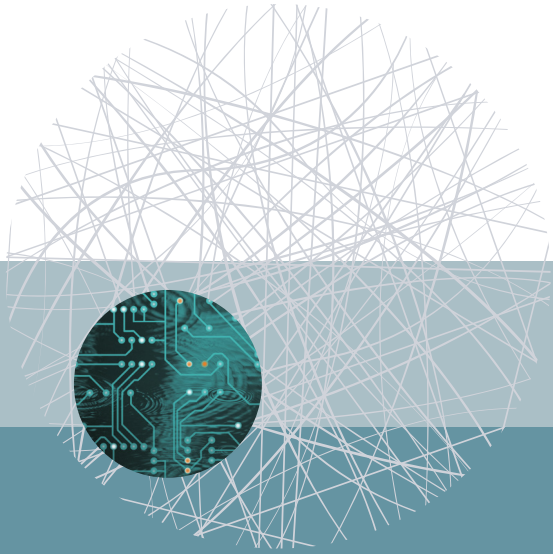
ITRC mistral

multi-scale infrastructure systems analytics



The UK Infrastructure Transitions Research Consortium

MISTRAL programme: 2016–2020

Multi-Scale Infrastructure Systems Analytics

The National Infrastructure challenge

National infrastructure systems form the basis for a society's economic and human wellbeing and environmental sustainability. These systems, which include energy, transport, digital communications, water supply, waste water, flood protection and solid waste, require very significant capital investments that have long lead-times and life-times.

Building infrastructure is a long-term commitment that is very difficult to reverse, which means that infrastructure decisions have major implications for sustainability, notable mitigation of carbon emissions and adaptation to the impacts of climate change.

Governments in advanced economies worldwide have to cope with an ageing stock of infrastructure that needs to meet growing demands for infrastructure services. Meanwhile major infrastructure investments are taking place in emerging economies which will lock in patterns of development for decades to come. Least developed countries struggle with the greatest deficit in infrastructure provision, including basic energy, water and sanitation services and transport connectivity that would enable trade and growth.

Standard & Poor's and McKinsey estimate that $57 trillion, or $3.2 trillion a year, will be needed to finance infrastructure development around the world over the next 15 years.

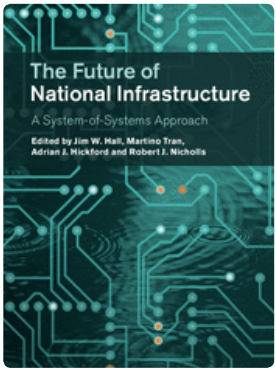
Countries worldwide are now at a critical crossroads where the pathways chosen for new and replacement capacity will both dictate future infrastructure supply security, and have critical environmental implications, especially climate change.

Now more than ever, it is essential that governments, utility providers, designers, investors and insurers have access to new methods that enable the evaluation of the performance and impact of long-term plans and policy for infrastructure service provision in an uncertain future.

Infrastructure forms the economic backbone of the UK. It is the fabric that defines us as a modern industrialised nation. The standard and resilience of infrastructure in the UK has a direct relationship to the growth and competitiveness of our economy, our quality of life and our ability to meet our climate change objectives and commitments.

HM Treasury: Strategy for National Infrastructure.

The work of ITRC is described in the book The Future of National Infrastructure, published in 2016. The book is an introduction to the NISMOD suite of models and tools. For the MISTRAL programme we are planning new advances in the NISMOD system and our analysis of national infrastructure.



The UK Infrastructure Transitions Research Consortium

The UK Infrastructure Transitions Research Consortium is delivering research, models and decision support tools to enable analysis and planning of a robust national infrastructure system. The research addresses major challenges for the energy, transport, digital communications, water, flood protection and waste, focusing upon the critical interdependencies between these sectors.

