# Vulnerability Analysis of the Public Transport System

## - Is VBZ-Alerto a Good Indicator for Disruptions Identification?

Xiao Sun
Institute for Transport Planning and Systems
Swiss Federal Institute of Technology, ETHz
Zurich, Switzerland
sunxi@student.ethz.ch

***Abstract*— Public transport systems are important infrastructure systems which are closely related to people's daily life and social welfare. However, it is almost inevitable that delays happen on the public transport systems, as such systems do not exist by itself but interact with other systems. Thus, it is of great importance to understand the vulnerability of public transport systems. VBZ-Alerto provides passengers with disruption alerts and helps operators and passengers to react accordingly to disruptions. This paper examines whether VBZ-Alerto is a good indicator for disruption identification and the result will further help future studies into public transport vulnerability.**

***Keywords*— *Public Transport System; Vulnerability; Disruption Identification; Open Data***

## I. Introduction

Public transport systems are important infrastructure systems which are closely related to people's daily life and social welfare. Many people use public transport for going to work, study, as well as doing other social activities. A well-designed timetable is of great importance so that vehicles can run accordingly, and passengers arrive at transport hubs at the right time.

However, delay happens on public transport systems inevitably. The impact of disruptions and delays should be minimized as much as possible. Since public transport systems react to the disruptions differently based on their capacity, connectivity, size of the disruptions and so on, it is of great importance to understand the vulnerability of public transport systems, i.e., how public transport systems are affected by different kinds of disruptions. This will help reduce the negative impact of disruptions in the future operation.

## II. Literature Review

Vulnerability is usually considered as: "susceptibility to incidents that can result in considerable reductions in road network serviceability" [2]. There have already been plenty of researches into vulnerability of transport systems. Based on the research methods, those researches can be roughly divided into four categories: topological feature-based methods, system-based methods, simulation-based methods, and empirical data-based analysis.

Topological features usually focus on the network itself and ignores the demand side; System-based method considers demand side, however in traditional ways, the demand side is usually static and won't change according to supply changes; Simulation method is closer to reality however currently only imaginary disruptions are examined. Thus, it is of great interest to analyze with real-life disruptions and evaluate their impacts on the network and passengers.

## III. Data Used

### A. SBB-IstDaten

SBB IstDaten [17] provides real arrival and departure records of public transport in the whole of Switzerland. Data on trams in Zurich from 1st to 31st Jan 2019 and 25th Feb to 20th May are selected for analysis in this seminar project.

### B. VBZ-Alerto Disruption Alerts

VBZ (Verkehrsbetriebe Zürich) is the operator of public transport in the city of Zurich. VBZ-Alerto [21] delivers current disruption information within VBZ operation area. Each alert contains information on lines influenced, disruption time and location, reason, measurement taken after alerts and whether alternative exists. Alerts from January to May 2019 are collected.

## IV. Results

### A. Delay under normal conditions

As delays are almost inevitable during the operation of public transport, it is of interest to have a look at how delays are distributed under normal condition frist, i.e. when no disruption is reported by VBZ-Alerto.

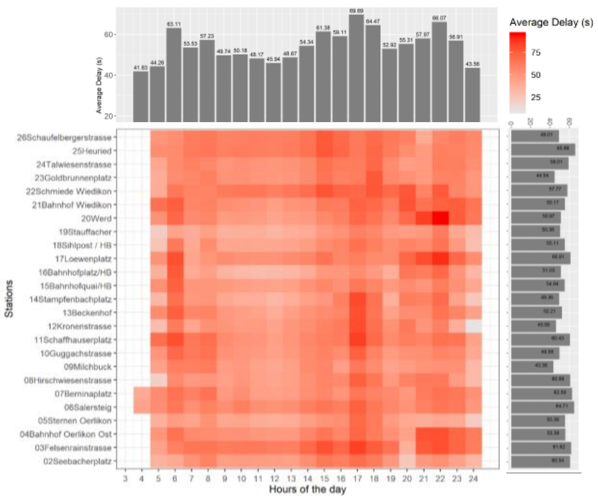


*Figure 1: Delay under normal conditions on line 14*

Delay of line 14 is used as an example in Figure 1. The average delay of each hour at each station is usually more than 40 seconds and less than 70 seconds. Delays (darker red) during morning peak and afternoon peak can be seen in Figure 1.

### B. Do Public Transport Systems run differently after disruptions reported by VBZ-Alerto?

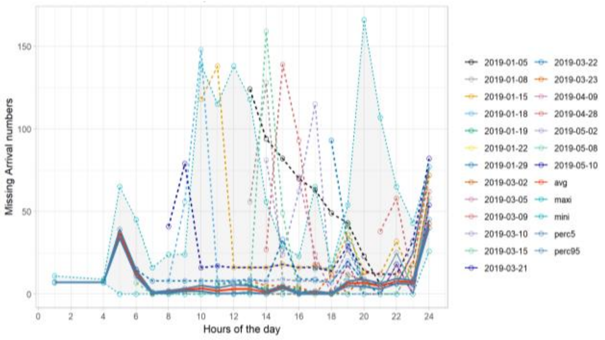


*Figure 2: Numbers of Missing Arrivals per Hour on Line 4*

The number of missing arrivals indicates how many arrivals are not made compared with schedules in one hour. It helps us to identify whether there's any reroute or stations being blocked

As shown in Figure 2, solid blue and red lines are 95%, 5% and mean values respectively. Colourful lines represent days when alerts were reported. We can see that the numbers of missing arrivals are higher than average missing arrival numbers when the alert just happened. It also gets higher in the next hour and will gradually flatten out after 2 hours.

