

Journal Pre-proofs

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PII: S2590-1982(21)00055-5
DOI: <https://doi.org/10.1016/j.trip.2021.100348>
Reference: TRIP 100348

To appear in: *Transportation Research Interdisciplinary Perspectives*

Received Date: 29 December 2020
Revised Date: 16 February 2021
Accepted Date: 10 March 2021

Please cite this article as: H. Tiikkaja, R. Viri, The effects of COVID-19 epidemic on public transport ridership and frequencies. A case study from Tampere, Finland, *Transportation Research Interdisciplinary Perspectives* (2021), doi: <https://doi.org/10.1016/j.trip.2021.100348>

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The effects of COVID-19 epidemic on public transport ridership and frequencies. A case study from Tampere, Finland

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ABSTRACT

The COVID-19 epidemic has created unforeseen effects in public transport in cities around the world, including Tampere, where a 70% decrease in the number of passengers occurred in spring 2020. The purpose of this paper is to study changes in public transport ridership, frequencies, and average fill rates during the epidemic in May 2020 compared to normal circumstances in January 2020 using map-based analysis. We used data provided by Tampere regional transport to create the public transport network and to assess the frequencies, ridership and average fill rates in different areas of Tampere. The paper presents the method used to analyze how the modified frequencies meet the decreased demand of public transport in Tampere. These results indicate that the decrease in ridership was great in almost all areas, except some eastern parts of Tampere. The frequencies were decreased in all areas but kept at a sufficient level. When analyzing fill rates, we found that the bus lines coming from east of Tampere were more crowded on average during the COVID-19 epidemic in May compared to January. In other areas, fill rates were lower. The results suggest that in Tampere, frequencies were mostly managed to maintain at a sufficient service level. However, the analyses also reveal that frequencies were not adjusted successfully in all areas with high fill rates in some routes. It is important to notice, that the public transport planners were facing a deviant situation with COVID-19 and that in future, there will be more information to help decision-making.

KEYWORDS: COVID-19, public transport, frequency, ridership, fill rate

1. Introduction

The worldwide COVID-19 epidemic has created unforeseen effects in transport and travel behavior. In Tampere, which is the third largest city in Finland with approximately 238,000 inhabitants (Statistics Finland 2020), there was a 70% decrease in the number of passengers (Tampere 2020) during the COVID-19 epidemic in spring 2020 due to schools being closed and recommended remote work. Thus, public transport frequencies had to be adjusted to meet the decreased public transport ridership due to financial reasons. It is important to evaluate how the decreased public transport frequencies have affected the accessibility to city center in different areas and if some areas have suffered from the decreased frequencies more. In the future, the analyses presented in this paper may provide knowledge about how to adapt supply with changing demand, especially when planning new transport services, such as MaaS or demand responsive transport.

Since public transport is important for everyday travel, it can't be completely shut down even during very deviant situations such as COVID-19. However, due to financial issues it is not possible to operate public transport at a normal level if there is a significant decrease in ridership. Thus, a balance between decreased ridership and sufficient frequencies should be found. There has never been data available from such a deviant situation in Tampere, even though there are changes in public transport frequencies during summertime. However, the decrease in ridership during summer is predictable every year, whereas the situation with COVID-19 was more abrupt. Never before has there been data available from such rapid and unpredictable changes in public transport ridership and adjusting frequencies accordingly. There is a gap in knowledge as to how the decrease in ridership and frequencies can be balanced in such a short period of time, which this paper will address.

In this paper, we will focus on public transport oriented towards city center, and the bus lines between suburbs are not included in the analysis. The research questions we seek to answer in this paper are (Figure 1):

- 1) How did the PT ridership change in Tampere during epidemic in different areas and routes and did the changes in ridership apply to whole region and routes evenly or to some areas or routes in particular?
- 2) How did the PT frequencies change in Tampere during the epidemic in different areas and routes and did the changes in frequencies apply to whole region and routes evenly or to some areas or routes in particular?
- 3) How did the average PT fill rates change in Tampere during the epidemic and did the changes in fill rates apply to whole region and routes evenly or to some areas or routes in particular?

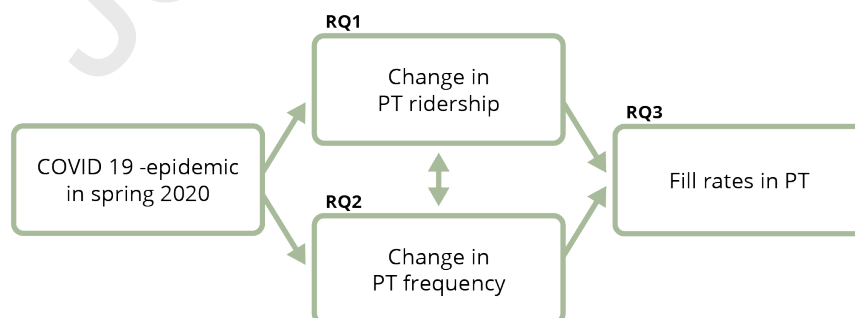


Figure 1. The study design and research questions.

