Impacts of COVID-19 on public transport ridership in Sweden:

Analysis of ticket validations, sales and passenger counts

Erik Jenelius
Division of Transport Planning, KTH Royal Institute of Technology, Stockholm, Sweden

Matej Cebecauer
Division of Transport Planning, KTH Royal Institute of Technology, Stockholm, Sweden

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Abstract

The paper analyses the impacts of COVID-19 on daily public transport ridership in Sweden during spring 2020, in particular the three most populated regions Stockholm, Västra Götaland and Skåne. The analysis is based on ticket validations, sales and passenger counts data. Public transport ridership has been hit particularly severely compared with other transport modes. Of the three regions, the decrease in ridership was the largest in Stockholm (ca 60 %) and the smallest in Västra Götaland (ca. 40 %). The reduction stems primarily from a lower number of active public transport travellers. Data from both Stockholm and Västra Götaland show that travellers switched from 30-day period tickets to single tickets and travel funds, while the use and the sales of short period tickets, used predominantly by tourists and other short-term visitors, dropped to almost zero. One-year period tickets and school tickets increased from mid-April, which could indicate that the travellers using these tickets are particularly captive to the public transport system. Comparison with data from international mobility service providers shows that proxy indicators based on human proximity to public transport stations and travel planner queries have overestimated the recovery of public transport ridership during the months following the outbreak. Collaborative effort is required to put the results in the international context.

Keywords: COVID-19, pandemic, public transport, Sweden, urban mobility, ticket validations
1 Introduction

The COVID-19 pandemic has prompted governments and authorities around the globe to impose restrictions on transport and mobility at an unprecedented scale and magnitude. As of early July 2020, the development is in an uncertain stage, where some regions and countries have started or are planning to lighten restrictions on mobility, while some areas are still suffering severely from the pandemic. In any case, an assessment of the first months of the pandemic is important to guide policy during its continuation as well as potential future pandemics and other crises.

The literature on the impacts of COVID-19 on urban mobility is, as of mid-2020, still limited. Aloi et al. (2020) combined data from traffic counters, public transport GPS and ticket sales data, and pedestrian flows from traffic cameras to provide an overall assessment for Santander, Spain. Mobility service providers have published data based on geographical location data (e.g., Google COVID-19 Community Mobility Reports), travel planner queries (e.g., Apple Mobility Trends) or app usage (e.g., Moovit Public Transit Index). Surveys of mobility patterns have been conducted in many places, e.g., Switzerland (Mollo et al., 2020), Chile (Tirachini et al., 2020) and Sweden (WSP, 2020). While geographical settings and data vary, a consistent pattern emerges that public transport has been hit particularly hard compared to private cars and other modes.

The decline of public transport ridership is likely due to both authorities’ restrictions and travelers’ own choices. Public transport stations and vehicles are recognized as high-risk environments for the transmission of COVID-19 due to the limited physical space available, the abundance of surfaces that help spread the virus, and the limited testing of crew and passengers who use the system (Musselwhite et al., 2020; UITP, 2020). Evidence from Sweden shows that bus and tram drivers were among the group of professions with the highest risk of being infected (Public Health Agency of Sweden, 2020). Anecdotal evidence from China further illustrate the propensity for virus transmission on public buses (Shen et al., 2020).

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1 https://www.google.com/covid19/mobility/, accessed 30 June 2020.
2 https://www.apple.com/covid19/mobility, accessed 30 June 2020.
3 https://moovitapp.com/insights/en/Moovit_Insights_Public_Transit_Index-countries, accessed 1 July 2020.
The major urban areas of Sweden have well-developed public transport systems with typically high mode shares. Unlike many countries, Sweden opted for a strategy relying mainly on recommendations rather than mandatory enforcements to limit human interaction. The distinct approach makes it interesting also from an international perspective to study the mobility impacts in Sweden. Since the middle of March 2020, Swedish citizens are advised to stay at home if feeling sick in any way and work from home if possible. Meetings involving more than 50 people are banned, and high schools, colleges and universities are closed for students. Since early April 2020, people are advised to travel with public transport only if necessary.

The aim of this paper is to analyse the impacts of COVID-19 on daily public transport ridership in Sweden during spring 2020, in particular the three most populated regions Stockholm, Västra Götaland and Skåne. Each region has its own systems for fare and data collection. The Stockholm data set contains the full set of ticket validations. The impacts are assessed separately for different modes (metro, commuter train, bus, tram/light rail transit, and ferry) and ticket product types. The effects are also split into the daily number of active cards and the daily average number of trips per active card. The Västra Götaland data set contains the daily number of boardings on public transport vehicles based on automatic passenger counting (APC) sensors in the vehicles, as well as daily ticket sales per ticket category. The data are available for different modes (bus, tram and train). The Skåne data, finally, contain the daily number of ticket validations for buses.

