Project work plan: Vulnerability Analysis of Public Transport Networks

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Introduction

Public transport networks play a crucial role in ensuring efficient mobility for millions of people in major European cities. However, due to maintenance disruptions, overpopulation, epidemics or changing urban dynamics, these networks often face challenges related to efficiency, robustness and vulnerability. In order to improve the overall performance of public transport systems, one must address these challenges and come up with innovative solutions. By analyzing the nuances of these public transit networks and identifying new potential connections or stops that can increase network connectivity, this project aims to explore strategies for enhancing the robustness of public transport networks in major European cities.

Research question:

Our research question is: how can public transport networks in major European cities be made more robust? We want to come up with possible added connections or stops that would make the network more connected. In order to do so we need to address a few key sub-questions first, like:

- How do we define robustness and vulnerability in the context of public transit networks?
- Which of the investigated cities is more/less vulnerable to disruptions?
- What effect does adding nodes have on the vulnerability of the network?
- Which added connections/stops increase the robustness the most?

Model Description:

We make use of an online dataset with network graphs of the public transport networks of a few major European cities, which we have imported into our Git repository. We plan to use Gephi, Jupyter Notebooks, NetworkX and other Python Libraries for the purposes of this project. The network data of each city contains network graphs for each mode of transportation (metro, bus, railway, etc.) and a combined graph, all as csv files. Within the dataset for an individual mode of transportation, we can access the connection between a pair of nodes (i.e. stops), the distance and average duration between the two, and the number of vehicles that operate through the connection in a day, and which routes the vehicles have operated for (Bieze, 2020). The names of the stops, latitudes and longitudes are stored in a separate file, networks_nodes.csv. We have used the geographical coordinates of the nodes to visualize the node locations on a street map (*Figure 1*).

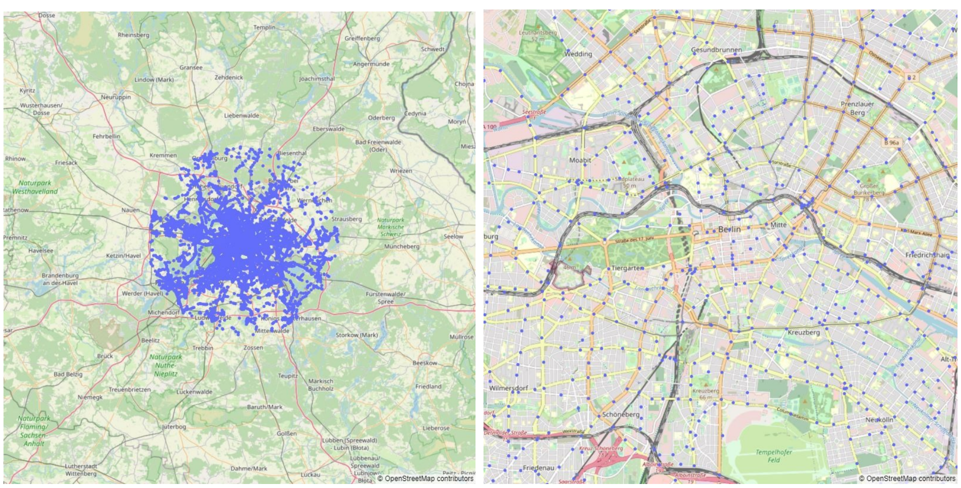

Figure 1. Street map of Berlin with nodes mapped on a street map

Experiments

For the initial experiments, we decided to start off by comparing two different cities, and then we will generalize the results to the other cities in the dataset. We chose the networks of Helsinki and Berlin, because although they have a different size, they both include the same types of transportation. This should lead to an interesting analysis.

- First, we will experiment with different definitions of robustness, and settle with one or two metrics that we can use to compare different networks. One such measure could be the average travel time to and from popular nodes, the percolation threshold, or the average closeness centrality of major nodes.
- Second, we will analyze the networks of the cities in our dataset with the measures that we defined, by performing random percolation and targeted percolation experiments, and testing which network holds up best (and is thus more robust).
- Third, by analyzing historical data, current infrastructure, and demographic factors, we will identify the most critical areas of improvement.
- Fourth, we will define an experiment where we add nodes and edges to the network, and then test if certain additions made the network more robust or less robust.
- Finally, we will analyze what factors make the addition of a node lead to a more robust network, and if we can come up with a general algorithm or rules that play into this. We can then come up with the additions that have the biggest positive impact on the robustness on the network, and with that answer our main research question.

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