In Finland, during the COVID-19 epidemic in spring 2020, a need for lower public transport frequencies was identified to meet the lower public transport ridership. According to Chen et al. (2018), social equity in transport supply can be measured by exploring the relationship between transport supply and demand from spatial context. According to Jenelius and Cebecauer (2020), it is important to assess the first months of the pandemic in order to guide policy during the continuation of the pandemic as well as potential future states of emergency. This paper will provide new knowledge about how public transport frequencies were adjusted to meet the lower demand in different areas of Tampere during the COVID-19 epidemic and about the accessibility of city center during the decreased PT frequencies. The results can be used to evaluate how the public transport planners succeeded in their efforts to adapt the frequencies according to lower ridership without reducing accessibility to city center. The results presented in this paper also provide information that can be used when planning actions for special circumstances in the future.

This paper is organized as follows. First, we present the material and methods used in the analyses. Second, we provide background for the research and the analyses. Then we present the results and finish the paper with discussion and conclusions on the findings.

2. Material and methods

We created a map-based public transport network of bus routes, stops, and timetables, and generated a picture of the public transport network during the decreased frequencies in May 2020 and during normal schedule in January 2020 in order to evaluate public transport frequency across the network. We chose these time periods because in January 2020 public transport was still operating normally and there were no restrictions related to COVID-19 epidemic yet. May was selected for the comparison period since the extensive COVID-19 restrictions had taken place and travel habits had been adjusted to new restrictions. We wanted to evaluate how the first actions in adjusting public transport frequencies succeeded in regards to meeting the needs of decreased ridership. After spring 2020, there has not been a need to decrease public frequencies more due to COVID-19, and thus data from spring 2020 is used to evaluate if the adjustments made were successful.

For the analyses, we used open data provided by Tampere regional transport (ITS Factory 2020). A GTFS-dataset containing the routes, lines and schedules for both January 2020 and May 2020 were obtained. Since we were interested on the accessibility towards city center, we used the data to calculate, how many departures there were towards city center on a regular Tuesday. The specific lookup dates used were 14th January 2020 and 26th May 2020. We defined the stops of city center by limiting the area using coordinates. The area and stops marked as center can be seen in Figure 2 below. The main stops in the city center are hosted in the middle of the given area, and even though part of the stops on the north-east corner of the area fall on different sides of our filter, they do not matter into our analysis, since buses on those stops will also use stops that are within the area, thus giving the line a correct indication of its direction in further analysis.

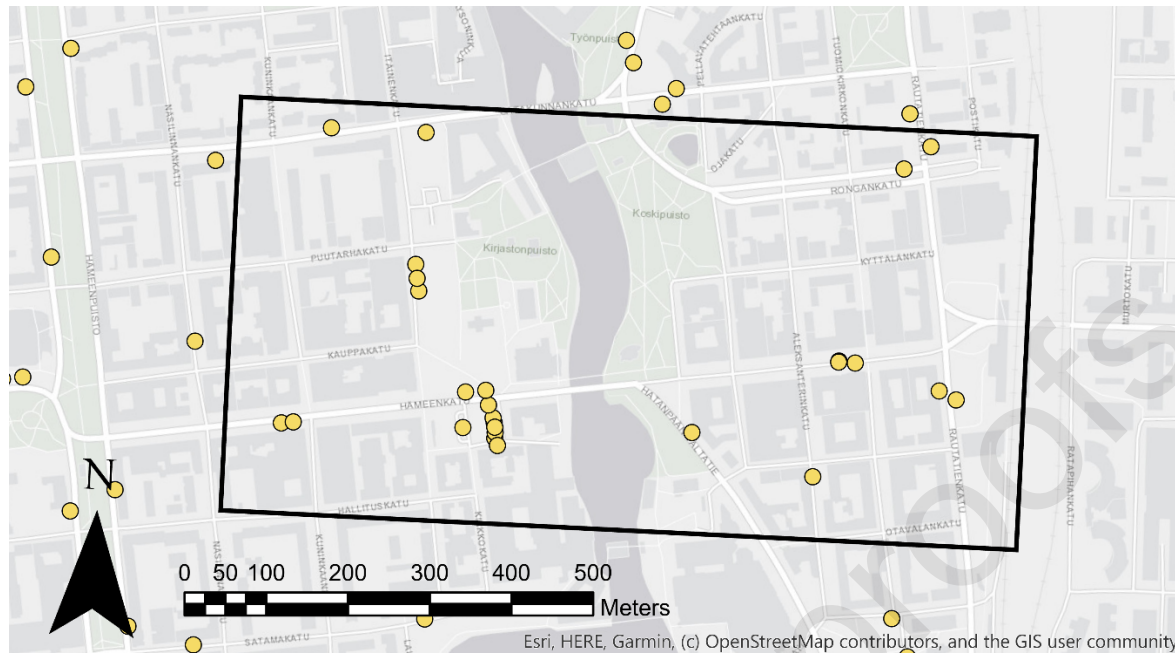


Figure 2. City center area limited by coordinates, stops inside the bordered area are marked as center stops.

