The influence of transit service frequency and station characteristics on passenger arrival time distributions: A smart card data analysis in the Copenhagen Region

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1 Introduction

Waiting time in public transport is perceived by passengers to be more onerous than actual travel time (Fosgerau et al., 2007). This makes it an important time component to consider when planning attractive public transport systems. Specifically, it is important to consider possible planning measures that ensure the shortest possible waiting time, e.g. by planning the station layout efficiently so that passengers can reduce their waiting time.

Generally, when timetables are available, some passengers will try to minimise their waiting time by timing their arrival to stations whereas others will arrive randomly (Csikos and Currie, 2008; Jolliffe and Hutchinson, 1975; Luethi et al., 2007). The share of passengers who time their arrival time is influenced by service characteristics such as headway time and reliability as well as other factors, e.g. time of day (Csikos and Currie, 2008; Luethi et al., 2007; Nygaard and Tørset, 2016). When headway time or reliability decreases a larger share of passengers will tend to arrive randomly as the potential benefit of reduced waiting time is reduced (Bowman and Turnquist, 1981).

This paper contributes to the existing literature by analysing passenger arrival rates and waiting time distributions at train stations in the Copenhagen Region. The contribution is two-fold. Firstly, the study deploys a large-scale dataset containing more than 1.5 million trips covering all modes of public transport in the Copenhagen Region during two months of 2015. Secondly, this study will analyse in details the influence of various station characteristics on the arrival patterns and waiting time distributions of passengers. This includes the land uses and built environment surrounding the stations as well as station amenities and layouts.

2 Background

Conventionally waiting time has been assumed to be half the headway time which assumes reliable service and random arrival patterns of passengers to stations (Ceder and Marguier, 1985; Hess, Daniel Baldwin; Brown, Jeffrey; Shoup, 2004). Such assumptions are reasonable at short headways, but as headway times increase a larger share of passengers will start timing their arrival (Csikos and Currie, 2008). Previous studies have found varying thresholds for when passengers start planning their arrival time. In Austin, Texas, passengers arrived randomly at bus headway times less than 10 minutes (Fan and Machemehl, 2002), whereas passengers timed their arrival at such short headways in Trondheim, Norway (Nygaard and Tørset, 2016). Even shorter headways were found to encourage some passengers to time their arrival in Zürich, Switzerland, implying different travel behaviour (Luethi et al., 2007). Also time-of-day effects have been analysed. In Melbourne, Australia, random arrivals were more common during off-peak travel as compared to travellers during peak hours (Currie and Csikos, 2007). Similar results were found in Luethi et al. (2007) where travellers during morning and afternoon commute experienced shorter waiting times than those travelling mid-day.

While these studies investigate passenger arrival times in details they do have shortcomings in i) being based on small-size convenience-sampling, ii) not investigating possible differences across modes, and iii) not analysing the influence of station characteristics, land uses or other characteristics which might affect the behaviour of public transport travellers.

3 Approach and data

This study is based on several data sources from the Copenhagen Region. The passenger travel information is based on the Danish Rejsekort data which is a tap-in-tap-out automated fare collection system. It holds information on when and where passengers check into and out from the public transport system as well as intermediate transfer locations. For this study the arrival time at the first station for each trip is analysed so arrival times are not influenced by transfer times from other modes of public transport, i.e. if arriving at a station using a bus as access mode. By comparing to the official timetable of all trains, i.e. metro, suburban railway, local railway and regional trains, it is possible to calculate waiting time distributions. Buses are not included because check in happens inside buses, hence arrival time is unknown.

The waiting time distributions derived from the automated fare card system are compared across stations with service frequencies ranging from 2 to 60 minutes. Data is validated using revealed preference data from the national Danish travel survey (Christiansen, 2012), and the analyses will compare distributions across various station characteristics such as availability of shops, station layouts, perceived safety and land uses surrounding the stations (Dyrberg and Christensen, 2015).

4 Results

The results indicate that the threshold for when passengers time their arrival at stations is at around 6-8 minute headways. This finding is not surprising since other studies find the range to be between 5 to 12 minutes (Fan and Machemehl, 2002; Jolliffe and Hutchinson, 1975; Luethi et al., 2007; Nygaard and Tørset, 2016; O’Flaherty and Mangan, 1970). The waiting times are generally longer at stations that are located underground or have confusing station layouts where passengers might have difficulties getting to the right platform to catch their preferred train. These results could indicate that passengers add an extra buffer time to their access time, thus increasing their waiting time by overestimating the buffer time. The findings also indicate time-of-day effects as passengers travelling at evening and night hours experience longer waiting times. At these hours most trips are leisure trips where passengers often cannot time their arrival time. Similar results were found for stations surrounded by land uses related to leisure trips (e.g. shopping, museums, stadiums or nature areas) when compared to those related to commute trips (e.g. residential, office or industrial areas). Also, the availability of shops induced a larger waiting time for the passengers which could be explained by passengers not being able to time the arrival to the station because of the need to do shopping on the way to the station platform.

Finally, the results of this study indicate important policy implications by highlighting the need for implementing easy accessibility to stations in order to reduce passenger waiting times and thus to ensure attractice public transport systems. Furthermore, the results can be applied in public transport route choice models to better represent passenger behaviour.

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