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Investigation of instantaneous effects of real-time crowding information (RTCI) availability upon urban public transport system performance – results from a simulation-based case study

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Introduction

The purpose of this study would be to analyse the implications of providing real-time crowding information (RTCI) on instantaneous (current) crowding levels of public transport (PT) services to travelers – and more specifically, to investigate the output RTCI impact for the on-going PT system performance, based on simulation works on a case study (city-level) network model. In recent years, an increasing emphasis has been put on development of various travel demand management tools and especially advanced traveler information systems (ATIS), which aim to overcome problems associated with ever growing passenger congestion in urban transport systems - and thus improve the overall travel experience, reliability and quality of service of the PT system. One of key ATIS developments has witnessed the widespread introduction of real-time information (RTI) systems [3], which provide passengers with information on current travel times of public transport services, waiting times at stops etc. Likewise, a further extension of these systems is highly feasible within the framework of modern-day ITS systems, as passenger flow data collected from various sources – APC and AFC systems, smart-card ticketing systems etc. – can be then utilized to inform travelers about the current passenger flows, i.e. real-time loading levels of public transport vehicles (the so-called RTCI system). However, this also indicates a substantial research gap as (to the best of our knowledge) there is still a fairly limited amount of relevant studies, with just individual sources having investigated the effects of RTCI provision in terms of simulation approach [2], [5] or survey analysis [6], [9]. Moreover, practical implementation of such systems in PT networks is yet (to this date) confined to limited-scale deployment, often on pilot (trial) basis. Consequently, little is known about the potential effectiveness of RTCI systems and their implications both on demand (passengers') side or supply (operators' side).

Method

For the purposes of this study, we utilize the the dynamic, simulation-based transit assignment model incorporated in the BusMezzo software [1]. The BusMezzo model assumes a detailed representation of both supply and demand sides of the PT system and their mutual interactions – especially, explicit representation of passenger congestion-induced phenomena. Crucially, the path choice algorithm allows to replicate the dynamic and sequential properties of passengers' decision-making patterns, and the possibility to reconsider their travel choices en-route with access to real-time travel information. To replicate the passengers' travel behaviour in the event of instantaneous access to RTCI, we utilise the extension of BusMezzo path choice algorithm [2] which addresses the following key steps of evaluating and disseminating the crowding information:

- Firstly, the observed RTCI is calculated (recorded) at each exit instance of PT vehicle (run) from a given stop – i.e. for each individual run ("stop-to-stop") segment. The observed RTCI is a function of the on-board volume-to-capacity ratio and is evaluated analogous to travel time valuations due to PT crowding, as commonly reported in research studies [7], [8].

- Secondly, the generated RTCI is calculated (updated) for each individual PT line segment at each instance a new PT vehicle (run) traverses that particular segment. Here, the generation RTCI can be evaluated as either equal to the observed RTCI of the latest run only (i.e. simply "overwritten"), or as an exponentially smoothed average RTCI of multiple runs (i.e. update to the previously stored RTCI value for a certain line segment).
- Finally, the RTCI anticipated by travelers is included as an in-vehicle travel time multiplier of each individual line ("stop-to-stop") segment and is equal to the latest available RTCI value stored for that particular segment – i.e. value at the time when passenger is making a travel decision. The traveler then chooses among the available travel actions (alternatives), considered in his (her) choice set, according to probability as evaluated by the generic (MNL) discrete choice model implemented in BusMezzo [1].

The above described model is then simulated on the transport model representing the core urban PT system of the city of Krakow, the second-biggest city in Poland (population of ca. 750,000). The network model consists of PT stops and lines within the central part of the city, with vehicle runs dispatched at regular intervals (headways) from the origin stops. Passenger demand is given in terms of O-D volumes between stops as observed for the afternoon peak period [4]. Simulations are carried out for distinct possible scenarios (assumptions), such as different RTCI penetration (response) rate among travelers, network congestion scenario, emergence of sudden service disruptions etc. – which should help better to point out the possible or condition-specific implications of providing access to RTCI.

In-vehicle congestion level	Vehicle load factor $Vol_s(\tau)/Cap_s$	Real-time crowding factor $\beta_s^{CL}(\tau)$
●○○○	< 0.30	**0.90**
●●○○	0.30 – 0.60	**1.10**
●●●○	0.60 – 0.80	**1.70**
●●●●	> 0.80	**2.20**

Fig. 1. The RTCI modelling framework: 1-to-4 RTCI representative scale and the corresponding crowding penalties (i.e. travel time multipliers) (source: [2]).

Fig. 2. Case study network – the urban PT system in the city centre of Krakow, Poland (source: kmkrakow.pl).

Based on the obtained simulation results, we examine both global (overall) changes as well as local-scale shifts in PT network performance due to RTCI access. The PT system performance is examined in terms of output indicators on passengers' and operators' sides, related to the generalized travel costs and network utilization costs. We investigate whether route (spatial) shifts induced by the RTCI provision contribute towards an improved network utilization and could help travelers to recognize the redundant system capacity (i.e. less-popular PT alternatives). We examine whether output changes in network performance are favourable or (conversely) counterproductive, how these translate into the system reliability, and consequently – what is the output share of passengers who benefit from access to RTCI and those who are actually worse off (i.e. who would be the RTCI "winners and losers").

Summary

The contribution of this study would be thus to shed more light on arising changes in PT system performance due to RTCI, as revealed by our simulation works on a real-world (city) public transport network. This study comprises the next step of our research collaboration, as part of which we have already designed the path choice algorithm accounting for passengers' access to RTCI and demonstrated the proof-of-concept on a sample network [2]. In this study, we apply this algorithm to a case study network (the inner-city PT system in Krakow, Poland) and investigate what are the within-day effects of providing RTCI to travelers. We show how output network performance and travel experience correlate with various simulation scenarios, such as RTCI penetration (response) rate and on-going PT service disruptions. Findings from our study indicate what might be the potential consequences of providing "raw", instantaneous crowding information for current PT system performance – and importantly, whether these might be indeed beneficial or not (or even counter-productive). Importantly, we hope that observations from our study would provide useful indications for future development of real-time crowding information systems in public transport networks, especially in terms of their practical implementation, designing an appropriate RTCI evaluation algorithm (e.g. a perhaps necessary shift towards crowding prediction), and thus - means of improving the overall effectiveness and accuracy of such systems.

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