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Environmental *Change* Institute

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eci

System-of-systems framework for global infrastructure vulnerability assessment

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Environmental Change Institute

University of Oxford

GGKP Annual Conference

Washington DC

November 28, 2017

EPSRC

Engineering and Physical Sciences Research Council

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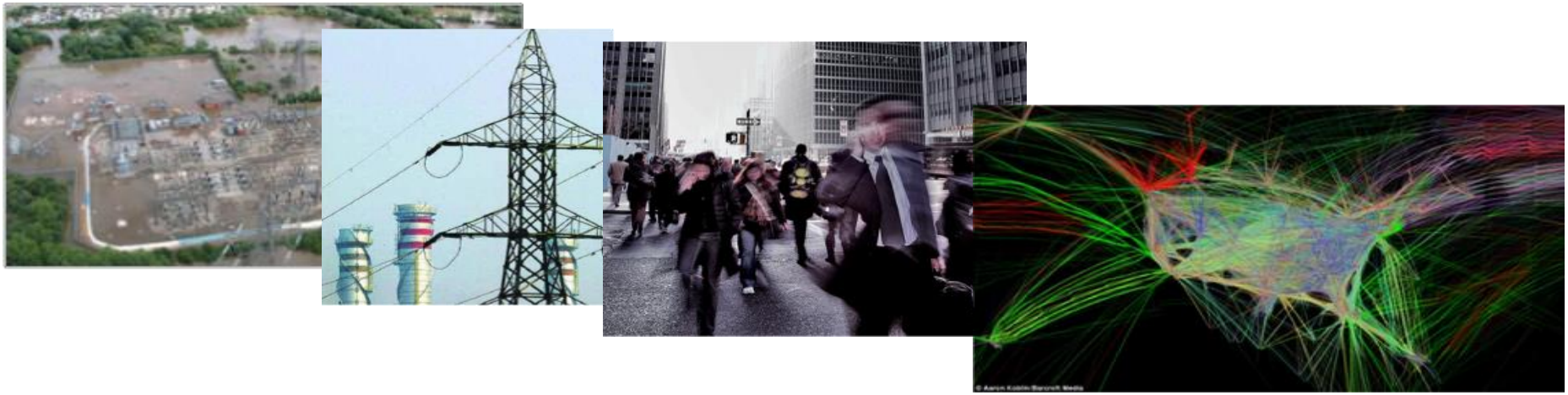
Understanding infrastructures

- Lifeline systems that support our society and economy
  - Energy, Transport, Water, Waste, Telecoms, Flood management



- Basic services
- Access to markets
- Employment
- Economic growth
- **Resilience**
- **Sustainability**

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Infrastructure development challenges

Infrastructure development plays a key role in addressing many of the sustainable development goals (SDG's):

- Equitable access to basic services
- **Climate change mitigation and resilience**
- **Disaster risk reduction**

But infrastructure development and planning suffers due to limitations inherent within traditional approaches:

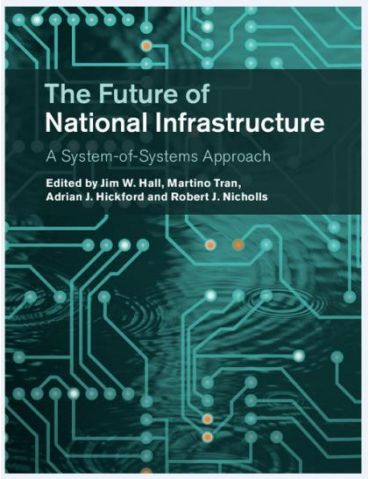
- Short termism
- Silo based thinking
- Failure to incorporate interdependencies
- Failure to address uncertainty
- Unquantifiable risks to investors
- **Lack of system-of-systems tools and models**

Dawlish rail failure – UK, Feb 2014. Source: BBC

Floods – Thailand, October 2011. Source: LA Times

ITRC and MISTRAL

UK Infrastructural Transitions Research Consortium (ITRC) - Multi-scale InfraSTRucture systems AnaLytics (MISTRAL)

