



# NIRD

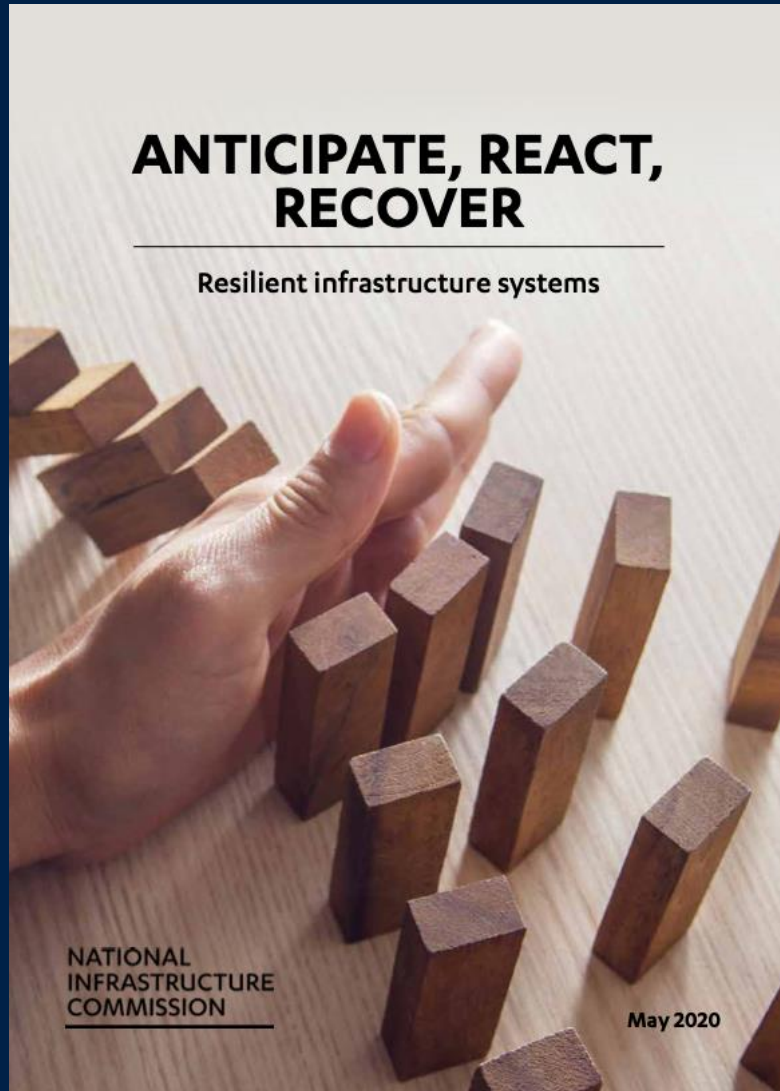
## National Infrastructure Resilience Demonstrator

