illustration purposes.

**Navigating complexity for next generation infrastructure: integrating governance and modelling analysis**

Katherine Lovell, Jim Watson, Ralitsa Hiteva
SPRU, University of Sussex

A key theme within the delivery of next generation infrastructure, in the UK and around the world, can be a focus upon the provision of infrastructure services rather than upon reinforcing existing technologically centred systems (e.g. appropriate mobility rather than a series of transport systems). This user-centred approach to infrastructure offers the potential to remove some of the assumptions and inefficiencies present in the existing bounding of infrastructure provision within sectoral silos. However, it also presents challenges over infrastructure decision-making and governance arrangements.

One way to work with the additional complexity involved in navigating interdependencies between systems is the use of modelling tools to examine the effects of infrastructure needs across sectors. However, the centralised, birds-eye view possible within techno-economic infrastructure models is rarely reproduced within infrastructure governance. In practice, except in a very local context, the information processing and knowledge requirements, as well as a need to create checks and balances and meaningful connections to key stakeholders, would overwhelm the capacity of centralised, single point decision-making. The reality of decision making about infrastructures is that it is complex and distributed
involving many actors and levels of authority. As a result, an awareness of the remits, priorities and processes of actors that are shaping both the performance requirements and development decisions taken in infrastructure is an important corollary to centralised techno-economic modelling analysis.

The research presented here brings together modelling and governance thinking on infrastructure decision-making. This paper takes a governance perspective to analyse the use of the NISMOD model developed by the Infrastructure Transitions Research Consortium (ITRC) within the National Needs Assessment (NNA) process concluded in 2016. The different strategies explored within the NNA process and used to structure the use of the NISMOD model are analysed to consider what they could mean for governance – what governance processes are assumed? What requirements might these strategies place upon governance actors? This analysis is illustrated for three UK infrastructure sectors: Energy, Transport and Water.

This paper highlights limitations within the application of this infrastructure model from a governance perspective. It also identifies several key areas of opportunity for improved treatment of governance within the modelling process. Further, points for the potential development of co-constituted modelling and governance analysis are suggested. This work is the first step in exploring possibilities for the systematic and rigorous incorporation and use of governance knowledge within infrastructure modelling.

Monday 11th September 14.00

Panel Session 2: Systems thinking to transform infrastructure services

It is now generally accepted that the value of infrastructure services is derived from a range of different systems, so invoking systems thinking as a design principle is vital. This session will discuss how the use of systems thinking is transforming our ability to provide more effective and valuable services.

Professor Colin Taylor CEng FICE, University of Bristol and UKCRIC (Chair)
Professor John Beckford, UCL and UKCRIC
Professor Cynthia Mitchell, UTS, Sydney
Anne O’Neil PE CSEP, Systems Engineering Strategist and Catalyst
Dr Ajith Parlikad, University of Cambridge

Contributed Talks 2a

The individual as the key-stakeholder of Next Generation Infrastructure: Defining the social value of transport infrastructure in the UK

Nikolaos Kalyviotis University of Birmingham & University of Illinois Urbana-Champaign
Chris D.F. Rogers University of Birmingham
Miles R. Tight University of Birmingham
Geoffrey J.D. Hewings University of Illinois Urbana-Champaign
Hemanta Doloi University of Melbourne Nikolaos Kalyviotis

The idea of social value has arisen from the psychological approach, and more specifically it is based on the principle of “independence of irrelevant alternatives” from the game theory introduced by Luce and Raiffa. According to this, each alternative situation \((j)\) has an utility/value \((V_{ij})\) for the individual, which is a function of the features of the alternative situation \((X_{i})\) and of the features of the individual who makes the choice \((S)\): \(V_{ij} = V(X_{i}, S)\). Beyond that, it assumed that the individual, who makes the choice, has a clear and measurable knowledge of the value,
which each choice provides. Although even after the evaluation of each choice, it is a tentative situation regarding the choice of the individual. In other words, there is an element of possibility. Under the same principle of Luce and Raiffa, the possibility of a choice is in direct ratio to its value. The above mentioned assumptions constitute the “strict utility choice mode”. The exponential form of the value function: 

\[ V_i = \exp[V(X_j, S_j)] \]

is achieved by simple transformations of the “strict utility choice mode”, where \( X \) and \( S \) have a linear correlation. The exponential functions of the total value have a sigmoid form relative to the linear function of the value of the possible choice. This means that the exponential function may have a sigmoid form relative to the X-axis or Y-axis, based on the defined axes and values. The key challenge addressed is a quantitative sense of value, when the perceptions of value are qualitative. To measure social value quantitatively is challenging, since it is observed that pricing systems are “not based primarily on the users’ identity or activity”, but on the ability and willingness of the final user to pay. The social value gained by the individual is difficult to calculate, since it is defined by human behaviour and human needs. According to Maslow’s Hierarchy of Needs, these needs belong to specific groups with specific hierarchy. Maslow developed value (utility) curves of each category of need relative to the age of the individual. The sum of the curves gives an almost sigmoid curve. Winters et al. created a Transportation Hierarchy of Needs and they found the following transport hierarchy of needs: [1] safety and security, [2] time, [3] societal acceptance, [4] cost and [5] comfort and convenience. This research studied value as something holistically affected by all the above factors (time, cost, comfort and convenience, safety and security), without considering their ranking, by asking individuals representative of the UK’s demography to evaluate the social value of eight transport modes (walking, cycling, rail, bus, car, taxi, water and air) and each factor for each mode with a questionnaire survey. The hypothesis tested is that the value to the individual, collectively, from the aforementioned factors should have an almost sigmoid curve, which was verified. After analysing and comparing some sigmoid functions, the two which mostly align with the curve are: 

\[ f(x) = \tanh(x) \] and 

\[ f(x) = e^{-\frac{x^2}{2}} \]

where \( f(x) \) the social value of each transport mode to the individual, \( x \): the sum of the values of the factors defining the social value to the individual; when \( x \in [-2.5, 2.5] \). The social value function fits with the hyperbolic tangent function, which is defined for all real numbers and is a strictly monotonically increasing function. It is obvious that its maxima (\( \Delta f = g(rf = 0) \) will be achieved at the infinity, but of interest to this study is where the rate of change achieves the maxima (\( f'' = 0 \)), as after that point the rate of the return of the value to the individual starts to reduce. This way it will be possible to evaluate each transport infrastructure investment by defining its aforementioned factors aligned with the political decisions and assumptions made by the investor.

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1 Luce, R.D. & Raiffa, H. Games and Decisions. (New York: John Wiley and Sons, 1957).
not satisfy the real need. Understanding the sources of uncertainty, what drives motivation, how private and public organisations and social groups influence each other is of great importance for planning and managing successful infrastructure projects. Although it is difficult, if at all possible, to quantify the influence that individuals and social organisations may have over the project, principles and insights taken from social and systems theories can help to create qualitative mental models that help in dealing with the inherent complexity of these large projects. This paper compiles principles and insights extracted from systems and social theories into a simple framework that can be applied by infrastructure planners and decision makers to better cope with complexity, development and managing projects with better chances of success. The paper concludes suggesting how modelling and simulation can be used to assess ‘what-if scenarios’ that would help in developing a better understanding of the consequences of social interaction in the success or failure of infrastructure projects.

The Engineering Comes Home was a research project that turned infrastructure design on its head. The objectives of the project were to:

- Demonstrate a new paradigm for engineering design starting from the viewpoint of the home, looking out towards systems of provision to meet household demands.
- Integrate thinking about water, energy, food, waste and data at the domestic scale to support user-led innovation and co-design of technologies and infrastructure.
- Test new design methods that connect homes to communities, technologies and infrastructure, enhancing positive interactions between data, water, energy, food and waste systems.
- Develop a robust Lifecycle Assessment (LCA) Calculator tool to support environmental decision-making in co-design.
- Working with residents of the Meakin Estate in South London, the project followed a co-design method to identify requirements, analyse options and develop and test a detailed design for a preferred option. The outputs were:

1) Ethnographic study of how residents use water, energy and food resources in their homes and key opportunities for engineering design to improve wellbeing and reduce resource consumption.

2) Co-design of decentralised infrastructural systems in three workshops in 2016-2017. The first workshop identified key priorities for development from the community using a novel token-based system design method, to enable participants to build up alternative designs for local provision of water, energy, food and waste services. The second workshop provided participants with factsheets and photographs of the candidate technologies, which were then analysed using a LCA Calculator tool. Rainwater harvesting was selected as the technology for further co-design in the third workshop, which focussed on scaling up a pilot installation.

3) Pilot-scale smart rainwater system was installed in partnership with the Over The Air Analytics (OTA). OTA’s system enables remote control of the rainwater storage tanks to optimise their performance as stormwater attenuation as well as non-potable water supply.
4) Lifecycle Assessment (LCA) Calculator to enable quick estimation of the impacts of new systems and technology to deliver water, energy and food, and manage waste at the household and neighbourhood scale.

5) Stakeholders, including utilities, design consultancies and community based organisations, were engaged in three workshops to inform the wider relevance and development of the co-design methods and tools.

6) Toolbox and method statements to standardise and disseminate the methods used in the project for wider application and development.

Contributed Talks 2b

Moving towards a resilient multi-modal transport network: Great Britain’s case study

Joe Urwin, Jitendra Agarwal
Department of Civil Engineering, University of Bristol, Bristol, UK

The continued operation of transportation network is vital to the economy of a nation. However, natural events and man-made accidents continue to cause disruptions to these networks. A significant amount of work has been done to examine road and rail transport networks on a national scale. Yet recent data for Great Britain shows that there were delays on the Strategic Road Network and a significant percentage of trains did not run on time. Also, whilst many cities are moving towards integrated local transport such a move at a national level is relatively unknown. The aim of this paper is to examine the resilience benefits to be gained from such a unified multi-modal network at a national level.

