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European Transport Research Review (2022) 14:28
https://doi.org/10.1186/s12544-022-00552-3

European Transport
Research Review

ORIGINAL PAPER Open Access

Assessing robustness in multimodal transportation systems: a case study in Lisbon

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Abstract

Introduction: Worldwide public transport systems are exposed to disruptions caused by malfunctions, accidents, maintenance, reduced fleet, and disasters, compromising mobility. Transport networks' multimodal planning and management can be explored to increase their robustness against these events. In this context, this research paper proposes and empirically compares methods to assess the robustness of a multimodal transport network, looking at aspects regarding the single-mode and multimodal network topology.

Materials and Methods: We hypothesize that the appropriate multilayered and traffic sensitive modeling of a multimodal transport network can help characterize robustness and further unravel vulnerabilities related to the integration of different transport modes. Using metric-based targeting, we evaluate how the network decreases performance when simulating failures on stations and pathways using different scenarios. The following six extraction strategies for nodes and edges were used in the simulation: Random removal; Initial Degree removal; Initial Betweenness removal; Recalculate Degree removal; Recalculate Betweenness removal; and Multimodal Hubs removal. Lisbon's public transport is used as a case study and is modeled as a multiplex network integrating eight different modes of transport. Proposing a novel normalized version of assessing the impact of failures, we were able to compare side by side the robustness of each modality layer, regardless of their size. Lastly, we simulate cascading events such as the breakdown of an entire transportation line.

Conclusions: Using different ways to induce failures in the network, we observe that to leave all nodes completely disconnected, we would need to remove about half the network nodes, highlighting the robustness of the Lisbon public transport network. Comparing different failure scenarios, methods that rely on recalculating network metrics yield a higher impact on the network robustness assessment. The impact of different events is quantified, showing that failures in stations are generally more dangerous than in pathways and offering views on the consequences of deactivating particular network modules. Overall, the results of this study allow decision-makers to gain further understanding of the topological vulnerabilities of a transportation network.

Keywords: Multimodality, Transport resilience, Multiplex networks, Robustness measurement