DAFNI Conference

Imperial College, London

12 September 2023

# Gaps in resilient systems analysis



## Recommendation

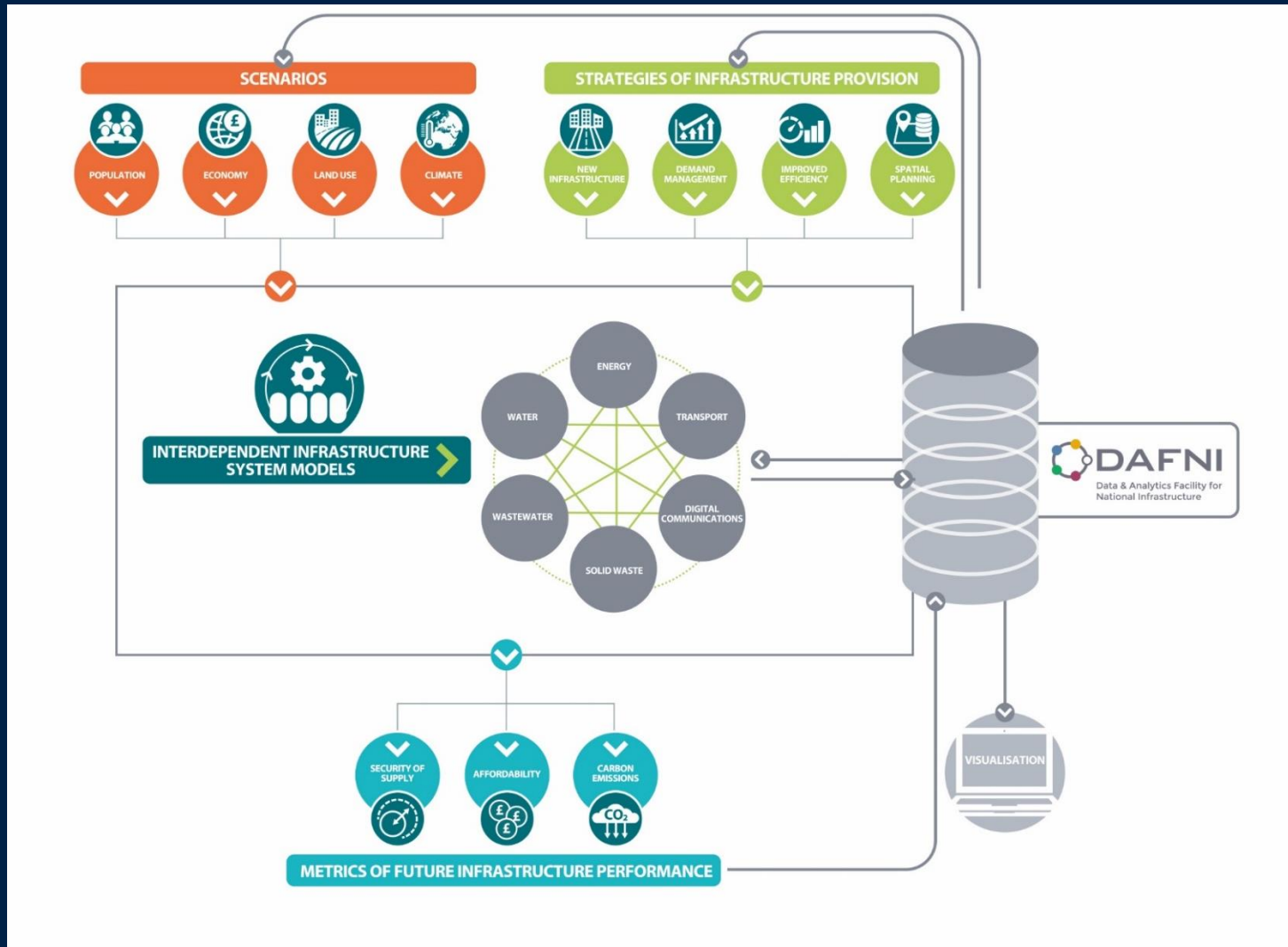
- Regulators should require a **system of regular stress testing by 2024 for energy, water, digital, road and rail infrastructure** operators, to ensure resilience standards for infrastructure services

## Gaps

- **Lack of understanding of infrastructure interdependence** remains a major challenge for operators in estimating and tackling climate risks
- **Lack of coherent data for modelling infrastructure interactions** and **inconsistent risk measures** that makes it difficult to compare resilience outcomes across different sectors

# ITRC-Mistral NISMOD

£10 million EPSRC funded programme of research to build **national-scale systems modelling capability [2010 – 2020]**



Reliability Engineering and System Safety

System of systems formulation and disruption analysis for critical national infrastructures

John Tucker, Stuart Bunn, Rachel Paul, Jan W. Hall

Journal of Reliability Engineering and System Safety, 2013

Abstract: Critical national infrastructures, including energy, transport, digital communications, and water, are prone to flood damage. This paper presents a novel approach to the problem of system of systems analysis (SoSA) for critical national infrastructures. The approach involves the development of a system of systems model (SoSM) that captures the interdependencies between different infrastructure sectors. The SoSM is then used to perform a system of systems analysis (SoSA) to identify potential vulnerabilities and to assess the impact of various threats on the system. The results of the SoSA are used to inform the design and operation of the infrastructure system, and to develop strategies for risk reduction.

