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Tram Expansion Effects on Reaching the City Centres—Case Study of Tampere and Braunschweig

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Abstract: This manuscript is based on cooperation between the universities in Tampere, Finland and Braunschweig, Germany. New tram lines are being built or extended in both cities to provide better connections to public transportation and increase accessibility. This research presents case studies from each city that have successfully increased public transport (PT) ridership during recent years. The aim of this study is to compare and analyse the effects of tram expansion projects in Tampere and Braunschweig from the public transport network users' viewpoint. These cities were selected because they are of similar size in terms of population and have similar modal shares of PT. Changes in accessibility to the city centres were analysed considering the tramline extensions. This was determined by calculating the travel time differences of the current network and the future network for both cities. For this total travel time, the ArcGIS Pro Service Area Tool was used to calculate the time taken to reach every grid of the investigation areas. The results vary due to the tram expansion and changes in the existing bus network.

Keywords: public transport; case study; tram; expansion; accessibility

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1. Introduction

In rural areas, people are usually not well connected by public transport (PT) and are therefore often dependent on their cars for daily migrations. Here, up to 70% of all trips are made by personal car. In the metropolitan areas, PT, bicycling and walking are increasingly common. Although people in large cities drive fewer cars than those in rural areas, car use can also be high because many people within the cities are poorly connected by PT. On average, metropolis residents travel 14 km, and residents of small towns travel 26 km per day by car [1,2].

In cities, CO_2 emissions are rising sharply due to urbanisation, and daily life is characterised by housing shortages, an increased number of cars, parking bottlenecks and other negative consequences [3]. The demand for urban transport grows with the urban population. The traffic problem caused by urbanisation cannot be solved by digitalisation and automation alone [4]. Providing mobility through a well-developed and reliable PT system is particularly important to encourage people to switch from their own cars to PT [3].

As PT is different in every country and city and its quality characteristics are different, it is difficult to compare cities by PT's Quality of Service, which is split into qualitative and quantitative features. Qualitative features include comfort, staff behaviour and safety, which are based on opinions or experiences that are typically evaluated with passenger surveys. Quantitative features include the level of service in terms of frequency, operating span, ride time, or walking distance to a stop, which can be measured directly [4,5].

This research presents a case study of two cities, Tampere (Finland) and Braunschweig (Germany), which have successfully increased PT ridership during recent years. They are of similar size in terms of population and have a similar modal share of PT. The aim is to analyse and compare the effects of the tram network's expansion projects from the tram passenger's viewpoint i.e., how passenger accessibility changes when a part of the PT network is modified. The accessibility of the two city centres is analysed by modelling the travel time taken to reach the city centre from other areas.

The central city area is comparable in both cities, as both work and leisure destinations are located there, and both networks are mainly built around these areas as a hub. As a hypothesis, it is expected that, even though the tram extensions will reduce the time taken to reach the city centres within the tram corridors, there may be areas that will have a reduction in their Quality of Service, as the tram extensions may also remove some existing direct bus lines and replace them with connecting lines to the tram network, thus, causing transfers and, therefore, increasing the travel time.

2. Theoretical Background

For the theoretical background, it is necessary to analyse how to compare the PT in different cities. Two cities with the same population, area size and number of stops can still have very different access to PT. As already mentioned, PT in Tampere and Braunschweig will be provided by buses and trams. Some bus lines will be discontinued as they are replaced by new tram lines [6].

As, in both analysed cities, individual bus lines will be replaced by the tram, it is important to present the advantages of a tram over bus. The two main advantages are the capacity and speed. The speed varies depending on whether the tram is on in-street, segregated, or operates on an independent track formations. The average speed of the tram and bus on in-street track formations is nearly the same—between 15–20 km/h. If the tram runs on segregated or independent track formations, the speed is higher than the speed of a bus. These two track formations also increase the punctuality of the tram because the independent tram is not at all affected by other road users and segregated trams are affected by other road users only at crossings and intersections.

As a result, the tram is not stuck in traffic jams and often has priority at intersections, increasing the average speed. Depending on the type of vehicle, the capacity of a tram is between 1000 and 3000 passengers per hour, and a bus can carry about 300 to 600 passengers per hour [7,8]. Another advantage of the tram is the psychological rail bonus stating higher attractiveness and resulting in a higher number of passengers for rail-bound PT compared to buses [9,10]. Due to this fact, it is possible that more people are willing to change from their own car to PT if they are connected by a tram, compared to a bus connection.

Another important factor for PT usage is the amount of transfers. Schnieder (2015) examined transfers in PT [11] and found that transfers are perceived as a barrier to the use of PT. However, it has been shown that travel time is more important to commuters than transferring and wait time while transferring. Therefore, it is important to provide passengers a wide range of destination choices when they have to transfer. This should be as convenient, comfortable, safe and fast as possible to increase the number of PT users. Therefore, appropriate information is needed to make connections easy and convenient [11].

Therefore, this paper will analyse to what extent the quality of PT, as measured by time taken to complete the journey, changes when there are more tram lines in the network.

In the past, other studies have compared PT services in different cities from different viewpoints, such as the perceived satisfaction with the PT service [12] or the PT experience [13]. These studies tend to present subjective views, whereas fewer studies use objective approaches—for example, by comparing the relationship between urban structure and the level of service in several cities in Japan, France and Germany [14].

According to [14], the population density in all three countries rose with increasing proximity to PT stations. Furthermore, there are 37 cities in Germany where 40% of the population lives within a radius of 500 m from railway and tramway stations, whereas there are only two cities in France and none in Japan where this ratio is achieved.

If the population grows more around the stops, more development takes place close to PT and the population density around stops increases. This makes PT more accessible.

In contrast, if the population distribution is evenly distributed over a certain area, without concentrations around stops, the accessibility of this region will be lower. When comparing cities, the frequency of departures and their distribution across lines and stops must also be considered.

With the same number of departures and stops in an area, a city could provide the majority of its population with a medium PT frequency. If the number of departures at certain stops would increase, half of the population could be served with a high-PT frequency and the other half with a low-PT frequency. Since some stops have only one departure per hour, while others have one or more departures per minute, the only way to define the accessibility of a PT service is to measure the proximity to a PT service [14].