A case study approach is followed where the characteristics and vulnerabilities of individual networks are assessed and compared with that of the multi-modal transport network. The key networks of highways, railways and airport within Great Britain have been modelled, ultimately leading to an interconnected multi-modal transport network. A range of analyses have been conducted using the suite of graph and network algorithms. These show that while there is a reduction in the vulnerability of several nodes when considering multi-modal transport network, some of the nodes continue to play a dominant role and measures should be taken to shift the reliance from them. A distinct critical node was noted in each region, while the lack of resilience of the connections between England and Wales is another leading issue. The need to undergo further works that will maximise the investment being made in HS2 was also identified. A case for policy shifts away from using population as a critical factor in future transport planning, as well as introducing a specific multi-modal policy to sit alongside each individual network policy is made.

Real-time multi-hazard risk of interurban highway networks

Anastasios G. Sextos, Reader in Earthquake Engineering, Department of Civil Engineering, University of Bristol, a.sextos@bristol.ac.uk

Highway networks are the most important civil infrastructure in highly developed countries. Recent earthquakes evidenced that some structural and geotechnical components of a highway network such as bridges and tunnels may be particularly vulnerable to strong motions. Network seismic risk is the probability that the network will incur a certain level of loss given its components vulnerability and the earthquake hazard to which they are exposed. Apart from direct loss, damage to network components may cause prolonged traffic disruption, which in turn results in large indirect loss in the affected area. Network resilience is a key concept in network seismic risk assessment since it can express the extent of both direct and indirect loss as well as the system’s ability to quickly recover its pre-earthquake state. This paper aims to present a methodology for the multi-criteria, resilience-based assessment of the possible loss that a highway network may experience due seismic events with different probability of recurrence and subsequent intensity measure distributions over the network region. It also proposes a framework for qualitatively and quantitatively assessing the time-variant loss that a highway network may experience from the onset of the earthquake throughout the recovery period, using resilience-based and scalar quantities, respectively. The above indicators also consist a useful risk management tool at pre-and-
post-earthquake level. At pre-earthquake level, they can be used for the identification of the optimum retrofit scheme, among a pool of alternatives, on the basis of two conflicting factors, namely the initial investment cost and the future network loss mitigation. At post-earthquake level, the emergency and recovery actions that lead to the minimum post-earthquake network loss can be defined. In the proposed approach, the two aforementioned levels of highway risk management are interdependently considered towards the adoption of an efficient loss mitigation plan.

Stick or twist? The transformative opportunities offered by infrastructure degradation

Paul Jeffrey (Cranfield University, UK), Marielle van der Zouwen (KWR Watercycle Research, The Netherlands), Jos Frijns (KWR Watercycle Research, The Netherlands), and Henk-Jan van Alphen (KWR Watercycle Research, The Netherlands)

Networked infrastructures such as water and wastewater systems have been characterised as “material mediators between nature and the city”[[i]]; facilitating modern urban life, and both channelling and modulating flows of information, goods, wastes and people. As large sections of these legacy infrastructures approach the end of their useful operational lives over the next 20-30 years, we are presented with an infrequent (arguably our first) opportunity to transform the technological, economic, and governance arrangements which mediate the provision of water services for our communities. We could seek to sustain or renew the existing physical system of treatment works, pumping stations and distribution networks which have, it must be acknowledged, served us well over past decades, or we could seek to realise (fully or partially – this is not a binary choice) alternative visions of water service provision that are, inter alia, less centralised, less linear, better integrated with other resource management processes, and more adaptive. The planners and engineers who installed much of our current water infrastructure would no doubt be both astounded and perplexed by the technologies that we currently have at our disposal. Given the opportunity outlined above, would they chose to replace or transform? Here we discuss two influential contemporary trends, the Circular Economy and the digitized society, that are shaping the agenda for a refashioning of water infrastructure and also usefully illustrate the advantages and hazards that such change might stimulate.

Of paramount concern should be the potential that these trends have to erode a fundamental principle of communal water service provision - the existing accommodation between society and water utilities which allocates responsibility for reliable and safe services to the latter party. An important, and surely non-negotiable, public health imperative lies behind the historical development of large scale, centralised water and wastewater infrastructures which safeguards the well-being of our communities. This cautionary note was heralded in some of the debates around splintered urbanism at the turn of the century[ii] and has found implicit echoes in more recent contributions which take the CE and social change agendas outlined above as their starting point.[iii] A more highly fractured infrastructure is not necessarily a threat to public health or cost effectiveness but if there is to be transformative change then any redistribution of risks and responsibilities must be comprehensively thought through to ensure that neither performance metric is sacrificed for the sake of novelty.


Contributed Talks 2c

Measuring Infrastructure Performance Indicators – a new approach based on the UN’s Sustainable Development Goals

Masterton, G.G.T., Findlay, T., Wright, M., Smith, S.D. Centre for Future Infrastructure, University of Edinburgh
National economic growth, social inclusion, environmental health, and community cohesion are dependent on a complex, interconnected, and dynamic system of infrastructure. The failure of this system can have catastrophic consequences for wellbeing and resilience. It is therefore important that we understand how to ensure the continuing sustainable development of infrastructure and how to improve its resilience against the consequences of failure. UK infrastructure is not currently measured adequately in terms of its impact on wellbeing or social resilience, and thus indicators of performance do not sufficiently reflect these aspects of sustainability. This paper presents a performance evaluation framework that moves towards addressing this omission, and helps policy makers assess and stimulate improvements in infrastructure’s contribution to national wellbeing in a more balanced way than current approaches.

Based on the United Nation’s Sustainable Development Goals, studies of the relationship between infrastructure and wellbeing, and the results of new research, twelve characteristics of infrastructure affecting wellbeing are developed. These characteristics are used to generate sets of infrastructure performance indicators. The model has general applicability, but when applied to the UK, results show that the performance of its infrastructure in relation to wellbeing and social resilience has improved over time, but recently these rates of improvement have been slowing and in some cases falling.

This work is intended:

i. To demonstrate a relationship between wellbeing, social resilience and infrastructure.

ii. To propose a new approach for deriving indicators of the performance of infrastructure with respect to all aspects of sustainability.

iii. To postulate a new framework for the performance measurement of infrastructure.

iv. To validate the framework by assessing recent performance of UK infrastructure in a balanced way, reflecting the Sustainable Development Goals, and including wellbeing and social resilience.

The process adopted in reaching an exemplar set of infrastructure performance indicators that are consistent with the UN Sustainable Development Goals is presented, with an insight into how some of those measures have performed in the UK.

Generally, the paper aligns with the over-arching theme of moving towards an outcome-focused model for Next Generation Infrastructure, and the Symposium questions:

- Thinking outside the Silo: system-wide purpose, vision and strategy – aligning decisions, performance and needs assessment with system-wide vision of aspirational outcomes?

- How can we engender coherence across government strategies – aligned high level purpose?

System-Of-Systems Infrastructure Modelling to Support National Sustainable Development Outcomes

Scott Thacker1, 2*, Jim W. Hall2, Tom Russell2, Raghav Pant2, Jade Leung2, Elco Koks2

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Infrastructures such as energy, water, transportation, waste and digital communications system provide services that underpin many of societies critical functions. Given their importance, evidence-based infrastructure development provides an opportunity to establish adaptable pathways to sustainable development. One major barrier to realising this opportunity is the current lack of data, methodology and tools, developed specifically to support decision-makers in this task. We address this need through the development of the first-of-its-kind National Infrastructure Systems Model (NISMOD) for International contexts. At the heart of NISMOD is an assessment process that has been designed to facilitate a systematic analysis of infrastructures to support national sustainable development outcomes. These outcomes are explicitly highlighted in the visualisation platform using, amongst others, performance metrics related to the United Nations Sustainability Development Goals, which have been calculated using system-of-systems infrastructure.
models. The visualisation platform has been specifically designed to step infrastructure decision makers through the assessment process, highlighting key information and insights and facilitating the iterative exploration and characterisation of adaptable pathways. We demonstrate the flexibility of applying NISMOD, to a range of different countries and contexts, by presenting a number of ongoing case studies. These include Palestine, Curacao and Syria, where the process and platform are being deployed, in collaboration with a range of organisations, to derive important new evidence and the opportunity to achieve measurable sustainable development.

NISMOD-DB++: A next generation spatiotemporal database framework for infrastructure systems analytics and modelling

Stuart Barr, Craig Robson, Maria Pregnolato, Qingyuan Ji
School of Engineering, Newcastle University, UK

In this paper, we present the work of the Infrastructure Transitions Research Consortium in the MISTRAL project (Multi-Scale Infrastructure Systems Analytics) to extend its existing national scale database system for infrastructure systems modelling (NISMOD-DB). The new spatiotemporal database framework considers buildings as the primary spatial entity of infrastructure demand which can be associated to infrastructure network assets via inferred ‘local’ spatio-topological distribution networks to facilitate scaling from individual buildings to neighbourhoods, entire cities, regions and broad scale administrative geographies. The resulting multiscale database framework, called NISMOD-DB++, employs a heterogeneous federated approach; one where ‘optimal’ NoSQL databases are used to represent the wide range of different types of data required for infrastructure systems analytics and modelling. Via a pilot implementation for the city of Newcastle-upon-Tyne we demonstrate the power of this framework for infrastructure systems analytics and modelling.

Tuesday 12th September 09.50

Panel Session 3a: Governance of Infrastructure Systems and Services

The infrastructure projects that are now being envisaged are much more complex and multi sectoral than twenty years ago; the opportunities this presents to those responsible for delivery is to engage at a larger scale, with better tools and better qualified staff. This session will elaborate on what it will take to deliver the NIP in the UK and how such activities are working elsewhere in the world.