Among all disruption alerts, 22.2% of them didn't lead to any missing arrivals higher than 10 times after alerts.

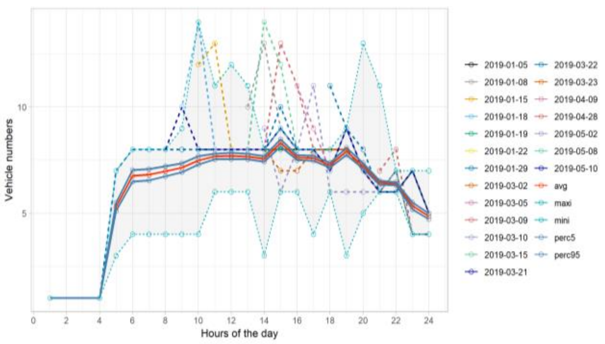


*Figure 3: Numbers of Rides per Hour on Line 4*

The number of rides is how many rides were made in one hour. One ride is made when one vehicle starts from the garage to destination without changing its direction. One ride will be separated into two when one part of the line is blocked.

As shown in Figure 3, solid blue and red lines are 95%, 5% and mean values. Colourful lines represent days when alerts were reported. We can see that the number of rides on alert days is mostly higher than average ride numbers, which means lines are blocked.

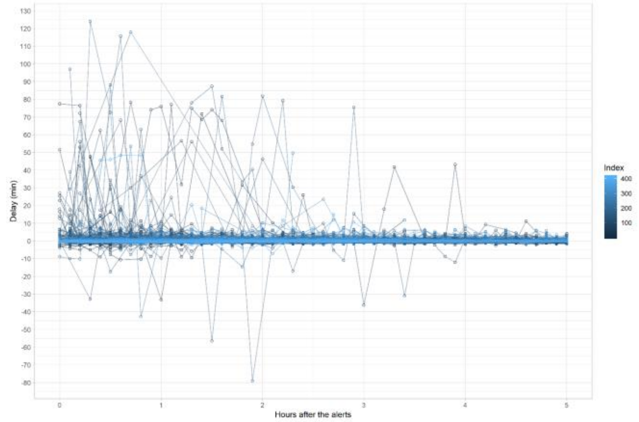


*Figure 4: Delay Impact of Alerts (Relative)*

In Figure 4, several alerts lead to extreme high values of delays in first two hours which can be as high as 1 hour and 30 minutes to 2 hours, while most of the alerts' delay impact seem to be very small. Actually, 43.2% of alerts are not followed by a delay higher than 3 minutes. Only 4.7% delays are followed by delays higher than 60 minutes.

When examining the number of missing arrivals and delay time together, 13% of the alerts neither have any obvious impact on missing arrivals nor delay time. However, other 87% of disruption alerts either have impact on missing arrivals, on tram delays or both.

### C. Can the impact of disruption alerts be grouped?

Three groups are made based on their disruption reasons: demonstration, technical problems, and collisions. For each two groups, the Wilcoxon Test was used (an alternative to T-test when normality doesn't hold) to compare whether every two groups are different regarding 6 different aspects (highest and average value of missing arrivals, number of rides and delays).

The test result shows that the distributions of alert groups caused by demonstration and technical are always significantly different regarding all 6 aspects, while the distributions of technical problem and collision groups are not significantly different in any aspect.

For group of disruption alerts caused by demonstrations, 22% of them have no obvious impact on the operation, i.e. relative delay increasement is smaller than 3 minutes, and the increasement of missing arrivals per hour is always smaller than 10 times; For the group of disruption alerts caused by technical problems or collision, only 4% have no obvious impact while 60% of those alerts have increased the number of missing arrivals by more than 50 times.

## V. Conclusion and Future Works

After reported by VBZ-Alerto, the number of missing arrivals increased, and the delay time of vehicles also increased. The impact of disruption alerts reported by VBZ-Alerto can mostly (87%) be recognised in the real-life operation data provided by SBB. Thus, VBZ-Alerto can be used as an indicator to recognize disruptions.

Technical problems and collision might have similar impact on the tram operation, the impact of demonstration and technical groups are considered to be different .

Alerts caused by demonstrations have a higher possibility to have no impact on the public transport operation, while the impact of technical problems and collision might lead to a severer impact compared to those caused by demonstrations.

Some future works include discovering the temporal impact of alerts, differentiating weekdays and weekends, and developing better methods to group the alerts for the future simulation work.

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