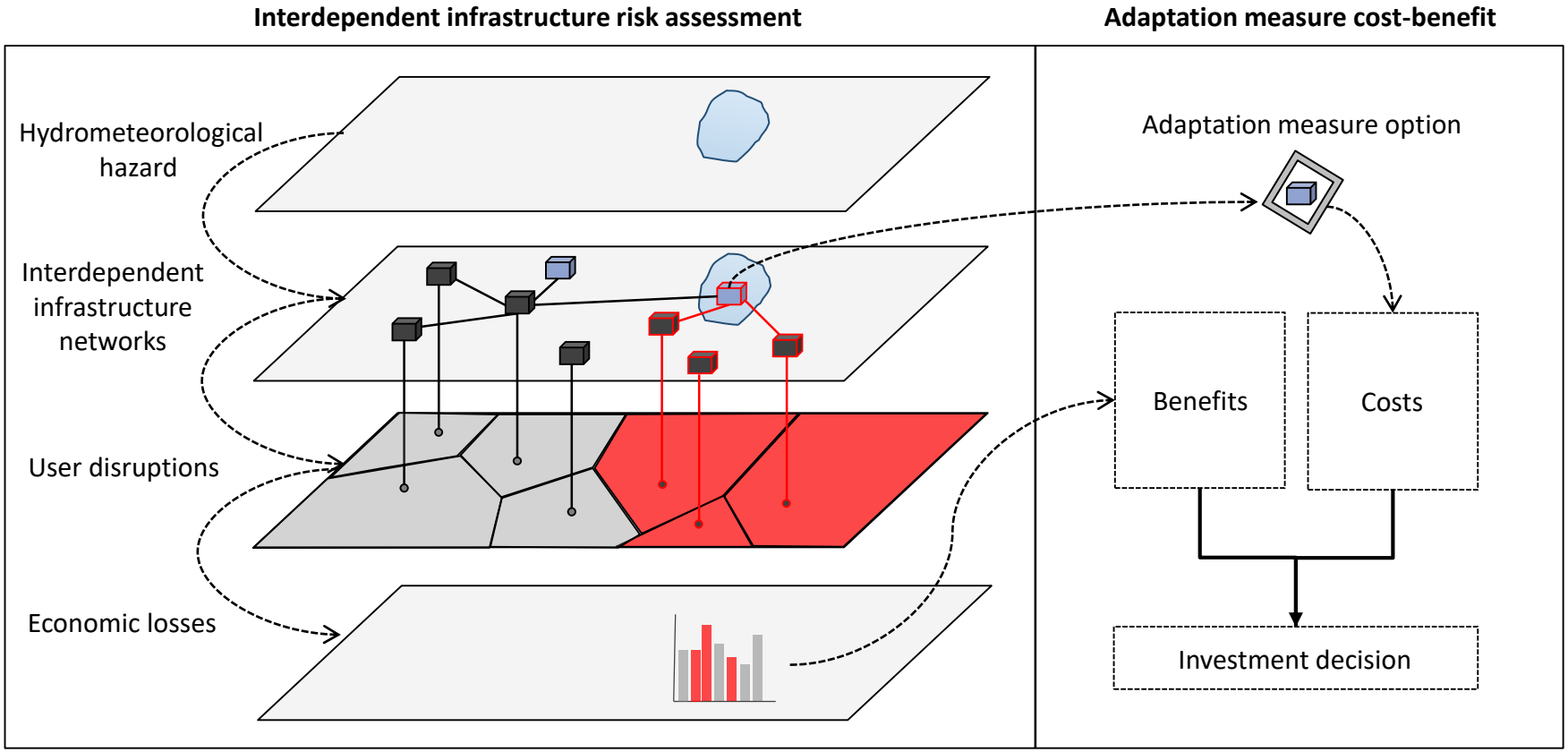


- ***UK research funded program: 2010 – 2020***
- ***> £10 million EPSRC + industry funding***
- ***Lead institution: University of Oxford***
- ***Global client group and stakeholders***

http://www.itrc.org.uk/

***Aim*:** To develop and demonstrate a highly integrated analytics capability to inform strategic infrastructure decision making across scales infrastructure**.**

Infrastructure vulnerability assessment methodology



Source: Thacker et al. (2017). Evaluating the benefits of adaptation of critical infrastructures to hydrometeorological risk. Risk Analysis. DOI: 10.1111/risa.12839.

- Where are key vulnerabilities in infrastructures concentrated?
- How do (inter)dependencies magnify risks to other systems?
- What are the wider consequences of infrastructure disruptions?

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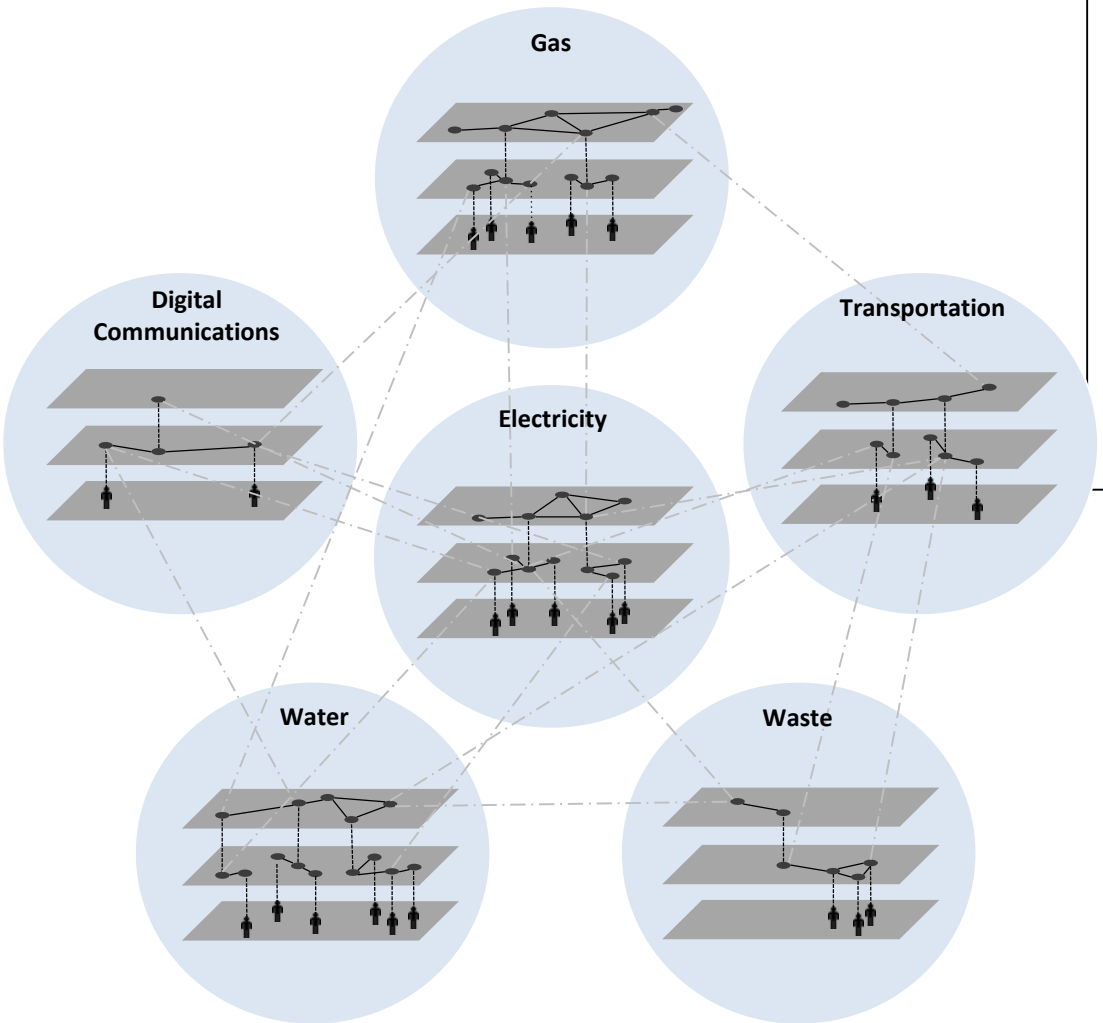
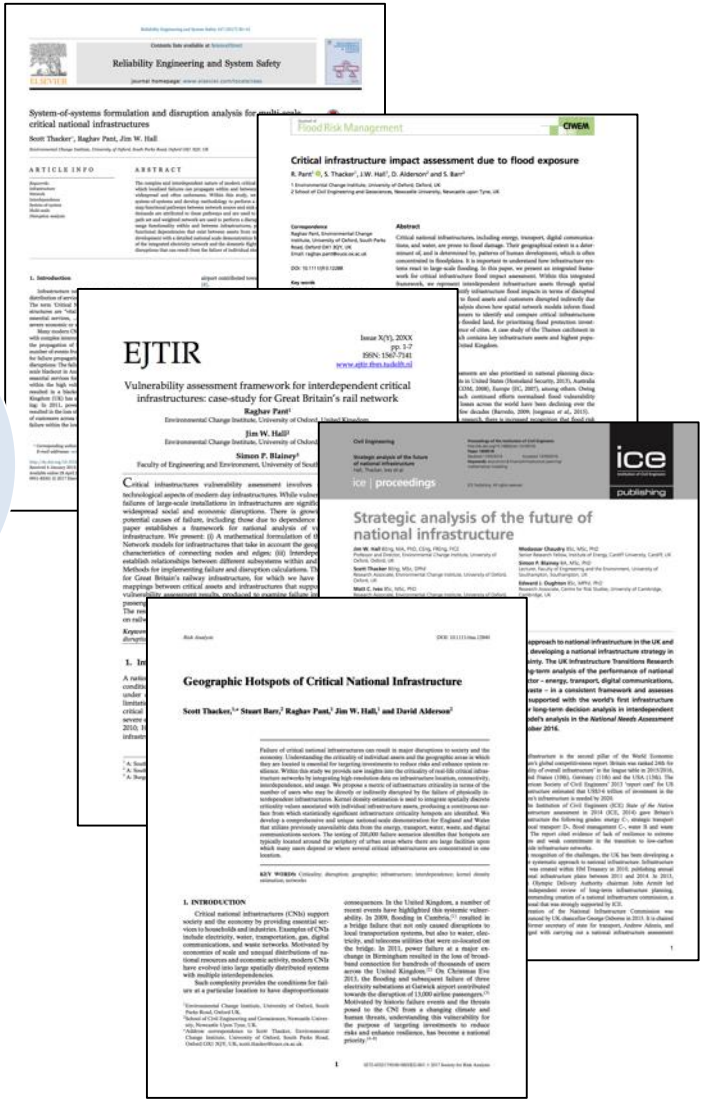
System-of-systems approach