Professor Brian Collins CBE FREng,
UCL and UKCRIC (Chair)
Sir John Armitt CBE FREng,
National Infrastructure Commission
Cees Brandsen, Managing Director, Rijkswaterstaat
Hon. Wayne Swan MP, Former Treasurer and Deputy Prime Minister of Australia; Member of the Australian House of Representatives, Australia

Panel Session 3b: Co-creating ‘responsive’ infrastructure: a case for systems capacity building

As our built infrastructure reaches its replacement and renewal phase – we can reconsider current and future needs to be served. With pressing technical, regulatory and integration challenges, the design development process for these socio-technical systems often focuses on solving the technical problem. Yet are we considering our customers’-context or operationally optimizing service delivery? This panel will explore “socio”-responsive infrastructure with case studies where user-engagement led to infrastructure design outcomes better addressing the people and communities served. Systems practices reinforce the need to balance the people, process and technology comprising our systems, plus understand user needs/constraints to develop responsive solutions. We’ll share approaches for facilitating such engagement and explore how the wider infrastructure community might measure “responsiveness” and generate the systems capacity to deliver.

Anne O’Neil PE CSEP,
Systems Engineering Strategist and Catalyst (Chair)
Dr Corina Kwami, UCL
Professor Nick Tyler CBE, FREng, UCL
Contributed Talks 3a

A decision support system to proactively manage subsurface utilities
Barry G. Clarke, Derek Magee, Vania Dimitrova, Anthony G. Cohn, Heshan Du, Quratul-ain Mahesar
University of Leeds
Ali M. Sadeghioon, Chris D.F. Rogers
University of Birmingham
David Gunn, David Enwisle, Helen Reeves
British Geological Survey
Richard Collins
University of Sheffield
Ross Stirling, Stephanie Glendinning
Newcastle University

Critical infrastructure assets are defined in terms of their purpose (e.g. roads, water, and energy) yet the ground, which supports these assets, can also be considered a critical asset leading to the conclusion that any assessment of critical infrastructure must consider the ground in that assessment. While the interdependency of critical infrastructures is recognised, the consequences of failing to recognise the ground as an asset can lead to failure of the infrastructure it supports. This motivates the need for a decision support system for subsurface utilities that takes into account the surrounding ground and the overlying road structure. These facilities mostly exist in an urban environment. The ground supports the road and the underlying utility which means the failure of any of these assets (road, ground, or utility) can trigger a failure in the others, the most extreme example being the collapse of roads due to erosion of the supporting ground by a leaking pipe. This paper describes the principles that underpin a novel decision support system for those engaged in street works of any kind, and how a multidisciplinary approach is being used to create a practical toolkit to reduce risk and minimise disruption to proactively manage subsurface utilities using site observations and investigations, public and private databases, expert opinions captured in a number of ontologies and an inference engine to produce guidance that takes into account risk and sustainability criteria.

Assessing the Underworld – Understanding the Context for Engineering the Next Generation Infrastructure
Chris D.F. Rogers, Nicole Metje, Lewis O Makana, Phil R Atkins, Farzad Hayati
University of Birmingham
Jen M Muggleton, Emiliano Rustighi, Ayad Al-Khoury
University of Southampton
Stephen R Pennock, Hugo Jenks
University of Bath
University of Sheffield

Next Generation Infrastructure (NGI) must integrate seamlessly with the existing infrastructure and its systems of operation. It must address the compelling needs of cities and urban systems – it must be sustainable, resilient, adaptable, smart and responsive to change (of context, addition, of use) – yet it must address the often overlooked issue of operational serviceability and maintenance. This is where this paper focuses: the nexus between new and existing infrastructure systems when attempting to deliver NGI fit for cities, and the urban systems they support, for the far future.

One core challenge is to understand the condition of the existing asset base, given that much of it is buried and thus out of sight and difficult to access. Following the philosophy of Mapping The Underworld, a new programme (Assessing The Underworld) is researching how remote sensing technologies can be deployed to reveal more than simply where the buried infrastructure is located, but what intelligence can we extract to understand its condition? Inherent in this endeavour is the appreciation that the transport and buried utility infrastructure systems are usually physically co-located and are interdependent: interfere physically in one of these systems and the other will be affected. Moreover, both are supported by the ground, and this can be conceptualised as a third, intervening, infrastructure, and all three are interdependent.

This paper describes the advances made in understanding the condition of the three infrastructures as a result of novel developments in sensing technologies as the platform for bringing a new evidence base on which to found decision-making for NGI.
Designing urban deep basements in South East England for future ground movement: Progress and opportunities for experimental simulation of long-term heave

Deryck Y.K. Chan, Prof. Gopal S.P. Madabhushi
University of Cambridge, U.K.

In recent years, there has been a boom in urban infrastructure projects in and around London that require deep basements to be excavated, such as underground railway stations and shopping malls. The permanent removal of topsoil due to basement construction inevitably causes upward movement of the remaining soil. In London clay and other over-consolidated clay strata, this upward movement continues over many years after the basement structure’s completion, a process known as long-term heave.

Urbanisation causes more and more of such deep basements to be constructed to greater depths and sizes than before. This has renewed interest in research on the long-term behaviour of base slabs in over-consolidated clay, because the basement structure must be designed to accommodate these long-term heave movements. The drive towards green construction techniques in next-generation infrastructure will require the methods of design need to be updated to allow more efficient use of material.

This paper reviews a range of current techniques used in the design of deep basement slabs where significant long-term heave deformations are expected. While current design guidance is sufficient in ensuring the safety of construction and operation of underground urban spaces, there is a strong feeling within the construction industry that the design criteria are inefficient and need to be improved with the help of experimental data.

Geotechnical centrifuge simulation is the main technique for physical modelling of long-term heave behaviour, as artificial gravity allows a year of real-life movements of soil to be replicated in a small-scale model in an hour of laboratory time. This paper reviews recent research in geotechnical centrifuge simulations on heave behaviour of deep excavations in over-consolidated clay, identifying key findings and pointing out areas that will require further research.

These experimental simulations will allow the effect of long-term heave to be quantified more accurately in future design guidance, thereby addressing the need to conserve construction material as the requirement for urban underground space increases.

Contributed Talks 3b

Next generation offshore infrastructure

Professor Susan Gourvenec
University of Southampton, University of Western Australia

Many thousands of structures have been installed in the world’s oceans to service the offshore hydrocarbon and renewable energy industries to provide energy resources to populations across the globe. Much of this infrastructure, particularly for hydrocarbon developments, has reached or is approaching the end of field life and requires decommissioning. Recent and future field developments, both for hydrocarbons and renewable energy, are setting up future waves of decommissioning activity.

This paper presents recent developments in, and outlines reshaping of, the offshore decommissioning agenda. The need for a multicriteria, multisector, transdisciplinary approach to inform offshore decommissioning and the design of the next generation of offshore infrastructure is demonstrated. Exemplar activities in this direction are described.

The opportunity for society and governments to transform the agenda for decommissioning offshore infrastructure is put forward. Reduction in cost and risk and improved environmental outcomes of future generations of offshore infrastructure may exist for future generations in our (global) society by resetting how decommissioning offshore infrastructure is carried out.
Vulnerability of Maritime Infrastructure: A Network Science Approach

Christopher James Papaioannou, Jitendra Agarwal
Department of Civil Engineering, University of Bristol, Bristol, UK

In the last half-century, global merchandise trade has grown from a fifth of global GDP to a half, largely due to the advent of the shipping container and this, despite the recent financial crisis, is likely to grow further in its economic significance. This paper aims to analyse the vulnerability of global shipping network and the impact of hazards such as bunker fuel price rises and under-utilisation. A model of the maritime network is built using the commercial schedule of a major shipping company. This uses a network science approach where each port is represented as a node and an edge represents service between the connecting ports. Edges weights are derived using an improved model of the transport costs. Different centrality measures and their distribution form the basis of performance assessment of the network and the ports. It is observed that (a) the global operations depend on the continued availability of a small percentage of the ports and (b) the changes in bunker fuel prices and utilisation on the network result in different global port hierarchies. These findings have potential uses in improving the network resilience and financial risk management. Finally, several port improvement scenarios are examined and their priority determined based on global operations.

Smart Biomimetic Construction Materials for Next Generation Infrastructure

Abir Al-Tabbaa University of Cambridge
Bob Lark Cardiff University
Kevin Paine University of Bath
Tony Jefferson Cardiff University
Tim Embley Costain

The resilience of building and civil engineering structures is typically associated with the design of individual elements such that they have sufficient capacity or potential to react in an appropriate manner to adverse events. Traditionally this has been achieved by using ‘robust’ design procedures that focus on defining safety factors for individual adverse events and providing redundancy. As such, construction materials are designed to meet a prescribed specification; material degradation is viewed as inevitable and mitigation necessitates expensive maintenance regimes; £40 billion/year is spent in the UK on repair and maintenance of existing, mainly concrete, structures. More recently, based on a better understanding and knowledge of microbiological systems, materials that have the ability to adapt and respond to their environment have been developed. This fundamental change has the potential to facilitate the creation of a wide range of ‘smart’ materials and intelligent structures, including both autogenous and autonomic self-healing materials and adaptable, self-sensing and self-repairing structures, which can transform our infrastructure by embedding resilience in the materials and components of these structures so that rather than being defined by individual events, they can evolve over their lifespan. We therefore advocate that next generation infrastructure will include next generation infrastructure materials based on smart biomimetic construction materials. This paper presents details of the national consortium that is leading international efforts in the development of those next generation infrastructure materials. It presents details of the work done to date, over the past three years, as part of the EPSRC funded project Materials for Life and the plans for work to be done over the next five years as part of a follow-on Programme grant: Resilient Materials for Life.
Tuesday 12th September 15.50

Panel Session 4a: Cities and Urban Systems

In the UK, the majority of people live and economic activity occurs in urban environments. Effective infrastructure services in urban and city environments are therefore essential to the wellbeing of society. This session will discuss how we might deal with the pressures being placed on such services, and hence the infrastructure systems that provide them, from the need for low carbon living and cleaner air, through demographic changes and associated urban growth and/or densification, to mobility services and changes in the pattern of work.