Journal of Risk Management

Critical infrastructure impact assessment due to flood exposure

A. Paul, J. Tucker, J. W. Hall, J. Abner, and S. Bar

Journal of Risk Management, 2013

Abstract: Critical infrastructure (CI) is essential for the functioning of a nation. However, CI is vulnerable to a range of threats, including natural disasters such as floods. This paper presents a novel approach to the problem of CI impact assessment (CIA) due to flood exposure. The approach involves the development of a CI impact assessment model (CIAM) that captures the interdependencies between different CI sectors. The CIAM is then used to perform a CIA to identify potential vulnerabilities and to assess the impact of various threats on the system. The results of the CIA are used to inform the design and operation of the infrastructure system, and to develop strategies for risk reduction.

EJTIR

Vulnerability assessment framework for interdependent critical infrastructures: case-study for Great Britain's rail network

Rachel Paul

Environmental Change Institute, University of Oxford

Journal of Engineering and Environment, 2013

Abstract: Critical infrastructure vulnerability assessment involves the identification of potential vulnerabilities and the assessment of the impact of various threats on the system. This paper presents a novel approach to the problem of CI vulnerability assessment (CIVA) for interdependent critical infrastructures. The approach involves the development of a CIVA framework that captures the interdependencies between different CI sectors. The CIVA framework is then used to perform a CIVA to identify potential vulnerabilities and to assess the impact of various threats on the system. The results of the CIVA are used to inform the design and operation of the infrastructure system, and to develop strategies for risk reduction.

ice proceedings

Strategic analysis of the future of national infrastructure

John Tucker, Stuart Bunn, Rachel Paul, Jan W. Hall, and David Abner

ice proceedings, 2013

Abstract: This paper presents a strategic analysis of the future of national infrastructure in the UK. The analysis is based on a number of key assumptions, including the need to meet the growing demand for infrastructure services, the need to ensure the resilience of the infrastructure system, and the need to reduce the carbon footprint of the infrastructure system. The results of the analysis are used to inform the development of a national infrastructure strategy.

Geographic Hotspots of Critical National Infrastructure

John Tucker, Stuart Bunn, Rachel Paul, Jan W. Hall, and David Abner

Journal of Risk Management, 2013

Abstract: Critical national infrastructure (CNI) is essential for the functioning of a nation. However, CNI is vulnerable to a range of threats, including natural disasters such as floods. This paper presents a novel approach to the problem of CNI hotspot analysis (CHA). The approach involves the development of a CHA framework that captures the interdependencies between different CNI sectors. The CHA framework is then used to perform a CHA to identify potential hotspots and to assess the impact of various threats on the system. The results of the CHA are used to inform the design and operation of the infrastructure system, and to develop strategies for risk reduction.

