Forecasting resilience of railway network under propagating uncertainty

DAFNI
Data & Analytics Facility for National Infrastructure

Background and context

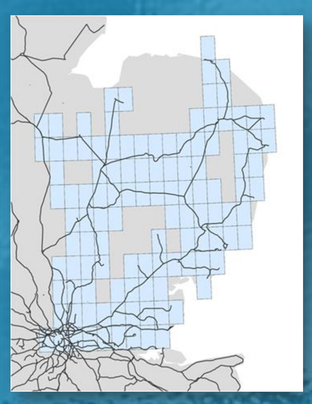
Network Rail faces annual losses of up to £100 million due to weather-related disruptions, highlighting the urgent need for improved forecasting and resilience in railway operations. A key challenge lies in accurately predicting weather-induced service disruptions and identifying weak links within the network system. However, several obstacles hinder progress, including the complexity of integrating diverse datasets, the high uncertainty surrounding weather events and asset failures, and the cascading effects of uncertainty across interconnected infrastructure. Additionally, the lack of readily available computational tools for decision-making further complicates efforts to enhance system reliability and efficiency. Addressing these challenges is essential for minimizing disruptions and ensuring a more robust and adaptive railway network.

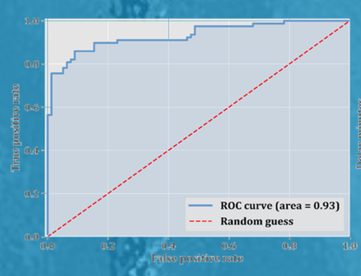
Connecting the asset failure probabilities to weather profiles in a Bayesian sense, allowing for data informed asset-specific fragility functions. Data included:

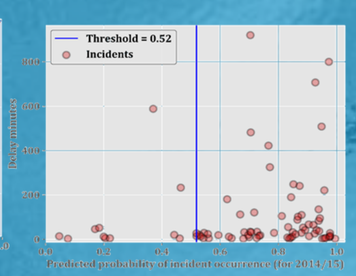
Historical rail

- Network Rail TRUST data (incl. time, location, incident, causation reasons and delay minutes)

- **Asset** (railway tracks)
- **Weather** (5× 5 km grids)
  - Temperature
  - Wind speed/direction
  - Precipitation
  - Relative humidity
  - Solar radiation



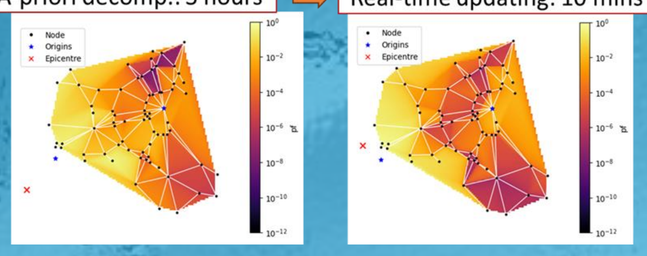




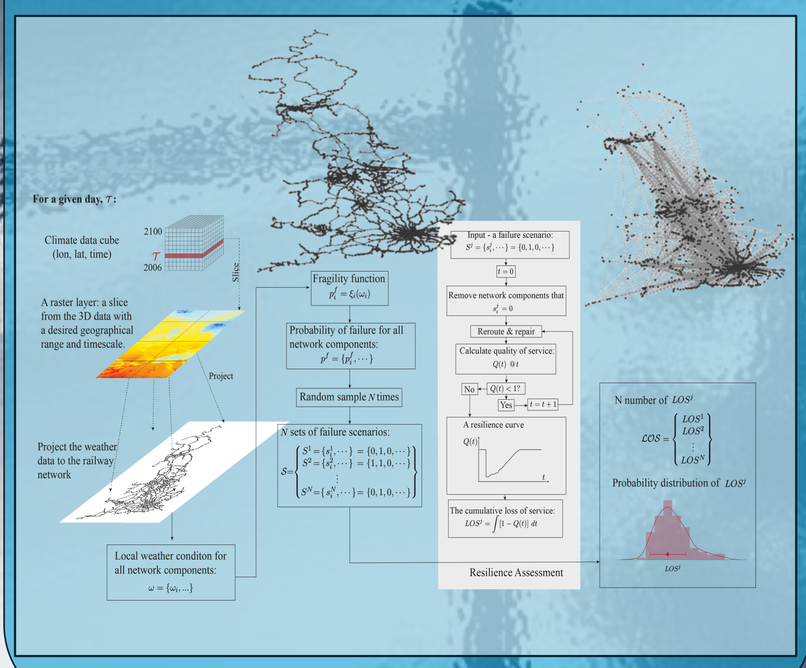
Combining research expertise models and data from three previous projects