Professor Chris Rogers, University of Birmingham and UKCRIC (Chair)
Julie Alexander, Siemens
Professor Robert Cervero, University of California Transportation Centre
Keith Clark CBE, Tidal Lagoon Power and Future Cities Catapult
Terry Hill, CBE FREng, Arup
Jeremy Skinner, Greater London Authority

Panel Session 4b: Impact of the Internet of Things on Infrastructure Asset Management

IoT represents a world in which any potential object can be connected with the Internet, including any infrastructure asset. IoT advocates paint a rosy future in which infrastructure asset management will be entirely data driven, promising step changes in the effectiveness and efficiency of infrastructure maintenance. The abundant use of sensors on all components of infrastructure systems not only enables more remote control of infrastructure operations. The biggest gain is expected in terms of asset specificity and pro-activeness of infrastructure management and maintenance routines. However, for all infrastructure providers currently experimenting with IoT applications in (parts of) their networks, it is evident that the promises of IoT will not materialize by just sticking sensors on their assets.

The overwhelming quantities of data generated need to be analysed and converted into actionable information. In other words, IoT relies on advanced data analytics and on employees who are skilled operators of the new software required as well as appropriately trained in handling sensitive sensing equipment. Another question that arises is how asset management processes and departments should be (re-)organised to reap the potential benefits of IoT.

So far, however, convincing evidence of the benefits of the large-scale use of IoT in infrastructure asset management is still missing. Neither did we find an in-depth assessment of the potential risks and new vulnerabilities introduced by IoT in the world of infrastructure provision, nor an analysis of the barriers within the current infrastructure industries that may negatively affect the ability of IoT to deliver on its promises.

In this discussion panel, we would like to exchange the experience gained with IoT applications across the infrastructure sectors, and more in particular, identify and discuss the hard evidence available for both positive and negative impacts of IoT in infrastructure asset management. The discussion will be started with short pitches (5 minutes max) from representatives of different infrastructure industries in the Netherlands and the UK.

Professor Mark de Bruijne, TU Delft
Esther Hardi, Alliander
Giel Jürgens, Port of Rotterdam
Annemarie Verbeek-Kalshoven, Vitens
Wim Verheul, ProRail

Join the conversation on Twitter with #ISNGI
Wednesday 13th September 11.20

Panel Session 5: Funding and Finance for Infrastructure

The so called infrastructure funding gap is well known and is huge, many billions of pounds. This session will discuss a range of options that might be available to close this gap and how generation and maintenance of trust, stability of fiscal and monetary policy, deal management and programme management are critical components for success.

Professor Phil Purnell, University of Leeds and UKCRIC (Chair)
Tom Bousfield, National Infrastructure Commission
Professor Philip Nelson, EPSRC
Ann Pettifor, PRIME

Contributed talks 5a

Tools for governance of next generation infrastructure: lessons from Medellin, Colombia

Corina Shika Kwami, University College of London

Pressure on national and local level governments to meet the demand for infrastructure is increasing due to tightening fiscal budgets and economic constraints as well the effects demographic changes (population growth, ageing populations and migration) and climate change. A problem, or snag is that current governance models for managing new and existing infrastructure are not designed with the characteristics required for infrastructure that will serve the citizens, societies and cities of the future. Described as next generation infrastructure (NGI), it is suggested that in order to meet those demands, systems of governance will have to account for different systems (environmental, economic and social) and how the actors within them relate. What places seemingly govern infrastructure in a way that accounts for the different, interconnected systems and at the same time accounts for the needs of citizens at different stages of planning?

What are examples of ways to govern in systems where this occurs? What tools are used to create linkages between different systems and actors and what questions might this raise? This paper explores these questions using a case study that explored different actors in the water sector in Medellin, Colombia in order to identify tools that resonate with the requirements for NGI to thrive and generate questions for consideration in the broader discussion of governance that is fit-for-purpose for cities of the future.

Towards the Development of an Energy City Systems Conceptual Framework

Lee, S.E., Quinn, A.D., Bryson, J.R. and Radcliffe, J. University of Birmingham

Cities are changing. New technologies, increasing demand for resources and a changing climate are leading to a reassessment of city systems and infrastructure. To understand the complex interactions of resources at the city level it is vital that the appropriate tools are available for use by policy makers. These tools need to aid "silo-free" decision-making to ensure the successful provision of long-term resilient infrastructure that is able to operate with reduced or low CO2 emissions. Such tools need to be representative of the key interactions not only within the city but with its wider hinterland.

This paper focuses on Whole Energy System Modelling and presents a conceptual model framework of a city system. This system consists of producers, distributors and consumers and includes not only energy but transport, water, housing and waste sectors. Qualitative and quantitative approaches of energy system assessment are discussed together with issues of spatial and temporal scale. An assessment of different modelling approaches needs to take place to create a model framework as a basis for translation across boundaries and to identify cross-sectorial stakeholder requirements.

It will engender system-wide purpose, vision and strategy. This process will ultimately lead to interfaces between existing models or a new holistic view of
infrastructure in terms of interconnected energy systems, which will in turn have the potential to facilitate a transformative outcome on future city and regional infrastructures.

Realising the circular economy in wastewater infrastructure the role of governance

Smith, H.M. 1 & Fantinel, F. 2
1 Corresponding author: Cranfield Water Science Institute, Cranfield University, Bedford, UK, h.m.smith@cranfield.ac.uk
2 SMART-Plant Exploitation Manager

Many believe that the next generation of water and wastewater infrastructure will need to be increasingly ‘plugged in’ to the circular economy. Advances in wastewater treatment technology are enabling more efficient and effective recovery of energy, nutrient products, and other resources. However, the governance of such practices still raises many questions. Technologies that ‘close the loop’ for wastewater treatment, and bridge the gap with other sectors (notably the energy and agricultural sectors), also bring together a number of policy and regulatory regimes. The interactions between these different policy spheres create numerous gaps and overlaps in regulatory requirements, which have a marked impact on the overall feasibility of utilising such technologies. Ultimately, the governance arrangements determine how and where key actors can realise value from circular economy approaches. This paper reviews the governance arrangements for resource recovery from wastewater, in order to identify potential barriers to the uptake of more ‘circular’ approaches (with a focus on current and emerging EU policies and regulations). The results demonstrate the existence of significant regulatory ‘pinch points’ which could have a marked influence on the overall configuration of a more circular wastewater infrastructure system. The findings shed light on the role of governance in supporting the emergence of more ‘circular’ approaches in infrastructure systems.

Contributed talks 5b

Solid Waste Infrastructure Modelling Software SWIMS: a dynamic optimisation and decision support tool for solid waste management

Keiron P. Roberts1, Jonathon Coello1,2, David A Turner1,2, Ibrahim Bello1, Anne M Stringfellow1, William Powrie & Geoff V R Watson2
1University of Southampton, Faculty of Engineering and the Environment, UK 2 Improbable, UK
3 Empa, Technology and Society Laboratory, Switzerland

Solid Waste Infrastructure Modelling Software (SWIMS) is a life cycle assessment model running for all 11 Government Office Regions (GOR) of Great Britain (GB). SWIMS is programmed to simulate the waste arisings, waste collection and management at a GOR, national and international level with interdependencies between levels.

SWIMS main aim and design is to operate as a decision support tool to determine the financial costs and potential climate impacts associated with the management of waste(s). Life cycle assessment (LCA) models were developed for each waste management (treatment) process (e.g. composting, anaerobic digestion, incineration, including multiple configurations of each). These models were developed based on the waste management process modules included in the LCA software, EASETECH. EASETECH, developed at the Technical University of Denmark (DTU), is the most sophisticated LCA modelling tool currently available for the environmental assessment of waste management technologies (Clavreul et al., 2014). The software has been used in previous LCA studies of solid waste management systems for the purpose of decision support (Yang et al., 2014; Butera et al., 2015; Turner et al., 2015).

SWIMS is governed by two main sets of variables; strategies and scenarios. Strategies define the waste arisings, policy and governance constraints (e.g. landfill tax and the constraints in the landfill directive and waste framework directive) as well as the range/priorities of new infrastructure (e.g. prioritising...
material recovery leads to different outcomes from prioritising energy recovery. Scenarios are based on models run within the ITRC NISMOD 1 project for demographics and economics that impact the regional GVA and population, which also affects waste arisings per GOR (Hall et al., 2016). Strategies govern the transfer of waste to facilities within a GOR, between GOR’s and internationally based on a series of pathfinder algorithms ensuring that for each year all waste has been treated (e.g. excess waste will be exported internationally for treatment).

Upon completion of a single year, SWIMS calculates the potential future capacity utilisation and determines the facility upgrades and new infrastructure that could be built to ensure all waste arisings are treated and meet the constraints set within the strategies for each GOR. The suggested infrastructure is then staged for commissioning to ensure all waste is managed according to the strategy selected.

SWIMS operates within a system of systems model that allows it to be governed beyond the scenarios and strategies of the standalone model, to enable other infrastructure areas to influence and be influenced by the model. The model is currently being used to advise the UK Government’s National Infrastructure Committee (NIC) to determine the solid waste infrastructure needs over the next 30 years.

A Systemic, Purposeful, Performance-led and outcome oriented approach to Infrastructure Need Assessment

Dr Tom Dolan
Senior Research Associate, UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC), UCL
Centre Manager and Senior Research Associate, International Centre for Infrastructure Futures (ICIF), UCL

In the absence of a clearly articulated, shared, collaboratively developed and mutually understood PURPOSE (a vision comprising the desired outcomes that we expect infrastructure to enable), it is not possible to fully evaluate system performance and therefore, not possible to undertake a complete assessment of underlying infrastructure system NEED (i.e. identify system performance gaps where actual infrastructure system performance is not sufficiently aligned to expected infrastructure system performance.) The ability to undertake such need assessment is significant for any country/region that aims to cost effectively improve the quality of its infrastructure systems and make fit for purpose infrastructure investments to enable the outcomes society expects from infrastructure systems.

Achieving long-term value for money from infrastructure systems is a question of ‘doing the systematically right thing right not the wrong thing better’. Therefore, it is of paramount importance that need assessment is underpinned by a set of transparent, systemic, structured, interconnected and flexible methodologies that enable a complete assessment of infrastructure need and prioritisation of those investments best aligned to enabling desired outcomes.