System-of-systems infrastructure methodologies and models





Application: Vulnerability assessment for UK infrastructures

Physical & Geographical interdependence

HM TREASURY

Identifying critical hotspots in UK's infrastructure networks for prioritising resilience building interventions.

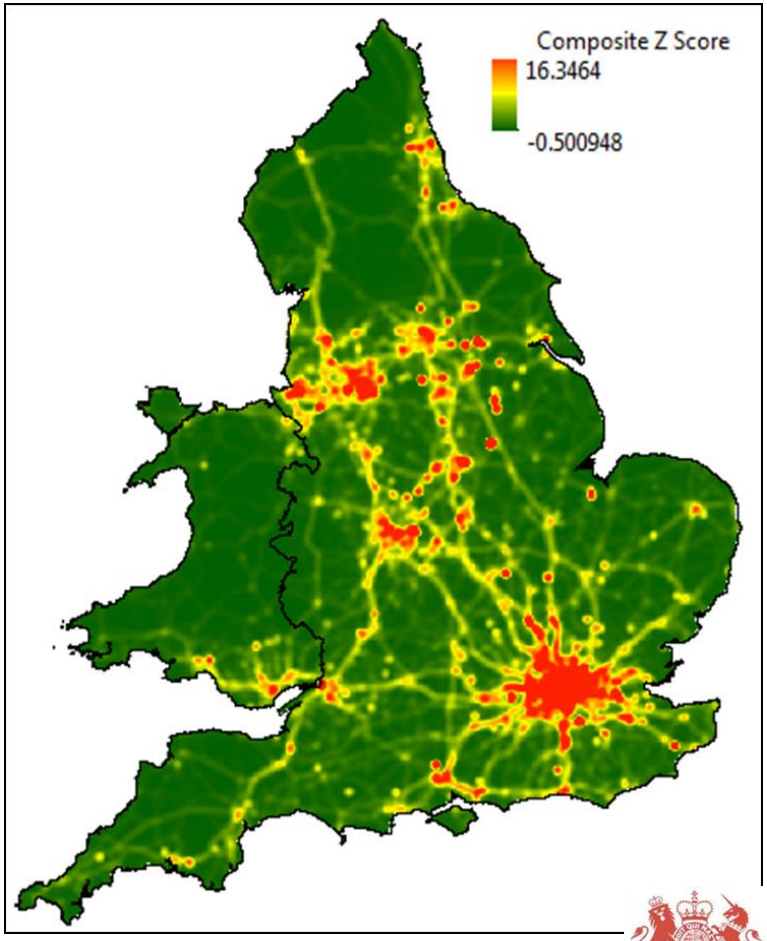
Department for Transport

Identifying points of vulnerability in UK's transport networks due to flooding, windstorms, heat and snow.

hs2 engine for growth

Assessing interdependency related climate change risks in the £55.7 billion HS2 railway network.