An event decomposition algorithm for coherent systems was used to produce a risk maps for earthquakes before

A-priori decomp.: 3 hours → Real-time updating: 10 mins



A network model to quantify the system-wide disruptions and resilience to end-of-century climate scenarios. These assumed fragility functions for all assets in a stylized way. This allow to produce a method for the assessment of the service resilience, moving beyond single assets or line segments.



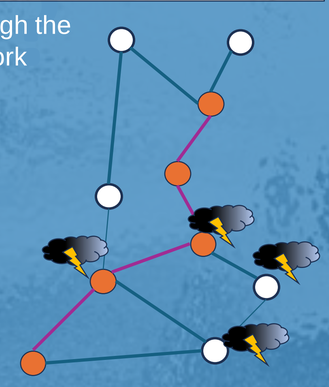
Weather
Time
Topography

Infer

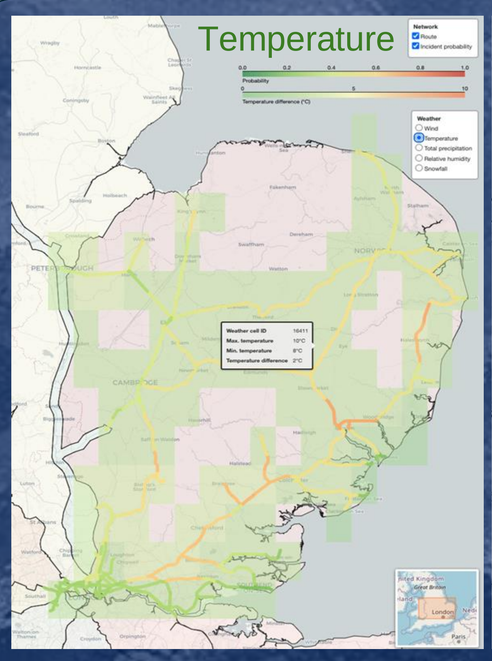
Local Failures

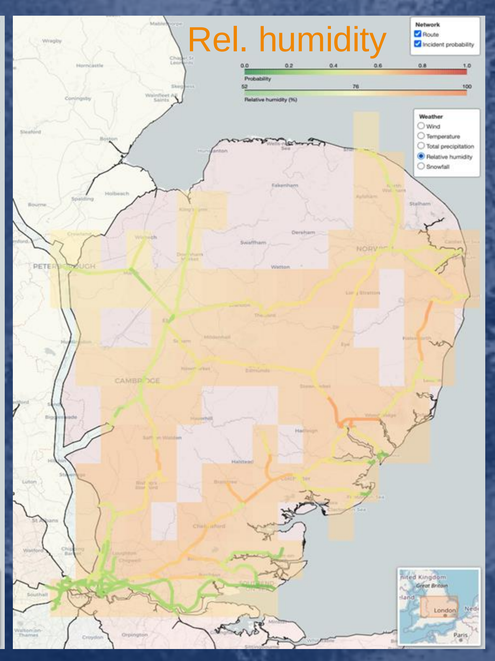
? Uncertainty evaluation

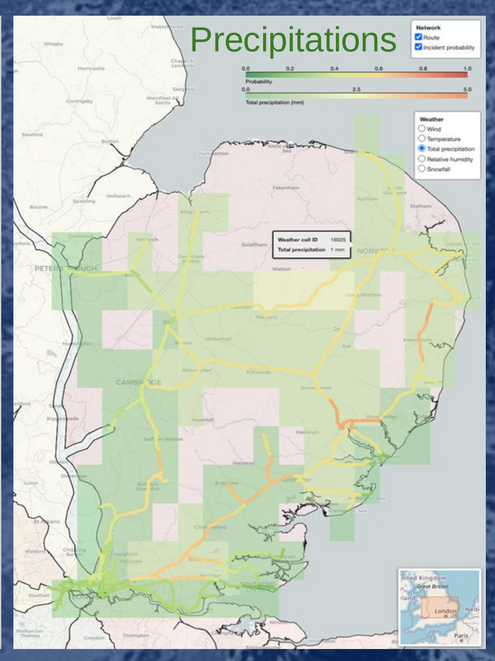
Through the Network

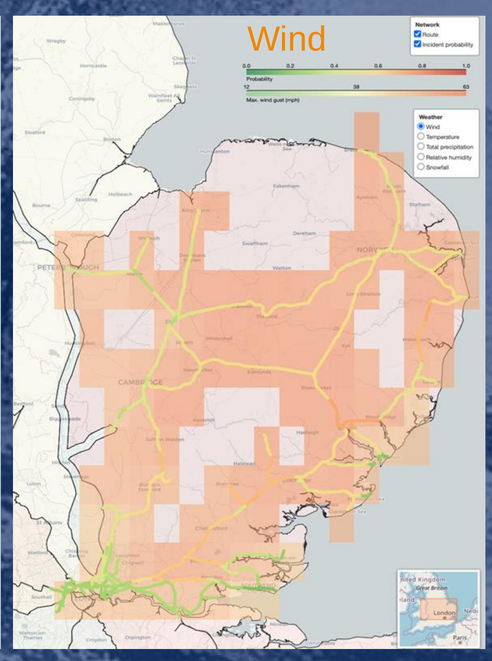


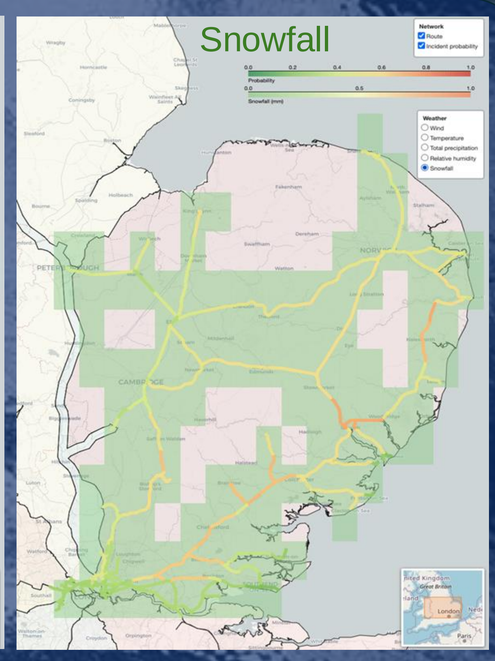
Origin-Destination reliability and resilience











Opportunities

Through the DAFNI platform, the project delivered a risk and resilience evaluation software package and a sample of the data, both shared with the research community through DAFNI. Data are of the same kind used by network rail, so that, as new data become available, the software can be retrained and provide reliable predictions of the path availability and probability of failure due to weather

DATA SHARING

Barriers

The legacy agreement about data sharing meant a separate process to secure the sharing of a larger dataset, making it impossible to achieve within the project. The computational architecture also meant issues with the data pre-processing before they could be deployed for the model.

External Engagement

Stakeholders from Network Rail (Dr Qianqian Li) were involved in the development of the project. We attended or planned the attendance to conferences and meetings, including

- *Rail Industry Association (RIA) Consultants Group on climate resilience and adaptation*
- *DAFNI Scotland Roadshow by Dr Byun,*
- *The UK Rail Research and Innovation Network (UKRRIN) Student conference*
- *The 11th International Conference on Railway Operations Modelling and Analysis (RailDresden 2025), Dresden, Germany, 1–4 April 2025.*

The Team

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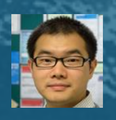

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