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Analysis of the Travel Time of Various Transportation Systems in Urban Context

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1. Abstract

What's the maximum detour for ride pooling that is accepted from the passengers' point of view? We address this question by determining the accepted detour of conventional public line transport, which is being accepted by its passengers. This is done using the Google Maps Routing application programming interface (API) for analyzing the travel times of different means of transport in 13 German cities. From the identified travel time ratios of public transport and motorized individual transport conclusions are drawn about the maximum reasonable detour when using ride pooling.

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2. Introduction

Conventional public transportation systems are based on static timetables that describe at what time each station is approached by public transport vehicles and the vehicles follow fixed routes. In contrast, flexible mobility concepts attune to changes in demand, thus creating demand-oriented transport offers (Atasoy, Ikeda & Ben-Akiva 2014; Sommer, Schäfer & Löcker 2016). The systems are backed by algorithms which match the travel demand of different users in real time and harmonize it in time and space for creating individual routes. Such ride pooling, also called Demand-Responsive Transportation (DRT), is a digital mobility concept with a high degree of spatial and temporal flexibility. The operation without fixed stops and the high flexibility due to the renunciation of timetables combines the advantages of both individual and public transportation in the sense of a mobility as a service (Laws 2009) and is assumed to deliver a high quality of service for the customer. Table 1 shows the key characteristics of the considered DRT.

Table 1. Characteristics of DRT.

The Demand-responsive Transportation concepts considered in this context are characterized by:
- renunciation of fixed stops, timetables and routes
- internet-based online booking systems with mobile apps
- real-time-based arrangement
- pooling (bundling) of spatially and temporally corresponding transport requests

Such a sharing concept is enabled by real-time and direct digital networking of passengers and represents a new challenge for transport and mobility research. One open question concerns the maximum reasonable detour for individual users resulting from the need to pick up and release other passengers.

One approach for determining the maximum reasonable detour that arises for individual passengers is to adapt it to the detour time that is accepted when using conventional public transport. Conventional public transport serves fixed stops along a route that is often not the shortest connection – like the ones used when driving an own car – between two points. From the identification of the travel time ratio of public transport and motorized individual transport, conclusions about the maximum reasonable detour may be drawn. This approach should only be understood as one of many for answering the question and should always be considered in context with the study conditions and goals.

Within our approach, the travel time of different means of transport in 13 German cities is analyzed using the Google Maps Routing application programming interface (API). The included means of transport are private passenger car, public transport, public transport with bus only and bicycle. Travel times are determined by Google Maps route calculation between origin and destination points inside the cities. The points are placed with a distance of one to three kilometers to each other. The location of the points is chosen on public transport stops to avoid the inclusion of the required access and egress walking times to public transport. In order to assess the travel times, two key figures are calculated: the air-line speed and the travel time ratio between the means of transport. A further aim of the study was to compare travel times of different modes of transport and to evaluate whether there is a link between the number of inhabitants of the city and the observed travel time.

In fact, the required time is from the users' point of view a decisive criterion for assessing the quality of services (Viergutz & Brinkmann 2018) and is also taken into account when planning transport networks (FGSV 2008). In the presented study this important criterion is used to compare the quality of transport systems in urban areas and to investigate the relationship between the city size and the time expenditure. In the analysis, motorized individual transport (MIT), local public transport (PT), cycling and bus transport as part of public transport are regarded. The analysis focuses on the one hand on a possible connection between travel speeds and city size and on the other hand on the comparison between transport systems.

The remainder is structured as following: In Section 3, the methodological approach, mainly including the decisions about the chosen performance indicators and the selection of the measurement points and the tools to use, is presented. Afterwards, the results of the computation are shown in Section 4, followed by a discussion in Section 5. This documents ends with a conclusion given in Section 6.

3. Methodological Approach

In the following, the methodological approach of this study is presented. At first, a motivation for the used performance indicators is given. Then, it is described how the origin and destination points within the cities were chosen. Afterwards, the selection of a map service for computing the travel times between the chosen points is described, followed by a presentation of the data preparation. Finally, an overview of the assumptions and choices is given.

