
# Robustness of Singapore Public Transportation Network

DAYLIGHT ANALYSTS

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# EXECUTIVE SUMMARY

There were eleven media-documented cases of train breakdown events in Singapore in the first three months of 2015, triggering waves of commuters' dissatisfaction. The team recognises the need for the Singapore mass public transportation system to be improved, but given limited resources, the need to identify critical stretches of train routes is strong. This proposal details the team's plan in mapping the Singapore mass transportation network, and in identification of segments of train routes which when removed, will result in significant impacts on the infrastructure.

# LITERATURE REVIEW

The analysis of the public transport system's resilience, reliability and robustness (or vulnerability) is a key concern in many countries and has been an important research topic for network analysis. Extensive measures, approaches and methods have been developed for this purpose over the years.

Network vulnerability studies in general, have had contributions from various disciplines and from various countries, evidenced from its available literature. For example, Eduardo et al., 2014[1] outlines measuring the vulnerability and criticality in public transport networks, considering the Madrid Metropolitan Area as a case study. O Cats and E. Jenelius (2012)[2] considers vulnerability analysis of public transportation in the circumstance of disruption due to non-continuous availability of services and facilities in Stockholm, Sweden. Along with analysis the robustness, various scenarios of natural disasters and social causations for disruption were factored into these literature (floods, terrorist attacks, hurricanes, etc.) Also, extending on vulnerabilities, other studies measure the resilience of a public transport system, defined as the recovering capabilities of a transport network in the event of a disruption(node or link being down).

Murray (2013)[3] has suggested using multiple methodologies for network vulnerability approaches, namely, scenario specific, strategy specific, simulation and mathematical modeling. After evaluating the different methods, two were identified that were applicable for the project. The first one is interdiction (simulation), where network elements (nodes and edges) are disabled intentionally to disrupt the flow of people through the network. In the context of public transport, the nodes will be the train stations and bus stops, and edges represent the distance between the nodes or the traveling time. The second is mathematical modeling to characterize vulnerability and identify which areas require reinforcement. Some of the characteristics mentioned are the maximal flow in a network, shortest path through the network, system flow, connectivity and access fortification.

Interdiction can be split into two types of methodologies for assessing robustness of networks (Knoop et al., 2012)[4], namely full computation methods and pre-selection of vulnerable links. For full computation methods, every separate link of the network is simulated to be disabled and effect is measured by the number of vehicle-loss hours. In public transportation, these can be measured using the increase in travelling time. The other is pre-selection of vulnerable links, to overcome the long computation time required in the first method. A combination of both can be utilised where full computation methods are applied on pre-selected vulnerable links.

Graph theory provides alternative measures of link importance (Scott et al., 2006)[5] where immediate connections (degree) and the betweenness centrality measures were used, with a conclusion that network vulnerability in terms of the size of the largest connected subset is more sensitive to betweenness centrality than to node degree. A network analysis of the travel routes using public transportation in Singapore (Harold Soh et.al, 2010)[6] with graph measures such as clustering coefficients and degree calculations directly correspond with a well distributed network structure. The number of cyclic paths (Derrible & Kennedy, 2010)[7] in a metro system also seems to correlate with the robustness of the network.

Singapore has a well connected array of public transportation modes such as buses, trains and taxis. Simulation models such as MATSim (Medina et al. 2013)[8] have been developed to stress test the resilience of the Singapore Transport system. The transport supply model used in MATSIM includes all modes of transportation to analyze traffic behaviour but for the scope of this project, we will not be taking into consideration taxis and private transport, only focusing on the train and bus systems.

# PROBLEM

There were eleven media-documented mass rapid transit (Includes train networks operated by both SMRT Corporation and SBS Transit) MRT breakdowns in Singapore in the first three months of 2015, sparking off waves of public criticism on the Singapore train network. While the intuitive step to resolve the issue should target at the root problem (i.e. maintenance issues), our team believes that a two-pronged approach should be considered, to include building an overall mass public transportation network that is resilient to failures.

# PROJECT OBJECTIVES

The team would like to analyse the current mass public transport network, to understand the robustness of the network, through removing selected edges between train nodes iteratively. This mimics the Singapore train breakdown impacts, i.e. an entire stretch of train station is affected, rather than the mere local site where the train fault is located at. The team would then seek to identify crucial train paths which when removed, will bring about significant impacts to the mass public transport network.

# PROJECT SIGNIFICANCE

This project identifies stretches of MRT paths which are critical to the mass public transport network. Specifically, removing these paths will bring about significant impacts to the public due to a lack of convenient alternative paths. The results of this study may be further disseminated to transportation companies so that special attention may be made to reduce chances of breakdown along these paths. The eventual goal would be improved public confidence on the mass public transport network, and better corporate image of train companies.