3. Materials and Methods

3.1. Investigation Area

Tampere is, by population, after Helsinki and Espoo, the third largest city in Finland and is located 180 km north of Helsinki [15]. The city has 235,000 inhabitants and the region includes 334,000 people. The modal split for the region is 55% for private motor vehicles (PMV) and 9% for PT. The PT is organised by Nysse and the modal split in the city is 12% [15–17]. The amount of passenger across the region increased from 40.3 million in 2018 to 41.3 million in the year 2019 but then dropped due to the corona pandemic during 2020 to 27.6 million [18].

Braunschweig is after Hannover the second largest city in Lower Saxony and is located 70 km east of Hannover. The population of the city of Braunschweig is 250,000 and 1,130,000 people live in the region. Together with the cities of Salzgitter and Wolfsburg, Braunschweig forms one of the nine main centres of Lower Saxony. The modal split is 45% for PMV in the city and 61% in the region. The modal split for PT is 13% in the city and 9% in the region. PT is organised by Verbundtarif Großraum Braunschweig (VRB) [19–21]. In 2019, 41.2 million passengers used PT in Braunschweig was [22].

In the following sections, the status of local PT in each city are discussed. The focus is on the upcoming extension and new construction of the tramway network in Braunschweig and the new construction of the tramway network in Tampere.

3.1.1. Tampere

Until now, PT in Tampere has been dominated by bus. In Tampere, there are eight different bus companies, which serve a network of about 60 lines. Nearly all lines connect the suburbs with the city centre [23]. The bus companies serve a network of approximately 18 million km per year in the Tampere region before the tramway network construction [24]. In 2016, the City Council of Tampere decided to build the first phase (red in Figure 1) of the tramway infrastructure with the depot and lines from Hervanta and the TAYS hospital region to the city. In 2020, the Council also decided to build the second section of the tramway network from Lentävänniemi to the city centre [25].

The new tramway lines in Tampere will replace a direct bus connection between city centre and Hervanta. There are also some lines that are moved to tram-connecting lines within suburbs, like Hervanta, where the number of bus connections are then decreased. The first phase opened in August 2021 and the construction of the second phase is planned for the years 2021–2024. The length of both phases will be 23 km. Three-quarters of trams will run on segregated track, separate from other traffic.

The trams are designed and manufactured by Skoda Transtech Oy, and they run on a 1435 mm gauge. The trams can reach a maximum speed of 70 km/h, with an average speed of 20 km/h. The capacity of a 37 m long tram car is 264 passengers [26].

Trams operating on the first phase of the tramway infrastructure have a frequency of 7.5 min during the daytime and an interval of three to four minutes on the combined route in the city centre. The line from Hervanta is the longer route. The travel time from the city centre to TAYS is approximately 10 min and from the city centre to Hervanta is approximately 21 min [27,28]. Operation in the first phase started on 9 August 2021 [29].

Second phase of the Tampere tram network covers the section from Pyynikintori, where the first phase ends, to Lentävänniemi. The route and stop points for the secondly planned extension are still partly under consideration [26].

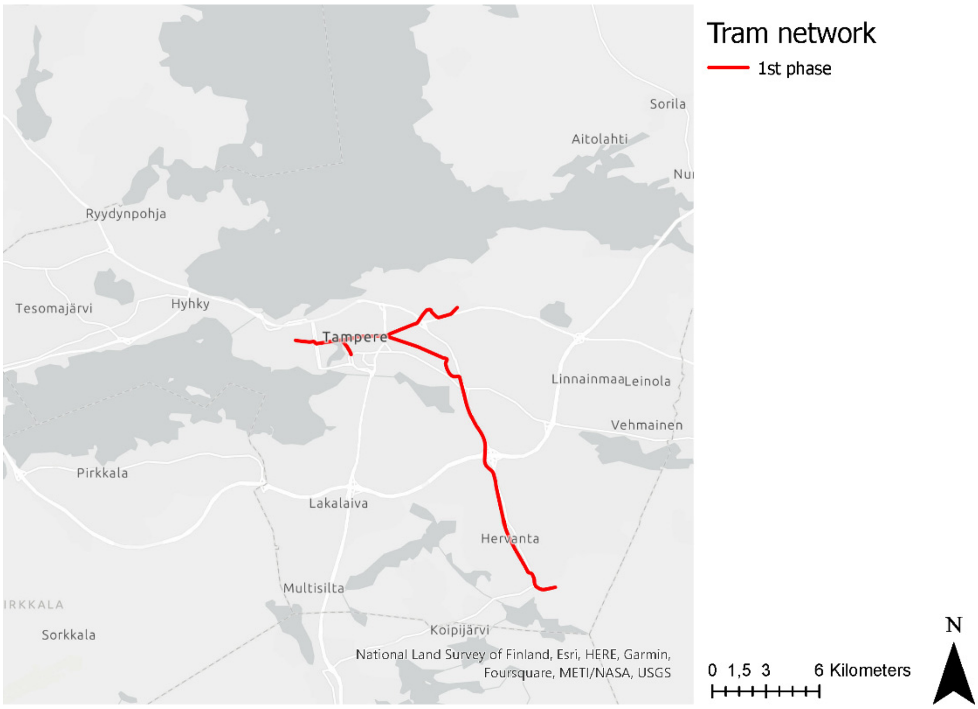

Figure 1. Developed tram network in Tampere Finland.

3.1.2. Braunschweig

There are six tram lines and 37 bus lines [30]. The six existing lines are currently 58.7 km long. The lengths of the individual lines vary considerably between 4 and 14 km. There is 81% of the current network on segregated or independent track [22]. Most of the trams are from the type Tramino designed and manufactured by Stadler Pankow GmbH (Berlin, Germany), and they run on a 1100 mm gauge. The total capacity is 211 passengers. The trams can reach a maximum speed of 70 km per hour with an average speed between 16 and 19 km/h depending on the line. The capacity of the 36 m long tram is 205 passengers [31,32].

On 1 April 2014, the city council of Braunschweig decided to investigate the extension of the tram system. The latest estimated cost for this project is 208 million €. On 21 February 2017, the city council of Braunschweig passed the basic decision for the tram expansion concept [33].

The decision allowed the detailed planning of the extension to continue. As given in the report dated 31 December 2017, 60% of the new tracks will be built on segregated track formations, while 40% of the remaining tracks will be built on in-street track formations. The completion of this expansion is scheduled for 2030. The BSVG's network plan for 2030 foresees for bus lines to be replaced by the new and extended tram lines.