Based on knowing the routes and these city center stops, we calculated every departure from every stop that took place between 6 AM and 10 AM and headed towards (at least) one of the city center stops. Trips arriving from city center or never visiting city center were not calculated. By using this approach, we knew, how many departures were made around the region towards the center on both regular schedule (January 2020, $n=20\ 719$) and schedules affected by COVID-19 (May 2020, $n=16\ 137$).

For changes in public transport ridership, we obtained passenger statistics for two weeks from Tampere regional transport. We have data from 13th to 19th January and 25th to 31st May 2020 containing hourly count of passengers per line and departure stop. We used the data from Tuesday to Thursday and calculated the average passenger count per line and departure stop, limited to same timeframe, lines and departure stops used in the public transport frequency analysis. The total count of passengers with these filters were 1 378 556 for January 2020 and 466 445 for May 2020. This method allowed us to gain information about the change of both frequency and ridership, and we can analyze whether they affect each other. The study design, data and analyses are presented in Figure 3.

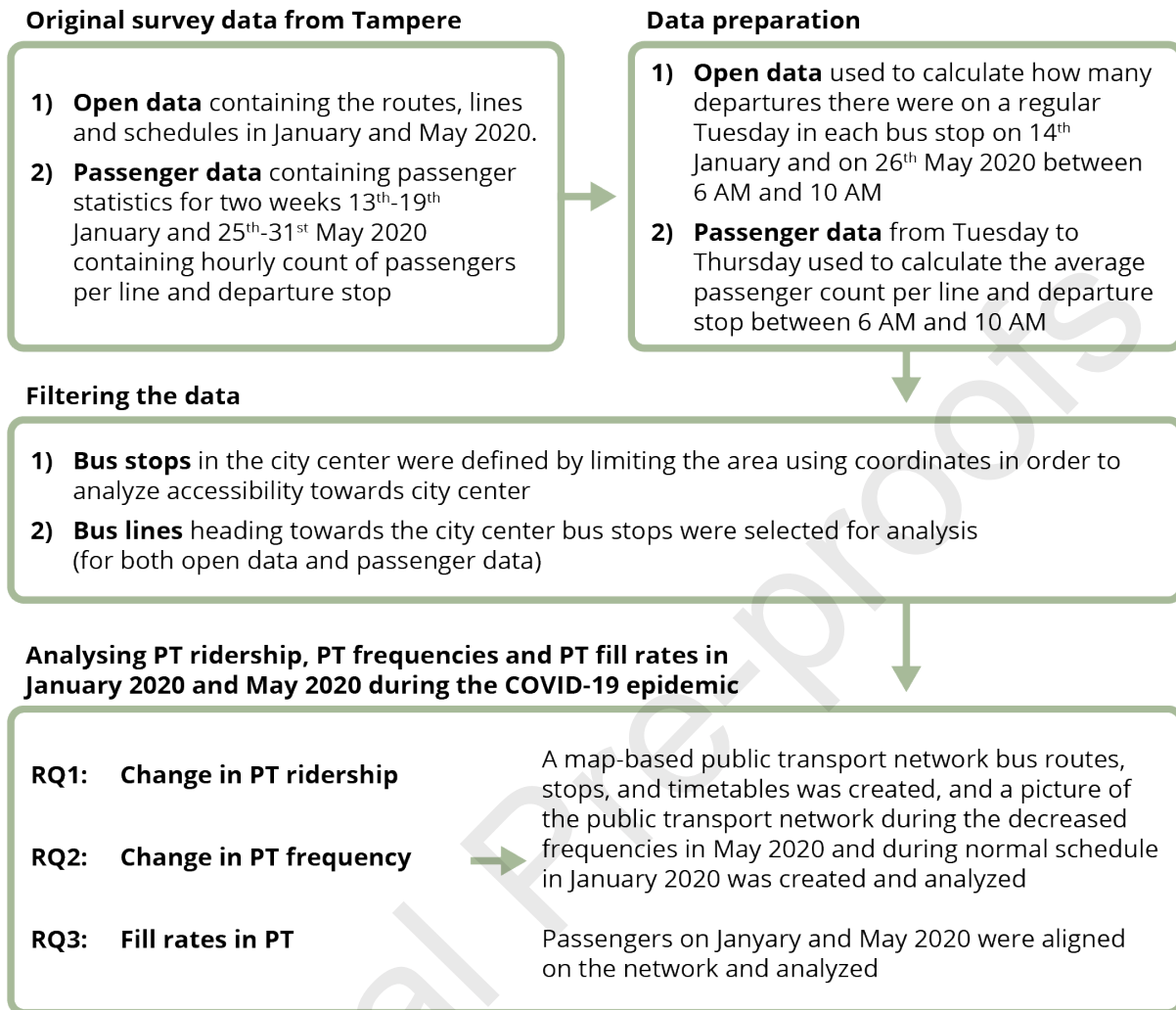


Figure 3. Study design, data, and analyses.