3.1. Selection of Relevant Parameters

The complex travel time considered in this study describes the time required for a change of location from the door of the origin address to the door of the destination address (Ahrens 2015). It consists of the following components, which depend on the selected traffic system (FGSV 2008):

- Access time: Walking time from the start point to the vehicle or public transport stop.
- Waiting time: Waiting time at the public transport stop.
- Transport time: Time from boarding the vehicle until leaving the vehicle. For public transport, this time also includes any interchange times and intermediate stops. With motorized individual transport, this time also includes the parking search time.
- Egress time: Walking time from the vehicle to the destination address.

For the evaluation of accessibility by the objectives under consideration, two further indicators are used, namely the air-line speed and the travel time ratio. The **air-line speed** is the quotient of the air-line distance and the real travel time. This implies that the distance travelled is taken into account, which makes it possible to compare travel times at connections of different distances. The **travel time ratio** is the quotient of travel times of different transport systems. In the context of integrated traffic planning, this measure is used for comparing competing transport systems. The travel time ratio can indicate the modal split and the traffic shift potential. The relationship can also be formulated as a politically defined minimum requirement or objective. This indicator reflects both, restrictions in motorized individual transport and the quality increases in public transport. In case the required travel time cannot explain the usage of a mode, the directness of a connection can be additionally determined.

Another parameter that can be considered is the **detour factor** being the quotient of the travel distance and the linear distance between a source and a destination. With increasing distance, the importance of the detour factor increases. Direct connections between a source and a destination are missing when time exposure and the detour factor are high. In public transport, the **frequency of interchanges** can be determined in addition to the detour factor. It is the number of changes of means of transport during the journey. I.e., getting in and out of the first or last vehicle is not counted. The characteristic values of the interchange frequency can also contain non-integer values as soon as several interchange frequencies are aggregated, for example over the course of the day.

Since time is the main criterion for describing the quality of an offer, the air-line speed seems to be the most suitable parameter for this purpose. For a direct comparison between public transport and car traffic, the travel time ratio should be used. The criteria detour factor and interchange frequency should only be used as a supplement in order to better explain ambiguous values of the air-line speed (FGSV 2008). Thereby, the parameters air-line speed and travel time ratio should be included in the evaluation. Albeit being used, the detour factor has only a limited explanatory power, because it is not the only factor that determines the travel times. The frequency of connections does not allow any direct conclusions about travel time as well.

The attachment times (access, waiting, and egress time in public transport) can be hardly determined using online map services. However, the calculation can be adapted in regard to the characteristics of different transport modes for obtaining comparable measures of the complex travel time. The tested online map services (see Section 3.3) take into account the access time from the start address to the start stop at which public transport is entered at as well as the time of departure from the destination station to the destination address. Although some online map services take walking times into account, the choice was made to set the reference points at existing stops. For the public transport routes, a consideration of access and egress time to stops is possible. But in this case, assumptions about the access and egress to private vehicles, including the time needed to find a parking space would have to be made, making a reliable evaluation difficult. If the density of stops is unknown, orientation values for access, departure and start waiting times could be taken from other studies or guidelines, even though they only represent approximate values and do not allow reliable statements.

Resulting, this work does not take attachment times into account for not distorting the computed travel times; the simple travel time is thus better comparable between the transport systems.

3.2. Selection of Examination Areas and Start-Destination Relations

For the comparative analysis of urban spaces, it makes sense to group similar environments for deriving transferable evaluations. This highlights the differences and similarities between different grades of urbanity. Small and medium-sized towns are urban areas in contrary to their rural surroundings. However, the degree of urbanity in small and medium-sized towns is significantly lower than in large cities making them rather comparable to the surroundings of the centers of bigger cities. An analysis of small and medium-sized towns would in many cases only mean a finer analysis of the rural surroundings of large cities. Thereby, it makes sense to focus the study on large cities.

The study distinguishes five different city size categories. Within each of these categories, three cities were selected, with Berlin being the only city in the category of 2.5 million inhabitants or more due to the large difference in population compared to the next largest German cities. The city categories and the associated, investigated cities are shown in Table 2.

Table 2. Classes of population of the cities under consideration.

Number of inhabitants		Considered cities
from	to	
2.5 Mio.	unlimited	Berlin
1 Mio.	2.5 Mio.	Hamburg, Munich, Cologne
500,000	1 Mio.	Düsseldorf, Stuttgart, Dresden
250,000	500,000	Brunswick, Wuppertal, Bonn
100,000	250,000	Oldenburg, Potsdam, Freiburg

The travel time must be determined by routing between large numbers of start and destination points. One possibility is the creation of starting points and targets at regular intervals over the entire study area. A sufficient number of measuring points should be selected for each investigated area so that the sample of start-destination relations is high enough. Because the number of queries is limited by the used tools (see Section 3.3), it is necessary to select fewer but more meaningful nodes.