A major advantage of these data compared to location-based data, such proximity of a person to a public transport hub, or travel planner queries is that they represent actual public transport trips. Further, unlike studies based on travel surveys they represent the full set of travellers and trips in the system rather than a sample. Based on the combined data sources, the paper addresses the following questions:

- How did the change in ridership vary across public transport modes?
- How did the impacts vary between regions?
- Were fewer people travelling, or was each person travelling less?
- Which type of tickets were travellers using?
• How was the ridership affected for school children, youths and seniors?

The rest of the paper is organized as follows. Section 2 describes the data and the methodology used to assess the impacts, Section 3 presents the results, and Section 4 discusses the findings and concludes the paper.

2 Data and methodology

The study uses data from the three largest regional public transport authorities in Sweden: Stockholm, Västra Götaland (including the second largest city Gothenburg) and Skåne (including the third largest city Malmö). Of the three regions, Stockholm was hit the hardest by Covid-19 between March and May 2020 in terms of both absolute number of cases and cases per capita, followed by Västra Götaland (see Figure 1).

Each region has its own systems for fare validation and data collection. Furthermore, the regions differ in terms of available transport modes and ticket products. This section describes the data available for each region and the methods used to extract the relevant information.

2.1 Stockholm

Stockholm Region has the largest public transport system in Sweden. Before COVID-19, on average 900 thousand people used the public transport system to make around 2 million trips per day. The

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system consists of four main transport modes: metro (44% of all trips), buses (39%), commuter trains (11%) and LRT/trams (6%).

The calculation of daily public transport ridership is based on ticket validation data from the digital ticket system SL Access. Tickets are loaded on contactless cards or on smartphones. The system is tap-in only, meaning that tickets are validated at the entrances of stations or vehicles but not at the exits.

The method of validation varies between modes and stations: In the metro and train systems tickets are generally validated at the station gates. On buses, tickets are generally validated at the front door near the driver. In the LRT and tram system, tickets are validated at the platform or manually on board. Cards are not personal and can be shared, e.g., within a household.

Every registered tap-in generates a record containing several attributes that are used in this study, in particular the transport mode (metro, commuter train, tram/LRT, bus, or ferry) and ticket product (various period cards, single ticket, travel funds, full or discounted rate, etc.). Furthermore, each record contains a unique id number for the card or mobile device carrying the ticket. This number has been anonymized by the Region Stockholm Transport Administration before we carry out our analysis.

We define a “trip” as the passenger movement corresponding to one tap-in. In general, a transfer between different public transport modes will generate a new trip, although exceptions exist at some major transfer hubs. A transfer between buses will also register a new trip, but a transfer within the metro or the commuter train system will typically not require a new tap-in. We split the trip counts into different transport modes and into different ticket products. SL Access includes a wide range of ticket products, which we group into four major categories:

1. Long period tickets (30 days and longer),
2. Short period tickets (1-7 days),
3. Single tickets and travel funds,
4. Special school and youth tickets.

The first three categories are further split into full fare and reduced fare tickets, while the fourth category is reduced fare by design. Reduced fare tickets are available to seniors (age above 65), youths (age under 20) and students.
The card id numbers allow us to count the number of active cards each day (i.e., smartcards that have registered at least one ticket validation that day), which in turn is used to compute the daily average number of trips per active cards. This separation is used to assess to what extent the overall decrease in ridership stems from a reduction of active travellers or from a fewer trips per traveller. Since cards are not personal, equating one card with one traveller is only approximate, but should in general be a reasonable interpretation.

Daily trip counts are calculated from 1 February 2020 to 31 May 2020. As reference, trip counts are also computed for the same time period the previous year, i.e., from 1 February 2019 to 31 May 2019. We calculate relative changes in ridership to the previous year by computing the ratio between the daily trip count in 2020 and the trip count of nearest day with matching weekday or holiday status in 2019. For example, Sunday 1 February 2020 is compared to Sunday 3 February 2019. This approach allows us to assess the relative ridership during Covid-19 considering the normal seasonal variations.

Since 17 March 2020, boarding on buses in Stockholm must take place through the rear doors to reduce the exposure of the drivers. Since ticket validation machines are generally installed at the front door, this means that ticket validations on buses have dropped to almost zero. It is therefore not possible to assess the effects of Covid-19 on bus ridership, and we generally exclude buses in the analysis.