The UK Infrastructure Transitions Research Consortium (ITRC) provides concepts, models and evidence to inform the analysis, planning and design of national infrastructure

In its first research programme, running from 2011 to 2016, the ITRC developed the world's first national infrastructure system-of-systems model, NISMOD, which has been used to analyse long term investment strategies for energy, transport, digital communications, water, waste water and solid waste. Crucially, NISMOD also provides insights into the vulnerability of infrastructure networks and the risks of cascading failure, in order to inform investment in improving resilience. NISMOD has been used to analyse the National Infrastructure Plan and the National Needs Assessment led by Sir John Armitt. The ITRC's work has also been used by:

- the Department for Transport to analyse the resilience of the transport network
- National Grid to help planning the integration of solar energy
- Lincolnshire County Council to help prioritise road maintenance
- Lockheed Martin to analyse the risks of cyber attach on electricity substations
- the Committee on Climate Change in the 2017 Climate Change Risk Assessment.

The MISTRAL programme Multi-Scale Infrastructure Systems Analytics

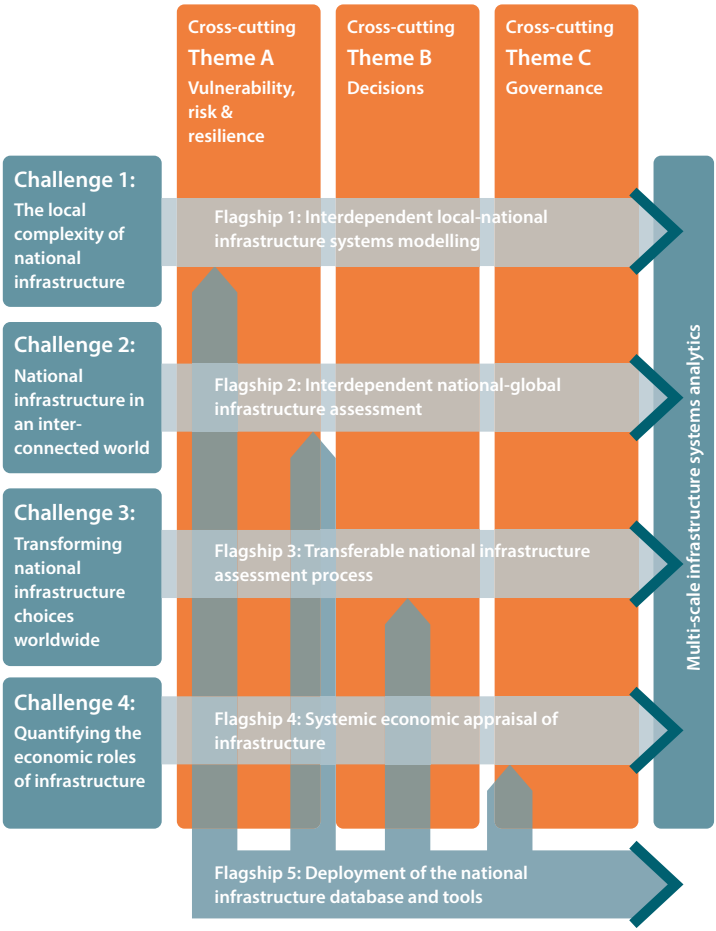
MISTRAL is the second research programme of the ITRC, which will run from 2016 to 2020. The MISTRAL programme has been awarded £5.3million of funding from the Engineering and Physical Science Research Council.

The aim of the MISTRAL programme is to develop and demonstrate a highly integrated analytics capability to inform strategic infrastructure decision making across scales, from local to global.

Our vision is for infrastructure decisions to be guided by systems analysis. When this vision is realised, decision makers will have access to, and visualisation of, information that tells them how all infrastructure systems are performing. They will have models that help to pinpoint vulnerabilities and quantify the risks of failure. They will be able to perform 'what-if' analysis of proposed investments and explore the effects of future uncertainties, such as population growth, new technologies and climate change.

MISTRAL will thereby radically extend the ITRC's pioneering infrastructure systems analysis capability:

- **Downscale**: from ITRC's unique representation of national networks to the UK's 25.7 million households and 5.2 million businesses, representing the infrastructure services they demand and multi-scale networks through which services are delivered.
- **Upscale**: from the national perspective to incorporate global interconnections via telecommunications, transport and energy networks.


