Modelling the Spread of Traffic Congestion

Using Epidemic Theory

Understanding Traffic Jams Through Network Science

STEM for BRITAIN

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Introduction & Objective

Traffic congestion does not stay local. It spreads through connected road networks, causing delays, higher emissions, and economic loss. Understanding how congestion propagates across cities is essential for better traffic management, faster recovery, and informed transport policy. Objectives:

- Model traffic congestion as a **spreading process**, inspired by epidemic theory.
- Capture how congestion spreads through **real road network connections**.
- Support **better prediction, control, and recovery** of congestion in cities.

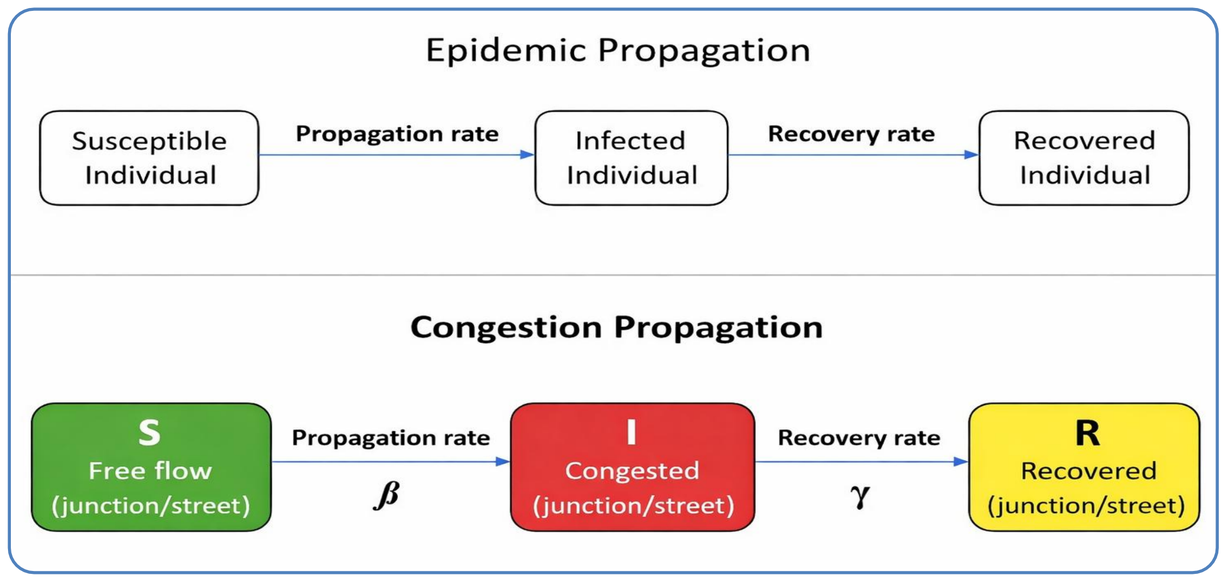

Figure 1. Physical mapping of congestion spreading on the SIR model.

Methodology

We apply ideas from **epidemiology and network science** to model traffic congestion. Each road junction is treated as a node that can be in one of three states: free-flow, congested, or recovered (Figure 1). Transitions between states are modelled using a **continuous-time Markov chain**, while an **adjacency matrix** captures real road connections, ensuring congestion spreads only between directly connected roads.