Composite criticality map



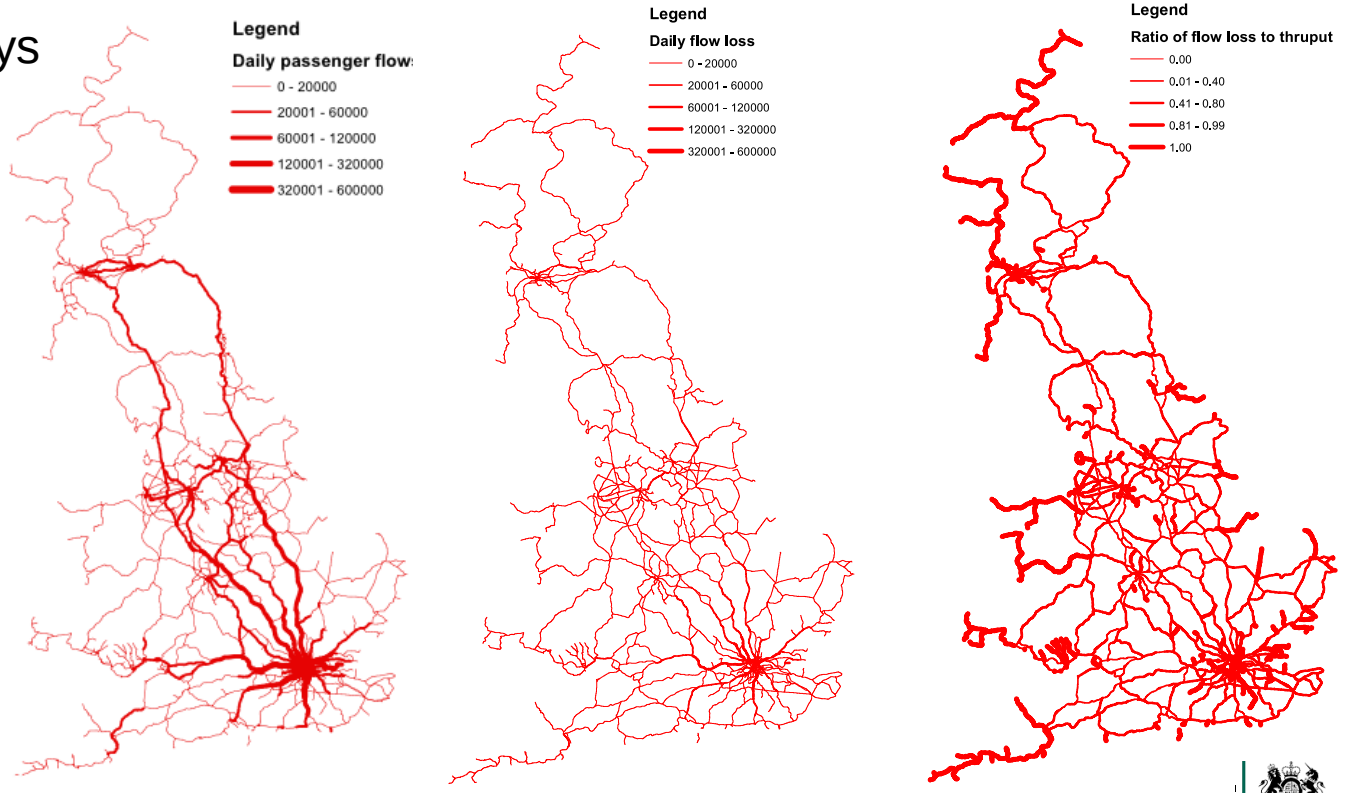
Energy, transport, water, waster , ICT

Infrastructure UK

Application: Criticality assessment of UK transport networks

Criticality is measured in terms of the **volume of flows** along routes, the **losses of flows** when routes are disrupted and the **ratio of post-disruption losses to pre-disruption flows**

Example: Railways



Department for Transport

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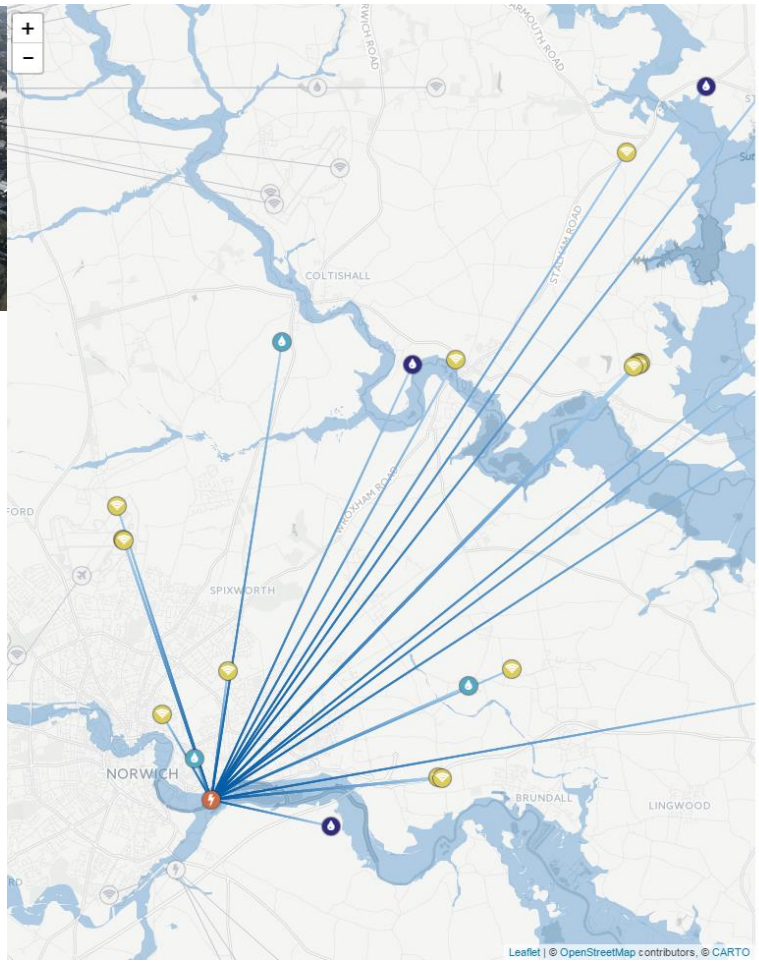
Application: Impact of Flooding in UK



Hazard Related Risks

The map on the left highlights a particular asset at direct risk of failure under a hazard scenario those assets which might then be indirectly at risk of failure (through the loss of a critical dependency).

