# Evaluating the Impact of Waiting Time Uncertainty on Passengers' Decisions

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## 1 Introduction

Service reliability is one of the main determinants of public transport level of service. Public transport services are subject to various sources of uncertainty related to traffic conditions, public transport operations and passenger demand. Passenger waiting time at stops is thus a random variable subject to day-to-day variations and the interaction between vehicle and passenger stochastic arrival processes. The uncertainty associated with waiting time could potentially impact passenger's departure time, mode and route choices. This has led to the incorporation of travel time variability into choice models and appraisal schemes [1].

Public transport service providers deploy various priority measures and control strategies designed to improve service reliability. In addition, the dissemination of real-time information (RTI) concerning predicted vehicle arrival times was found to reduce the perceived waiting time [2] as well as the actual waiting time [3]. Previous studies that modeled the impact of RTI on passengers' decisions considered the benefits from assisting passengers to shift their expectations closer to the actual waiting time [4]. However, they did not account for its potential to reduce the uncertainty associated with this expectation. The extent of uncertainty reduction achieved by RTI provision clearly depends on its prediction accuracy and perceived credibility.

The analysis of waiting time uncertainty and its impacts on passengers' decisions requires the dynamic modeling of public transport supply and demand. This paper presents a dynamic passenger path choice model which accounts for scheduling constraints, experienced service reliability and RTI credibility. The model was applied to test the impacts of alternative measures to reduce service uncertainty using an agent-based public transport assignment model.

## 2 The Dynamic Path Choice Model

Traveler decisions are modeled in the probabilistic framework of random utility choice models. The evaluation of alternative travel actions depends on traveler's preferences and expectations with respect to future travel attributes. These expectations depend on: (a) Prior knowledge - the static information passengers might have prior to trip (e.g. schedule, planned frequencies); (b) Experience - the accumulated first-hand experience with service performance, and; (c) RTI – with respect to next expected arrival time, in case available. The anticipated waiting time of traveller $n$ for line $l$ at stop $s$ is obtained from the integration of three types of information as follows:

$$AWT_{n,s,l} = \alpha_n^{pk} AWT_{n,s,l}^{pk} + \alpha_n^{\exp} E\left(AWT_{n,s,l}^{\exp}\right) + \alpha_n^{rti} E\left(AWT_{n,s,l}^{rti}\right)$$

Where $AWT_{n,s,l}^{pk}$, $AWT_{n,s,l}^{\exp}$ and $AWT_{n,s,l}^{rti}$ are the anticipated waiting time based on traveller's prior-knowledge, experience and RTI provision, respectivly. In the case of experience and RTI, the expected value is derived from the accumulated experience with respect to either actual waiting times or the difference between them and the respective RTI projections. Their integration consists of a weigthed-average of their expected values based on the corresponding credibility coefficients, $\alpha_n^{pk}$, $\alpha_n^{\exp}$ and $\alpha_n^{rti}$. The credibility coefficients as well as traveller's accumulated distributions are updated through day-to-day dynamics which perform an iterative network loading.

The dynamic loading of travellers and their interaction with the public transport system is emulated through successive travel decisions. The within-day path choice model incorporates scheduling considerations in line with the study by Ettema and Timmermans [5] who based their model on the schedule-delay model of Noland and Small [6] in the context of trip departure time choice. It is hence assumed that each traveller $n$ has a preferred arrival time at the destination. The deterministic part of the utility function of individual $n$ for a path alternative $i$ takes thus the following form:

$$u_{i,n} = \gamma_n X_{i,n} + \beta_n^{sde} ASDE_{i,n} + \beta_n^{sdl} ASDL_{i,n} + \beta_n^{late} p_{i,n}^{late}$$

Where $\gamma_n$ is the vector of path attributes' coefficients and $X_{i,n}$ is the vector of anticipated values of the corresponding attributes (e.g. waiting time, number of transfers). $ASDE_{i,n}$ and

$ASDL_{i,n}$ are the average anticipated early and late schedule delays, respectively. $p_{i,n}^{late}$ is the probability of late arrival and $\beta_n^{sde}$, $\beta_n^{sdl}$, $\beta_n^{late}$ are the corresponding scheduling coefficients. Note that model formulation allows accommodating uncertainties associated with various travel aspects other than waiting time.

## 3 Implementation

The modeling of waiting time and RTI uncertainty and their impacts requires the dynamic representation of the underlying stochastic processes in order to emulate public transport operations and reliability patterns. Moreover, the process in which RTI is generated and disseminated has to be modeled in detail and passengers' progress in the network has to be represented dynamically.

The implementation of the dynamic path choice model was embedded in a public transport simulation model, BusMezzo [4,7]. It performs an agent-based public transport assignment through simulating the progress of vehicles and travellers in the public transport system and yields the temporal and spatial distribution of the latter over the former. BusMezzo generates a population of individuals based on a time-dependent origin-destination (OD) passenger demand matrix. Travellers' perception is shaped by their prior-knowledge, accumulated travel experience as well as information availability.

The different sources of public transport operations uncertainty including traffic conditions, vehicle capacities, dwell times, vehicle schedules and service disruptions are modeled explicitly. The emulation of public transport conditions mimics the instantaneous generation of real-time data which facilitates the application of alternative prediction schemes concerning the remaining travel time until arriving at downstream stops. The dissemination of RTI may influence travellers' perceptions and ultimately passenger flows.

## 4 Application

The model was applied to the Stockholm metropolitan rapid public transport system which consists of commuter train, metro, light rail trains and trunk bus lines. The accumulated experience of the travellers' population - with respect to experienced waiting times and its deviation from the RTI projection - was first established for each stop-line combination chosen along their path over many days. The model however does not account for trip departure time choice. The expected values of these distributions were then calculated as well as the reliability coefficients for each traveller.

The case study evaluated alternative measures to reduce waiting time uncertainty by either improving the ground-truth service reliability or by improving RTI availability and hence supporting better estimates of the expected waiting time. The case study demonstrates the importance of capturing the impact of waiting time uncertainty on passengers' decisions through accounting for the credibility associated with alternative information sources.

## References


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