The need for such a methodology is particularly significant in the UK, where a pipeline of future infrastructure projects is regularly published, the National Infrastructure Commission (NIC) has a mandate to undertake a National Infrastructure Assessment (NIA) once per parliament and infrastructure was prioritised in a recent Industrial Strategy consultation, because the proposed methodology for NIA does not allow a complete assessment of infrastructure need. It is also significant to any country or region already grappling with these challenges or considering creating their own National Infrastructure Commission. It is also relevant to society groups, infrastructure practitioners, and infrastructure financiers who want to influence decision making, ensure that the infrastructure investments available to them are closely aligned with actual expectations, demonstrably enable a mutual understood vision and are less likely to experience less problems in the planning phase and deliver stable returns for the investments lifecycle.

This paper introduces, briefly explains and justifies the importance of a set of principles any methodology to assess future infrastructure needs assessment should seek to embody. These principles build on earlier research undertaken on behalf of Infrastructure UK and the Infrastructure Projects Authority (IPA) on
outcome oriented performance indicators to evaluate the alignment between actual and expected system performance, and research developed in direct response to the launch the National Infrastructure Commission and consultation regarding NIA methodology.

In brief these principles are:

- Meaningful decision making requires a clearly articulated systemic vision comprising sector, solution and technology neutral desired outcomes (expectations)
- System Health priorities related to system problems must be identified and placed at the core of needs assessment processes
- Whole system performance evaluation requires a suite of performance indicators (PI) covering Technical PI, Quantity PI, Outcome Oriented PI, System Health PI
- Performance Gaps between expected and actual system performance can diagnose 4 types of infrastructure needs (maintenance/renewal, Quantity of provision, Alignment, System Health PI)
- Need requires sector, solution and technology neutral framing. A collaborative system-wide process is needed to identify options to address need (conversion of need into solution is non-trivial)
- Options can include intentional change to any component of the dynamic context in which an infrastructure system operates.
- Clearly defined outcome-linked selection criteria and system health selection criteria are needed to evaluate the relative merits of different options
- Regularly review of desired outcomes underpins the validity of the needs assessment
- Needs Assessment Processes must be clearly linked to established plans

A Systems Thinking Approach to the Development of Alternative Infrastructure Business Models

Christopher J. Bouch, Christopher D. F. Rogers
University of Birmingham, UK

Alternative business models are required that can maximise value capture from infrastructure projects, thereby giving private investors the confidence to invest. It has been suggested that the interdependencies between infrastructures, which are an increasingly frequent feature of modern infrastructure systems, provide opportunities for value capture; however, other than in the rare event of designing a system-of-systems from scratch, experience has shown such opportunities to be few and far between, relying as they do on chance alignment of a wide range of infrastructure characteristics with market requirements. A significant amount of research has been carried out on interdependencies of systems-of-systems over the last 25 years, but this has focused on infrastructure system resilience, rather than looking for opportunities to improve value capture. This paper describes research on a new approach to developing business models for infrastructure that seeks to break away from the infrastructure/infrastructure viewpoint of current literature, exploring instead a methodology that aims to maximise capture of value arising from dependencies between an infrastructure business and its wider environment. It builds on earlier work by others that postulated a unified, 3-stage approach to business model development. This paper describes the 3-stage approach and how it has been used to create a methodology to identify dependencies between an infrastructure system and its wider environment. It goes on to describe on-going research around application of the methodology to a case study centred on the Tyseley Energy Park development in Birmingham, UK, and concludes by suggesting further areas for research.

Planning pathways to climate-change-ready mobility infrastructure

Dr Andrew Quinn, School of Engineering, University of Birmingham, Dr Erika Palin, Science for Impacts, Resilience and Adaptation, UK Met Office
Dr Victoria Chapman, Surface Transport, UK Met Office, Mr John Dora, UK Infrastructure Operators Adaptation Forum

The mobility infrastructure serving the next generation of society will be composed of many elements that already exist combined with a variety of new pieces ranging from numerous small renewals
and upgrades through to major new projects. How resilient this new system-of-systems is to the changing context of climate, society and economy, will depend on our ability to imagine and implement adaptation processes and measures in an effective and holistic way. This cannot be separate from operational business-as-usual but rather needs to be embedded across organisations as well as promoted through inter-agency working and engagement across the breadth of stakeholders. A consensus is beginning to emerge, discernible from the commonality in the adaptation strategies and implementation plans of individual organisations and stakeholder discussions, which builds on concepts of risk analysis and intervention for resilience. However, without a holistic concept of resilience such plans cannot come together synergistically to promote the necessary inter-agency working. The proposed framework is a foundation on which to encourage such developments.

A Storm Cometh: Can we better protect infrastructure from the impacts of approaching storms using rational assessment frameworks?

Wilkinson, S., Dunn S., Adams, R., Ford, A., Fowler, H.J. and Kirchner-Bossi, N.  
School of Civil Engineering and Geoscience, Newcastle University, Newcastle (UK)  
Mendes, J. and Palin, E. Met Office, Exeter (UK)

The latest generation of weather forecasts are now approaching sufficiently high resolutions to enable us to make estimates of localised weather phenomena that are approaching site-specific scales. Similarly new methods of obtaining, storing and manipulating observational data is enabling better attribution of damage, disruption and other impacts. In this paper, we present a rational framework that exploits these two developments to provide a method of producing probabilistic estimates of damage and disruptions for weather related events. We demonstrate our method for the case of electricity distribution networks impacted by windstorms. In our example, vulnerability relationships have been produced by coupling an extensive number of fault observations (approximately 3,000 faults) to high-resolution reanalysis data. These are then coupled with weather forecasts to make near-time predictions of wind-induced impacts (number of faults) and consequences (customers without power). Our results demonstrate how our framework can translate weather forecasts into forecasts of societal consequences. We conclude by setting out our vision for a new consequence forecasting paradigm that will provide the public with daily estimates of site-specific weather consequences rather than simply providing regional estimates of weather variables.

Designing a road traffic model for the cross-sectoral analysis of future national infrastructure

Milan Lovrić, Simon Blainey, John Preston  
University of Southampton

This paper presents a UK national road traffic model developed as part of the ITRC MISTRAL - a large interdisciplinary project of the Infrastructure Transitions Research Consortium (ITRC). The proposed model includes passenger and freight vehicle flows on major UK roads and predicts future demand in the form of an inter-zonal origin-destination matrix, using and elasticity-based simulation approach. An important part of the model is the network assignment step during which predicted flows are assigned to the road network. This allows for the assessment of road capacity utilisation and facilitates the identification of “pinch points” where future infrastructure investments might be targeted. Several policy interventions are studied in the paper, including road expansion with additional lanes, new road development and vehicle electrification. The model also explicitly considers cross-sectoral interdependencies with other infrastructure networks, primarily with the energy sector where the transport sector is the largest consumer, the digital communications sector, water supply and waste management. In future extensions, the model will also be able to estimate the environmental footprint and assess the risk and resilience of the transport network. This model has the potential to inform policy makers about the long-term performance of UK road infrastructure, considering a range of possible future scenarios for population growth, technological innovation and climate change.
Wednesday 13th September 11.20am

Panel Session 6: Digital Transformation

The pervasiveness of digital transformation is now recognised as a destabilizing influence on current ways or working and a major opportunity for enhanced productivity, effectiveness and growth. This session will elaborate on these opportunities in all aspects of the lifetime of infrastructure systems and across a range of sectors. It will also address the risk issues that arise from inadequate attention to cybersecurity.

Dr. Jennifer Schooling, University of Cambridge and UKCRIC (Chair)
Dr Mark Bew MBE, PCSG, UK BIM Task Group
Mark Enzer, Mott MacDonald
Dr Stephen Lorimer, Greater London Authority
Dr Rick Robinson, Amey

Contributed Talks 6a

Intelligent Brokerage in the UK Water Sector: A collaborative approach to supply chain innovation

Dr Andrew Hale, Dr Arthur Thornton
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In recent years, unprecedented socio-technological developments have placed new demands on the UK’s ageing infrastructure. Exacerbated by rapid digital development, these demands require organisations to react in novel and innovative ways. In response, inter-organisational collaboration has been a favoured vehicle to enhance innovation. Specifically, many organisations have developed supply chains, seeking to maximise their innovative capability through multiple partnerships with firms who possess specific skill sets.

However, whilst supply chains can bring many benefits, organisations often struggle to develop them optimally. Specifically, due to the complex nature of the problems at hand, organisations often do not possess or articulate a true perspective of the problem context they wish to address. Further, traditional procurement processes mean that supply chains are usually formed for the purpose of developing solutions; there is scant evidence of supply chains being used to help define the problem. Consequently, supply chain engagement can often be ineffective as the wrong challenges are identified and communicated to a sub-optimum chain. As a result, effective innovative solutions are rarely delivered, causing significant financial cost to the lead organisation.

This paper addresses that problem. Through the development and application of the Intelligent Brokerage (IB) approach, this paper illustrates how engaging with a diverse set of actors, aligned to focus on the problem structuring phase of complex challenges, can generate a more complete understanding of the problem system, enabling more effective innovation opportunities to be identified.

To demonstrate the approach, the paper outlines a case study in which Intelligent Brokerage is applied to support a client in the UK Water Sector better engage with Small and Medium Enterprises (SMEs) for the purpose of innovation. The case study illustrates how the IB approach enables improved problem understanding to benefit the identification of appropriate innovations and SMEs with which to work, de-risking the procurement process and enhancing the effective innovative capacity of the client.

Finally, the paper provides key findings and conclusions, outlining how Intelligent Brokerage may further enhance innovation opportunities outside the water sector and support the delivery of next generation infrastructure.
Financing supply chain resilient infrastructures via resilience bond

Yang Song PhD, QASER Laboratory, UCL, Francesca Romana Medda, Director of QASER Laboratory, UCL

Supply chain disruption is one of the top 5 factors that influence companies’ revenue, which causes 14% downside risk to the UK and Germany, 5% for France and 17% for North America. Critical nodes and links are sensitive to disruption within a supply network, and it will bring ripple effects to entities once the connection fails. Although many researchers have provided different approaches and tools for supply chain resilience, we must look beyond these methods and consider the funding resources for a resilient infrastructure project. The paper is to discuss if resilience bonds can provide financial resources for a supply chain resilience project on a theoretical basis, especially focusing on the investment for Intermodal Logistics Hub (ILH) within the supply chain. We will review the resilience bond and supply chain disruption. Then, we model the process of resilience bond to fund supply chain infrastructure project. Results show that resilience bond will not only provide financial insurance, but also bring more potential benefits for the construction of infrastructures.