The plots below indicate the number of assets in **South-East England** at direct and indirect risk of failure through exposure to **synthetic hazard scenarios** of differing likelihood.

Direct Risk

Electricity assets

Indirect Risk

Airports

Seaports

Water treatment

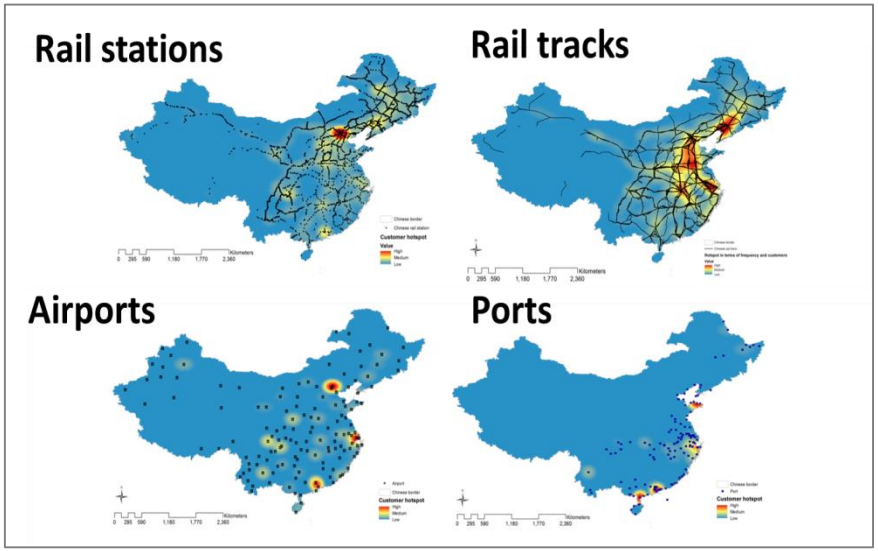
Waste water treatment

Published: Pant et al. (2017). Critical infrastructure impact assessment due to flood exposure. Journal of Flood Risk Management. DOI: 10.1111/jfr3.12288.

SAGE
Scientific Advisory Group for Emergencies

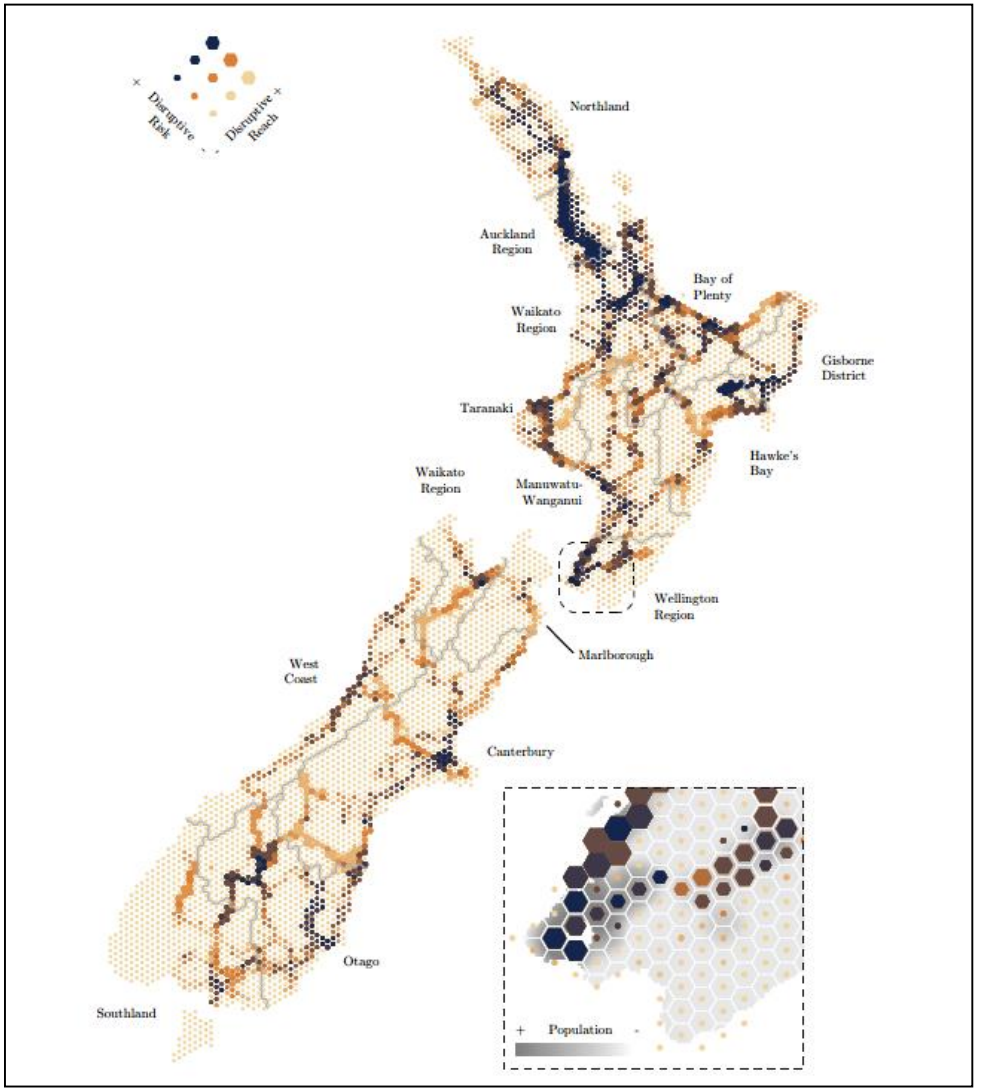
Application: Other countries

China



Source: Hu, X. et al. (2015). The spatial exposure of the Chinese infrastructure system to flooding and drought hazards. Natural Hazards, 80(2): 1083-1118.