3. Background

Significant decrease in public transport use has been reported in many countries during the COVID-19 epidemic (Aloi et al. 2020; Beck & Hensher 2020; Bucksy 2020; Budd & Ison 2020; De Vos 2020; Jenelius & Cebecauer 2020; Teixeira & Lopes 2020). In Tampere (Finland), public transport system consists of comprehensive bus network, and a tram line is being built to meet the public transport demand. In March 2020, Tampere was forced to decrease public transport frequencies due to a 70% decrease in the number of passengers. Most of the bus lines that served mainly school children were cancelled, and other bus lines were re-scheduled gradually during the spring. (Tampere 2020)

In public transport, latent demand described as the activities and travel that are desired but unrealized because of constraints, can be due to insufficient spatial or temporal coverage of origins and destinations, poor service levels such as low frequencies, slow speeds or connectivity gaps (Curtis et al. 2019). According to De Vos (2020), the COVID-19 epidemic may result in a situation where people avoid using public transport since it is viewed unsafe. According to Dong et al. (2020), COVID-19 has caused concerns about the safety of public

transport, since people have to be close to each other buses can be poorly ventilated. If avoiding public transport is not an option, people might try to avoid peak-hours, which might be difficult if the public transport capacity or frequency is decreased (De Vos 2020). Iio et al. (2020) found a disparity among income brackets in travel distances in Houston during COVID-19, with larger mobility reductions among higher per-capita income groups. It might be likely that people with lower income did not or could not reduce their mobility as much as people with higher income during the COVID-19 pandemic due to having a higher probability of being an essential workers with no opportunity to work remotely. (Iio et al. 2020)

Jenelius and Cebecauer (2020) state, that the decline of public transport ridership observed during COVID-19 spring may be due to both restrictions set by authorities as well as travellers' own choices. In case of the COVID-19 epidemic in Tampere, decreased public transport ridership might result from a combination of remote work, closed schools and fear, but if the lower frequencies in public transport were continued for long, lower number of passengers may have partially resulted from latent demand related to poor service level.

According to Sasidharan et al. (2020), there is a controversial debate in the COVID-19 epidemic on the potential benefits of mobility reductions and social-distancing attained by closing the public transport systems. From a policy perspective, a trade-off between potential health benefits and socio-economic impacts of reducing mobility needs to be achieved. (Sasidharan et al. 2020) In urban environments, public transport plays a central role in the accessibility levels (Guzman & Oviedo 2018). Hernandez (2018) describes accessibility as a resource required to obtain new resources, and argues that accessibility and mobility must be seen as assets that should be protected for all the citizens (Hernandez 2018). This should be recognized during the COVID-19 epidemic, and mobility and accessibility should be ensured during the special circumstances. If public transport can no longer serve mobility needs in urban environments, this could lead to forced car ownership in areas, where car is not normally considered as a necessity. According to De Vos (2020), during the COVID-19 epidemic out-of-home activities may become inaccessible for those who do not own a car if public transport supply is decreased. This might lead to lower well-being. De Vos (2020) encourages public transport operators not to reduce public transport supply as a result from low ridership. Governments should temporarily support public transport operators in maintaining a certain level of public transport supply. (De Vos 2020)

According to Basso et al. (2020), besides accessibility to certain locations, accessibility measures in public transport should also consider time as a critical element. They argue that shorter travel times translate into well-being. (Basso et al. 2020) Decreased public transport frequencies may result in increased waiting times and the need to take an earlier bus since there are no suitable alternatives later. Meng et al. (2018) argue that travel time is one of the key elements that affects passengers' opinions about the public transport quality and that the total travel time includes all supplementary travel times between the origin and destination, such as waiting time. Waiting time is often perceived longer than it actually is, and passengers tend to consider in-vehicle time more acceptable compared to out-of-vehicle time. (Meng et al. 2018) Low public transport frequencies may increase waiting times and thus, increase the time needed for travel among the people who don't have the option to use car for their trips. It is important to protect the mobility of the people with no car by ensuring acceptable levels of public transport frequencies even during special circumstances, such as the COVID-19-epidemic.