2.2 Västra Götaland

Public transport services in Västra Götaland Region are provided by Västtrafik. Services are provided through buses, trams, trains and ferries. Before COVID-19 around 450 thousand travellers used the system and around 950 thousand trips were made per day. The data used in this study comes from two different sources: The daily number of trips per transport mode is based on automatic passenger counting (APC) sensors at the vehicle doors. These sensors are available for a subset of the vehicle fleet and the number have been scaled up to be representative of the entire fleet. These data contain all transport modes except the ferries. As for Stockholm, data are available from 1 February 2020 to 31 May 2020 and the same time period the previous year. Unlike Stockholm, passenger load data for buses are available also during COVID-19.

Data are also available on the daily number of sold tickets for different ticket categories and, for some categories, the total daily sales revenue. It should be noted that there is a difference between the tickets
used a particular day, which the Stockholm data contain, and the tickets bought that day. The tickets bought represent the travellers' current assessment of the suitability of different ticket types. Especially for long period tickets (30 days or more), meanwhile, the tickets used include a lag from past ticket purchases.

2.3 Skåne

Skånetrafiken provides public transport services with buses and trains in Skåne Region, the southernmost part of Sweden. Around 465,000 trips were made each day before COVID-19. Tickets can be bought and validated in a number of ways: through an app, a contactless card, paper tickets bought in ticket machines, or directly by credit card. For this study only data from the buses are available. The data contain the daily number of trips in total and for different ticket types (including school and seniors tickets). Data are available from 1 February 2020 to 30 April 2020; for the baseline, data from 1 February 2019 to 31 May 2019 are used as for the other regions.

3 Results

3.1 Ridership per transport mode

Figure 2 shows the number of trips per day for the main public transport modes in Stockholm: metro, commuter trains, trams/LRT and buses. The solid and dashed lines show the daily ridership in 2020 and 2019, respectively. There is a clear weekly cycle in the ridership level for all modes. The ridership levels for the two years started to diverge in the beginning of March. This coincides in time with the Swedish Public Health Agency increasing the risk level of COVID-19 spreading in Sweden from “low” to “moderate” on 2 March. A drastic drop in ridership occurred around 10 March, when the Public Health Agency increased the risk level to “very high”.
Figure 2: Stockholm, daily number of trips in the metro (top left), commuter trains (top right), trams and LRT (bottom left) and buses (bottom right).

Metro and commuter trains show similar trends over time. For both modes a minimum level of ridership can be observed around 10 April. From then until at least 31 May, ridership has increased slowly but consistently. The large decline in tram and LRT trips can be explained in part by less active ticket validation, which to some extent is done manually, to reduce exposure of the crew. Bus ridership is only shown until 16 March, after which boarding through the front doors was prohibited and ticket validations do not represent actual ridership.

Figure 3 shows the number of trips per day in the main public transport modes of Västra Götaland: commuter trains (ca 6 % of all trips in 2019), trams (46 %) and buses (48 %). The solid and dashed lines show the daily ridership in 2020 and 2019, respectively. The three modes show similar patterns over time. Compared to Stockholm, the minimum level was reached at around the same time in early April, followed by a similar moderate recovery.
Figure 3: Västra Götaland, daily number of trips in the trains (top left), trams (top right), and buses (bottom left).

Figure 4 shows the ridership relative to the baseline level represented by the previous year for Stockholm (left) and Västra Götaland (right). In Stockholm, ridership for both metro and commuter trains fell around 60% mid-March and has remained at a similar level until end of May. The smaller decrease for commuter trains compared to metro may reflect that long-distance travellers, which dominate on the trains, have fewer alternatives and are more captive to public transport. Until 17 March, when ticket validation data ceased, bus ridership followed a curve close to those for metro and trains.
Figure 4: Daily relative change in number of trips from 2019 to 2020. Stockholm (left) and Västra Götaland (right).

In Västra Götaland, ridership on trains decreased around 60%, similar to Stockholm. The decrease for trams was somewhat smaller, around 40-50%. The smallest decrease, around 30%, occurred on the buses.

3.2 Active travellers and trips per traveller

Figure 5 shows the daily total number of active smartcards and the daily average number of trips per active card (bus trips excluded) in Stockholm. The solid and dashed lines show the numbers for 2020 and 2019, respectively. The daily number of active cards dropped from the normal level of ca. 650,000 on weekdays pre-COVID to ca. 200,000 post-COVID. Compared to the baseline of the previous year the decrease is ca. 60%. The average daily number of trips per active card on weekdays dropped from 2.25 to 2.1. The change relative to the previous year is around 5%. Thus, the major part of the reduced ridership comes from fewer active travellers. This is intuitive since public transport is typically used to travel both to and from a location (in particular, the daily commute). Hence, it is difficult to reduce the average daily number of trips per traveller below 2.
Figure 5: Stockholm, daily number of active cards and daily average number of trips per active card, in absolute numbers (left) and relative to the baseline (right). Bus trips are excluded.

