A Framework for Incorporating the Network-Wide Fundamental Diagram into Large-Scale Emission Estimation

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Background:

Estimation of vehicular emissions is one of the main challenges that planning agencies and municipalities encounter. This is particularly the case for large cities that typically struggle with congestion problems. Microscopic models are widely used to estimate the vehicular emissions. These models assist system planners in proposing strategies to control the level of emission. However, applications of these microscopic models are limited to estimation at the facility-level or small networks. To estimate emissions for large-scale networks, which is a major challenge for city planners, macroscopic models are typically proposed. However, these models fail to consider traffic flow dynamics. This study proposes a mesoscopic approach that is capable of estimating emission for large networks, as well as capturing the effects of traffic flow dynamics.

Methods:

The concept of network-wide fundamental diagram (NFD), which relates network-wide average values of traffic flow and density, has recently gained popularity among urban transportation planners. NFD is used to monitor the traffic flow state at network level and subsequently apply different control strategies to prevent flow breakdown and congestion. In this paper, we extend this concept to include network-wide traffic flow characteristics in the estimation of vehicular emissions. Based on this relationship, system planners can estimate the emission level simply by monitoring NFDs under different demand and supply conditions. To this end we integrate an existing microscopic emission model with a mesoscopic traffic simulation tool to calibrate and validate a network-wide emission model. The network-wide emission model is calibrated through linear regression based on the average traffic flow, traffic density, and vehicle types proportions.

Results:

The model is calibrated for the metropolitan network of Chicago that includes around 4,800 links. Simulation results under various scenarios using the actual traffic data of fifteen days are used to calibrate and validate the model. To this end, trajectory data for about 800,000 simulated vehicles are analyzed. The results demonstrate satisfactory calibration of the model and successful validation with acceptable deviation between emissions estimated using NFD and emissions calculated using the microscopic model.

Conclusions:

The proposed framework in this study successfully showed that for a large-scale network, the vehicular emission can be estimated using NFD with enough accuracy. Also, a 3D diagram which incorporates the traffic flow state into the network-wide emission is characterized. The results of this study enable system planners to monitor emissions generation and find optimal policies to control the level of emissions in large cities.

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