ABSTRACT

Zhan, Xianyuan , Purdue University, August 2017. Novel Approaches to Model Congestion Evolution and Dependencies in Complex Road Networks. Major Professor: Satish V. Ukkusuri.

Road network defines a basic template that strongly constraints the development of other infrastructure networks, thus plays a prominent role in human mobility and activity analysis, as well as more aggregated level studies that look into the land use or urban growth patterns. One of the most important phenomena on urban road networks is the traffic congestion. It is a typical functional failure process on road networks caused by traffic loading and poses huge impacts on urban systems. The structural characteristics and functional features of road networks interact in complex ways that jointly determine how and where the congestion emerges, how it propagates, and why the failure patterns look distinct in different networks. Although there is extensive literature on analyzing traffic congestion using conventional flow-based approaches, there are gaps in our knowledge regarding the underlying mechanisms of congestion evolution on road networks.

The goal of this dissertation is to investigate the coupling of structure and function of complex road networks, and develop a complete solution to monitor, model and suppress traffic congestion on urban road networks using both data-driven and complex network approaches. Specifically, the dissertation consists of three parts. The first part is devoted to develop new data-driven models and tools to monitor and infer various functional state measures of road networks. These include: (1) network-wide short-term link travel time estimation using large-scale taxi trip data without detailed trajectory information; (2) real-time link-level queue length estimation using license plate recognition (LPR) data; and (3) network-wide traffic state estimation and prediction using partially observed LPR data. The second part of

the dissertation studies the underlying mechanisms of traffic congestion. A vertex split-recovery model is proposed to explain and model the congestion evolution process on road networks. As an extension, a design problem is also formulated based on the vertex split-recovery model, which focuses on suppressing the network-wide traffic congestion level. The last part of this dissertation focuses on other functional dependencies of road networks.The spatial dependency of road networks and urban sprawl is first analyzed to reveal the role of road networks in determining future urban sprawl. Lastly, a new road network growth model is constructed which establishes a linkage between the city-wide demand pattern and the formation of future road networks.