Link Vulnerability Analysis in Public Transportation Networks: A case study on the suburban railway network of Munich before and after the opening of "Trunk line 2”

Master‘s Thesis of Itir Coskun

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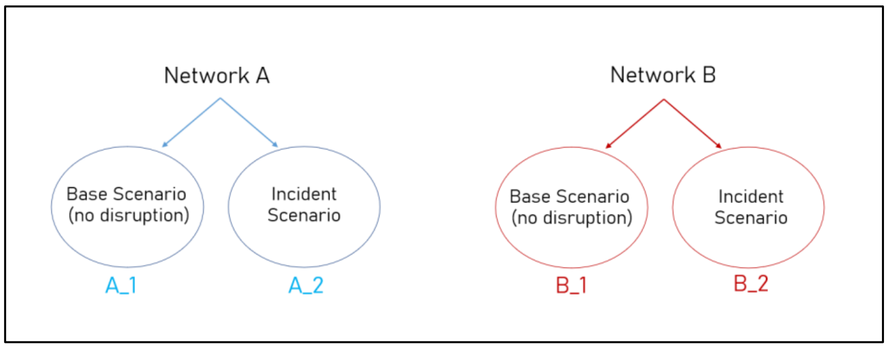
Objective of the study

To propose a transferable methodology to analyze the vulnerability of a public transport network based on evaluating network elements and measuring the impact of a disruption on the network. Following this objective, a two-step methodology is developed in order to utilize the two common approaches in the field: topological approach and system based approach. The methodology is then applied to the case study of the Munich suburban railway network to evaluate the impact of the second trunk line on the network´s vulnerability.

Methodology

The two-step analysis is based on the scenario scheme below. The evaluation is done through comparisons of the scenarios.



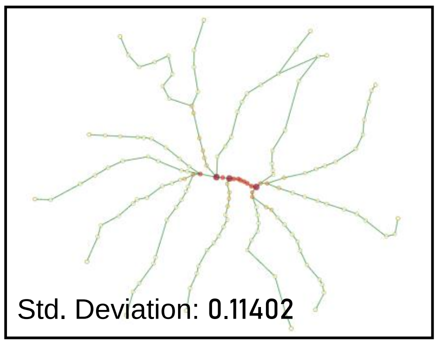
Step 1: Betweenness Centrality Analysis

$$C_B(v) = \sum_{s,t\in V} \frac{\sigma(s,t|v)}{\sigma(s,t)}$$

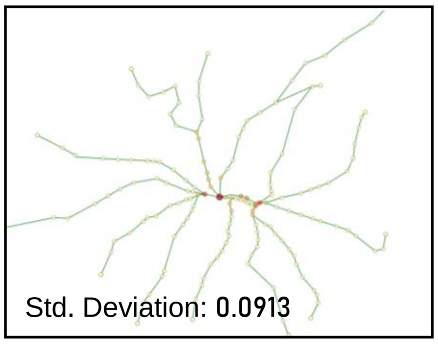
This analysis calculates the the number of times that node fall into the shortest path between two other nodes in the network.

For this analysis, stations are modelled as nodes and lines as links. Because of the simplistic approach, a full-scan analysis of the network is possible. It is implemented only for the “Base Scenario”. The goal of the analysis is to identify the *critical* stations, as well as the distribution of the *criticality* within the network. Two indicators are Identified: the standard deviation and the ranking of nodes.
The implementation of the analysis on the Munich suburban railway network can be seen below.

Current S-Bahn Network



Future S-Bahn Network

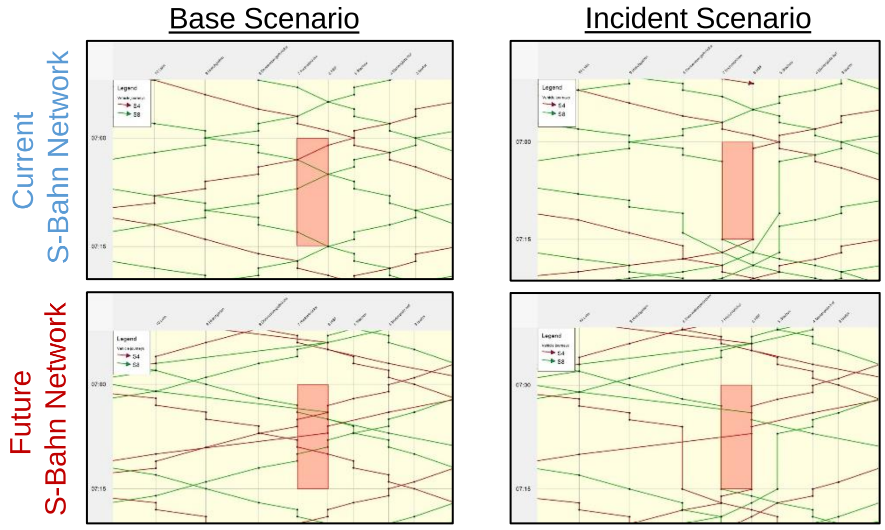


The lower standard deviation in the future network shows a more evenly distributed criticality of stations. It means that the probability of severe disruption of the network due to a failure of a single station is lower in the future network than in the current network which indicates the future network to be less vulnerable.

The stations of Hackerbrücke and Hauptbahnhof show a sharp drop in their criticality after the implementation of the second trunk line. This link is selected for the second step to simulate an incident on.

Step 2: VISUM Model

In this step, the behavior of the transportation network during an incident is analyzed. Due to the required computational effort, only a part of the network is modelled. It is implemented for both “Base Scenario” and “Incident Scenario”. The percentage changes of the defined indicators due to the incident in each network are obtained after the execution of the model. Later, the changes are compared between networks.
For the case study, S4 and S8 lines are modelled. Closure of the link between Hackerbrücke and Hauptbahnhof between 07:00 and 07:15 is simulated by adjusting the timetables.



Indicator	Current S-Bahn Network $[(A2-A1)/A1]$	Future S-Bahn Network $[(B2-B1)/B1]$
Mean journey time	-0.06 %	-0.51 %
Mean transfer wait time	-4.92 %	-13.51 %
Total number of transfers	0.13 %	0.66 %
Total passenger trips (linked)	0 %	0 %
Passenger Km Travelled	0̃ %	0̃ %
Passenger Hours Travelled	0.12 %	0.08 %

Simultaneous evaluation of the indicators indicate that the future network is less affected by the incident due to the alternative routes it provides.

Conclusion

By combining two approaches, a holistic and yet detailed analysis of transportation vulnerability is aimed to be provided in this study. Evaluation of multiple indicators in the 2. step provides a possibility to understand the reasoning behind the vulnerability of the network.