# National Infrastructure spatial network database

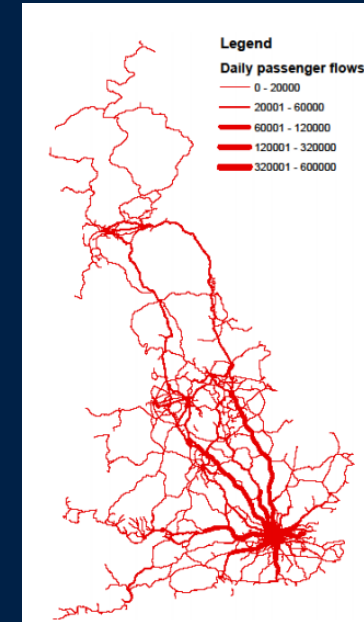
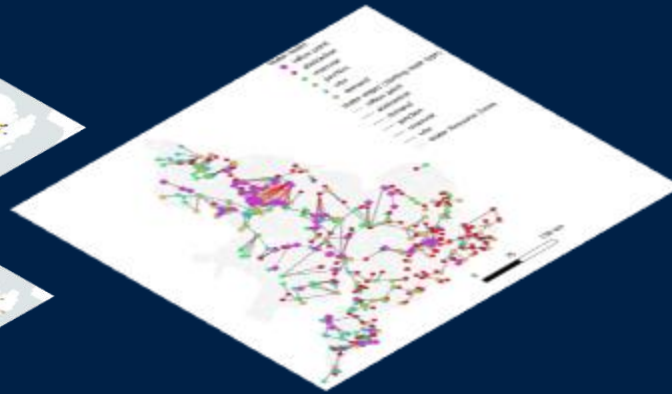
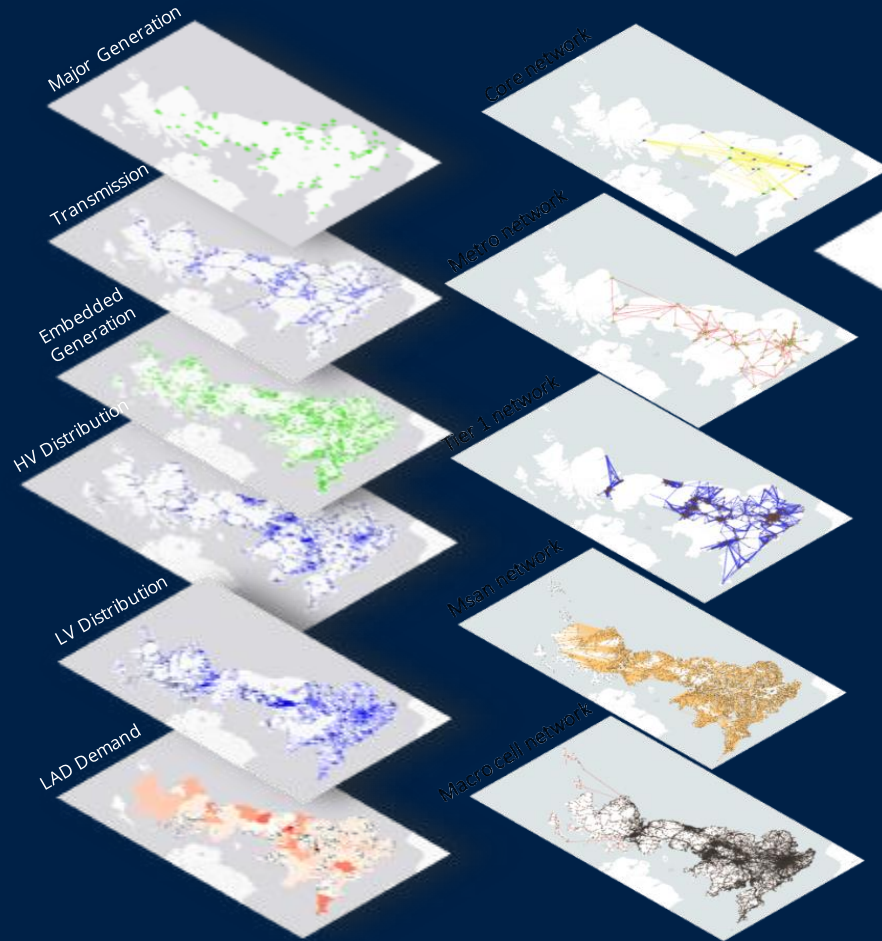
## Electricity