New Zealand

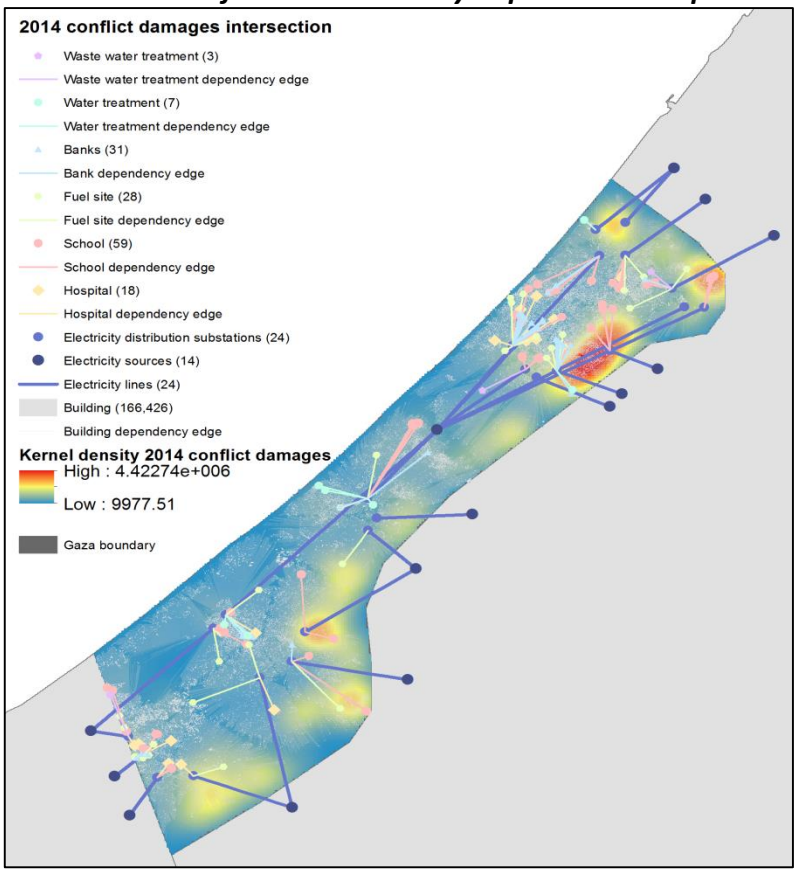


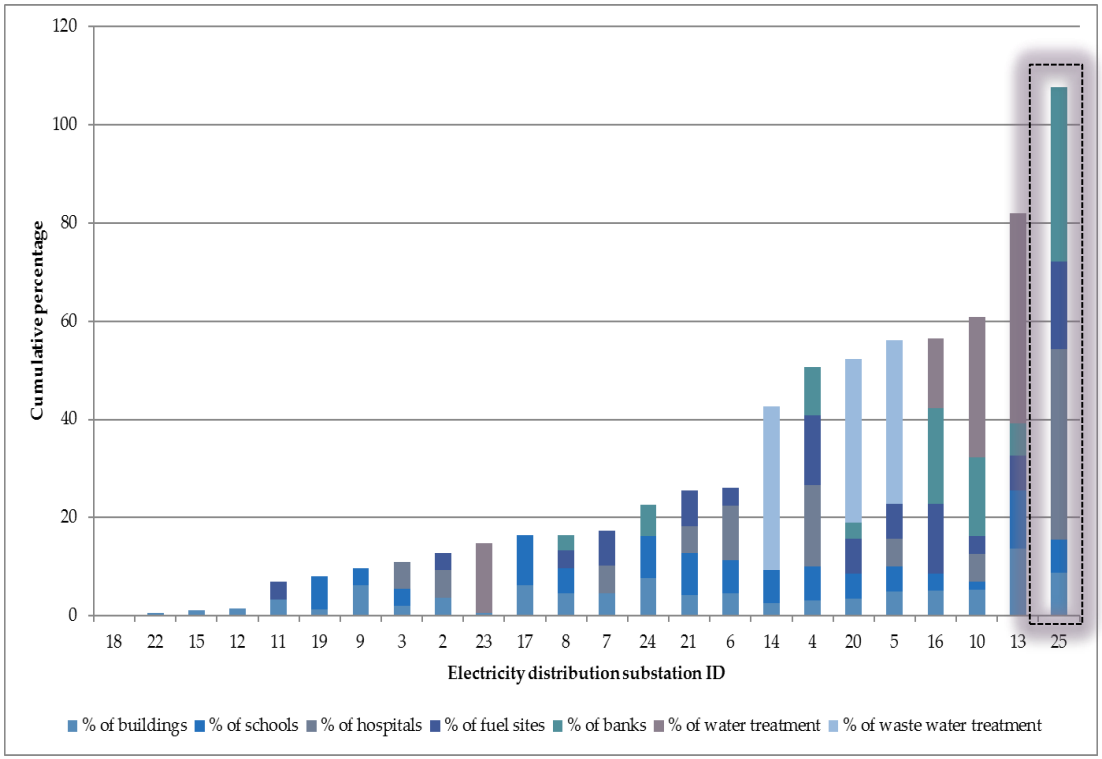
Source: Zorn, C. et al. (2018). Evaluating the magnitude and spatial extent of disruptions across interdependent national infrastructure networks. [in review]