For distances between the measuring points a minimum distance of 1 km and a maximum distance of 3 km were chosen. This is a compromise between a high number of routes and the possibility of using the online map services free of charge. As well, it cannot be guaranteed that another relevant stop will be found in the vicinity if the distances between the reference points are smaller. The routes between two reference points can be in principle calculated in both directions and the study has shown that the travel times of the two directions can differ. The reasons may be the existence of one-way roads or different traffic times for different directions (inbound, outbound) over the day. Due to the high number of routes in the examination area, it is assumed that the unidirectional sample is already large enough and well reflects the travel times when determining the simple route.

Since attachment times are not taken into account, the origins and destinations are selected in such a way that only the travel time is calculated using the online map services. In car traffic, the start and destination points of a route are automatically assigned to the next point on the next road. All online map services under consideration neglect the calculation of the footpath from the starting point to reaching the road from where the vehicle can be used. Theoretically, the reference points could also be off-road and the route is calculated accordingly from the next point on the road network. For public transport routes, the footpath from the starting point to the starting stop is included in the calculation. In order to calculate only the travel time for both transport systems, the chosen starting and destination points are located directly at public transport stops. This theoretically results in a zero connection time for public transport and, as described, no connection time is calculated for car traffic anyway. The starting and destination points of the lines to be examined are called reference points in the following. Figure 1 shows the reference points in the examination area of the city of Hamburg as an example, where 21 reference points were selected.

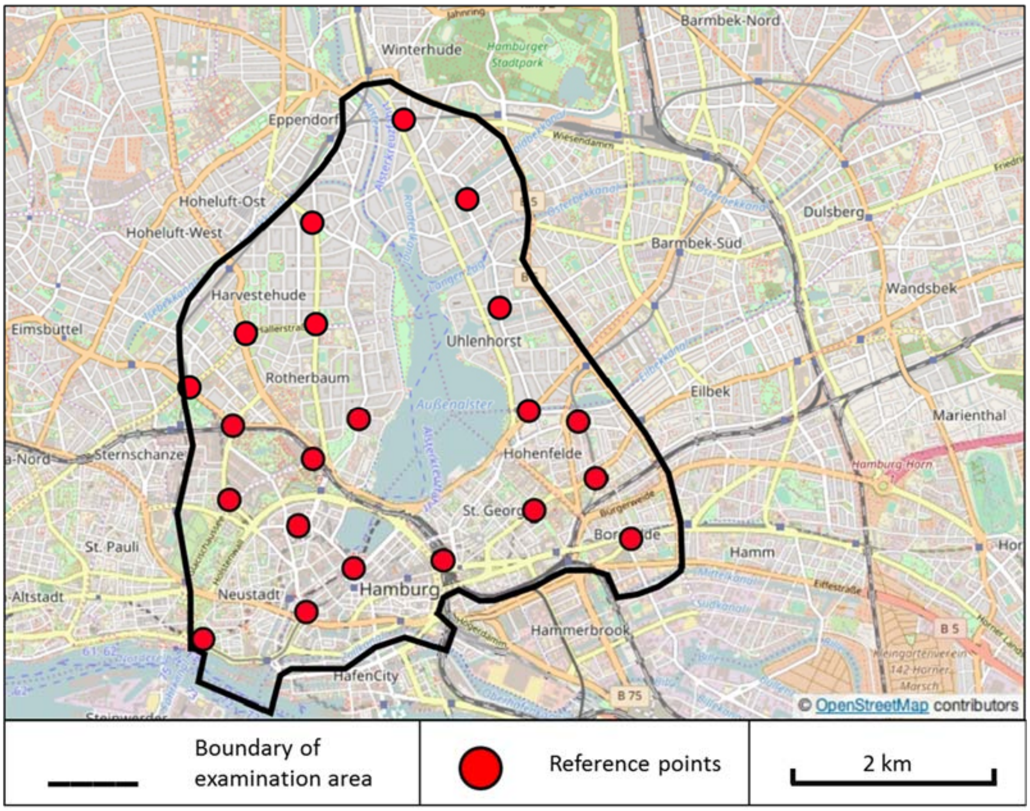


Fig. 1. Reference Points in Hamburg.