## Telecoms

## Water supply

## Railways

## Roads (major)

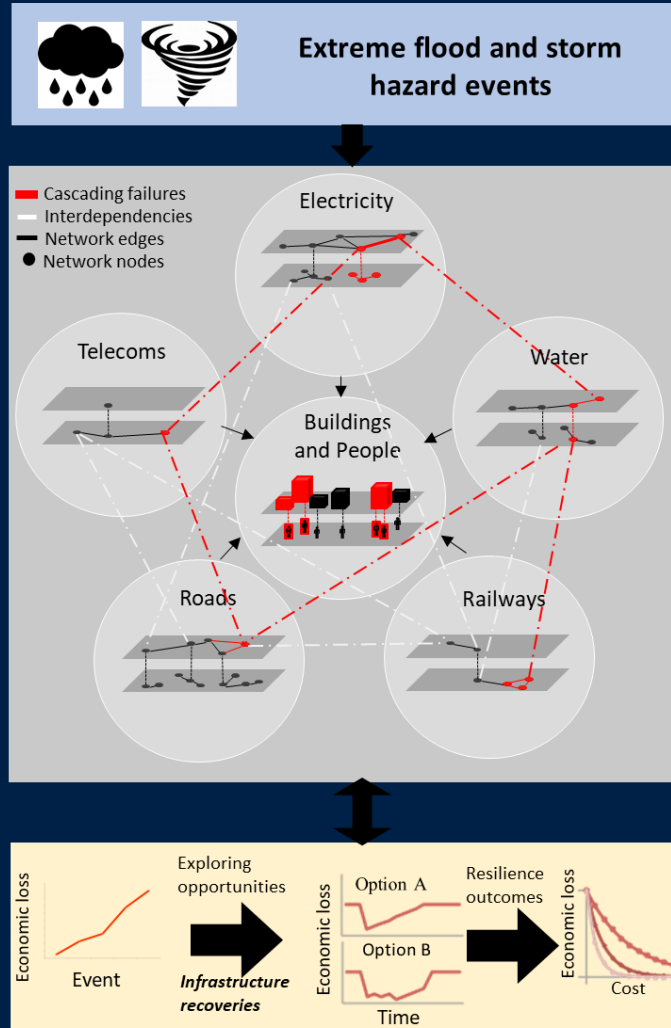


- ~78,000 nodes
- ~140,000 edges
- 5 networks
- customer/user demands mapped on each network



# NIRD

## National Infrastructure Resilience Demonstrator



### Objectives

- (1) Stress-test networks with **extreme flood and storm** events
- (2) Model **interdependent network failure cascades** to quantify losses to people and economic activities
- (3) Explore **resilience options** in reducing network failure losses

### Project outcome

Deliver accessible **national-scale modelling capability and software tools** for quantifying UK infrastructure risk and resilience to extreme flood and storm events, supported by a unique spatial database of interdependent networks, population and economic activities

# Vision for implementation on DAFNI platform

**2-3 flood and storm event examples** from JBA and Copernicus datasets

Database of **infrastructure networks** from ITRC-MISTRAL

**Population and buildings** datasets from Census and footprint datasets



## *Codebase*

1. Hazard-network intersections and **asset failure sampling**
2. Network **flow disruption** analysis
3. Population and economic activity **loss estimation**
4. Risk and vulnerability **metrics**
5. Resilience **options** testing



## *Usability and Reproducibility*

1. User-manual with input-**data specification**
2. Jupyter notebooks with **example demonstrations**
3. Sample output **visualisations**



# Timeline

WP	Activity	2023			2024												2025				
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar		
0	DAFNI integration		D1																		
0	Data and code creation and documentation																		D4		D5,D6
0	Stakeholder engagement			S1																	S3
1	Hazard event assembly																				
2	Infrastructure network data assembly																				
3	Socio-economic data assembly																				
4	Network service assignment																				
5	Infrastructure direct damages																				
6	Infrastructure service disruptions																				
7	Resilience options analysis																				
D1 - Scoping report of DAFNI integration process		D2 - Uploading of input datasets on DAFNI						D3 - Damage loss assessment results on DAFNI													
D4 - Resilience options results on DAFNI		D5 - Final user guide, codes and presentations						D6 - Journal academic paper													
S1 - Project awareness workshop		S2 - DAFNI conference to present risk results						S3 - Final project dissemination event													



# NIRD team members



## Principle Investigator

Raghav Pant

Senior Research Associate, ECI



## Co-Investigator

Jim W. Hall

Professor, ECI



## Lead Software Expert

Tom Russell

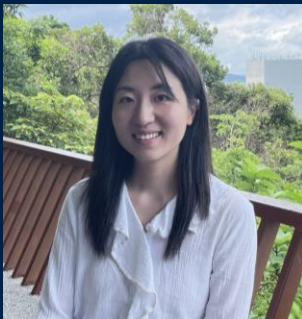
Senior Research Software Engineer,  
ECI



## Research Software Expert

Fred Thomas

Senior Research Software Engineer,  
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## Lead Model Developer

Yue Li

Post-Doctoral Research Associate,  
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