Application: In conflict and long-term planning

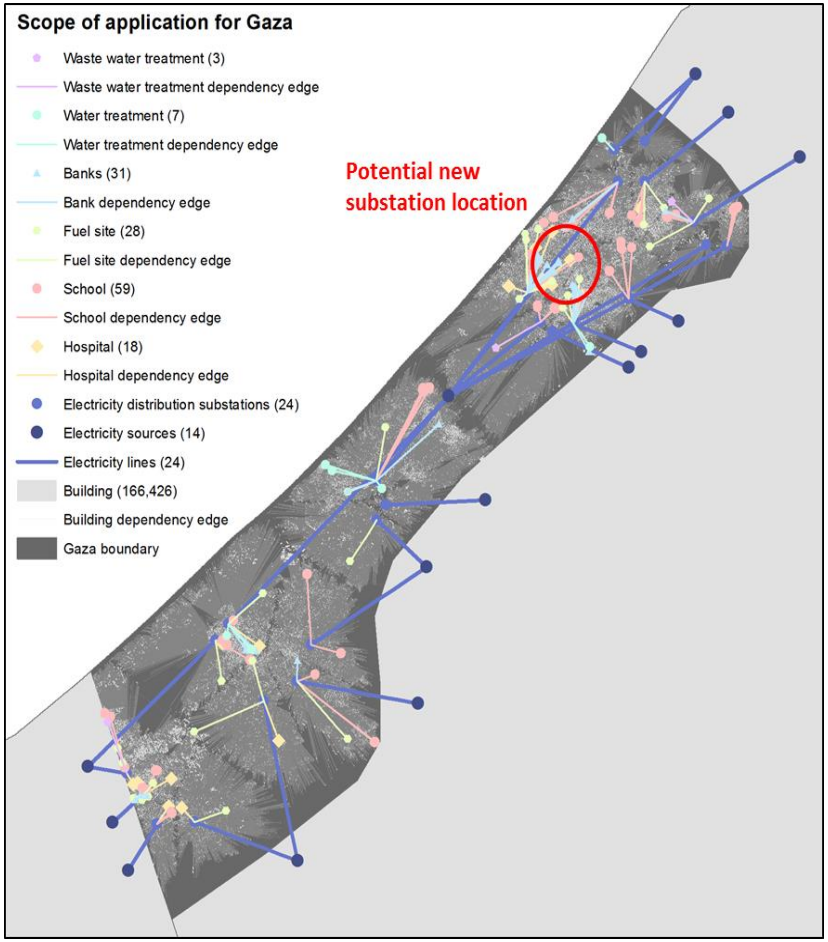
Understanding the risks to national system-of-systems infrastructure networks in Gaza