3.3. Tool Selection

The choice of the online map service can influence the research results, as the providers calculate different routes. Examples of online map services that can be used for route calculation are: Google Maps, HERE Maps, Bing Maps and Mapquest. In most cases, the use of these services is restricted with regard to the number of free route calculations or requests to the server and excludes certain uses such as commercial use of the data.

A comparison of the functions of different online map services (see Table 3) shows that not every online map service is suitable for processing the task. All providers allow performing a large number of queries for free, with Bing Maps offering the highest number. The selected reference points in the investigation areas result in 1,833 origin-destination relations, which are calculated three times, once for each of the regarded modes of transport. This results in a total of 5,499 routes to calculate. With this number of routes, in principle, all four online map services could be selected.

Table 3. Comparison of routing tools (Current state: June 2017).

Provider	Goole Maps	HERE Maps	Mapquest	Bing Maps
Number of free queries	2,500 per day	100,000 per month*	15,000 per month	50,000 per day
Car	yes	yes	yes	yes
- Real-time data	yes	yes	yes	yes
Public Transport	yes	yes	yes	yes
- Coverage	good	good	unknown	low
- Only bus	yes	yes	no	no
- Real-time data	partially	partially	no	yes
Bicycle	yes	yes	yes	no
Road network basis	Google	HERE	HERE	HERE

* 90 days test access

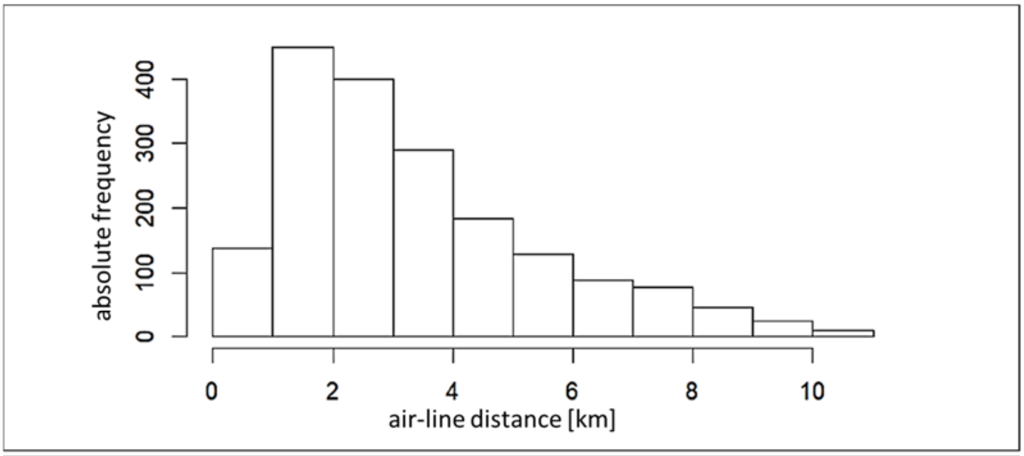
All four online map services offer route calculation for both car and public transport, partly using real-time data, i.e. information on longer journey times due to high traffic volumes and delays in public transport. While no statement can be made about the quality of car routing, there are differences in the coverage of public transport routing. All considered online map services but Mapquest published lists of facilities for which timetable data is available on their websites. HERE Maps has integrated most public transport timetables, while Bing Maps has very little timetable data. Both Google Maps and HERE Maps have timetable data for all 13 examination rooms. As well, real-time data for public transport is only available on Google and HERE Maps for very few cities or transport associations. Furthermore, Mapquest and Bing Maps do not have their own data base for the road network, but use the data from HERE Maps.

One advantage of HERE Maps over Google Maps is the possibility whether the fastest or the shortest route shall be calculated. Such a differentiation is not offered by Google Maps. Google Maps probably uses internal criteria for calculating the “best” route for both MIT and public transport in order to find a compromise between time and distance, yet these criteria are not disclosed.

Despite similar features of the online map services, there are other differences in detail, such as the calculated routes, which can be decisive in using Google Maps instead of HERE Maps. The HERE Maps API for route search is much more adaptable and comprehensive than Google's API. However, the high coverage of cities with public transport routing according to the documentation could not be confirmed when using the API. Since an evaluation of travel times does not make much sense if public transport routes in five of 13 cities consist mainly of footpaths, new cities were selected that support public transport routing according to Google documentation. For an initial comparison, both map services were used. However, the evaluation of travel times is based on data from Google Maps, as it could not been determined whether all newly selected cities are supported by HERE Maps in public transport routing.

