COMMUTING FLOW PREDICTION FOR ADAPTABLE AND RESILIENT TRANSPORT SYSTEM: A GRAPH NEURAL NETWORK APPROACH FOR MODELING NATIONAL COMMUTING SCENARIOS ACROSS UK

ABSTRACT Commuting flows reflect complex socioeconomic interactions critical for urban planning, transportation policy, and climate adaptation. Understanding these flows is essential for developing decarbonization pathways and building resilient transport systems under climate change. This study develops and evaluates three modelling approaches for predicting origin-destination (OD) commuting flows between Local Authority Districts (LADs) across Great Britain: 1) a gravity model, 2) a spatial interaction model incorporating extended socioeconomic variables and spatial dependencies, and 3) a Graph Neural Network (GNN) model.

By representing LADs as nodes and commuting flows as weighted edges, the GNN model leverages node-level and edge-level embeddings to capture higher-order spatial dependencies and non-linear relationships in mobility patterns. The models were calibrated/trained using historical UK Census data (2011 and 2021), complemented with additional data on wages, housing costs, travel distance, and time.

Results demonstrate that the GNN model achieved better predictive accuracy (R^2 0.954) compared to the spatial interaction model (R^2 0.927) and the gravity model (R^2 0.860). The GNN framework generated more realistic flow distributions, particularly in sparse, rural areas and long-distance OD pairs, where commuting volume tends to be underestimated by regression-based approaches. Feature importance analysis identified population size, household counts, and travel and rental costs as critical determinants, which conform to traditional location choice theories. Given the high costs and hence low frequency of producing large-scale OD flow data, the study demonstrates that GNN-based approaches offer a useful tool for generating commuting patterns under alternative scenarios. Transport decarbonization scenarios were tested using the calibrated model.