The bus lines around the city centre will be partially diverted [33]. Figure 2 shows all lines of the Braunschweig tram. The green lines are the current network, and the red lines are the new planned extensions. The areas that will be served with a tram in the future network are currently served using regular bus connections.

3.2. Methodology

In this study, we analysed how the accessibility of different locations changed with the tramline extensions. We achieved this by calculating the differences between travel time on the old network and the current network in Tampere and planned future network

Braunschweig, in different case areas for both analysed cities. Analysis was undertaken using the Service Area analysis tool in ArcGIS Pro.

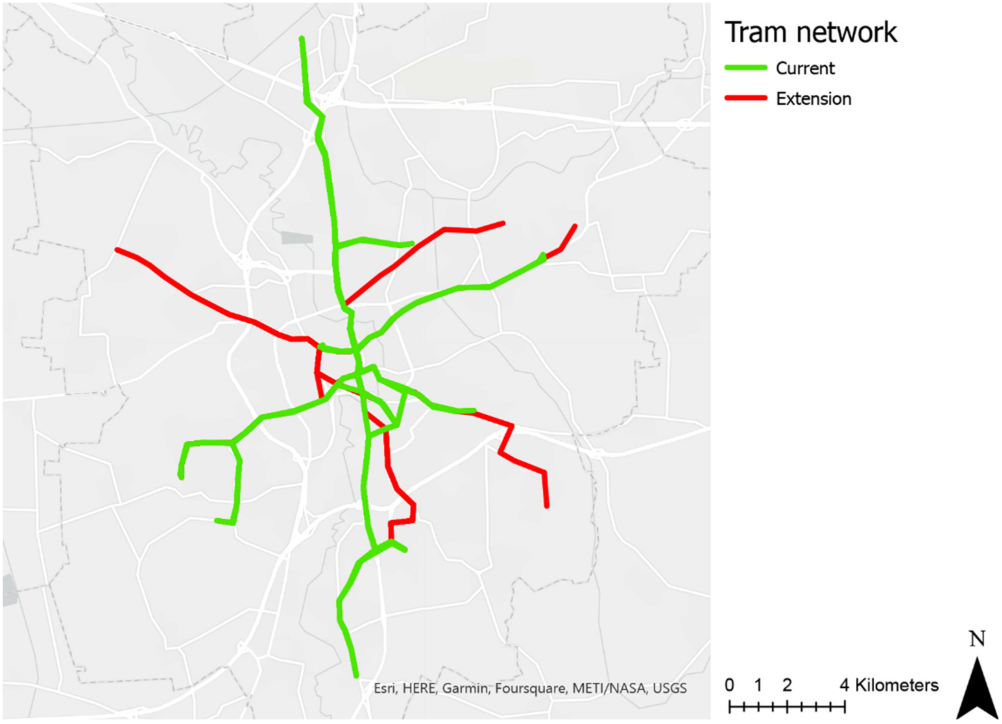

Figure 2. Current and planned tram networks in Braunschweig, Germany.

3.2.1. Route and Schedule Date

To indicate the current level of PT routes and schedules in both cities, we used General Transit Feed Specification (GTFS) datasets [34,35] containing all the necessary information regarding our analysis (routes, lines, line types and timetables). The timetables in the GTFS datasets were issued without actual dwell time information on stops (i.e., arrival and departure time are the same); however, the dwell time was estimated as part of the travel time between concurrent stops.

For both cities, we selected a regular Tuesday for analysis. For Tampere, we selected the date of 22nd March 2016, since we wanted a date before there were any roadworks or route changes caused by construction of the tram system. For Braunschweig, we selected 26th February 2019 based on the availability of GTFS-data. The current and old level of travel times were calculated based on these datasets; however, for the planned network, we manually generated the routing data.

The ticket fares were known but not accounted for in the analysis, as in both case cities the fares are based on the area and not on the travel mode, and therefore there is no fare difference whether the trip is made with the tram or using the bus network. For Tampere, as the tram network is operational, we used the GTFS-dataset from Tampere Region [36] to build the network with the first phase of the tram in place.

As for the other datasets, we chose a regular Tuesday (25th January 2022) as a point of comparison. However, for Braunschweig, a more manual approach was used. We used the planned network map of 2030 [37] as source of new routes and stops. For entirely new sections, we used the plans [38] to estimate the locations of new stops. In cases where there were alternatives for the route, we estimated the stop location as the average of the different plans.

For the timetable, the network map [37] provides information about the planned intervals on different routes of the 2030 network. We estimated the driving times between stops using the current network. If a connection between stops on the 2030 network were found in the 2019 network dataset, we used the same driving time, which included the dwell time. For new sections, we estimated the driving times based on the plans and current driving times given by online routing tools [39,40] and rounded it up to the full minute to estimate the effect of dwell time.

We filtered out regional bus lines since the schedule did not provide enough information. This was controlled for in our spatial analysis by focusing the analysis area on only the core network of 2019 and 2030. Based on this information, we manually created the GTFS dataset representing a regular Tuesday of 2030 for use in the spatial analysis. There were some limitations caused by the incomplete travel times based on the intervals.

The current networks are planned to allow connections between different lines, whereas on this new network, the departures are not planned to allow for the best possible arrival and transfer times on stops, as this information is not currently available. However, the Braunschweig 2030 network lines that share major parts of their route with each other were adjusted to have sensible departure intervals on their shared stops.

3.2.2. Spatial Analysis

For spatial analysis, we selected the city centres as the study area. The travel time was calculated based on how fast the edge of the area can be accessed from anywhere else in the city region. For Braunschweig, we also analysed the central railway station accessibility, as it is not located in the city centre area but can be seen as a clear destination need for the citizens. The study areas are presented in Figure 3.

Figure 3. The city centre areas used in the spatial analysis, Tampere, Finland on the left and Braunschweig, Germany on the right.

As stated, we used ArcGIS Pro to calculate the travel times by using the build in service area analysis -tool. For both current and planned network, the GTFS datasets provided the route, timetable and stop information. Since the first and last stage of the journeys, as well as some connections may require walking, we had to use road data, to indicate, where walking connections are possible. For Tampere, we based the roads on the open Digiroad dataset [41]. For Braunschweig, we used an extraction from OpenStreetMap [42,43] as the base and manually cleaned some broken connection links existing in the data to get the end results to match actual network.