Conflict and Electricity dependent disruptions in Gaza

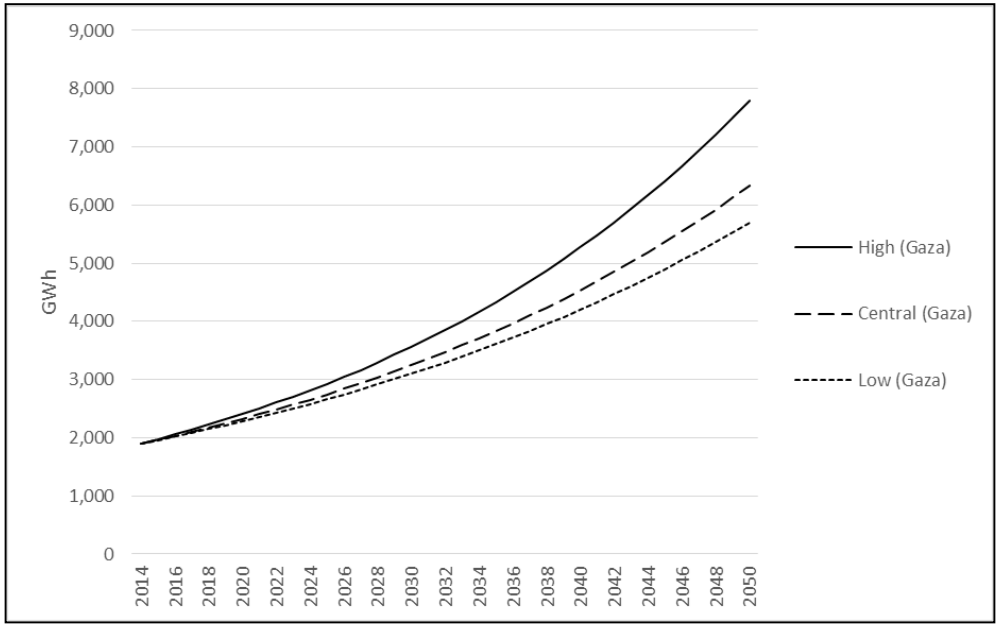




Application: Gaza – Informing long-term infrastructure planning



Forecast cross-sectoral long-term electricity needs



Application: Tanzania – Transport risk analysis

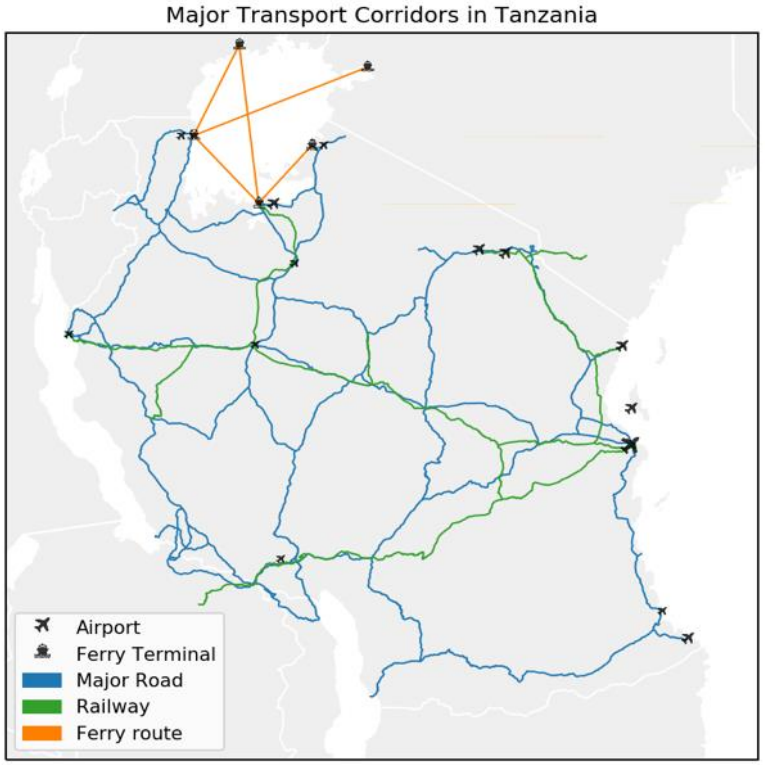
- *Transport Risk Analysis for United Republic of Tanzania* - provide **detailed understanding of major transport infrastructures**, in the present and the future, at a national scale.

- Identify significant '***points of failure***' which are '*locations on the strategic intermodal transport routes which are vulnerable to flooding in such a way as to significantly threaten the flow of essential services and economic activity*'.

- Provide important new insights into the **magnitude and location of current and future risks** faced on Tanzania's transportation corridors.

- Provide **recommendations for risk reduction and resilience** building activities to address the aforementioned risks.

- Specific case of evaluating risks to **fluvial flooding, but wider applicability.**



Further Opportunities: Global Networks Analysis

Opportunities are being created through the emergence of newly available global infrastructure network datasets

- Creating a global database of interdependent infrastructure network systems

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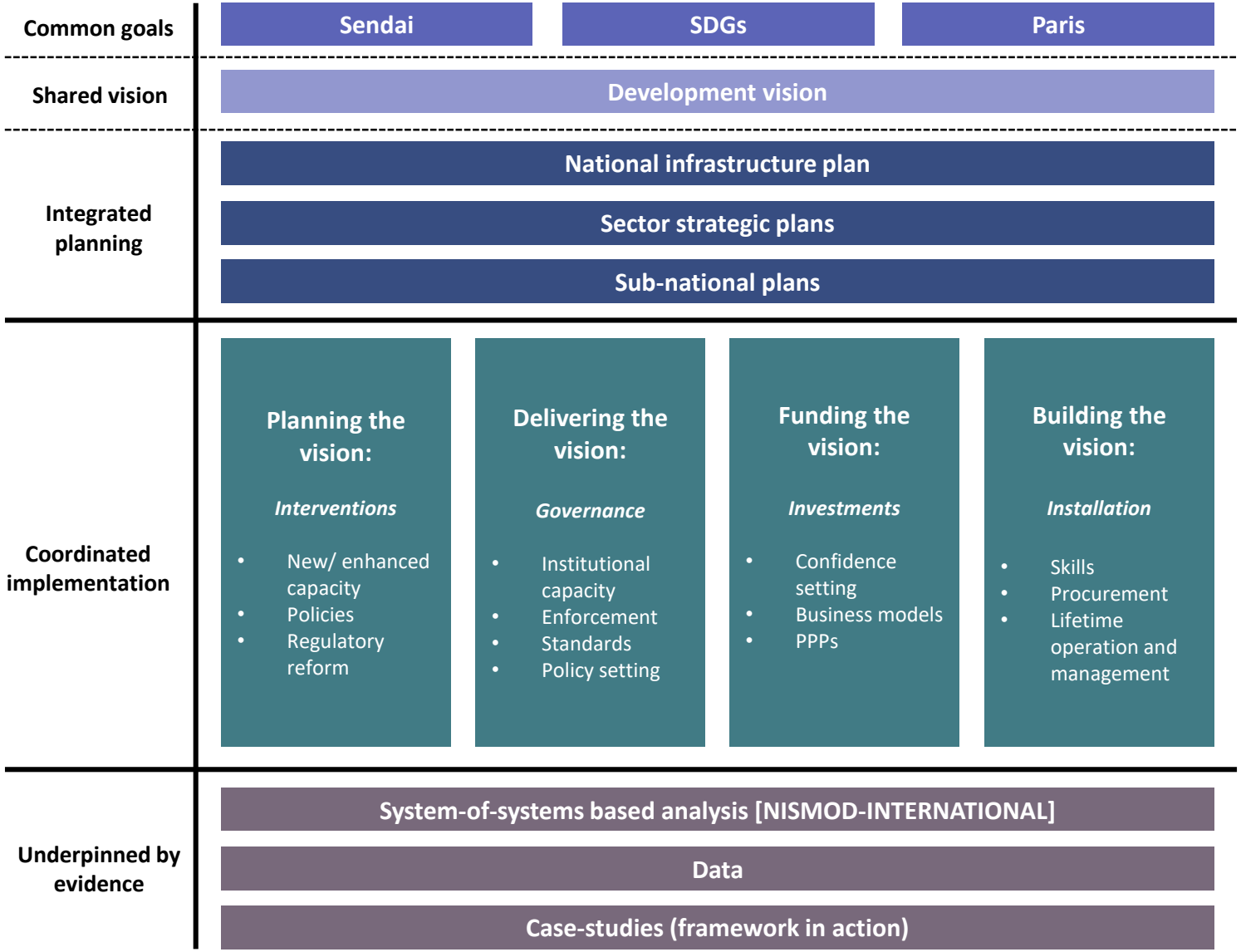
Next steps: Evidence based infrastructure assessment framework

Evidence Based Infrastructure Development Framework (EBIDF)



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Acknowledgments

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Any questions?

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