According to Beck et al. (2020), when COVID-19 restrictions are relaxed, an increase in commuting trips by car can be expected in Australia. Also Hensher et al. (2020) suggest that if people start commuting only few days a week compared to five days a week, a greater use of

car can be expected due to commuters being more prepared to put up with congestion and parking costs. This would have an effect on arranging public transport and rethinking the structure of fares. (Hensher et al. 2020) To restore trust in public transport safety after COVID-19 epidemic, Dong et al. (2020) highlight the importance of providing timely, accurate, and abundant information to the passengers. Public transport operators should monitor public opinions to transmit effective messages on safety to the passengers. The public transport operations should also be adjusted in terms of increasing frequencies and providing spacious stations to avoid crowding. (Dong et al. 2020) According to Chen and Pan (2020), related to COVID-10 pandemic, it is important to discuss more about avoiding contact between people and maximizing the transport service function of public transport vehicles.

4. Results

4.1 Changes in PT ridership (RQ1)

The first research question was, how did the PT ridership change in Tampere during the epidemic in different areas and routes, and did the changes in ridership apply to whole region and routes evenly or to some areas or routes in particular? We used public transport passenger data from Tampere regional transport to analyze changes in PT ridership by creating a PT ridership ratio (1).

$$PT\ ridership\ ratio_{grid\ cell\ y} = \frac{Passengers\ in\ May\ 2020_{grid\ cell\ y}}{Passengers\ in\ January\ 2020_{grid\ cell\ y}} \quad (1)$$

We calculated the PT ridership ratios to grid cells using the total amount of passengers boarding towards center in stops within that grid cell to analyze the public transport ridership in different areas (Figure 4). The lower the ratio, the greater the decrease in ridership has been. As presented in Figure 4, the decrease in PT ridership has been dramatic in many areas, and in most areas, there were less than half of the passengers in May compared to January. However, the passengers travelling from east have not suffered such decrease in PT ridership. In the city center, the decrease in the number of passengers was the most dramatic. In many grid cells close around the city center, there were less than 15% of the passengers in May compared to January. However, these passengers may be incorrectly counted as they are travelling towards center, even though they would travel to a more remote locations but the line travels through center after the passengers have boarded. In the transport system in Tampere region, the boarding can only be allocated to check-in, as no check-out information is collected, and therefore not available.

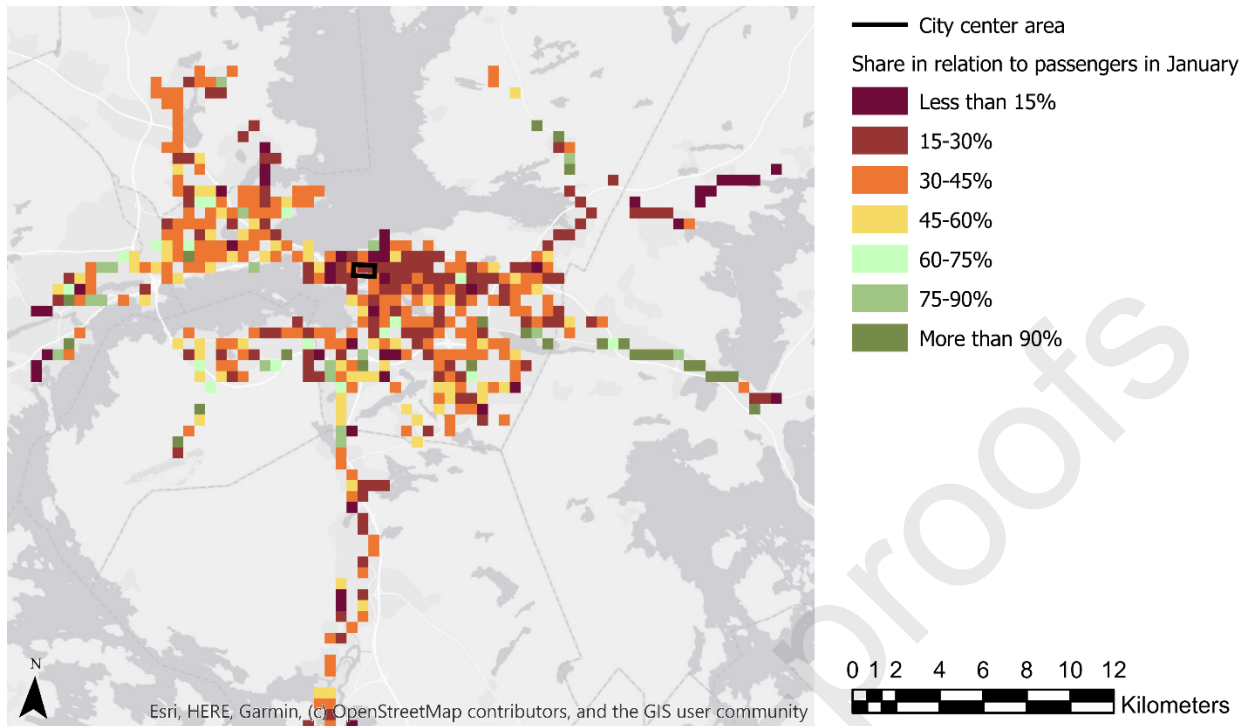


Figure 4. Passengers in May 2020 compared to passengers in January 2020 per grid cell.