In the model, the travel time was calculated to consist of walking times to and from stops, waiting times on stops and interchanges and running times of the bus or tram. All time calculated was equal, and there was no added weight to longer walking times or number of transfers. The running time of bus or tram was calculated through the departure and arrival times present in the GTFS-data and walking time was calculated based on the shortest route with a walking speed of 5 km/h.

We wanted to calculate the difference between the accessibility of the study areas in the morning period. To allow comparison between the networks, we made a 500 m by 500 m grid in the areas and then ran service area analysis towards every case area for every minute between 8:50 to 9:10. We then selected the minimum travel time required for every grid in the network from this 20 min phase. We chose the best connection from the 20-min phase, as it does not favour one network over another, as a choice of only one fixed minute would.

Based on this information, we used the Service Area tool to calculate the difference of travel time to case locations from every grid of network and map out where there is an increase in time for tram network and vice versa. In this analysis, we only looked into how the network development changes the actual time taken to reach the city centres. We limited the analysis to this as the network for Braunschweig was not yet finalized and the actual timetable and route data was, therefore, not available.

3.2.3. Population Analysis

In addition to the map-based results, we assessed how many people are affected by the network changes and how their travel time would differ in the future. We used the population data to perform a population count to every grid in the research area. For Tampere, we used the Finnish YKR spatial statistical grid layout and data [44] to achieve this information. Since similar data were not available in Braunschweig, we used the population data from statistical districts of Braunschweig [45] and divided these in our formed grid based on the area. This allowed us to estimate how many people were located in these grids and how the changes will generally affect people.

4. Results

Table 1 depicts how the introduction of new tram extension changes the accessibility of case areas and how many people are affected by the change.

Table 1. The accessibility changes of case areas per how large of a population they affect.

Accessibility Difference 8:50–9:10/ Amount of Residents in Accessibility Zones	Tampere City Centre	Braunschweig Inner City Ring	Braunschweig Central Station
Access only by old network	294	0	0
Old over 20 min faster	297	0	0
Old 10–20 min faster	235	151	1
Old 6–10 min faster	424	1246	1685
Old 3–6 min faster	13,098	13,583	8984
Within 3 min	**299,473**	**207,643**	**200,275**
New 3–6 min faster	31,501	15,353	27,687
New 6–10 min faster	5705	1353	213
New 10–20 min faster	8627	31	380
New over 20 min faster	2914	0	0
Access only by new network	7920	46	181
Average time gain per person in 2030 (min)	**0.9**	**0.1**	**1.2**

The changes in both cities are positive (i.e., the new network has shorter travel time) on average for these case areas. For Tampere city centre, the majority of users will have the same travel time, for about 4% of citizens the time to reach the city centre is longer, whereas for 15% of citizens, the new will be faster. For Braunschweig city centre, the change on average is neutral, with the 7% of citizens with shorter travel times roughly equal to 6% of citizens with increased travel times. However, for the central railway station, there will be more benefits, with as about 12% of citizens able to reach the station quicker, whereas only 5% has longer travel times.

4.1. Tampere

Figure 4 describes the time change between the old, bus-based and the new, tram-based, network. The green hues depict areas where the new tram-based network is faster and brown hues depict areas where the old, bus-based network is faster. The blue grid indicates the location of the city centre area used in the analysis.

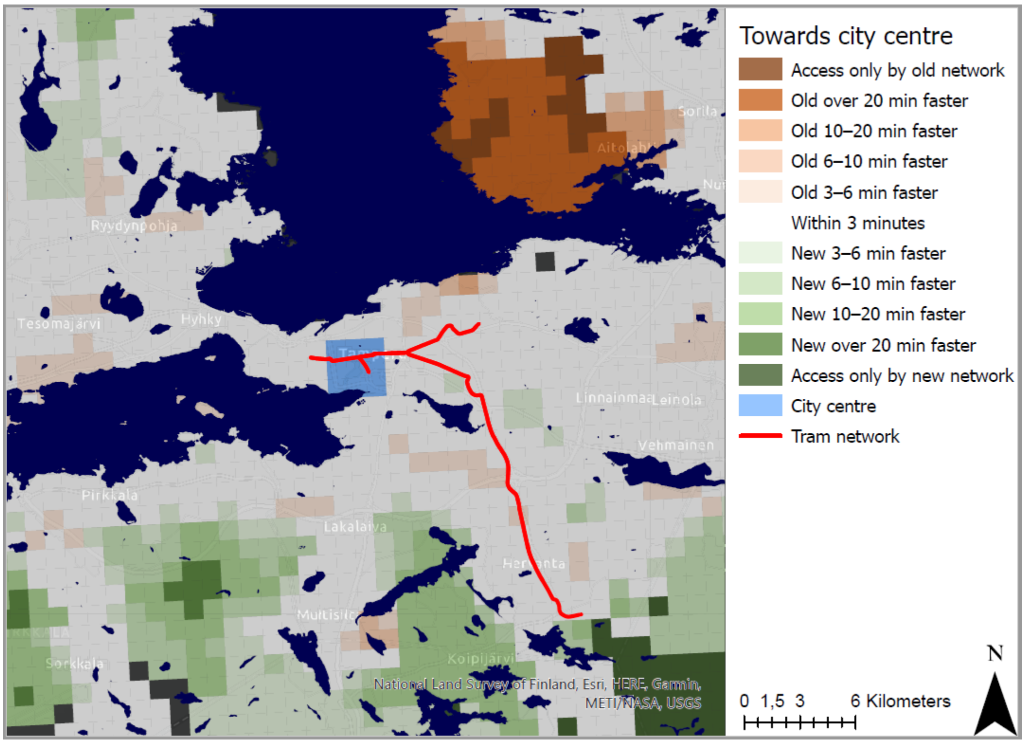

Figure 4. Difference on time taken to reach the city centre in Tampere, Finland.

Northeast corner on the map (Aitolahti) has mostly slower connections towards the city centre. This area is mostly rural with a couple of sparse neighbourhoods connected to city centre via a feeder line serving a trunk line in both the new and old, bus-based, networks. On the new, tram-based network, there is only one direct line to the main transfer point lines in Aitolahti, whereas, on the old network, there were two lines with different intervals. As such, the Aitolahti-has a lower service quality in the new network. However, this is not a major limitation, as the population of the area is small compared to other parts of the city, and the results of the area have minimal impact on the results presented in Table 1.