3.3 Ridership per ticket type

Figure 6 shows the daily number of trips per ticket type in Stockholm: 30-day, 90-day, and 1-year period cards, short period cars (7 days and less), and single trips and travel funds. Only full fare tickets are included. The majority of trips are carried out with 30-day period cards, which are common among commuters and other daily public transport users. Relative to the baseline from the previous year, single tickets and travel funds increased substantially between mid-March and end of May. The 1-year ticket cards also increased during this period. Meanwhile, the relative change for 30-day cards remained more or less constant while the 90-day period cards continued to decrease. This indicates that the moderate increase in overall ridership that occurred during this period can be attributed to passengers travelling with single tickets or travel funds, and with yearly cards. The former ticket category may be the option for occasional travellers, while the latter may be an option for captive public transport users. Travel with short period cards has dropped to almost zero. This may be an effect of the national and international travel restrictions that more or less stopped travel for tourism and business.
Figure 6: Stockholm, daily number of trips per ticket type in absolute values (left) and relative to the baseline (right), full fare tickets only. Bus trips are excluded.

Figure 7 shows the daily ticket sales amount in Västra Götaland divided into three categories: single tickets and travel funds, short period tickets (from 90 minutes to 14 days) and long period tickets (from 30 days to one year). The patterns are similar to Stockholm: single trip tickets and travel funds increased steadily between mid-March and end of May. Sales of short period tickets all but stopped but have also seen a moderate return. A weekly recurring pattern can be observed for both short and long period tickets, and sales of long period cards display a large variability between days. However, no clear increase or decrease can be observed from mid-March and onward.

3.4 Ridership among school children, youths and seniors

In Stockholm, reduced fare tickets can be purchased by seniors, students or youths. Youths also have the opportunity to purchase extra subsidized youth and school tickets. Figure 8 shows the daily
number of trips in Stockholm with discounted fare tickets of different types: single trip tickets and travel funds, short period cards (7 days and shorter), long period cards (30 days and longer), and youth and school tickets. The patterns for the first three categories are similar to the full fare counterparts (compare Figure 6): Single tickets and funds decreased around 60 % but has since bounced back to some extent. Long period cards dropped more than 70 % and remained at that level until end of May, while short period tickets dropped more than 80 %. Youth and school tickets dropped by at most around 60 % but had recovered to around 50 % of the baseline by end of May.

Figure 8: Stockholm, daily number of trips per ticket type in absolute values (left) and relative to the baseline (right), reduced fare tickets only. Bus trips are excluded.

3.5 Total ridership per region

Figure 9 shows the relative change in the total daily number of trips for the three regions Stockholm, Västra Götaland and Skåne. For Stockholm bus trips have been excluded. For Skåne the data only reaches 30 April. In all regions the ridership dropped around the same time, but at different rates. Stockholm and Skåne experienced dramatic drops in ridership the first days and reached reductions of around 60 %. Västra Götaland had a slower decline and reached a maximum loss of ca. 40 %.
Figure 9: All regions, daily number of trips, relative change from the baseline. Data from Skåne only available until 30 April 2020.

As comparison to the results above, Figure 10 shows indicators of public transport use as reported by Google and Apple based on mobile devices located near public transport stations and travel planner use respectively. Both data sources are proxies for the actual public transport ridership. In the latter case, data are available at the city level and not the regional level. Hence, we show data for the largest city in each region: Stockholm, Gothenburg and Malmö, respectively. The proxies agree with the ridership data in some aspects: the rapid decline in mid-March and the subsequent recovery are captured, and the fact that Stockholm suffer the largest reduction. However, both proxy indicators appear to underestimate the reduction in ridership, in particular for Stockholm. Furthermore, both proxies indicate a stronger recovery in ridership during April and May than what can be observed from actual ticket validations and boarding counts.

Figure 10: Left: Mobility activity at public transport stations. Source: Google COVID-19 Community Activity Reports, https://www.google.com/covid19/mobility/ (accessed 30 June 2020). Right: Public transport travel...
planner search activity. Source: Apple Mobility Trends, https://www.apple.com/covid19/mobility (accessed 30 June 2020).

