ASSESSING THE INFLUENCE OF DRAINAGE CONDITION ON RAILWAY TRACK PERFORMANCE THROUGH BAYESIAN NETWORK ANALYSIS

ABSTRACT The resilience of railway track network is increasingly challenged by water-related hazards such as extreme rainfall, flooding, and groundwater ingress. Track performance depends not only on direct climatic stressors but also on the interdependencies between environmental variables, geotechnical conditions, and drainage system performance.

To address these complex and uncertain relationships, this paper develops a Bayesian network (BN) model that integrates rainfall intensity, soil type, groundwater presence, drainage asset condition, and track geometry. BNs provide a probabilistic, graph-based representation of dependencies that supports both causal inference and forward prediction, enabling risk-informed resilience analysis for critical infrastructure.

The framework is applied to four UK mainline railway routes that span diverse geological and hydrological settings. The analysis highlights drainage condition and water-related stressors as the dominant drivers of track degradation, with soil permeability acting as a key mediator. Counterfactual analysis demonstrates that targeted drainage interventions can mitigate degradation risks, particularly in low-permeability soils, while in highly permeable geological contexts, drainage effects are less pronounced, underscoring the importance of adaptive maintenance regime.

The findings emphasise the central role of drainage in sustaining track quality and provide evidence to guide more effective maintenance strategies. By quantifying causal pathways, exploring “what-if” scenarios, and prioritising interventions under uncertainty, the proposed approach equips operators with a structured approach to address weather-related stressors. Explicitly modelling the coupled behaviour of track and drainage systems advances the application of probabilistic methods in railway engineering and contributes to the development of robust, adaptive strategies for railway network resilience.