The eastern part of Tampere (Linnainmaa and Leinola) has a mix of same or slightly slower travel times. On the bus-based network, there were multiple trunk lines between this area and city centre. On new network, these are partly substituted to a transfer line heading towards the end stop of the northern tram line at TAYS, thus increasing travel times due to the need to transfer. However, some direct lines still exist with a reduced service frequency.

For the regions located southeast of the city centre, some deviations in travel times (3–6 min range) are caused by the differences in how lines are routed in the city centre, as it differs between the 2016 and 2021 networks, even though the networks in those areas are still about the same and no tram connections to this area exist.

Hervanta-area (the end of the southern tram line) is mostly within the same reach on both the new and old network based on the schedules. However, it should be noted that the old bus connections use the congested road network towards Hervanta, whereas the tram will use a segregated path allowing it to stick to its schedule, as delays on old network were common. The southern parts of Hervanta are better served with the new tram network as the route extends to these areas that were previously not served, as they have been developed only during the last years.

There are some differences on the southern parts of city as well in connections to municipality of Lempäälä located south of Tampere. Those areas are served better on new network compared to old one, as there are a couple of new lines to this direction. However, there are some differences in accessibility of different areas inside the city centre, as these southbound connections do not necessarily continue their journey to city centre but connect to the bus station located a couple stops south from the city centre (right at the southern edge of our case area).

The municipality of Pirkkala (located southwest of city centre) is connected with one main line operating with dense intervals on the main road connection and with feeder lines connecting other residential areas to the city centre with longer intervals. For most parts of Pirkkala, the network has the same reach, as the area is served with the same principles. However, there are some changes in the network on the southern parts of Pirkkala, as the lines for those areas have changed between the new and old network, even though there is no direct connection to the tram.

Tesoma (West of city centre, around Tesomajärvi) has a commuter train connection towards the city centre, which would allow faster connections to the area than what is possible in the old network. However, since the commuter trains are handled by a different operator, they were not included in the dataset used in the analysis, thus giving a slightly lower service level around the commuter train stop.

The north western parts of the city have mostly the same level of connections towards the city centre, where they then can further link to the tram network. Even though no major changes have happened, the analysis shows parts of the area to have faster accessibility to city centre. This may be due to the tunnel construction work on national road 12 that is the main connection point between north western parts and the city centre, which was ongoing during the 2016 analysis period, causing delays to the bus network in that area.

4.2. Braunschweig

Figures 5 and 6 show the differences in accessibility between the new and the current network. With the new tram network, destinations can be reached in less time from the locations coloured in green, whereas it is faster in the current network from the locations marked in brown. The white area shows time changes within three minutes, regardless of the tram network status.

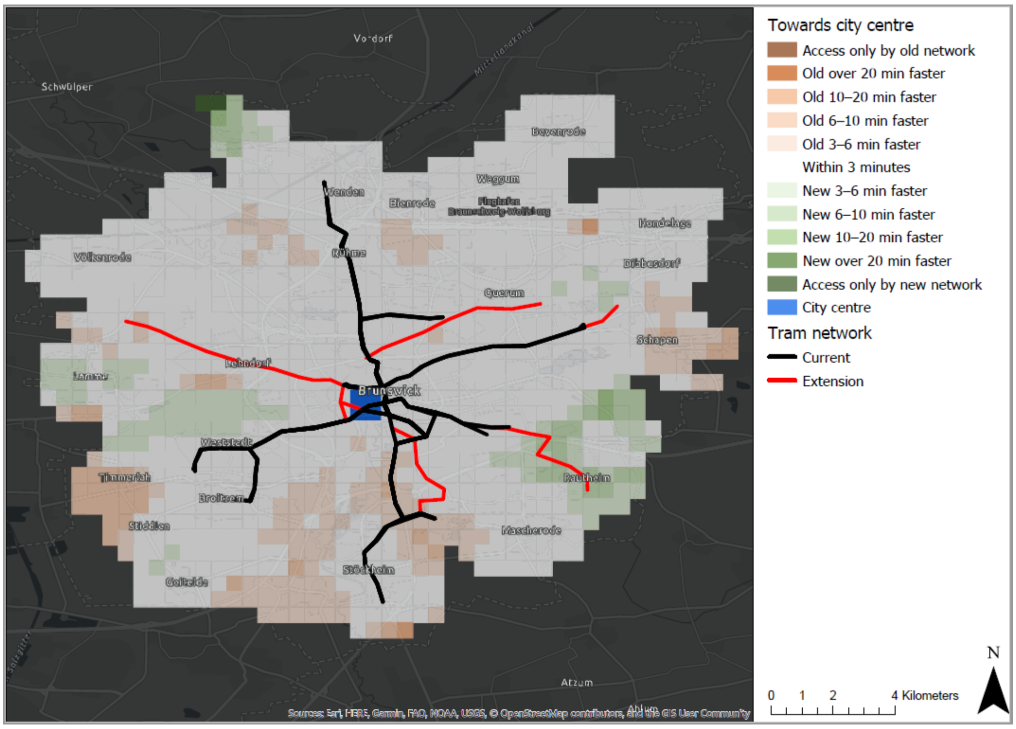

Figure 5. Difference on time taken to reach the city centre in Braunschweig, Germany.