4.2 Changes in PT frequencies (RQ2)

The second research question was, how did the PT frequencies change in Tampere during the epidemic in different areas and routes, and did the changes in frequencies apply to whole region and routes evenly or to some areas or routes in particular? Comparing the decreased frequencies in May 2020 with the normal schedule in January 2020, we calculated frequency ratio accordingly (2).

$$Frequency\ ratio_{grid\ cell\ y} = \frac{Frequency\ in\ May\ 2020_{grid\ cell\ y}}{Frequency\ in\ January\ 2020_{grid\ cell\ y}} \quad (2)$$

We calculated the frequency ratios from total departures towards city center in stops within the grid cells to analyze public transport frequencies in different areas (Figure 5). The lower the ratio, the more the PT frequencies have decreased. This also means, that waiting times have increased compared to the normal schedule in the grid cells with lower ratio. As presented in Figure 5, public transport frequencies during May were 75 % or higher when compared to the normal schedule in most areas. However, it can be seen that in the bus routes from east or northeast, the frequency ratio has been lower than in many other areas in general. Near city center and on the larger roads the frequency ratio was higher since there were several different bus lines that operate on the same routes. This means, that even though journeys on single lines were cancelled, there were still other lines that passed through the grid cell. Further from the center, decrease in frequency had a greater effect on frequency ratio since there was only a single or a few bus lines in use.

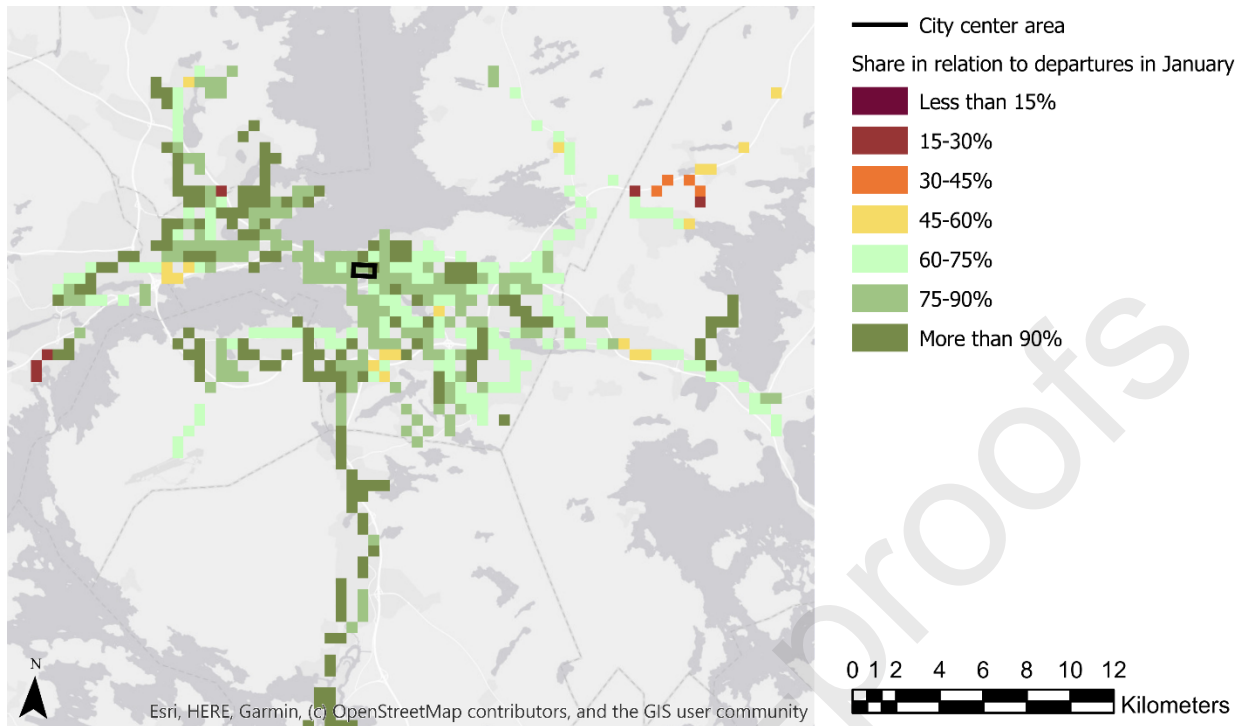


Figure 5. Departures in May 2020 compared to departures in January 2020 per grid cell.