Impact of Next Generation Infrastructure on Australian Cities

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The quality of the physical infrastructure in our major cities is just as critical as human capital development in terms of driving long-run growth in productivity and rising living standards. The provision of high-quality and reliable infrastructure network services (like roads, rail and telecommunications) can have significant social, environmental and economic payoffs.

Notwithstanding the obvious intuitive connection between infrastructure investment and economic growth, the link between the two is still debated. One reason is that not all infrastructure investment supports growth over the long-term. Building a road or rail line that is not used for instance lowers productivity and economic growth in the long-term. A second reason is that establishing an empirical relationship between infrastructure and economic growth is confounded by a number of statistical issues. The most important of these relates to identifying the direction of causality between infrastructure and measures of aggregate output (GDP).

This study takes a microeconomic (or case study) approach to understanding the impact of next generation infrastructure (NGI) on the effectiveness of our cities in supporting economic growth and higher living standards.

We first look at the theoretical links between infrastructure investment, productive cities and economic growth. We then focus on a hotly debated infrastructure project – the South West Illawarra Rail Link, which could potentially better link the Wollongong region to Sydney.

Contributed Talks 6b

Mapping out the landscape of long-term national infrastructure demands for the U.K.’s National Infrastructure Assessment

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Silberman, A., Letti, B., Large, J., National Infrastructure Commission
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The National Infrastructure Commission has been tasked by the U.K. government to provide expert, independent advice on pressing concerns.
regarding England’s infrastructure and to provide in-depth assessments of her national infrastructure needs up to 2050. A cornerstone of this work is the development of the National Infrastructure Assessment (NIA), which will evaluate England’s future infrastructure needs under a range of scenarios of future uncertainty, exploring alternative driving forces and pressures on infrastructure.

Scenarios of future infrastructure supply and demand have been developed by the NIC based on empirical evidences regarding past trends and analyses of key drivers of demand, including changes in the economy, population and demographics, climate and environment, and technology. These scenarios have been quantified, tested and analysed using the National Infrastructure Systems Model (NISMOD) developed by the Infrastructure Transitions Research Consortium (ITRC) to model key infrastructure sectors including energy, transport, waste and water. This manuscript focused on the results provided by the NISMOD tool but also provides contrast with the results from other major departmental models including those used by the Department for Business, Energy & Industrial Strategy, the Department for Transport, Water U.K. and Department for Environment Food & Rural Affairs.

The modelled projections in this baseline analysis provide a sobering outlook for policy planners. Demands on infrastructure services rise relentlessly into the future even under modest levels of socio-economic growth. Primary sources of uncertainty around future demands were highlighted through the use of a diverse range of scenarios and technological variants.

Arguably the most novel component of this analysis is the exploration of model structure uncertainty undertaken through the comparison of the NISMOD outputs with those of other models used by the various U.K. government departments. The influence of alternative model structures on modelled outcomes has long been recognised in other fields of research and the results presented here give testimony to its potential impact on infrastructure planning. The impact of the differences between the structures of the models assessed was shown to be most prominent around the modelling of efficiency improvements and behavioural change in energy demand and around the modelling of autonomous vehicles in transport. Such differences could be enhanced further through the cumulative effects from interdependencies between these sectors, such as in the case of the electrification of transport.

This modelling analysis of future demands on U.K.’s infrastructure, in collaboration with the NIC, provides a broad-brush overview of the future landscape for four key sectors essential to maintaining our high standards of living. In doing so this paper also provides a summary of the NIC’s policy baseline approach as well as an interesting case study on the application of system-of-systems infrastructure modelling to policy development. As such it represents a thorough application of modelling to national infrastructure policy recommendations that should be of interest to those contemplating undertaking a similar task elsewhere around the world.

**Next Generation Infrastructure Modelling for Next Generation Infrastructure Decision Support**

Dr. Will Usher, Prof. Jim Hall  
*Environmental Change Institute, University of Oxford*

Building on the pioneering work in developing the UK’s unique system-of-systems modelling capacity under the EPSRC funded Infrastructure Transitions Research Consortium (ITRC) project, work is now underway in the ITRC-MISTRAL programme to develop the next generation of infrastructure systems-of-systems modelling capacity.

Capital investment in infrastructure represent some of the largest investments that can be made in assets with long-lifetimes and path-dependent characteristics. The UK alone is considering a pipeline of projects worth almost £500bn over the next decade.

Infrastructure systems are complex and are becoming increasingly intertwined. For example, many sectors now rely on digital communications to obtain greater operational efficiency at the potential expense of increasing cyber-security risks.
Current modelling capabilities to support infrastructure decisions are confined to individual or a couple of sectors. At best, this encompasses system-wide insights relating to the sector. And decision makers’ understanding of the relationship between sectors is confused by the range of different scenarios and assumptions made in these individual models.

The siloed approach to infrastructure is reflected in the wider decision-making sphere. Many independent financial institutions, responsible for funding large infrastructure in many developing country contexts, conduct decision making on a project-by-project basis, with little widespread evidence of strategic thinking that goes beyond individual infrastructure sectors, or consideration of the implications of an infrastructure investment for other sectors. There are notable exceptions.

For example, in the United Kingdom, the National Infrastructure Commission (NIC) was established to counteract the short-term politicisation of key national infrastructure investments, and to provide strategic oversight and advice to government on the portfolio of opportunities across sectors.

The National Infrastructure Systems Model, NISMOD v2.0, includes highly spatially and temporally resolved simulation models of six infrastructure systems: transport, energy supply & demand, water supply & treatment, flood defence, digital communications and solid waste.

Each of the models is developed by sector experts and represents the cutting edge of research within their respective disciplines.

The models are coupled together into a modular system-of-systems model using an open-source toolkit smif, enabling new infrastructure system models to be added in the future and models to be swapped in and out. Models of differing spatial and temporal resolutions can be incorporated using smif to convert data across models. The modelling is underpinned by NISMOD-DB, a data store specifically constructed to handle the large quantities of spatially explicit infrastructure data. Together, as a coupled system-of-systems model, NISMOD v2.0 will revolutionise infrastructure decision support by providing new insights that cut across sectors.

NISMOD v2.0 leverages the new DAFNI facility currently under development by the Science and Technology Facilities Council (STFC), to harness large distributed computing resources to run detailed infrastructure simulation models.

Many objective cost benefit analysis through stakeholder co-production

Julien Harou
University of Manchester

This talk describes multi-criteria approach to evaluating interventions in complex infrastructure systems at regional, national and transboundary scales. Interventions include both new infrastructure assets and new policies that regulate the use of infrastructure and/or resource systems. The approach links systems simulators that track physical, engineered, and socio-political performance to a search process which filters through the decision-space to reveal the most efficient and robust options given future uncertainties. Results take the form of efficient sets of interventions (the non-dominated Pareto-optimal ones) that maximise benefits and satisfy constraints over multiple plausible future states of the world. The enables decision-makers to visually survey where specific interventions options are located in performance space and what benefit trade-offs exist between the major areas of system performance. Various case-studies demonstrate the approach in the area of water resource management and planning ranging from regional studies (e.g., London's water supply system or South and East England's utilities) to multi-country studies (e.g., covering several east African countries). Embedding the analytical tools into a shared vision planning approach where a range of interested system ations develop the preformance measures and carry out the iterative assessment of interventions is dissucussed. Interactive graphics which help involve stakeholders and structure negotiation processes are demonstrated. Finally, extenstions like the use of multi-agent behavioural simulators or system of systems simulators within this framework are discussed.
Contributed Talks 6c

A hybrid framework for evaluation of long-term energy infrastructure systems: an empirical study in downstream critical oil and gas infrastructures

Dianabasi Etie Akpan
University of Birmingham, UK

Critical energy infrastructures are pivotal to our everyday living and well functioning of the modern society. Over the last decade, there has been an increased global focus on ensuring long-term delivery of critical energy infrastructure systems, in terms of both output and outcome. This is particularly due to scientific projections of increased pressure to meet the future demands of expanding cities, coupled with increased complexities with interdependent infrastructure systems, economic and political uncertainties, threats from modern technology and cyber security issues, climate change impacts etc.

Oil and gas are the most essential energy resources albeit renewables energy resources are more environmentally friendly. However, with the increasing uncertainties associated with renewables and other alternatives e.g. unreliable weather conditions, difficulties associated with producing large quantities of energy etc., oil and gas remain essential for future energy needs particularly the advantages from supply diversification perspective. Consequently, oil and gas availability are crucial for energy security, evident in the continuous global demand and as means for revenue and economic sustenance across the globe. Downstream critical oil and gas distribution infrastructures (DCOGIs) are vital complex socio-ecological energy systems for providing constant supply of produced and processed oil and gas products to domestic and industrial end users. Disruptions to their normal functions usually have wide ranging socio-economic and environmental implications. As such, the study presents a methodology to quell the urgent need, to efficiently assess the recovery implications and mitigate causes of disruptions to the operation of oil and gas distribution infrastructures.

