Special Issue on: Quantitative Approaches to Resilience in Transport Networks

Transportmetrica A: Transport Science

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Transport networks are vital for sustainable development, wellbeing, and security of a society. However, they can be vulnerable subject to various natural and man-made disruptions. With the increasing global population, urbanisation, and climate change, factors that can undermine these critical infrastructures are greater than ever. Robustness and resilience of transport networks can be enhanced by introducing redundancies. Nevertheless, the associated investment can be very expensive. Sustainable and feasible strategies call for effective management of existing infrastructure which relies on thorough understanding, modelling, and optimisation of the underlying complexity of the network systems when disruptions occur.

This special issue presents some recent developments in quantitative approaches to modelling and maximising resilience of transport networks subject to non-recurrent disruptions. After a rigorous peer review process, a total of seven papers are selected ranging from static to dynamics analysis, empirical data-driven to analytical network modelling approach, with consideration of both deterministic and stochastic settings:

This special issue starts with the paper by Anbaroğlu, Cheng, and Heydecker which presents and tests two novel algorithms for detecting non-recurrent congestion in urban road networks. The authors make use of the journey time data collected from Central London for their case study. The investigated methods are percentile based detection and Space-Time Scan Statistics (STSS). Both methods capture the spatial variance in urban journey times by fitting the data into lognormal distribution functions. The experimental results obtained from the Central London case study suggest that the STSS method, which is an established machine learning technique, performs better than the percentile based method in terms of the accuracy and robustness in identifying occurrence of non-recurrent congestion.

The paper by Pien, Han, Shang, Majumdar, and Ochieng then looks at the robustness of European air traffic network which is a highly complex system consisting of a vast number of airports and control centres. The paper adopts an analytical linear programming approach to measure the system robustness through estimating the changes in maximum network flow subject to capacity degradation at different locations and define a new indicator called relative area index. This linear programming approach and the indicator are applied to the European air traffic network over three busy workdays. It is revealed that the proposed method outperforms the traditional topological approaches using indicators, including betweeness centrality and air traffic flow management delays, in terms of capturing the impact of capacity degradation. The proposed method is a useful tool for airspace managers and planners for assessing of robustness of air traffic networks.

Jansuwan and Chen consider the effect of stochasticity and develop a novel network efficiency measure that takes into account of traveller’s perception errors as well as flows, behaviours, and costs for assessing link importance in congested transport networks. The core component of their model is a probabilistic route choice model which is embedded in a network equilibrium framework. The importance measure, which is defined as the relative network efficiency drop, is developed to rank the importance of links in the network. The methodology is applied to two test networks for assessing the importance of the network links with respect to capacity degradation, demand level, and travellers’ perception error. The results demonstrate that the proposed importance measures are useful in both theory and applications.

The paper by Jenelius and Cats presents a methodology for assessing the value of adding new links for improving the robustness of public transport networks under disruptions. The value is evaluated based upon the passenger welfare under disruptions and the associated investment costs of the new links. With incorporation of the interaction between travel behaviour and prevailing network conditions, the proposed model generates more realistic estimates compared with most practical approaches which consider only network topology alone. The proposed model is applied to evaluate a new cross-radial light rail transit line in Stockholm, Sweden. It is shown that introducing redundancy increases welfare levels over all scenarios and has a positive impact on overall network robustness. It is also observed the value of introducing redundancy depends on the new link’s role as a complement or substitute, as well as passengers’ knowledge and ability to utilize the spare capacity during disruptions.

Bhavathrathan and Patil present a stochastic model for measuring the resilience of transport networks subject to degradation of link capacity. Their paper starts with defining the critical state that corresponds to a situation where the network operator is unable to decrease the total expected system cost through rerouting traffic. A minimax optimisation is then formulated to determine the set of link capacities in the network that could result in such critical state. It is further shown that the total system travel time realised in the critical state is unique. The proposed minimax optimisation is solved by the genetic algorithm and it is applied to a set of test networks with demonstration of retrofitting the Sioux Falls network.

For dynamic networks, Li, Lam, Shao, and Gao present an analytical dynamic traffic assignment (DTA) model for assessing the spatio-temporal impact of traffic incident on network travel reliability. The proposed model can estimate stochastic link flow patterns and route travel time distributions, and hence the impact on on-time arrival probability due to the occurrence of incidents. The paper also presents a set of test scenarios with and without dynamic speed limit control. It is shown that traffic incident on congested road during peak period can greatly decrease the on-time arrival probability. Under certain circumstances, appropriate deployment of dynamic speed limit can reduce the impact of the traffic incident.

Finally, Wang, Liu, Han, Friesz, and Yao present a day-to-day tolling scheme which maximises the rapidity of recovery of road traffic systems subject to disturbances caused by natural or man-made events. The theory of projected dynamical systems is applied to model the transient behaviour of network traffic under disruptions. The paper further provides three computationally tractable solution methods for designing the toll scheme under various assumptions on the information availability. The effectiveness of the proposed tolling scheme is guaranteed by theoretically established estimates. Numerical experiments on several test networks demonstrate the effectiveness of the dynamic tolling mechanisms in improving the rapidity of recovery and the potential cost efficiency of traffic management systems.

The papers published in this special issue are by no means an exhaustive collection of all emerging quantitative techniques to assessing and optimising resilience of transport networks. However, we believe this special issue can share and highlight some recent developments in the area. We hope this special issue can facilitate our understanding of the complexity of transport network resilience, and generate new research ideas on the development of cost-effective approaches for enhancing urban resilience and security.