4.3 Changes in average PT fill rates (RQ3)

The third research question was, how did the average PT fill rates change in Tampere during the epidemic, and did the changes in fill rates apply to whole region and routes evenly or to some areas or routes in particular? We used the frequency data and the passenger data to calculate average fill rate in each grid cell and then compared the fill rates of May and January 2020 to create a fill ratio for grid cells (3).

$$Fill\ ratio_{grid\ cell\ y} = \frac{(Passengers / Frequency)_{grid\ cell\ y, May\ 2020}}{(Passengers / Frequency)_{grid\ cell\ y, January\ 2020}} \quad (3)$$

The lower the ratio, the fewer passengers there were in each bus on average in May compared to January computationally. We do not actually know if the passengers were distributed unevenly in the buses with some buses being crowded and some travelling with only few passengers, since based on our data, we could only link the passengers in a certain hour of a certain bus line instead of a certain specific journey. If the fill rate ratio is greater than 1, it means that, in average, there were more passengers per bus in May compared to January. As we can see from Figure 6, the average fill rate in May has been mostly 75% or less compared to January, but in east and in the furthest parts of the bus lines the fill ratio is over 1,5 in many grid cells.

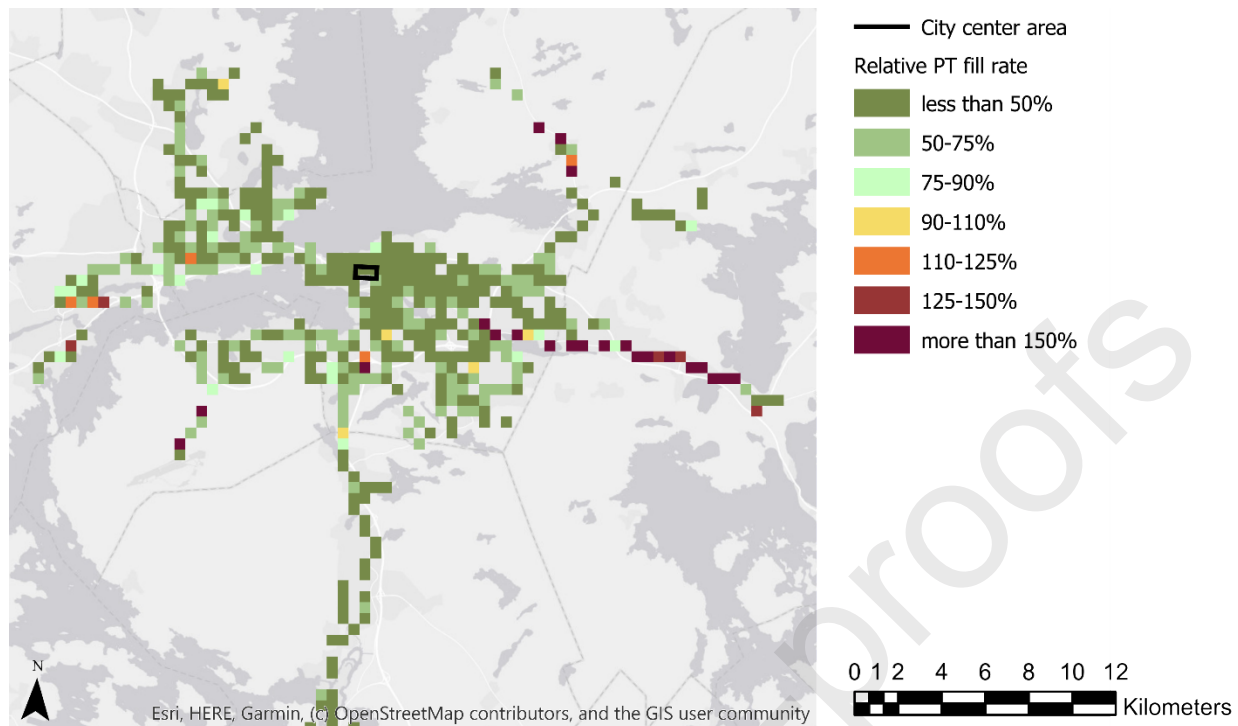


Figure 6. Fill rate of May 2020 in relation to fill rate in January 2020 per grid cell.

5. Discussion

The worldwide COVID-19 epidemic has created unforeseen effects in the use of public transport. In Tampere, public transport frequencies were decreased during the COVID-19 epidemic in spring 2020. The research questions in this paper were: 1) How did the PT ridership change in Tampere during epidemic in different areas and routes, and did the changes in ridership apply to whole region and routes evenly or to some areas or routes in particular? 2) How did the PT frequencies change in Tampere during the epidemic in different areas and routes, and did the changes in frequencies apply to whole region and routes evenly or to some areas or routes in particular? and 3) How did the average PT fill rates change in Tampere during the epidemic, and did the changes in fill rates apply to whole region and routes evenly or to some areas or routes in particular?