3.6 Comparison with other modes

The public transport ridership may also be compared to other modes of transport. Figure 11 shows the evolution of bike flows, pedestrian flows and motorized road traffic in Stockholm city based on stationary sensors and the congestion charging system. Bike and pedestrian flows are available per week for both 2019 and 2020 and are divided into the inner city and the outer city, and into weekdays and weekends. Motorized road traffic flows are available for the congestion charging cordon around the inner city and for the motorway Essingeleden passing through the city. Here, baseline values from 2019 were not available.

Figure 11: Stockholm city, weekly relative change in bike flows (top left) and pedestrian flows (top left), daily number of motorized road vehicles (bottom). Source: City of Stockholm, http://miljobarometern.stockholm.se/trafik/covid-19/ (accessed 1 July 2020).
Bike flows show no clear decline during COVID-19 compared to the previous year. In fact, biking increased in the outer city on both weekdays and weekends. However, this trend appears to have started already before the pandemic outbreak. It should be noted that bike flows are dependent on temperature and other weather conditions. Pedestrian flows remained stable in the outer city, but a significant drop occurred in the inner city. The magnitude of the decline reached 60% at most, which is on par with the public transport ridership. Road traffic flows, finally, dropped somewhat at the onset of the closedown but have since recovered to the same levels as before.

4 Discussion and conclusions

This paper has examined the effects of COVID-19 on public transport ridership in the three largest regions of Sweden based on ticket validation, ticket sales and passenger counting data. The public transport systems in the three regions differ from each other: for example, trams are only operated in Stockholm and Västra Götaland, and metro only in Stockholm. Further, the data from the three regions differ in terms of coverage and collection method. Hence, the comparison between regions must be done with some care. On the other hand, the data sets complement each other and allow for a broader set of questions to be addressed.

The data from Stockholm shows that the reduction in ridership stems primarily from a reduction in the number of active public transport travellers. The daily average number of trips per active traveller decreased from 2.25 to 2.1, and it is difficult to reduce the daily use much further. While the data do not allow a comparative analysis, we expect that this holds true also in the other regions.

Regarding ticket types, data from both Stockholm and Västra Götaland show that travellers switched from 30-day period tickets to single tickets and travel funds, while the use and the sales of short period tickets, used predominantly by tourists and other short-term visitors, dropped to almost zero. Data from Stockholm also reveal that 1-year period tickets and school tickets increased from mid-April, which could indicate that the travellers using these tickets are particularly captive to the public transport system.

The results are inconclusive when it comes to the impact for different transport modes. In Stockholm, ridership declined similarly for metro, trains and, until ticket validation data ceased, buses. The larger decrease for trams and LRT may be partly attributed to lower ticket validation activity. In Västra...
Götaland, the decline is strongest for trains and weakest for buses. A deeper analysis is required to assess whether these differences between regions can be attributed to demographic differences among the public transport travellers using different modes.

Comparison with other transport modes in Stockholm shows that public transport ridership has been hit particularly severely; only pedestrian flows in the inner city reached similar low levels compared to previous year. The shift from public transport to private cars and to some extent bikes is in line with existing evidence (e.g., Molloy et al., 2020; WSP, 2020).

Of the three regions, Stockholm was hit the hardest by COVID-19 cases between March and May 2020. The analysis shows that it was also in Stockholm where the decrease in public ridership was the largest (ca 60 %). The smallest decrease occurred in Västra Götaland (ca. 40 %). From mid-April, ridership in both Stockholm and Västra Götaland compared to last year’s baseline slowly but steadily increased. It is notable that the number of reported COVID-19 cases in Västra Götaland increased sharply in June 2020 (not shown here) and exceeded the number of cases per capita in Stockholm by the end of June. Whether these facts are connected is beyond the scope and ability of this study to address.

International comparisons of COVID-19 mobility impacts have so far been based on data from mobility service providers such as Google, Apple and Moovit (e.g, Tirachini and Cats, 2020). However, our analysis indicates that proxy indicators based on human proximity to public transport stations and travel planner queries have overestimated the recovery of public transport ridership during the months following the outbreak. Hence, collaborative effort is required to put the results here, which are based on actual ridership data, in the international context.

Tirachini and Cats (2020) outline a number of urgent issues and important directions for research in order to cope with the ongoing crisis while continuing the development towards a sustainable transport system. As the pandemic develops, the analysis of how people adjust their mobility behaviour must continue in order to understand both the trends at the societal level and the mechanisms at the individual level. Central to the analysis and research will be the question: can public transport ridership recoup and exceed the levels pre-COVID, and what actions are required in terms of policy, infrastructure, technology, service planning, operations, real-time control etc. to get there?
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