Cross-cutting
Theme A
Vulnerability, risk & resilience
Cross-cutting
Theme B
Decisions
Cross-cutting
Theme C
Governance
Challenge 1:
The local complexity of national infrastructure
Challenge 2:
National infrastructure in an inter-connected world
Challenge 3:
Transforming national infrastructure choices worldwide
Challenge 4:
Quantifying the economic roles of infrastructure
Flagship 1: Interdependent local-national infrastructure systems modelling
Flagship 2: Interdependent national-global infrastructure assessment
Flagship 3: Transferable national infrastructure assessment process
Flagship 4: Systemic economic appraisal of infrastructure
Flagship 5: Deployment of the national infrastructure database and tools
Multi-scale infrastructure systems analytics

- **Across-scale**: to other national settings outside the UK, where infrastructure needs are greatest and where systems analysis represents a business opportunity for UK engineering firms.

Five years ago, when we started on the ITRC journey, proposing theory, methodology and network models that stretched from the household to the globe, and from the UK to different national contexts would not have been credible. Now, thanks to what we have achieved in ITRC, the opportunity for multi-scale modelling is coming into sight.

MISTRAL research challenge 1: The local complexity of national infrastructure

Many innovations in infrastructure services and networks are occurring at small scales in space and time: smart meters and grids, heat networks, autonomous vehicles, sustainable drainage, etc. There is an increasing emphasis on decentralised systems and devolution of infrastructure governance to cities and regions. MISTRAL will embed new detailed analysis of infrastructure systems at a building and community scale, for all of the UK, within the NISMOD national systems analysis framework.

To address **Challenge 1** we are extending our system-of-systems modelling capability downscale to communities and buildings. We will use this new bottom-up capability to analyse the implications of radical technological change and to enable transition to resilient infrastructure systems.

MISTRAL research challenge 2: National infrastructure in an inter-connected world

UK infrastructure is embedded in global networks of transport, energy and digital communications. Analysing the UK without consideration of this interconnectivity potentially overlooks critical interdependencies and drivers of future change. Representing continental and global networks is a challenge, but datasets are becoming available, so we can now study interconnectivity. MISTRAL will explore the risk and opportunities of ever-greater connectivity and how network resilience can be enhanced in the global context.

To address **Challenge 2** we are simulating the coupling between the UK's infrastructure and networks at continental and global scales. We will use this understanding to quantify the risk and opportunities of ever-greater global connectivity and to identify the ways in which global network resilience can be enhanced.

MISTRAL research challenge 3: Transforming national infrastructure choices worldwide

Given the scale of infrastructure investment required around the world, from post-disaster situations to rapidly industrialising economies, it is not surprising that ITRC has been invited to apply its approach in situations outside the UK, from Palestine to China. MISTRAL will develop a generic infrastructure systems assessment methodology for use in diverse national settings, making use of rapidly emerging global datasets and country-specific engineering insights.

To address **Challenge3** we are developing an analysis process and modelling platform for national infrastructure assessment in countries worldwide. We are demonstrating and promoting this methodology in partnership with researchers and decision makers.

MISTRAL research challenge 4: Quantifying the economic roles of infrastructure

Whilst there are a growing number of empirical studies of the relationship between infrastructure investment and economic growth, the mechanisms by which infrastructure influences economic activity are not well understood in quantitative terms. MISTRAL will tackle this knowledge gap through new empirical analysis, theory and modelling, including an ambitious new initiative to extend an agent-based model of the UK economy to incorporate the economic roles of infrastructure.

To address **Challenge 4** we are combining engineering systems models with empirical evidence and new economic thinking to quantify the relationships between infrastructure investment and regional/national economic growth. We will use this understanding to enable rigorous appraisal of the benefits and risks of infrastructure investment.

The UK national infrastructure database and simulation platform

The ITRC's unique national infrastructure database (NISMOD-DB) is being reconfigured to handle the big data challenges of storage, retrieval and computation required for MISTRAL. This will underpin all of the modelling and analysis research taking place across the programme.