3.4. Data Processing

The obtained data consist of 1,833 routes for which travel time, length, air-line speed, travel time ratio to MIT and detour factor are available for all regarded transport modes. Figure 2 shows the distribution of the linear distance of the origin-destination relations. For this purpose, distance classes with a width of 1 km were selected. It is striking that the strongest occupation lies in the distance class of 1 to 2 km and the occupation decreases in the following classes. In order to take equal account of all distance classes, weighting factors were determined on the basis of their occupation (see also Figure 2). The distance class with the highest occupation receives a weighting factor of 1 and the other distance classes a weighting factor that corresponds to the ratio of the highest occupation to their own occupation. The weighting simulates that all distance classes are equally represented.



Classes of population [km]	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11
Occupation	137	448	400	289	184	128	88	77	47	25	9
Weighting factor	3,28	1	1,12	1,55	2,44	3,51	5,1	5,83	9,55	17,96	49,89

Fig. 2. Occupation and Weighting of Classes of Population.

3.5. Summary of assumptions

The following assumptions can be noted for the selection of examination areas and the connection between start and destination:

- 13 city centers of German cities as examination areas;
- Four categories by number of inhabitants;
- At least ten reference points per examination areas;
- Distance between reference points from 1 to 3 km;
- Reference points at important public transport stops;
- Routes from any point to any other point.

The route search for each traffic system is performed in the following way:

- Usage of Google Maps API to calculate the fastest route;

- Single trip time, i.e. without arrival and departure times;
- Reporting time: 19th September 2017 at 8 o'clock;
- Inclusion of historical travel times for obtaining the real travel times;
- Considered transport systems: cars, overall public transport, buses, bicycles.

The following parameters are used to evaluate the travel time:

- Travel time ratio (comparing means of transport);
- Air-line speed.

4. Results

Table 4 shows the weighted average values of the key figures per city and city category, sorted by the number of inhabitants. On the one hand, the travel time ratio of motorized individual transport and local public transport (PT/MIT) varies depending on the size of the city, and on the other hand due to local influences of the transport infrastructure and supply quality. From a city size of 500,000 inhabitants, the average travel time ratio between public and private transport is usually below that of smaller large cities and in cities with more than 1 million inhabitants the values are very low. Nevertheless, there are exceptions, for example in the comparison between Dresden (1.39) and Potsdam (1.13). The cities in the city categories can therefore not be regarded as homogeneous, but as very heterogeneous (see also figure 3).

This is also evident from the two extreme values of the average travel time ratios of MIT and PT: Oldenburg, the smallest city under consideration, has the highest travel time PT/MIT ratio (1.95). The lowest is in Munich (0.64). However, both values differ greatly from other two cities of the same city category. In cities with up to 500,000 inhabitants, the average air-line speed of public transport is between 9 and 13 km/h, while for the MIT it is between 11 and 19 km/h.

Table 4. Averages of travel time ratio and air-line speed by city.

Number of inhabitants	100,000 to 250,000				250,000 to 500,000				500,000 to 1 Mio.				1 Mio. to 2.5 Mio.				From 2.5 Mio.	Aver-age
City	Oldenburg	Potsdam	Freiburg	Average	Brunswick	Bonn	Wuppertal	Average	Dresden	Düsseldorf	Stuttgart	Average	Cologne	Munich	Hamburg	Average	Berlin	All
Travel time ratio																		
- PT/MIT	1.95	1.13	1.34	1.43	1.30	1.66	1.78	1.71	1.39	1.10	0.98	1.25	1.08	0.64	1.01	0.81	1.00	1.05
- Bus/MIT	1.93	1.32	1.37	1.83	1.36	2.33	2.07	1.96	1.34	1.50	1.19	1.37	0.82	1.23	1.39	1.31	1.44	1.54
- Bicycle/MIT	1.37	1.09	0.95	1.17	1.05	1.08	1.69	1.58	1.30	1.24	1.31	1.30	1.18	1.01	1.19	1.11	1.32	1.29
Air-line speed																		
- MIT [km/h]	19	15	11	15	13	15	19	19	17	15	12	16	12	11	14	12	17	17
- PT [km/h]	10	12	9	12	10	10	10	11	12	15	14	13	13	21	16	19	18	17
- Bus [km/h]	11	10	10	10	10	7	9	9	12	12	11	12	9	9	10	10	11	10
- Bicycle [km/h]	13	13	12	13	12	13	11	12	13	12	10	12	10	11	12	11	13	13
Number of routes	45	45	45	135	45	45	55	145	105	55	66	226	105	171	190	466	861	1,833