# ASSUMPTIONS

The team made the following assumptions to help scope this project:

1. Train networks by SMRT Corporation and SBS Transit form the core train network in Singapore;

2. Bus services by SMRT Corporation and SBS Transit form the core bus network in Singapore. All other smaller-scaled bus operators operating on flexible routes (These routes are predominantly in industrial estates, connecting factories to the nearest MRT station) have small-to-negligible impact on the overall transportation network resilience; and

3. Bulk of mass public transport commuters will choose to complete their journey via mass public transport, as such, we do not factor impacts of cabs in the study of resilience of mass public transportation network.

# DELIVERABLES AND SUCCESS MEASURES

The team aims to deliver the following at the end of the project:

1. An analysis on the robustness of the Singapore mass public transport network
2. Identification of stretches of train paths which when removed, will impact the transport network most;
3. Cross-validation of (2) against historical breakdowns, i.e. verify if train breakdowns in the past stirred public sentiments (e.g. twitters posts) to extents as anticipated by the severity of impact on transportation networks.

# REQUIREMENTS

This project requires the following datasets which the team has verified to be available for the project, either through scraping off websites, or downloading with open source agreements.

| NO | PURPOSE | DATA | SOURCE | URL | METHOD |
|---|---|---|---|---|---|
| **1** | Nodes | Geo-coordinates of bus stops and MRT stations | Openstreet Maps | http://www.openstreetmap.org | Download |
| **2** | Edges | Bus and MRT Routes | TransitLink | http://transitlink.com.sg/eservice.aspx | Scrape |
| **3** | Edge Label | Path distance | TransitLink | http://transitlink.com.sg/eservice.aspx | Scrape |
| **4** | Geospatial Visualization | Shape file of Singapore | Openstreet Maps | http://www.openstreetmap.org | Download |
| **5** | Nodes Edges (Alternate Source) | Geo-coordinates of bus stops and MRT stations; Bus and MRT Routes | mytransport.sg | http://www.mytransport.sg/content/mytransport/home/dataMall.html#Public_Transport_Related | Download |

The team has tentatively shortlisted the following tools for the project, but will re-evaluate suitability as the project progress:

iGraph – network visualization and out-of-the-box social network calculations

Python, C++ – data transformation and manipulation; customized calculation

ESRI – geospatial visualization

# PROJECT PLAN

The team has decomposed the projects into the following four stages:

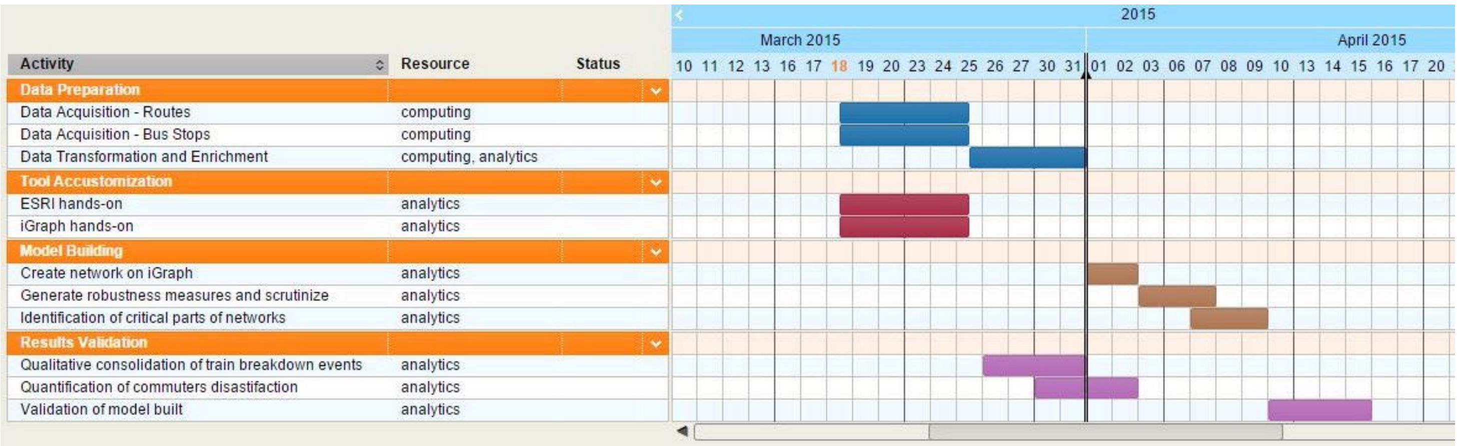
1. **Data Preparation**: Obtain, cleanse, and transform data to required formats. Includes data enrichment.

2. **Tools Accustomization**: To gain experience on new tools identified for this project.

3. **Model Building**: Create network, apply and study robustness of network with selected measures.

4. **Results Validation**: To study if model created is indeed a good representation of the physical domain.

The below gantt chart gives details to each stage, and specifies the timelines the team has committed to, as well as interdependencies between each stages.



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