

Dynamic Rail Schedule Delay Forecasting: A Case Study with Network Rail

Xu Feng, Khuong An Nguyen, Zhiyuan Luo

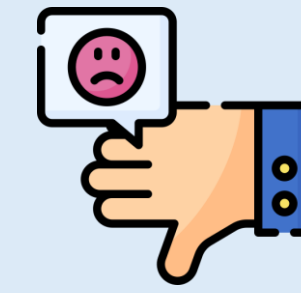
Rail Reliability in Crisis



Only **67%** of trains arrived on-time last year.



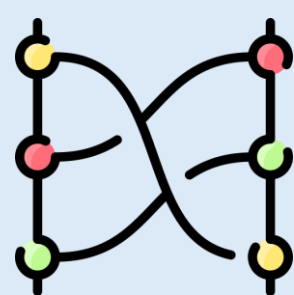
8.3 million compensation claims were processed last year, exceeding **£150 million**.



69% of passengers were **unsatisfied** with their train operator last year.

Why can't AI fix this?

Where AI Falls Short



Most systems **overlook latent correlations** among train operations.



Existing systems output a single best-guess estimate, **ignoring unpredictable conditions**.



Train operators cannot act on 'Black Box' AI **without uncertainty guarantees**.

How certain is certain enough?

Reliable Train Delay Forecasting

The AI model M was trained on **comprehensive rail operational data** (e.g. timetables, signalling, and asset status) to capture the full complexity of delay propagation across the network.

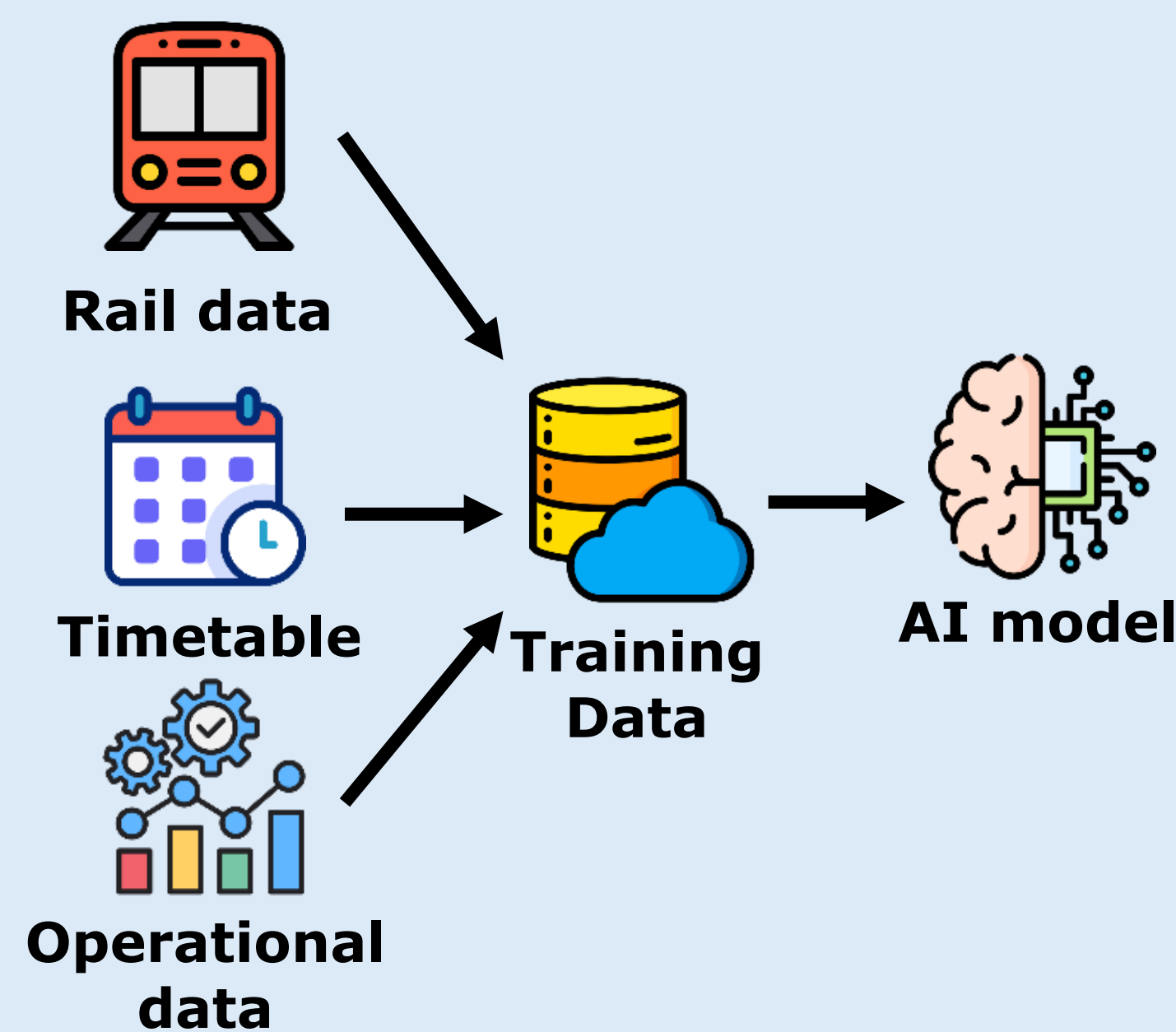
$$\hat{q} = \text{quantile} \left(\left\{ |T_k - M(\Omega_k)| \right\}_{k=1}^m \cup \{\infty\}, \frac{[(m+1)(1-\alpha)]}{m} \right)$$