Results: Model Comparison

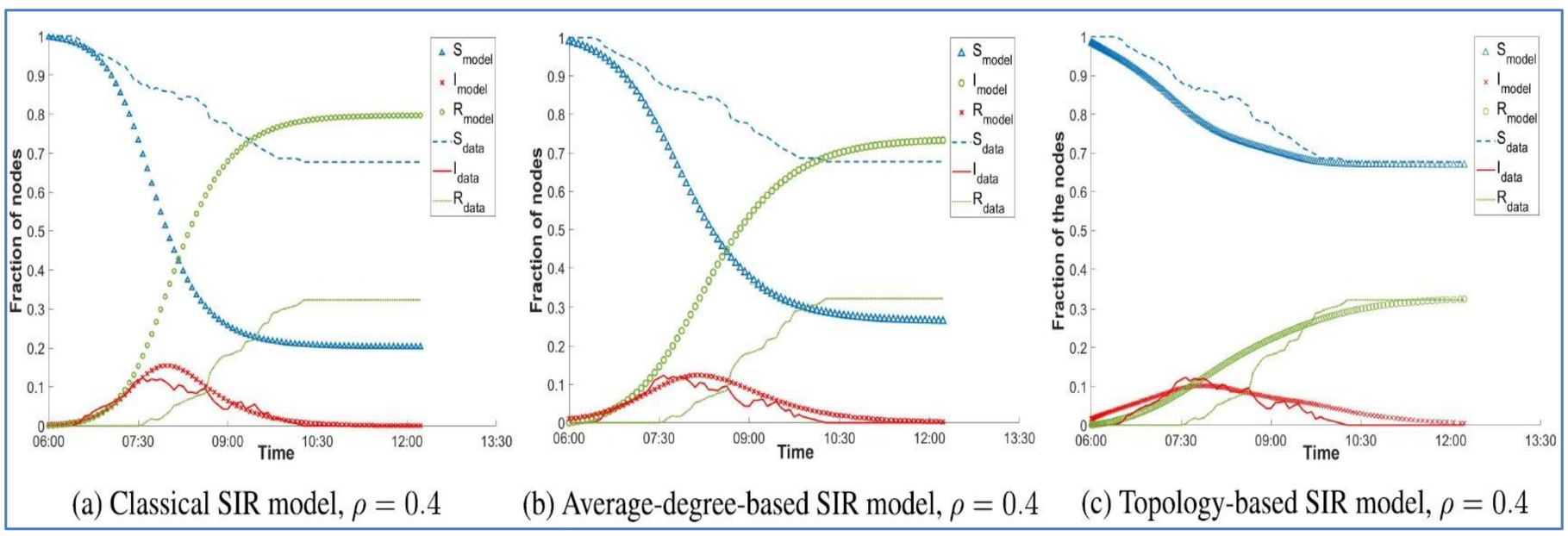

Figure 2. Models vs data - Time evolution of node states on the PEMS-BAY dataset.

METR-LA

PEMS-BAY

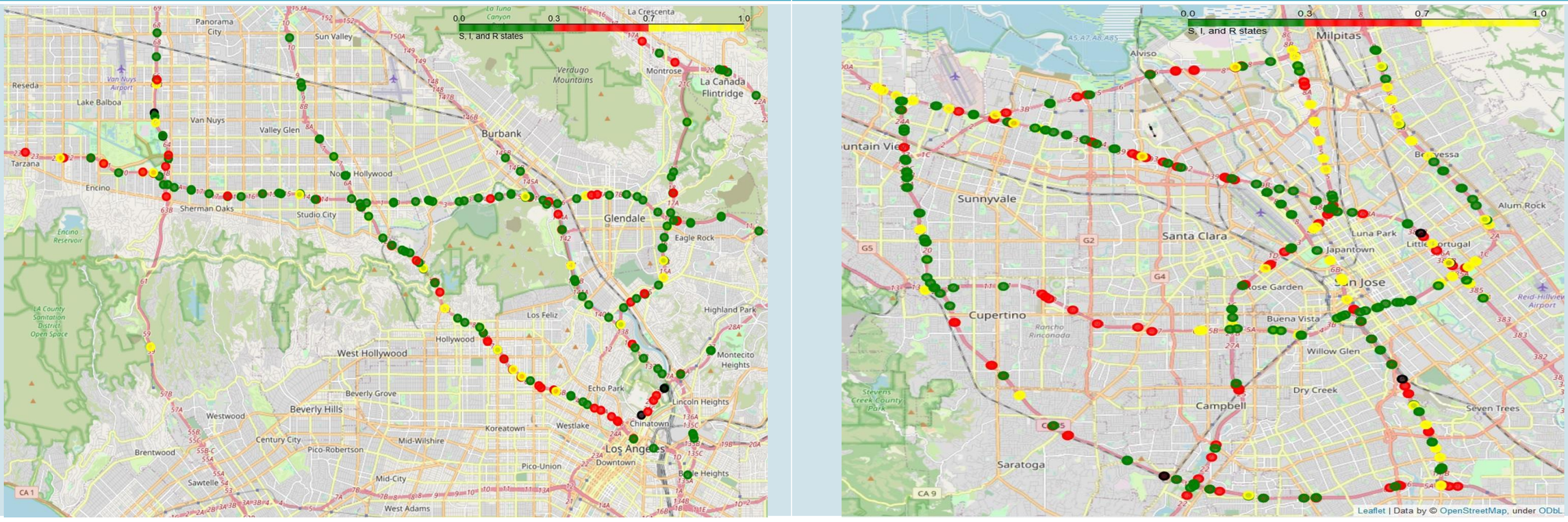

Figure 3. Congestion map based on the model. Node colour coding: black – seed nodes, green – free flow, red – congested, and yellow – recovered.

Conclusion & Impact

This study demonstrates that traffic congestion spreads across cities in a **networked**, **epidemic-like** way. By incorporating real road network connections, the topology-based SIR model predicts congestion dynamics more accurately than traditional approaches. Validation using real traffic data shows consistent outperformance of classical models. The approach is transferable and can be applied to UK city networks, enabling earlier intervention and faster congestion recovery.

- Supports evidence-based transport policy and infrastructure investment decisions
- Enables earlier and more targeted interventions to reduce congestion duration
- Improves urban mobility while reducing emissions and economic loss
- Scalable and transferable, requiring no complex or data-heavy inputs
- Relevant to smart cities, digital traffic management, and Net Zero strategies

Reference: Kozhabek, A., Chai, W. K., & Zheng, G. (2024). Modeling traffic congestion spreading using a topology-based SIR epidemic model. IEEE Access, 12, 35813-35826.

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