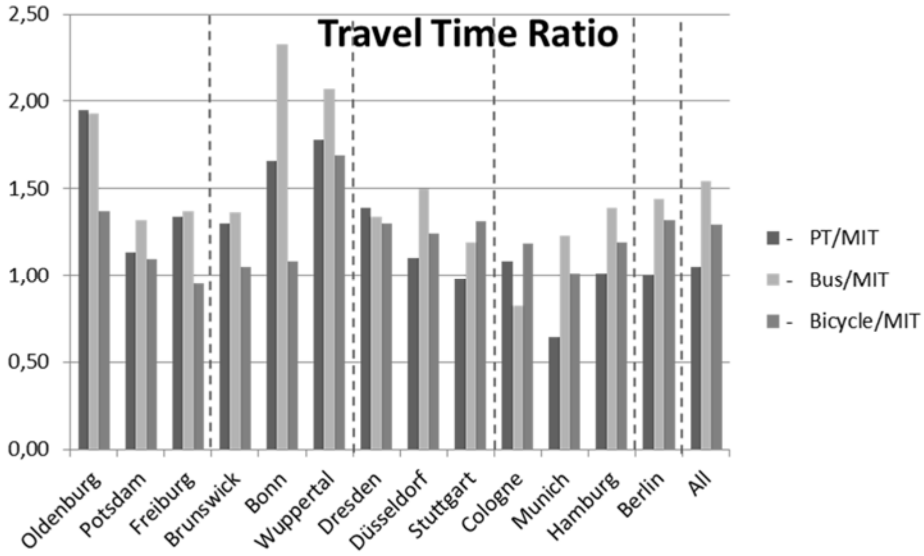


Fig. 3. Reference Points in Hamburg.

The key values of the MIT air-line speed are more heterogeneous than those of public transport. This suggests that differences in the travel time ratio of public transport to private transport between cities with up to 500,000 inhabitants can be attributed more to the speed of private transport than to public transport. For example, Oldenburg city center is located less than 1.5 km from the A28 motorway and is therefore easily accessible with the MIT. In Munich's city center, the network of underground and tram lines is very dense and accessibility via the MIT is restricted by one-way streets and pedestrian zones, resulting in a very low travel time ratio PT/MIT of 0.64.

A look at public transport routes travelled by bus only shows that the average travel time ratio bus/MIT is higher in all city types than for PT/MIT in general. Only in the cities of Cologne and Dresden the travel time ratio for buses is lower than for public transport in general. In 8 out of 9 cities with a population of up to 1 million, the bicycle/MIT travel time ratio is below that of public transport. The average air-line speed of the bike is between 10 and 13 km/h in all cities and thus spreads less than MIT and public transport. In the city category of 1 million to 2.5 million inhabitants, the air-line speed of the bicycle is 1 to 2 km/h lower than in the other cities (11 km/h). However, since the air-line speed of the MIT is also lower in these cities (12 km/h) than in the other cities, the travel time ratio bicycle/MIT is still 1.11. If connection times for searching for parking spaces or access times to bus stops in public transport would be taken into account for all transport systems, this would presumably result in an even lower travel time ratio between bicycle/MIT and bicycle/PT, since these times are presumably very short when using a bicycle.

In public transport, direct walking may be the fastest route instead of using public transport. For ten (10) of the 1,833 investigated public transport routes, it was proposed to walk. These footpaths are spread over eight cities and the influence on the characteristic value calculation is to be estimated as small.

In all city categories, a large part of the measured values of travel time ratio are below a value of 2.0. It is striking that especially in the city categories from 1 million inhabitants many values of less than 1 and less than 0.5 are achieved. One explanation is that some of the public transport systems, such as underground and suburban trains and trams, are not influenced by jams due to using their own, separated tracks.