New visual analytics tools will be integrated to enable scrutiny of, and interaction with, the data. Working in partnership with data providers and end users, we will 'open up' the database (whilst respecting licencing restrictions and security concerns) so that it becomes a national hub for infrastructure systems research.

Our partners

The UK Infrastructure Transitions Research Consortium (ITRC) is funded two Programme Grants from EPSRC. The first ITRC Programme Grant was for £4.7 million and ran from 2011 to 2015. Given the research breakthroughs and applied impact that ITRC managed to achieve, EPSRC has awarded the ITRC a £5.3 million grant which will run until 2020.

The ITRC is a partnership of seven of the UK's leading universities:

- University of Oxford
- Newcastle University
- University of Southampton
- Cardiff University
- University of Cambridge
- University of Leeds
- University of Sussex

The MISTRAL grant has been supported with £9.97million of cash and in-kind support from partners in the UK and around the world. The ITRC is working in close collaboration with practitioners and policy makers:

- Government departments, agencies & local authorities
- Contractors
- Utility companies
- Engineering & multi-disciplinary consultants
- Insurers
- Engineering institutions
- NGOs
- Research organisations & data providers

Who we are

ITRC brings together a team of 15 academics, 22 post-doctoral researchers and 10 PhD students. Their expertise covers all of the relevant infrastructure sectors, along with cross-cutting issues of economics, demographics, risk and governance. The ITRC team are experienced in delivery of integrative and interdisciplinary responses to complex scientific and societal challenges.

Prof Jim Hall FREng, University of Oxford, Director of the ITRC and an expert in water infrastructure and climate risks.

Prof Nick Jenkins FREng, Cardiff University, expert in energy supply and transmission

Prof Jianzhong Wu, Cardiff University, expert in energy systems.

Dr Nick Eyre, University of Oxford, expert in energy demand.

Prof John Preston, University of Southampton, expert in transport systems.

Dr Simon Blainey, University of Southampton, expert in transport modelling.

Prof David Cleevely CBE FREng, Cambridge Centre for Science and Policy, international telecoms expert.

Prof Chris Kilsby, Newcastle University, expert in water and flooding.

Prof William Powrie FREng, University of Southampton, expert in solid waste and geotechnics.

Dr Stuart Barr, Newcastle University, expert geospatial databases.

Prof Robert Nicholls, University of Southampton, expert in the impacts of climate change on the coast

Prof Peter Tyler, University of Cambridge, expert in regional economics.

Prof Doyne Farmer, University of Oxford, one of the world's leading complexity scientists.

Prof Mark Birkin, University of Leeds, expert on analysis of demographic change.

Dr Jim Watson, University of Sussex, expert in infrastructure governance.

Miriam Mendes, University of Oxford, ITRC Programme Manager

Impact of the MISTRAL programme

MISTRAL aims to change the ways in which strategic infrastructure planning, investment and design decision are made. By the end of the MISTRAL programme we aim:

- to have MISTRAL's national infrastructure system analytics in use and informing decisions by governments, utilities and regulators at a range of scales in the UK;
- for MISTRAL's national infrastructure database to become a shared national resource and a focal point for research and industrial collaboration;
- for MISTRAL's systems analytics to be used in infrastructure planning and design around the world;
- to be engaging a wide range of stakeholders, including the general public, in understanding infrastructure performance and choices.

As we embark upon the next phase of development of the NISMOD system, we have convened a high level Client Group, to guide the design of the system and ensure that it is rapidly taken up in practice.

MISTRAL will also be guided by an International Advisory Board to ensure that our research continues to be of the highest international academic standards, and to help us grow our international network.

We will grow our collaborations with partner organisations in order to fully understand the infrastructure challenges they face and to promote the uptake of the MISTRAL research.

We have set aside resource to enable us to take up opportunities to transfer the MISTRAL research into practice in the UK and globally.

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EPSRC

Engineering and Physical Sciences Research Council

Find out more and get involved

To discuss collaboration with our research programme, please contact miriam.mendes@ouce.ox.ac.uk.

@UKITRC

www.itrc.org.uk