How can we better plan for the unplanned?

Designing and operating more robust public transport systems

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Introduction

Traditionally, transport systems have been designed to perform well under normal conditions assuming that everything works as planned. As anyone that uses public transport can testify, deviations from planning are a recurrent phenomenon. Investments in public transport are therefore increasingly motivated by the need to improve their reliability and robustness to disturbances and disruptions. Public transport systems are especially vulnerable to disruptions due to their lower density, the rigidity of service planning and operational constraints. In a series of studies, Assistant Professor Oded Cats investigates how public transport systems can be planned and operated to better withstand unplanned conditions.

Body text (approx. 750 words)

On my way to Schiphol last Friday, when the train approached Den Haag HS station, the announcement informed passengers that the train will not continue beyond this station. After another minute, came the clarification, a man that commits a suicide attempt between Den Haag and Leiden sabotaged all train traffic along this critical corridor. Suicide attempts are one of the main causes of disruption in the railway network. Other causes include mechanical and technical failures, degradation of the physical infrastructure (e.g. due to weather conditions). Disruptions can also be planned (e.g. construction or maintenance works) or malicious terror attacks.

Clockwise - Strained bus in Stockholm after a snowstorm; Power outage in Rotterdam metro; Public communication in Boston; Strained passengers in the UK after “a signal failure caused gridlock”
How can we make public transport systems more robust? Since our resources are limited, we have to prioritize the locations and services that are most critical to maintain system functionality and we need to consider the trade-off between system efficiency and its reliability and robustness. The robustness benefits induced by alternative investments should already be taken into consideration in the project appraisal phase. In order to estimate the economical and operational benefits associated with a robust design, not only the effects but also the probability that various disruptions occur need to be estimated. Based on data from The Hague-Rotterdam area, probabilities of a range of disruptions can be estimated per link for different modes as function of link properties. In addition, our perceptions and value-of-time in case of severe delays and uncertainty. For example, in the absence of any other alternative, I decided after ten minutes elapsed without any change to look for a cab so that I would still have a chance to make it on time to catch my flight from Schiphol. Everyone started considering rerouting options but of course the viability of such alternatives varies considerably depending on their destinations. In front of the stations, large number of passengers congregated waiting for trams. The morning peak hour crowding did not offer much residual capacity to absorb all the excessive demand, prolonging the time the trams were delays at stops and leaving many unhappy passengers behind, potentially resulting with spill-over effects.

Redundancy should be therefore inserted in strategic locations to both infrastructure and timetable design to make the system less fragile and prevent small disturbances from spreading like wildfire and lead to knock-down effects. A robust strategic and tactical planning requires methods to identify the most critical network and service elements. Using a dynamic agent-based assignment model, one can evaluate the impacts of service disruptions on network performance and the respective total time losses. Behavioural models are required to assess how passengers response to planned and unplanned service disruptions. Do you change your travel plans? How do you acquire and respond to information? The result of all our individual decisions are network flows and network performance depends on its topology, reliability, capacity and saturation level as illustrated below for the Amsterdam network. The new metro line will help relief the effect of severe disruptions.
Amsterdam rapid public transport network with (right) and without (left) the Noord-Zuid metro line.
Graphs show the change in generalized passenger travel time by trip origin in case of a temporary closure of Nieuwezijds Kolk-Centraal Station tram segment (red depicts a significant increase)

Strategic and tactical planning can elevate the impacts of disruptions. However, once a disruption occurs, real-time mitigation measures have to be deployed. System operators and service providers need to decide in very short time frames and with limited information, how to inform passengers and what resources to allocate. The impact of the disruption will depend on how passengers are informed and how quickly the service recovers back to normal operations. The total effect of network performance when considering the recovery time is coined resilience. Perhaps counterintuitively, research demonstrated that providing more information can be counterproductive under certain conditions due to the herd phenomenon. Hence, information generation and prediction methods should account for the behavioural response when provisioning prescriptive travel information. What about my flight? Thanks for asking. Half way to Schiphol, I checked flights departure times hoping that my flight is slightly delay. I got more than I wished for – it was cancelled...