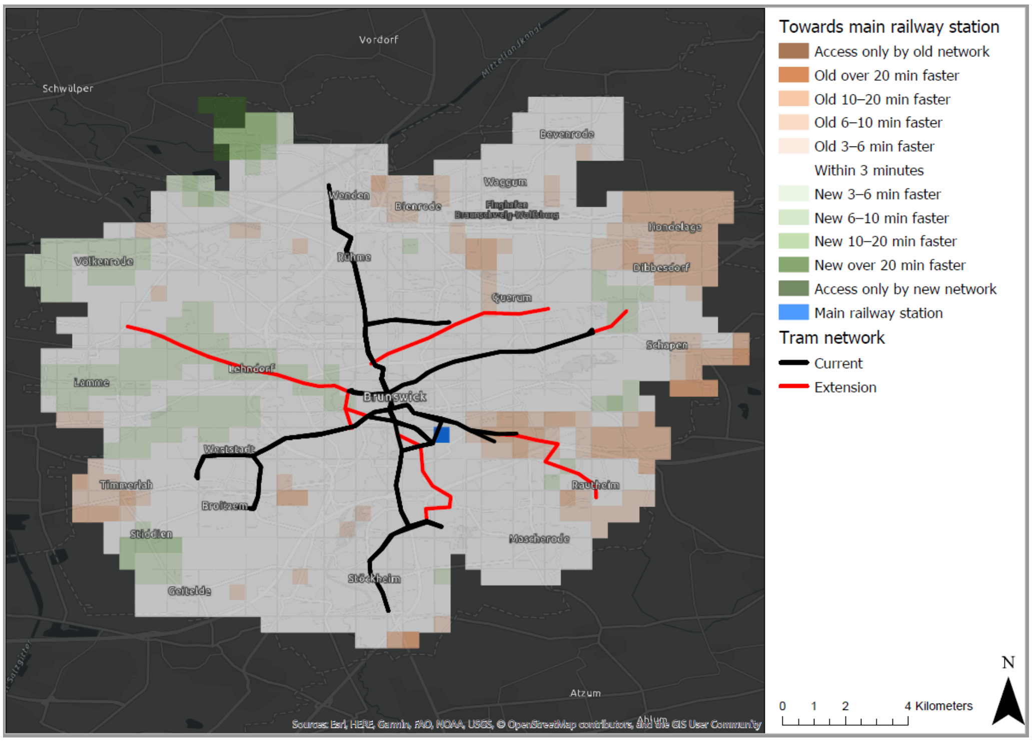

Figure 6. Difference on time taken to reach the main railway station in Braunschweig, Germany.

Figure 5 shows the accessibility around the inner city ring of Braunschweig. The people around Rautheim are better served by the new connections from the inner city of Braunschweig. The passengers living in the area around Weststadt are connected directly to many stops around the inner city by the old and new tram lines.

Rautheim and its surrounding areas are directly connected by a tram line from the city centre in the new network, whereas they currently have to change between different bus lines, as the extension of the tram line in the direction of Rautheim does not exist in the current network.

The green area from the south of Lehndorf can be reached faster through the new network. The new bus line bypasses the city centre and has fewer station on the route. Therefore, the travel time in the new network is reduced. The people have access from the city centre by a new tram line instead of a bus line, which is going to be faster.

The area around Heidberg, south of city centre, is better connected by the current network, as the area can be reached directly with a tram line, which runs on segregated track formations most of the time between the city centre and the central station. The new planned tram line runs mostly on in-street track formations on another route, which is longer and has more stations than the old tram line. Timmerlah is better connected in the current network than in the new one, although the connection is the same with the new network.

The new network offers an improved connection for almost 15,000 people who are living in the inner city ring (Table 1). Travel times cannot be improved for all passengers, there always will be people who are worse connected due to a new or different routing or a bus or tram line that will no longer operate.

The main station is not the direct hub for PT in the inner city of Braunschweig. Nevertheless, it is an important connection point, since almost all tram lines and a lot of bus lines connect the main station to local and long-distance train stops.

People from the western parts of the city will have a better connection with the new network (Figure 6). This is the result of the improved connection in the direction of Lehndorf and Lamme.

With two new lines, people can travel from the central station towards Lehndorf and Kanzlerfeld (located west of Lehndorf) without changing lines. In the current network, one bus line goes directly from the central station to Lehndorf, Kanzlerfeld and Lamme, this bus route will no longer exist in the network in 2030. Kanzlerfeld can be reached without a change in the current network and in the planned network. By using the tram, the travel times are reduced, which is due to a higher average speed of the tram and its independent tramway.

In the 2030 network, Lamme can be reached with one transfer, as the direct connection by bus will no longer exist. A possible route would be to use a tram to one station in the area of Kanzlerfeld and change to the bus at this point. Although Lamme is no longer directly served in the target network, the connection is better in 2030.

The people who live in Timmerlah and the surrounding area will not be better connected by the new network. Travel times will get less attractive according to the current data. In the current network, one tram line stops at the central station and a connection to Timmerlah is possible with one transfer between a tram and bus line. The new tram line is this area no longer stops at the central station; therefore, PT-users have to change lines at least two times.

People who live in the suburbs Dibbesdorf and Hondelage are better connected with the current network. From the central station to Dibbesdorf, people currently only have to change from one bus line to another bus. In the future network, they have to change twice. Hondelage can be reached with two changes in the current network. In the future network, it will be possible to get to Hondelage with only one change; however, this is only provided by a bus connection with many stops, which increases the travel time. The connection via tram to Hondelage includes at least two changes.

The south of Rautheim is currently connected by two bus lines. In the new network, due to the operation stop of one of the bus lines, this area can no longer be reached as quickly as before. Rautheim is connected to the new tram network by the tram, nevertheless the residents in the area around Rautheim are not better connected by the new network because tram line 4 does not go via the central station. Furthermore, many bus lines in the area north of Rautheim will no longer exist or use new routes in the network.

The new network offers an improved connection for approximately 28,000 people for the central station. The main station shows an average improvement of 1.2 min per person (Table 1).

5. Discussion

Overall, in the future both cities will have a tram transport system that is mainly built on segregated tracks. This allows the trams to avoid congested traffic and run on schedule. In addition to this, at least in Braunschweig, multiple parts of the city can be reached by tram-only connections, which may be more favourable compared to bus network, as the travel takes less time. Therefore, it can help PT to interest new passengers. For Tampere, this is not yet the case, as most areas are still connected by bus; however, after new extensions, same "rail factor" effect could be seen.

5.1. Tampere

While only looking at the scheduled travel times, the effects of the tram may seem minor, or they even show some signs of lower levels of service in some areas. However, it should be noted that for many of these areas, where tramway were built, congestion caused the bus to be delayed during peak hours, when PT is mostly used. The tram will mainly run on its own segregated path in these areas, allowing it to follow its timetables even during those congested hours.

5.2. Braunschweig

In general, it can be noted that PT is becoming more attractive for many people in Braunschweig. Especially for the people who are connected to the new tram lines. This includes the area around Rautheim and the area around Lehndorf. The connections to these suburbs in the new network are between 6 to 20 min faster.

