CASE STUDY

ClimaTRACKS: creating more climate resilient rail networks & reliable journeys

Director of Sheffield Urban Flows Observatory, University of Sheffield

Introduction

Weather conditions have a dramatic impact on rail services. For example, in July 2022[1], temperatures soared in excess of 40°C, resulting in blanket speed restrictions across much of the rail network in England and Wales. In August 2020, a passenger train in Scotland was derailed by a culmination of factors including a landslide caused by heavy rain and incorrect installation of a drainage system, sadly resulting in loss of life. As of this year (2025),[2]eight of the Rail Accident Investigation Branch safety recommendations relating to that incident remain unresolved.

The impact of climate change on railways is becoming more severe, with new weather extremes now more prevalent.

The UK's complex and, in many, places saturated rail system means that a rail line out of service in one area can quickly have a knock-on effect across an entire region or even further afield, creating delays, cancellations and lack of trust in the rail network.

The ClimaTRACKS team brings together expertise from research in climate resilience, rail networks, reliability & availability of assets, and uncertainty quantification and propagation. Their work culminates in a revolutionary forecasting and resilience tool for rail operators.

[1] *https://www.theguardian.com/business/2022/jul/15/rail-passengers-urged-to-avoid-train-travel-in-extreme-uk-heatwave*

[2] *https://www.bbc.co.uk/news/articles/c307lpv2j6po*

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What would you identify as the main impact of this work?

ClimaTRACKS is the first project to develop a working model that demonstrates how weather-related disruptions propagate across a railway network, using a novel methodology.

The research is timely, given the increasing frequency of extreme weather events and growing interest from rail operators globally to move towards digitalising decision-making processes.

Dr Giuliano Punzo, lecturer and director at the Sheffield Urban Flows Observatory, University of Sheffield, explains, ***"Ultimately our model will help improve operational efficiency and reliability of freight and passenger rail services.***

"Operators will be able to minimise losses faced by disruptions, and passengers will gain more accurate travel data so that they can better prepare their journeys and gain enhanced trust in rail journeys. This will encourage more passengers to travel by train, a more sustainable method of transport than other choices, and more freight to move by train."

Key challenges that ClimaTRACKS aims to solve

Modelling network failures caused by weather conditions is a key challenge for rail operators. The weather can impact many aspects of operation, from impact on 'assets' such as tracks and bridges, to the track's environment such as coastal degradation, high waves, falling trees, or the infamous 'leaves on the line'.

"The fast-moving nature of day-to-day operation of a railway system means that to be useful to rail operators, our model must walk a narrow path between a desk-based modelling study and what service changes it's possible to deliver in real-life," adds Dr Giuliano Punzo.

What was the key aim of the project?

Dr Ji-Eun Byun, Lecturer in Smart Sustainable and Resilient Infrastructure at the University of Glasgow, says, "Our ultimate goal with ClimaTRACKS is for our software to appear on the Network Rail operator's dashboard. When poor weather is predicted, the software will allow operators to identify where to put services on hold, the impact across the network, and how best to reallocate resources in response to the weather.

"Ideally, weather forecasts will be continuously updated until the very moment the disruption happens – integrated into the core operation of the network."

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What did DAFNI allow you to do that you could not have achieved otherwise?

Each team member had previously developed separate research strands. The DAFNI project allowed them to bring these together within the thematic challenge, and to gain a vehicle to engage with a wider and more diverse audience.

Dr Qian Fu, Research Fellow at the Birmingham Centre for Railway Research and Education, developed the code for the tool, bringing together three completely different models: asset failure probabilities and weather profiles, risk mapping, and quantification of system-wide disruption and resilience.

These were integrated to develop a new modelling framework, and then refined it to make it suitable for upload this to the DAFNI platform.

Qian explains, ***"This work is the first of its kind – we haven't seen any similar work in literature as applied to railways or multimodal transport! The DAFNI project has been an excellent opportunity to develop this model and share it with researchers and commercial operators in the railway and wider transport field."***

He notes that the DAFNI technical team were extremely helpful when uploading the model to work on the DAFNI platform – assisting with and suggesting modifications to the original model during the process to enable it to sit on the DAFNI platform where it is now accessible to other researchers.

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What outputs from the project have you put onto the DAFNI platform?

- A computational model to perform probabilistic analysis on network performance and simulations of rerouting and unmet demand
- A probabilistic map to demonstrate when assets may be taken out of commission due to wind and why, and what is associated with asset commissioning – some assets more likely to fail than others and this adds up to uncertainty.
- Dataset – data on Anglia region including historical rail delays, assets and weather in 5 x 5km grids
- Examples of the ClimaTRACKS model outputs with visualisations for wind and temperature

How do you anticipate other researchers, policymakers and stakeholders using this work?

DAFNI has helped the team to take their ideas to a wider community. Discussions are now ongoing with UK rail operators, researchers and transport hubs, along with interest from rail operators and research institutes around the world, including Germany, Italy, China and Korea, so far!

Giuliano adds, ***"We have already presented our work at a number of conferences, with more planned. Ji-Eun and Qian introduced the concept at the Rail Industry Association in Edinburgh in 2024, then demonstrated the initial prototype model at the Rail Dresden conference in Germany in April 2025. They will present a refined version of the model at the European Working Group on Transportation in Edinburgh in September 2025."***

Positive feedback was received from both industry and academics at the events.

How could this work benefit society as a whole?

Network Rail currently faces weather-related disruptions of up to £100 million a year, with some costs being absorbed and others ultimately resulting in higher ticket prices, reduced services, and disaffection with rail by passengers and freight shippers.

Qian says, **"The ClimaTRACKS work is a great demonstrator of proof of concept. We anticipate organisations such as the UK's Network Rail as well as rail operators further afield using ClimaTRACKS methodology to dramatically improve their decision-making platforms and revolutionise how they quantify cascading impact into their rail networks.**

"We have deliberately designed these tools so that they can be used by rail operators who do not have expertise in computational tools, making them ultra- accessible."

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Next steps

The team is now focusing on propagating uncertainty and the likelihood of asset failure or service failure passing from local failure to system wide failure. Ultimately, they plan to provide a metric of the resilience of the system to points-wide failure.

A journal paper is being prepared currently with a view to publishing in the coming months.

The researchers plan to incorporate new angles into ClimaTRACKS in the future, such as more elements from the social sciences or behavioural side.

Who's involved?

The ClimaTRACKS project is led by **Dr Giuliano Punzo** from University of Sheffield, where he is a lecturer and director of the Sheffield Urban Flows Observatory. Together with Giuliano, the team is made up of **Dr Ji-Eun Byun**, Lecturer in Smart Sustainable and Resilient Infrastructure at the University of Glasgow, **Dr Qian Fu**, Research Fellow at the Birmingham Centre for Railway Research and Education, University of Birmingham, **Dr Tohid Erfani**, Associate Professor in Computational Modelling and Infrastructure Systems Engineering at University College London, **Dr Iryna Yevseyeva**, Associate Professor in Computer Science at De Montfort University, **Professor Konstantinos (Kostas) Nikolopoulos**, Professor in Business Information Systems and Analytics at Durham University Business School, Durham University, **Dr Samantha Ivings**, Postdoctoral Research Associate: Sustainability in Transport Systems, University of Sheffield, and **Marta Zarantonello**, Postgraduate Research Student at University of Glasgow.

When did the project start and finish?

The project ran from 1st of April 2024 to 31st of February 2025.

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