For the analyses, we used a GTFS-dataset containing the routes, lines and schedules for both January 2020 and May 2020 and passenger statistics from Tampere regional transport. For RQ1, we found that the PT ridership dramatically decreased in most areas during the COVID-19 epidemic in spring 2020, but the passengers travelling from east did not suffer such a dramatic decrease in PT ridership. A big decrease in ridership had been observed in many countries during the COVID-19 epidemic (Aloi et al. 2020; Beck & Hensher 2020; Bucksy 2020; Budd & Ison 2020; De Vos 2020; Jenelius & Cebecauer 2020; Teixeira & Lopes 2020).

For RQ2, we found that in most areas public transport frequencies were 75 % or higher in May compared to the normal schedule, but that coming from east or northeast, frequencies were lower than in other areas compared to normal schedule. This could be due to the fact that there are only single buses that operate from furthest parts of the area, for which the decrease in frequency in these bus lines reflects strongly on the frequency ratio. De Vos (2020) states that the public transport operators should not reduce public transport supply even though there is a decrease in ridership during COVID-19 epidemic, and that a certain level of public transport

supply should be maintained. In Tampere, the decrease in frequencies was moderate even with such a great decrease in the number of passengers.

For RQ3, we compared the average fill rates in May and January 2020. The average fill rate in May was mostly smaller compared to January, but in eastern bus routes and in the furthest parts of the bus routes the fill rates had increased in May compared to January. The use of public transport could be viewed as unsafe during the COVID-19 epidemic (De Vos 2020). If fill rates in the buses are low, it could increase trust among the passengers that travelling with public transport is safe even during the epidemic.

The results from this paper suggest that in Tampere, PT frequencies were mostly managed to maintain at a level that served sufficiently the decreased number of passengers. However, the analyses also reveal that frequencies were not adjusted successfully in all the bus routes since the bus lines coming from east had higher fill rates in May compared to January, even though it is important for the distances between the passengers to be greater during the epidemic. This suggests that the number of passengers and the fill rates should be carefully analyzed in real time and that adjustments should be made in the bus routes where the fill rates are found to be too large. However, it is worth noticing that people should be able to depend on fixed timetables and that changing the timetable too often affects the predictability and the usability of public transport. Maybe in the future, new transport services such as demand based MaaS (Mobility as a Service) or advanced paratransit could tackle this problem better. The pandemic being a new challenge for public transport, the planners were forced to make decisions fast. In the light of the results from this study, the planners succeeded rather well in this difficult task.

6. Conclusion

Understanding the critical role of public transport in maintaining mobility in cities among the people who don't own a car, it is not possible to fully shut down all public transport even in the time of COVID-19 epidemic. Since politics has promoted the use of public transport and encouraged people to give up cars for long due to environmental issues, responsibility should also be taken to ensure that the ones who have given up cars and started to use sustainable transport modes still have the option to travel even during an epidemic. This is why PT frequencies should not be decreased too much. If travel options are not secured during states of emergency, people might not be willing to give up their cars in future since they cannot trust that public transport will be available if needed. Hopefully soon the society will be able to return to normal after long recommendations for remote work. The situation with COVID-19 has increased the need to learn more about how public transport can be adjusted rapidly in changing circumstances. Perhaps this will also highlight the need for new, flexible transport services, such as MaaS and demand responsive transport in Tampere. These new transport services will need an advanced real-time system for monitoring fill rates and passenger ridership, such as presented by e.g. Pu et al. (2021).

The results presented in this paper apply only to Tampere, and the results can't be generalized elsewhere due to different restrictions regarding COVID-19 and different actions taken in public transport. However, the methods used in this paper can be generalized to any areas with similar data available to create same type of analysis. Nevertheless, there were limitations to this analysis. There was actually no knowledge if the passengers were distributed unevenly in the buses with some buses being crowded and some travelling with only few passengers. For further studies, this type of information would be available, and it could be used to better estimate the fill rates of the buses. However, since there is no check-out procedure in Tampere, an actual fill rate cannot be calculated, as we do not know when people disembark the bus.

Some cities' transport systems however also collect this data, and in those cities, the same kind of methods could be used to better estimate the changes of fill rates. Same applies also to direction of passengers. We looked for passengers towards city center, but some of these passengers may use the same line to go into a remote area but the line just travels through the city. This could also be addressed if there would be data about disembarks.

In future, it would be interesting to study how people adjusted their travel during the epidemic, how many public transport trips were not made at all and how many trips were made with a different mode instead of public transport. Analyzing bus card data could provide knowledge about which groups continued using public transport and which groups stopped using public transport during the COVID-19 epidemic in spring 2020.

Acknowledgements

The authors would like to thank Tampere regional transport for providing the data used in the analyses. This work was supported by Kone Foundation (grant number b4b919)

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Author contributions

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Highlights

- Map-based analysis was used to study changes in public transport during COVID-19.
- Great decrease in public transport ridership was observed in most parts of Tampere.
- Public transport frequencies were decreased but maintained at a sufficient level.
- Fill rates were smaller in other parts of Tampere except eastern bus routes.