In Braunschweig, the main part of the tramway will have a segregated track formation, which may increase the average speed on some lines, even compared to bus lines that operated there before. Due to the new lines and new routes of the existing lines, almost the entire city centre is accessible by tram. This is not the case in the current network. Furthermore, there may be more punctuality on the lines when a bus is replaced by the tram.

Due to the fact that many places are connected with a tram line, bus lines no longer exist or have longer distances and more stations to serve. As a result, some people get a worse connection with more changes or have longer travel times overall.

Nevertheless, there are also examples of passengers having to transfer in the new network; however, the travel time is still reduced. In some areas the passengers have to change from tram line to tram line or bus line to tram line. The average speed of the tram is higher and some of the stops are further from each other, so the travel time is shorter than in the current network, even though there is a transfer.

Furthermore, based on this analysis, it can be assumed that there will be also significant improvements for the surrounding area from other stops in Braunschweig with new tram lines.

6. Conclusions

There are major differences when comparing the estimated effects of new tramline constructions in Tampere and Braunschweig. One major aspect causing this is network effect in PT on city centre accessibility. Even though one line could be majorly invested and developed, it will not cause the same effect for the whole network, as then the problems may move away from the developed area of network to a new area. This is mainly the case when a new tram track is constructed; however, for most other areas of the region, the service will be still operated by the old bus network system than previously.

The bus lines will connect to the tram at some point of the journey; however, this journey will still have the same drawbacks as the original bus lines, such as using a congested road. Therefore, for example, the schedule benefits of the tram having a segregated path will not have a wider effect on accessibility, since most of the network is still served with the buses on congested roads. However, the tram may allow the passengers to reach the transfer point faster in comparison to the old bus network.

If there is already a tram network and this construction phase will only be an extension to the already available network, several advantages can be achieved. The area served only by the tram network—not running on the same congested road as buses—can be extended, the benefits of this are applied to much wider areas, which can be seen in our results.

It is also important to note the geographic differences of the two chosen case areas. The centre of Tampere is located on a narrow land area between two lakes with a limited number of connections between east and west, whereas Braunschweig does not have the same kind of geographic limitations regarding the directions where the network can be extended. For example, the mentioned area of Pirkkala is located on the other side of a lake when looking from the city centre, making it not economically viable to create more direct connections than those that already exist.

Based on the analysis of the results, it could be assumed that, when the first parts of a tramway are completed, the benefits will be gained on a larger area when building new connecting tramlines. When the area served via a segregated tram network is larger, the same benefits would at least be applied to those catchment areas as well.

For further research, it would be important to note how finalized schedules of the network affect the accessibility of different areas, as the transfers between lines may be better matched. The same type of approach method can also be used when the network for a western extension of the tram is planned in Tampere to learn whether it could cause effects on larger areas than only the areas located next to the tramlines, since the same type of data will be available after the developments are finished.

It should also be noted that this study solely investigated the travel time as a measure, and therefore it only provides information of that part of quality of service. There may be changes in other aspects, such as the ride quality or transfers needed to reach the destinations, which, among others [5], are also crucial parts of forming the total quality of service. For further research, when the actual timetable and route data are available for both networks, multiple aspects of quality of service should be studied together to investigate the perceived change to passengers. There is no comparison of the results from this study with previous studies and projects, and there are no comparable studies in the relevant literature.

Furthermore, additional key areas in the cities of Tampere and Braunschweig can be compared in further research, as they are not part of this study. The topic of this case study can be a reference for tramway expansion projects worldwide through further investigations on this matter. This could make it possible to better control tram extension projects and plan the extensions in a specific way that benefits as many residents (potential passengers) as possible.

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References

1. Martens, K. *Transport Justice-Designing Fair Transportation Systems*; Routledge: London, UK, 2016.
2. Nobis, C.; Kuhnimhof, T. Mobilität in Deutschland-MiD Ergebnisbericht. In *Studie von infas, DLR, IVT und Infas 360 im Auftrag des Bundesministers Für Verkehr und Digitale Infrastruktur (FE-Nr. 70.904/15)*; Infas: Bonn/Berlin, Germany, 2018.
3. Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung. Stadt, Verkehr und Klima. 2019. Available online: https://www.bmz.de/de/themen/klimaschutz/Stadt-und-Klima/index.html (accessed on 30 August 2019).
4. Palonen, T.; Viri, R. Benchmarking Public Transport Level of Service with Open Data. *Transp. Res. Procedia* **2019**, *42*, 100–108. [CrossRef]
5. Schütze, C.; Schmidt, N.; Liimatainen, H.; Siefer, T. How to Achieve a Continuous Increase in Public Transport Ridership?—A Case Study of Braunschweig and Tampere. *Sustainability* **2020**, *12*, 8063. [CrossRef]
6. Fellesson, M.; Friman, M. Perceived Satisfaction with Public Transport Service in Nine European Cities. *J. Transp. Res. Forum.* **2012**, *47*, 3. [CrossRef]
7. Scherer, M.; Dziekan, K. Bus or Rail: An Approach to Explain the Psychological Rail Factor. *J. Public Transp.* **2012**, *5*, 75–93. [CrossRef]
8. Verband Deutscher Verkehrsunternehmer (VDV). *Jahresbericht 2020/2021*; Verband Deutscher Verkehrsunternehmer (VDV): Köln, Germany, 2021.
9. Varela, J.M.; Börjesson, M.; Daly, A. Public transport: One mode or several? *Transp. Res. Part A Policy Pract.* **2018**, *113*, 137–156.
10. Chowdhury, S.; Ceder, A.; Sachdeva, R. The effects of planned and unplanned transfers on public transport users' perception of transfer routes. *Transp. Plan. Technol.* **2014**, *37*, 154–168. [CrossRef]
11. Schnieder, L. *Betriebsplanung im Öffentlichen Personennahverkehr*; Springer Vieweg: Berlin, Germany, 2015.
12. Woods, R.; Masthoff, J. A comparison of car driving, public transport and cycling experiences in three European cities. *Transp. Res. Part A Policy Pract.* **2017**, *103*, 211–222. [CrossRef]
13. Matsunaka, R.; Oba, T.; Nakagawa, D.; Nagao, M.; Nawrocki, J. International comparison of the relationship between urban structure and the service level of urban public transportation—A comprehensive analysis in local cities in Japan, France and Germany. *Transp. Policy* **2013**, *30*, 26–39. [CrossRef]
14. Poelman, H.; Dijkstra, L. Regional Working Paper 2015-Measuring access to public transport in European cities. *Reg. Urban Policy* **2015**.
15. Tampere. Information on Tampere. Available online: https://www.tampere.fi/en/city-of-tampere/information-on-tampere.html (accessed on 8 September 2020).
16. Tilastokeskus. Latest Statistical Releases. Available online: https://www.stat.fi/ (accessed on 26 October 2020).
17. Traficom. Henkilöliikennetutkimuksen 2016 Tuloksia Taulukoina. Available online: https://www.traficom.fi/fi/ajankohtaista/julkaisut/henkiloliikennetutkimuksen-2016-tuloksia-taulukoina (accessed on 2 March 2021).