This novel empirical study explores the complexities of downstream oil and gas infrastructure management from conception to decommissioning, viewed through the lenses of sustainability and resilience. The literature on global discourses of sustainability and resilience assessments highlights unique opportunities for civil engineers in applications to buildings and urban environments, very few studies exist for generic transport infrastructure systems and none exist for DCOGIs. We adopt a socio-ecological systems approach to evaluation and using empirical data, firstly, this study addresses the gap in the literature with regards the lack of bespoke sustainability and resilience evaluation framework for DCOGIs. Secondly it presents a novel Hybrid Framework “The RESOGI” (Resilient and Sustainable Oil and Gas Infrastructure), the first of its kind, in an effort to address the debates in extant literature regarding combine assessment of sustainability and resilience. The study involved conducting a survey with Practitioners, Oil and Gas Industry Personnel’s, Academics, Prominent Community Locales, Non-Government Organizations and Interest Groups, using semi-structured questionnaires, interviews, industry focus groups and the group model building. Data used in developing the framework was drawn from a thorough analysis of survey responses; the study also adapts suitable assessment tools e.g. the ARUP SPeAR that examine the vital indicators for sustainability and the necessary conditions to achieve resilience in DCOGIs. The outcome being an unbiased, easy to use, robust decision support tool that is readily available to they range of internal and external stakeholders of the oil and gas industry, and for planning towards achieving long-term energy security including existing DCOGI systems rehabilitation.

Ecological interdependencies of infrastructure projects

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Infrastructure projects have conventionally been approached in relative isolation, with inadequate
consideration given to how they integrate and interact with broader systems that make up the context surrounding them. By synthesising extant literatures on infrastructure interdependencies and project complexity, we argue that projects are not isolated or self-contained, and assert that projects intervene in the context of ecological as well as technological and societal systems.

We draw on literature on infrastructure interdependencies which has developed typologies by which interdependencies can be identified, understood and addressed, considering this in relation to the extant research on project complexity to understand infrastructure projects as interventions. The project complexity literature has developed frameworks and approaches for understanding interdependencies within the products and services that are delivered through a project and in the organizations that deliver them, but has given limited attention to the interdependencies that arise as projects intervene in existing contexts. There is acknowledgment that no project is an island, but any consideration of context has focused on technical and organisational interconnections, with external factors considered as stakeholders to the project. Ecological contexts in particular are only rarely considered with appropriate complexity. A contribution of this work is to show how the project contexts can be recognised as systems and integrated into project management approaches through their interdependencies with the project, rather than as passive recipients.

Using the infrastructure megaproject as an illustrative case, with specific examples of Crossrail, the Olkiluoto 3 and Flamanville 3 nuclear power stations and the Thames Tideway Scheme, this paper contributes by developing new understanding of projects as interventions in broader systems, building on recent work on interdependencies in infrastructure systems. Drawing on secondary data on each of the examples, we articulate both where careful actions to approach the megaproject in a novel way that recognises interdependencies and the broader systems context exhibits favourable results and where budget and time overruns stem, in part, from the approach to governance structure which has little attention to interdependencies within the projects and between the project and the broader systems around it.

From current findings and analysis we conclude that complex projects should work to recognise and respond to the systemic contexts in which they are placed. This context encompasses technological, societal and ecological systems, all of which may contribute to and be impacted by the project in diverse and complex ways. Appropriate placement of a megaproject within this context holds potential benefits for project operation, governance, cost and time efficiency, stakeholder satisfaction, and the effective delivery of both primary and serendipitous benefits.

Not if, but when? Simulating the impact of timing the nuclear phase-out in Switzerland

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Swiss electricity companies are faced with uncertainty with regards to the future operation of nuclear power plants in the country. After Fukushima in 2011, the government decided on a gradual phase-out, but only provided a tentative planning. Hence, no new nuclear power plants can be constructed but the old power plants will be allowed to operate until they are no longer deemed safe by the nuclear regulator ENSI. However, the first of the five Swiss nuclear reactors will shut down in 2019, following a decision of the owner, not ENSI, three years ahead of the government’s original schedule. Recent efforts by politicians and citizens to fix the date of the phase-out were unsuccessful. In this paper, we look at the effect of the timing of the phase-out and the associated uncertainty on the wider electricity market. More specifically, we look at the impact on investments, security of supply, wholesale electricity prices and amount of greenhouse gas emissions. We developed a simulation model using system dynamics to increase our understanding of the Swiss nuclear phase-out. The system dynamics model includes modules for merit order dispatch, international trading, investment analysis, generation capacity expansion, hydropower storage and dispatch, and other renewable energy production. The model is calibrated with data of the Swiss energy system and includes anticipated policy changes of the wider energy
transition in Switzerland. Preliminary results, using various scenarios of both timed and untimed nuclear phase-outs with varying levels of uncertainty, show that the timing uncertainty does not significantly impact the market development as investors prefer to wait for observable rather than anticipated market changes, but that delaying the nuclear phase-out does have significant advantages in terms of greenhouse gas emissions and security of supply. The implications of these findings are discussed in the context of the Swiss Energy Strategy 2050 and the country’s obligations under the Paris Agreement.

Panel Session 7: Future research and innovation agendas for next generation infrastructure systems

The infrastructure industry has a record of being less innovative than other industries, and having an immature research base in the UK post privatisation. This session will discuss how UKCRIC will start to enhance the research base and offer thoughts on what else is needed. It will address the innovations that are critical to the success of future programmes across all sectors and skill sets.

Professor Gordon Masterson FREng, OBE
University of Edinburgh (Chair)
Roger Bailey, Thames Tideway Tunnel
Professor William Powrie FREng, University of Southampton
Clare Wildfire, Mott MacDonald

Contributed Talks 7a

Distributed Ledger (Blockchain) Model for City Services

David Traub-Werner, IBI Group

Cities are the trusted authority for the issuance and record of, amongst others, property deeds and licensing. With the maturity of digital services, today these records are almost exclusively digital, creating a dependence on individual and third party corporations for the protection and security of public record data. This paper considers models whereby cities can utilise distributed ledger technology as a means of recording and verifying transactions, while encouraging local tech sector development.

Distributed ledger technology, also known as blockchain, intends to solve the digitization of assets. As a robust and secure architecture relying on network consensus, the technology has begun to be regarded as the “internet of trust”. Relying on the disintermediation of a distributed network, the technology can be regarded as more democratic when compared to databases controlled and secured by an owner or a third-party on behalf of same. In the models presented, decentralized city records allow for a platform to facilitate transactions of public record between citizens. By further migrating towards regulator, and away from record keeper, the city would maintain a read-only node on the network to oversee transaction activity. It is further proposed that the verification of changes to city records (transactions) would be performed by citizen-miners, utilizing personal processing power to solve blocks of transactions. To do so, an incentive could be offered possibly shifting operations costs to reward citizens.

Quiet Streets and Clean Air

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Unfortunately, exposure to pollutants is worst when travelling in ways that are otherwise beneficial such as walking, cycling or using public transport. Driving a car is generally less hazardous, due to the effective filtration in modern vehicle ventilation systems. The cleanliness of the air we breathe in our cities is vitally important for our health. Airborne pollutants from traffic such as nitrogen oxides, heavy metals, volatile organic carbon compounds and ultrafine particles have a range of serious effects. These include damage to the heart similar to the damage from smoking, exacerbation of asthma, bronchitis, cancer, diabetes and damage to the unborn. Children and the aged are particularly susceptible to harm.
We have taken the first steps towards creating a tool that will allow travellers to choose a safer route to their destination. We tested low-cost sensors that could be deployed as a network to inform an app that will display a map of traffic pollution and noise “hot-spots.” Our study evaluated the potential of cheap IoT sound sensors to estimate airborne pollution from traffic. The sensors run on freely available, low-power wireless network (LoRaWAN) and have batteries that can last for 2 years.

The Role of Infrastructure in Smart Cities

Marianna Cavada, Dr Dexter Hunt, Prof Chris Rogers University of Birmingham, UK

The idea of ‘smart cities’ was initially introduced by corporations to provide technological solutions to overcome contemporary challenges. The semantics for smart cities’ lacks a coherent vision and the use of technology therein is currently under scrutiny for its ‘liveability’ qualities. Therefore, the conception (and then design) of infrastructure needs to focus on the philosophy of what is truly smart, necessitating the assessment of smartness of solutions in relation to liveable cities.

As a result of the growing research base, there is an opportunity now to frame the role of infrastructure within the smart cities vision beyond the traditional meaning of the term – one that empowers infrastructure and offers opportunities for innovative outcomes related to openness, collaboration and delivery of smartness in cities. In this paper, smartness, as a holistic practice, is reflected through the initiatives that cities have adopted in order to become smart. It is, therefore, proposed that a smart dataset not only provides a benchmark for smart cities, but underpins a new set of criteria by which we can assess the efficacy of changes to urban systems and positively influence smart cities, leading to innovative solutions to current and future urban challenges.

Contributed Talks 7b

What Economics are needed to Shape Sustainable Infrastructure Investment?

M. Goodfellow-Smith
University of Birmingham – iBuild and Liveable Cities programmes

C. Rogers, M. Tight
University of Birmingham

This is not a lengthy treatise on economic theory but we will commence with an assertion of Sir Crispin Tickell:

“Out of date economics should be recognised as a dangerous mental condition.”

Entrepreneurial economic theory might have the potential to achieve a radical transformation of the general approach to infrastructure development whilst utilising some of the existing economic tools available.

Gross Domestic Product remains the overriding measure of economic progress worldwide; its inadequacy is highlighted by many organisations yet we cling stubbornly to this measure. Would alternative measures provide a more coherent policy framework in which resilient and sustainable infrastructure would achieve a far quicker implementation schedule?

Economic theories can be found to be partially in conflict with reality and frequently based on intentionally unrealistic assumptions; such as Arbitrage Pricing Theory and the Production Possibilities Frontier. Such tools are applied with an almost blind faith that the results will give the right solution to economic growth requirements even given the internal inconsistencies that can be apparent.

These key economic tools have an enormous impact on the type of infrastructure that is contemplated for implementation – generally described as short-term profit maximising infrastructure investment or long-term profit maximising infrastructure investment. Application of such tools to simply
achieve profit has generated, broadly speaking, the infrastructure that now provides important functions. However, improvements to these tools might enable an acceleration of investment in sustainable infrastructure.

Often project developers are required to draw in investment from various sources and generally under severe time constraints. Accessing appropriate finance as quickly as possible is the main default position. Very little attention is focussed on the cost of the finance package and most strikingly on the longer term financial and wider societal costs. A tool to assess the cost of finance has been developed which is explained and improvements suggested. Utilisation of such a tool would enable more finance to be available for future infrastructure investment.

