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Analysing the impacts of the Frederikssund S-line closure on passenger travel behaviour using Rejsekort data

Nils Breyer[1] (nils.breyer@liu.se), Morten Eltved[2] (morel@dtu.dk), Jesper Bláfoss Ingvardson[2] (jbin@dtu.dk), Otto Anker Nielsen[2] (oani@dtu.dk)
[1] Linköping University, Sweden
[2] DTU Management, Technical University of Denmark

1 Introduction

Disruptions in public transport are the major cause of passenger dissatisfaction (van Lierop et al., 2018) and they result in decreased public transport usage (Nazem et al., 2018). Much of the research on disruptions has focused on robustness of networks (Cats, 2016), network planning during disruptions (van der Hurk et al., 2016), and passenger information provision (Bruglieri et al., 2015). However, limited focus has been on understanding the changes to travel behaviour caused by planned long-term disruptions, such as closures due to construction work. Hence, this study analyses the effects of a long-term closure of an important suburban railway line in the Greater Copenhagen area (Denmark) on the travel behaviour of public transport passengers. Using a large-scale smart card dataset the travel behaviour before, during and after the closure is compared and analysed across different groups of travellers focusing on both short-term and long-term changes to the travel patterns across groups.

2 Background

Disruptions in public transport systems can be unplanned, for example due to an accident, or planned, for example due to construction works. Planned disruptions, such as the closure of a station or an entire corridor, are not uncommon and can often last over a long period. However, the effects of planned long-term disruptions have not yet been studied extensively.

In Denmark, the Copenhagen S-train network has had several maintenance and other construction projects affecting the operations, both short-term such as closures of short segments during weekends and longer term such as track renewal on entire S-train lines. While there is much information on changes to actual usage within the corridors and network-wide during these disruptions less is known on how the disruptions influence travel patterns of various passenger types; both on the short term (e.g. changed routes or mode) and on the longer term in terms of whether (and when) passengers return to the public transport system.

Previous studies show numerous uses of smartcard data for strategic, tactical and operational public transportation planning (Pelletier et al., 2011). Only a few studies have used smart card data to investigate the effect of long-term disruptions (Yap et al., 2016). Nazem et al. (2018) analysed travel behaviour changes due to a closure of a single metro station and showed that even a mid-term disruption can have long-term impacts on travel behaviour. Clustering of travellers based on travel characteristics has been studied well, e.g. El Mahrsi et al. (2017), Briand et al. (2017), Kieu et al. (2015). However, these studies have not focused on analysing changes of travel patterns due to such disruptions, and specifically how patterns vary across user groups. Hence, this study will also fill this gap in literature.

3 Data

The project utilises the Danish public transport smart card data, Rejsekortet. This data includes complete information on route choices of the public transport passengers as it requires passengers to check-in at origin and transfer stations, and check-out at the destination station. The analysis deploys data for the full years of 2017, 2018 and 2019 covering the entire Greater Copenhagen area. In addition, monthly passengers numbers for each line of the network are utilized allowing for filtering out seasonal effects through analysing these across years and across lines in the area (DSB, 2020).

The study mainly analyses the planned disruptions at the S-train line linking Frederikssund to Copenhagen, which was closed for three months due to track renewals in 2018 (see Figure 1). The line, which normally has 87,600 daily passengers (DSB, 2013), corresponding to 11.7% of total S-train passengers, was closed in the period June 1st - August 26th 2018. Replacement buses were operating in this period resulting in much increased travel times, less comfort and additional transfers for passengers.

Figure 1; Map of the Copenhagen S-train (colours) and metro (grey) network including the closure of the Frederikssund-lines between Frederikssund and Valby during Summer 2018 (dark blue).

4 Methodology

To study the effect on different types of passengers (for example daily commuters or leisure/weekend travelers) the smart cards are clustered by the time profile of the journeys made (El Mahrsi et al., 2017). We use clustering techniques such as K-means (Ma et al, 2013) in order to identify passengers with similar travel patterns.

For each group of travellers we study the travel behaviour before, during and after the disruption, e.g. in terms of number of trips made and time of travel. The analysis includes how the previous train users change travel behaviour by either using the replacement bus, switching routes, or even stop using the public transport system completely. We also study the travel behaviour in the phase after the closure to analyse if (and how quickly) passengers return to their previous patterns, i.e. the speed of recovery of the system to the state before the disruption.