Labels:
 - T_k : scheduled train travel time
 - $M(\Omega_k)$: historical operational data
 - \hat{q} : confidence
 - α : prediction interval

Our model provides a guaranteed **prediction interval** for each delay prediction in the network.

$$P(\Phi_{test} \in [\hat{\Phi} - \hat{q}, \hat{\Phi} + \hat{q}]) \geq 1 - \alpha$$

Labels:
 - Φ_{test} : actual delay
 - $\hat{\Phi}$: prediction
 - \hat{q} : prediction interval



"Your train is 7 minutes late (90% confidence)."

A Network Rail Case Study



Extensively assessed on **12.8 million** UK train records over **4 years**.



14-second delay prediction error on average **across the network**.

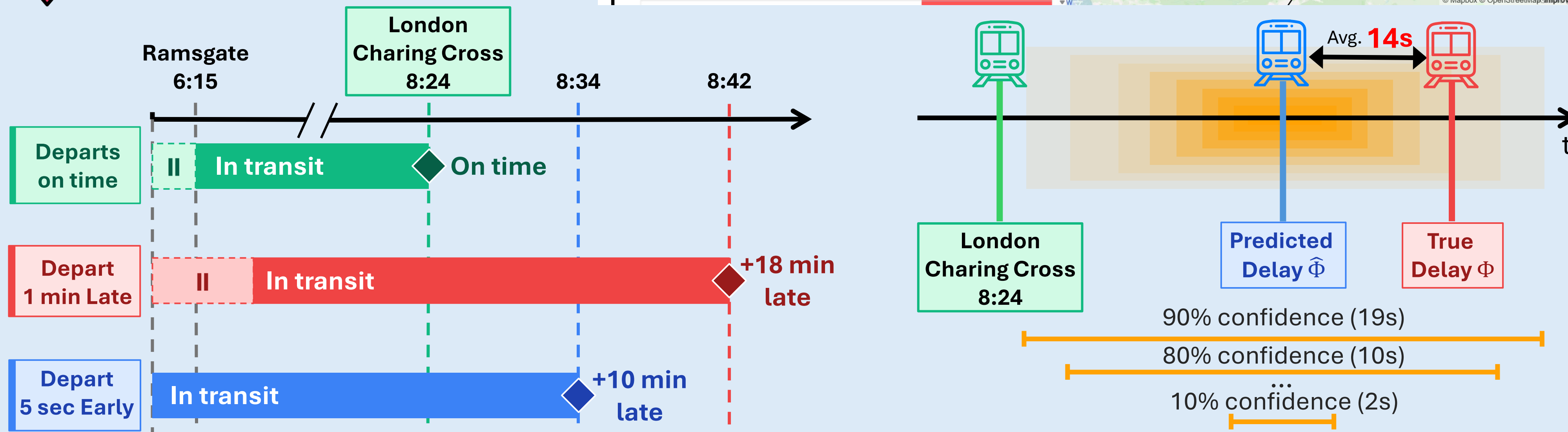
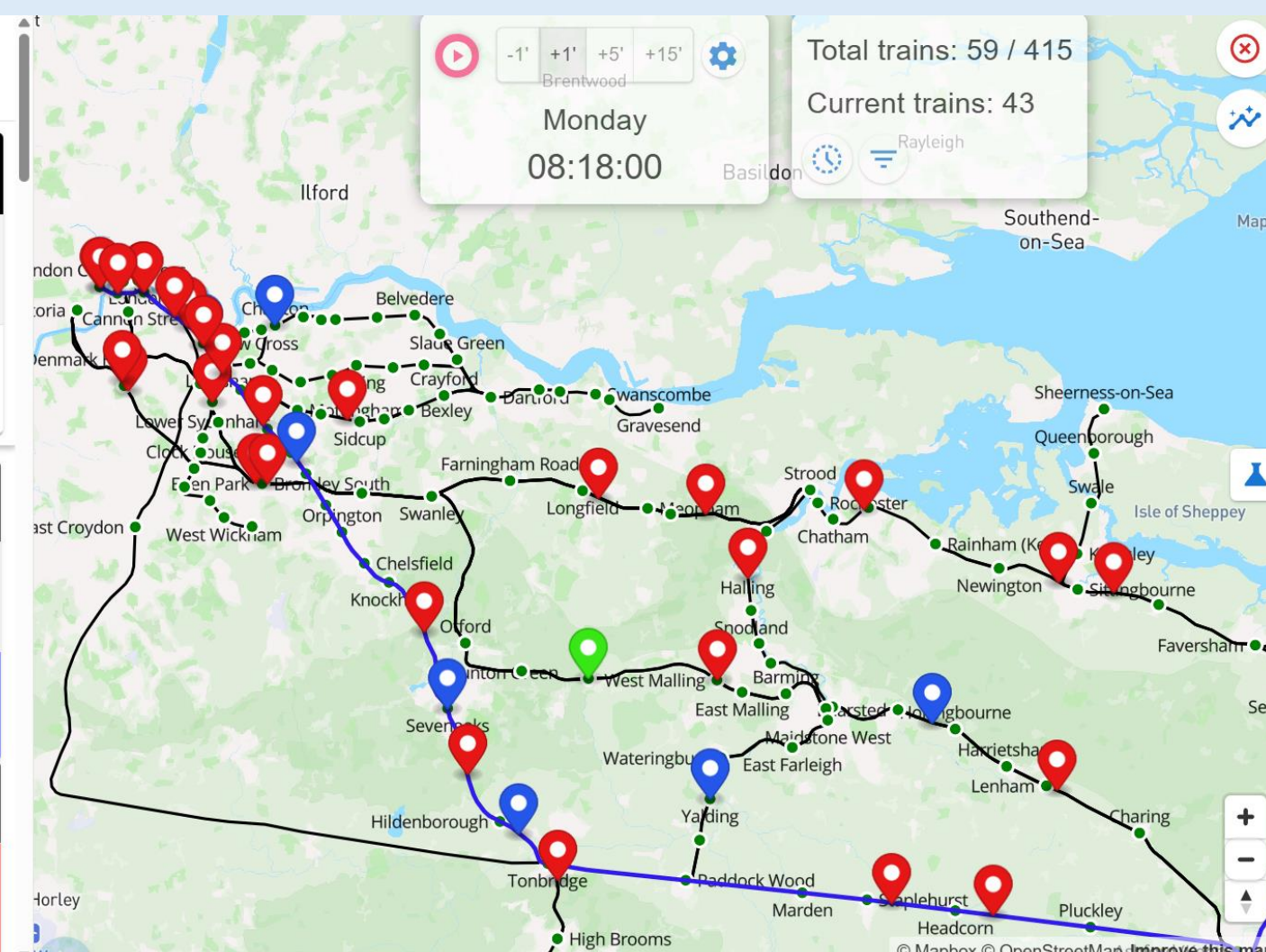


25% fewer peak-hour delays on the busiest Southeastern routes since 2024.

2W16BA		
Station	Booked time	Actual time
From Ramsgate	06:15:00	06:14:55
To London Charing Cross	08:24:00	08:34:18

Ramsgate		
	Booked time	Actual time
Arrival		
Departure	06:15:00	06:14:55

Minster		
	Booked time	Actual time
Arrival	06:20:30	06:20:54



Smarter rails, fewer fails.