18. Nysse. Tampereen Seudunjoukkoliikenteen Vuosikertomus 2021. 2021. Available online: https://www.nysse.fi/media/julkaisut/vuosikertomukset/nysse-vuosikertomus-2021.pdf (accessed on 16 August 2022).
19. Destatis. Bevölkerung: Kreise, Stichtag. Available online: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsstand/_inhalt.html#sprg233974 (accessed on 19 February 2021).
20. Wermuth. *Mobilitätsuntersuchung für den Großraum Braunschweig*; WVI Prof. Dr. Wermuth Verkehrsforschung und Infrastrukturplanung GmbH: Braunschweig, Germany, 2012.
21. Regionalverband Großraum Braunschweig. *Nahverkehrsplan 2016 Großraum Braunschweig*; Regionalverband Großraum Braunschweig: Braunschweig, Germany, 2016.
22. Braunschweiger Verkehrs-GmbH. Wissenswertes-Zahlen, Daten, Informationen zur Verkehrs-GmbH. Available online: https://www.bsvg.net/fileadmin/user_upload/downloads/Flyer/Neues_CI/20-179_BSVG_Relaunch_Flyer_Wissenswertes_02_ansicht.pdf (accessed on 17 June 2020).
23. Nysse. Schedules and Routes. Available online: https://www.nysse.fi/en/schedules-and-routes/lines.html (accessed on 11 March 2021).
24. Periviita, M. (2018, November 29). Interview about Public Transportation in Tampere.
25. Tampere. Tampereen Valtuusto Päätti Raitiotien 2 Osan Rakentamisesta Sekä Seuturaitiotien Linjauksista. Available online: https://www.tampere.fi/tampereen-kaupunki/ajankohtaista/tiedotteet/2020/10/19102020_5.html (accessed on 26 October 2020).
26. Tampereen Ratikka The First Stage of the Tramway will be Completed in 2021. 2019. Available online: https://www.tampereenratikka.fi/en/ (accessed on 30 July 2021).
27. Tampere. Tampere to Receive a Tramway. Available online: https://www.tampere.fi/en/city-of-tampere/info/current-issues/2016/11/10112016_1.html (accessed on 10 November 2016).
28. Tampere. Tramway. Available online: https://www.tampere.fi/en/transport-and-streets/tramway.html (accessed on 23 May 2019).
29. Tampereen Ratikka. Tampere Tramway Timeline. Available online: https://www.tampereenratikka.fi/en/timeline/ (accessed on 25 January 2022).
30. Braunschweiger Verkehrs-GmbH. Über die Verkehrs-GmbH. Available online: https://www.bsvg.net/unternehmen/ueber-die-verkehrs-gmbh.html (accessed on 19 February 2021).
31. Braunschweiger Verkehrs-GmbH. Tramino Stadtbahn. Available online: https://www.bsvg.net/unternehmen/tramino-stadtbahnen.html (accessed on 19 February 2021).
32. Braunschweiger Verkehrs-GmbH. Fahrpläne. Available online: https://www.bsvg.net/fahrplan/fahrplaene.html (accessed on 25 August 2022).
33. Stadt.Bahn.Plus. Über das Projekt. Available online: https://www.stadt-bahn-plus.de/ueber-das-projekt (accessed on 18 February 2021).
34. Connect Fahrplanauskunft GmbH. GTFS Static Transit. 2019. Available online: http://www.connect-fahrplanauskunft.de/unsere-services/opendata.html (accessed on 13 November 2019).
35. Braunschweiger Verkehrs-GmbH. Liniennetzplan Stadtbahn + Bus. Available online: https://www.liniennetz-bs.de/index.php/de/netzplan (accessed on 19 October 2020).
36. ITS Factory. Tampere Public Transport GTFS Feed. Available online: http://wiki.itsfactory.fi/index.php/Tampere_Public_Transport_GTFS_feed (accessed on 25 January 2022).
37. Stadt.Bahn.Plus. Projekte. Available online: https://www.stadt-bahn-plus.de/projekte/ (accessed on 19 October 2020).
38. HERE. HERE WeGo. Available online: https://wego.here.com/ (accessed on 19 October 2020).
39. Google. Google Maps. Available online: https://www.google.com/maps (accessed on 19 October 2020).
40. Väylävirasto. Digiroad-National Road and Street Database. Available online: https://vanha.vayla.fi/web/en/open-data/digiroad (accessed on 19 October 2020).
41. BBBike. BBBike.org OpenStreetMap Extract Service. Available online: https://extract.bbbike.org/ (accessed on 19 October 2020).
42. OpenStreetMap. OpenStreetMap-data CC-BY-SA. Available online: https://www.openstreetmap.org/ (accessed on 19 October 2020).
43. Stadt Brauschweig. Statistische Bezirke. Open Geodata. Available online: https://www.braunschweig.de/leben/stadtplanung_bauen/geoinformationen/ogd_statistbezike.php (accessed on 30 July 2021).
44. Ympäristö. Yhdyskuntarakenteen seuranann aineistot (YKR). Available online: https://www.ymparisto.fi/fi-fi/elinymparisto_ja_kaavoitus/yhdyskuntarakenne/tietoa_yhdyskuntarakenteesta/Yhdyskuntarakenteen_seurannan_aineistot (accessed on 19 October 2020).
45. Stadt Brauschweig. Einwohner nach Statistischen Bezirken. Einwohnerzahlen. Available online: https://www.braunschweig.de/politik_verwaltung/statistik/ez_statistische_bezirke.php (accessed on 31 December 2020).