A specific challenge of the analysis is to distinguish between the decrease in ridership due to the disruption and due to regular seasonal variations. Commonly, construction works are planned during typical holiday times, as also in the case of the Frederikssund closure. To compensate for these effects, we investigate the seasonal patterns even in years not affected by a closure.

5 Preliminary results

Preliminary analysis has focused on identifying minor and major disruptions in the S-train network in order to identify seasonal and non-seasonal variations. Figure 2 shows the total number of travellers on the five branches of the network from 2015 to 2020. From the figure major reductions in passenger numbers can be observed in Summer periods, but a specifically large decrease of approx. 60% on the Valby-Frederikssund line during the Summer of 2018, which was the time of the major closure. The seasonal fluctuations are necessary to consider for the further analysis of the impacts of disruptions on passenger travel patterns.

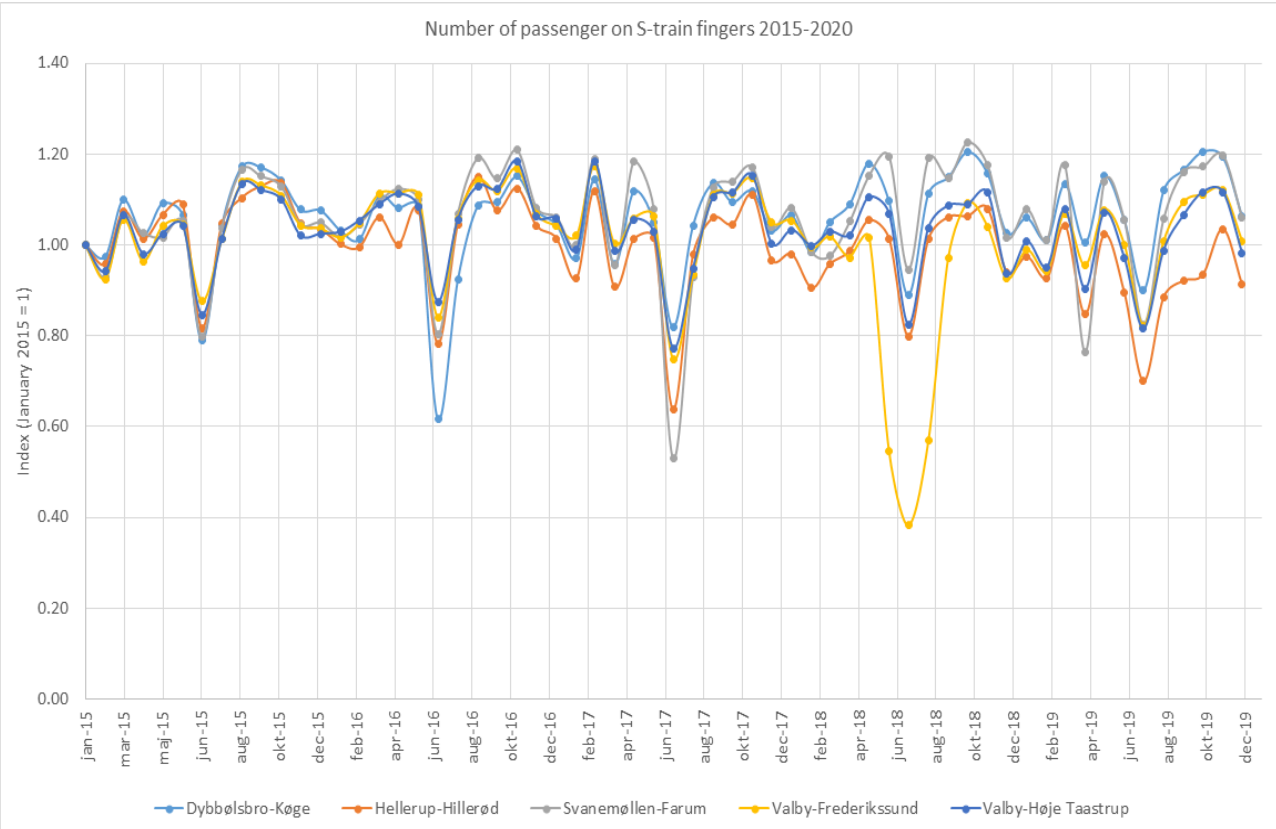

Figure 2; Passenger counts across the five branches of the Copenhagen S-train network (DSB, 2020).