Given that city living is in profound need of radical transformation and that the majority of economic theory discounts natural capital and well-being measures; what type of economic thinking could lead to a rapid implementation of liveable city infrastructure? Improvements in the assumptions and application of economic tools will provide useful improvements but it is argued that a new form of entrepreneurial, restorative economic theory has greater potential to achieve radical transformation of the nation’s cities.

Slow Spots and Not Spots: Alternative Business Models and Access to Broadband in Rural Areas

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Meng Song, Welsh Economy Research Unit, Cardiff Business School, University of Cardiff
Catherine Harris City-Region Economic Development Institute, Birmingham Business School, University of Birmingham

In an ideal world every household and business would have access to fibre broadband connections. Many rural communities in the UK are in areas known as “slow spots” where broadband speeds are less than 2 megabits per second (Mbps) for frequently used applications (Digital Britain, 2009) or “not spots” where broadband is not currently available. Obtaining access to broadband is impossible in some areas using the existing asymmetric digital subscriber line (ADSL) infrastructure. In such places, distance from the exchange is too great for the broadband signal to travel and such places are termed “not spots”. “Not spots” or “slow spots” produce local distortions that operate at the interface between national and local infrastructure. They reduce the ability of residents living in such places to develop and grow local businesses and also to facilitate the relationship between everyday living and access to broadband. The latter includes education, e-commerce and access to digitally provided public services.

This paper explores the development of novel next generation infrastructure (NGI) business models that are being designed to facilitate multiple value capture and investment risk reduction to provide access to broadband in rural areas. The paper identifies five different business models that have emerged to finance and fund broadband to slow/not spot areas. These business models include conventional approaches that have emerged from the private sector, but are often subsidized by government, or target wealthy areas. There are also more alternative business models that include localised solutions. These include business models that are subsidized by local communities providing voluntary labour and free access to land. Such models may initially be based on local community solutions involving voluntary inputs, but ultimately user charges may provide a revenue stream to cover operating costs, enhancement and maintenance. One alternative business model operates at a county level and this reflects a NGI business models that can be scaled up and is being scaled up. This scaled-up alternative business model represents a partnership between the Church of England and the private sector and uses heritage assets (church towers) to provide a county-wide broadband network.

Municipal Bonds As A Means Of Accelerating Local Infrastructure Investment

Francesca Romana Medda, UCL QASER Lab f.medda@ucl.ac.uk

The recent financial crisis has certainly hindered the ability of local authorities to raise funds for
capital investment, in particular, for infrastructure. In response, many municipalities and regional authorities around the world would benefit by broadening their financial channels and exploring new flexible financial options. In the United States, municipal bonds represent the backbone of local public finance. Nearly three-quarters of core infrastructure in the US is financed by municipal bonds, with nearly $400 bn in issuances every year. However, the municipal bond market is not a rose without thorns. Against this background, the present paper examines, through case studies, different successful and unsuccessful experiences of local authority bond implementations for infrastructure investment. In particular, the objectives here are twofold. We first examine the limitations and advantages of the more widespread use of bond issuance as a financial tool for infrastructure investments. Secondly, we enquire into whether collective solutions can become the financial cornerstone for infrastructure investment, as we observe in the case of Sweden. The paper reaches some interesting policy recommendations and describes effective strategies through which local authorities can take advantage of bond tools for infrastructure investments.

Contributed Talks 7b

Analysis of Electricity Network Risks from Daily Maxima Wind Gusts using a High-resolution Climate Model

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Worldwide, the exposure of civil engineering infrastructures to extreme weather results in frequent and catastrophic interruption of vital services. This typically occurs at spatial scales that exceed by far those of isolated faults, with networked infrastructures being affected more by the lack of systemic integrity than by local malfunctions. System-wide disruptions caused by extreme weather are likely to be compounded by the extent of the network and the size of the affected customer base. The ensuing outcomes are as profound as to alter entire socio-economic landscapes. The level of interdependency and complexity behind these interactions makes impact studies a crucial informative element of adaptation strategies, which are likely to receive more attention in the future due to inauspicious climate projections. Current approaches to adaptation include fragility modelling, real-time assessment of weather impacts, and failure probabilities, although the coarse spatial resolution of the datasets used is often a limiting factor. Building on the latest developments in Climate Models and power grid fragility curves, we investigate the vulnerability of a two-tier, overhead distribution electricity network subjected to high winds. By mapping fragility-driven faults and the affected customer base onto a multidecadal dataset from a state-of-the-art, high-resolution climate model, we identify the total impact of wind gusts on the two-tier network in terms of faults multiplied by the number of customers served. A set of preliminary results suggests that the total impact of the lower tier network is one order of magnitude larger than the upper tier network, and that the size of the network plays a much more fundamental role than the number of customers served.

A Next Generation of CAT (NG-CAT) models

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Cities across the world are becoming particularly vulnerable to natural hazards due to societal, technological and environmental changes. The backbone of cities is constituted by urban infrastructures, such as transport and electricity networks. To protect cities from current and future catastrophes, developing infrastructure resilience is fundamental. Current approaches to assess urban risk from natural hazards are currently focused on buildings or direct (e.g. physical) damages. Catastrophe (CAT) modelling is a standard practice
for computing direct losses to building stock, within the insurance and reinsurance industries. However, in the context of infrastructure systems, detailed assessment is rare, and models for estimating losses to infrastructure sector are uncovered in literature.

Infrastructure losses are not limited to direct monetary losses (e.g. road pavement damages), but mainly include indirect losses such as transport disruption or business interruption linked to the performance loss of the system. A Next-Generation (NG) of CAT models can be re-thought expanding the exposure elements to infrastructure systems and losses to both direct and indirect losses, within a new approach to threat and risk analysis. This paper presents current case studies of NG-CAT models: (i) the impact of flooding on road transport network; (ii) the impact of wind gusts on electrical distribution systems; (iii) the impact of heat waves on railway system.

**Challenges in SpaceTime - Coupling Models of Next Generation Infrastructure**

Dr. Will Usher, Tom Russell  
*Environmental Change Institute, University of Oxford*

Under the EPSRC-funded MISTRAL project, a new National Infrastructure Systems Model is being developed by the Infrastructure Transitions Research Consortium: NISMOD v2.0. The model includes highly spatially and temporally resolved simulation models of six infrastructure systems: transport, energy supply & demand, water supply & treatment, flood defence, digital communications and solid waste.

One of the key challenges in coupling simulation models of infrastructure systems is the differing spatial and temporal resolutions used by the models. We have developed a general approach to spatiotemporal data conversion which has been implemented in smif, an opensource simulation modelling integration framework.

Simulation models use discrete ‘intervals’ to model the passing of time during a year. The number of intervals used to divide up a year of time is a function of both the resolution of the phenomena under investigation, seasonality (particularly of demand) and whether the system incorporates storage or is more flowbased. Spatial representations and resolutions also differ between models. These differences are driven by the unique network topologies found in each sector, data availability, and the intersection of the infrastructure system with physical geography. These spatiotemporal differences between models are essential to accurately represent the pertinent phenomena in each sector, but create a problem for coupling models: data which is defined over space and time must be converted from one spatio-temporal resolution to another. Conversions down-sample or upsample data over space or time. Downsampling smooths, averages over, or discards information. Upsampling interpolates or requires additional information. In some special cases, conversion is necessary to rescale data over the same spatio-temporal resolution better suited to the destination model. Remapping operations deal with situations where only a small proportion of space or time is modelled in a system which exhibits cyclic phenomena (more commonly over time)
The UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC) is the next step towards a coordinated and coherent, world class, UK-based national infrastructure research community. Initially spanning 14 universities, UKCRIC was formed and is funded to address the urgent need, and transformative opportunity, to develop and exploit major advances in scientific and engineering understanding (in materials, mechanics, systems thinking, data handling, sensor technology and in the social and environmental sciences) and connect these with the evolving needs and ambitions of the UK and cities within the UK and elsewhere.

Adopting an ethos of collaboration and openness, UKCRIC is an exciting new approach to academic research operations. It combines a coordinated and collaborative research strategy; improved knowledge transfer between academia, citizens, industry and government; and a series of open access state-of-the art research facilities. A central coordinating body provides the oversight needed to quickly deploy the network’s new technologies, techniques, and insights; and to respond agilely to changing research needs and priorities.

The first phase of UKCRIC is the establishment of a linked network of new or enhanced physical facilities, established through a £138M capital investment by BEIS with matching contributions (capital and running costs) from universities, users and industry, formally announced in 2015. Rather than a single physical centre, the national facilities are distributed throughout the UK, building on existing hubs of research excellence. These experimental testing facilities will be complemented by and integrated with:

- a series of “living city” observatories, through which the actual functioning of cities and infrastructure – including, crucially, how people actually use them – will be monitored, analysed and assessed, and results used to improve system design; and
- a distributed capability for infrastructure data, visualisation, modelling and simulation.

The second phase of UKCRIC is the creation of the Coordination Node, a central body to provide the clear leadership, coordination and management required to deliver such an ambitious step-change in research operations. The initial focus of the managing body is to:

- set the transdisciplinary research agenda that will enable the UK’s infrastructure and urban systems to be appropriate, affordable, flexible, sustainable and resilient (research strategy);
- deliver collaborative, multidisciplinary moving towards transdisciplinary research that can be both exploited and progressively enhanced to maintain and develop the physical infrastructure and urban systems needed to retain the UK’s position as a world-leading intellectual and economic power, while ensuring that UKCRIC’s facilities are used widely, fully and effectively in pursuit of the above (research integration); and
- ensure the results of UKCRIC’s research are implemented for the benefit of society, the environment and the UK economy (research impact).

There is an opportunity for UKCRIC to act as a focal point for cities and infrastructure research worldwide, maintaining and extending the UK’s knowledge and innovation leadership in the design, planning, delivery, management, and operation of cities and infrastructure. It is actively seeking new collaborators to realise this ambitious vision and utilise its network of state-of-the-art research facilities.