Preliminary analysis of the travel patterns has focused on travellers between the four specific stations furthest from the city on the Frederikssund line (Frederikssund, Ølstykke, Egedal and Stenløse) to three major stations in the city (Valby, København H and Nørreport). Figure 3 shows a preliminary visualisation of how the travel behaviour changed during the disruption for those passengers during the three months prior to the track closure. Many of the users who travelled frequently before the track closure had very few trips during the closure and after the track re-opened indicating that some passengers dropped out of the public transport system due to the service of replacement busses during the track closure. However, a quite big group of passengers, who travelled very frequently before the closure, maintained the same number of trips after the track re-opening, hence suggesting a large degree of loyalty.

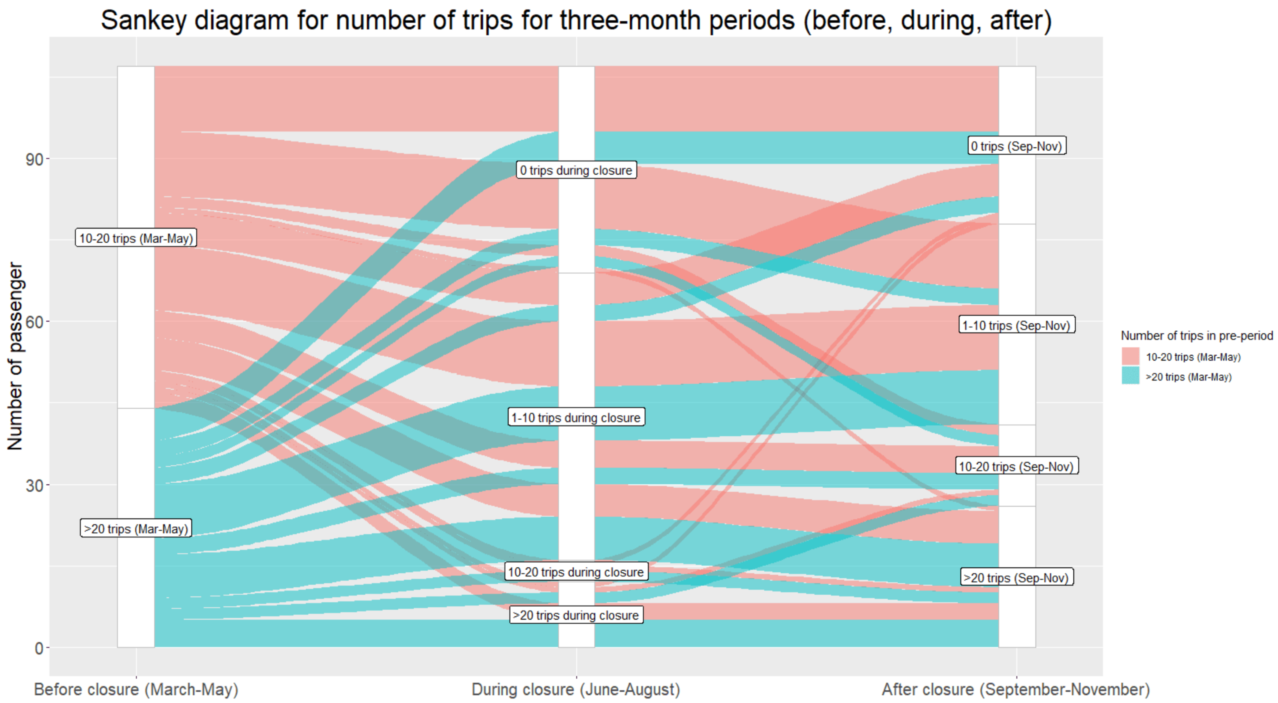

Figure 3; Preliminary visualisation for frequent travellers in the pre-period (Mar-May) and whether they continue travelling from the selected origin stations to the selected destination stations during the track closure (Jun-Aug) and after the track closure (Sep-Nov).

The subsequent analysis of travel patterns will expand the analysis to the entire line, and provide further details on passenger types that change behaviour. This will result in important insights on how major planned disruptions affect travel patterns of passengers. Not only the magnitude of impacts, but more interestingly, which groups of passengers are most likely to change travel patterns - and how the patterns specifically are changed.

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