5. Discussion

Overall, it can be said that one can find large differences between cities of the same category and the city categories are thereby very heterogeneous. MIT and public transport measurements show a connection between city size and travel time. In cities with more than 1 million inhabitants, the MIT has usually a lower air-line speed than in the smaller cities and the public transport has a higher air-line speed than in the smaller cities. This is also reflected in the travel time ratio between public transport and private transport.

However, it cannot be said that with increasing city size the travel time ratio between public transport and private transport always decreases. Cities between 250,000 and 500,000 inhabitants have on average the highest travel time ratio between public transport and private transport. The air-line speed of public transport increases slightly for cities with at least 500,000 inhabitants. This can be possibly explained by the existing rapid transit systems. If only routes covered by bus are considered, there are hardly any differences between the city types – the bus has similar air-line speeds in all cities. Regarding cycling, there is no correlation between city size and travel time either – neither at air-line speed nor at the travel time ratio bicycle/MIT. Thanks to separate cycle traffic infrastructure, the travel time of cycle traffic is probably neither dependent on the traffic volume of the MIT nor the time of day, what could justify the similar air-line speed of cycle traffic in all cities.

The comparison of Google Maps and HERE Maps shows that HERE Maps has weaknesses in the calculation of public transport routes despite more extensive adjustment possibilities in route calculation. Therefore, the use of Google Maps is recommended when calculating public transport routes.

6. Conclusion

The study performed a detailed analysis of travel times in urban areas using the selected methods for route calculation. Comparative analyses of the travel times of the transport systems were carried out and correlations between city sizes were investigated.

When investigating which mode of transport has the shortest travel times in a respective city category, one could state the following: In cities with up to 1 million inhabitants, MIT usually has the highest air-line speeds. The air-line speed of the bicycle traffic is usually between the one of MIT and the one of public transport. Only in Freiburg city center bicycling is the fastest mode, while public transport is the fastest mode of transport in Stuttgart's city center. In cities with more than 1 million inhabitants, the travel times of MIT and public transport are often similar and the bicycle somewhat slower.

One of the objectives of the study was the identification of the maximum reasonable detour caused by bundling different requests when using ride pooling. The existing travel time ratio between private and public transport may be used as an approximation for this detour. The presented study has revealed that the travel time of public transport in cities of about 100,000 to 250,000 is at about 1.43 as high as the travel time when using MIT. The ratio within Oldenburg is the highest one identified in this study: On the considered routes PT passengers have to accept a travel time that is about 1.95 as high as the MIT travel time. A DRT that allows passengers to reach their destination quicker could be of great benefit.

In the city center of Berlin the ratio is at 1.0, which means that passengers in Berlin are used to a public transport system that can compete with a journey by car. In the big cities Hamburg, and Cologne the results are similar. In Munich PT even enables a faster ride than MIT. While establishing a DRT in big cities this fact should be taken into account: DRT will be only successful if travel times are short or when it is planned as an access mode to fast rail-based modes of transport that use an own infrastructure.

It should be noted that the study can only give an approximation to the actual maximum reasonable DRT detour. Drawing conclusions from the travel time ratio between PT/MIT in different cities is yet questionable due to the high differences in urban structure and existing infrastructure of the considered cities. The results of the study can thus serve as a basis for discussion, but should be supported by more in-depth studies, such as studies on user requirements and acceptance. The full study can be found on DLR electronic library at http://elib.dlr.de/114455/.

References

Ahrens, G.-A., 2015. Sonderauswertung zum Forschungsprojekt „Mobilität in Städten“, SrV 2013. Städtevergleich. Dresden, 2015.

Atasoy, B.; Ikeda, T.; Ben-Akiva, M., 2014. The Concept and Impact Analysis of a Flexible Mobility on Demand System. Available at: https://its.mit.edu/sites/default/files/documents/Atasoy,%20B.,%20Ikeda,%20T.,%20Song,%20X.%20and%20Ben-Akiva,%20M.%20E.%20(2014),%20%E2%80%9CThe%20Concept%20and%20Impact%20Analysis%20of%20a%20Flexible%20Mobility%20on%20Demand%20System%E2%80%9D,%20Transportation%20Research%20Part%20C-%20Emerging%20Technologies.%E2%80%9D.pdf

Forschungsgesellschaft für Straßen- und Verkehrswesen e.V. (FGSV), 2008. Richtlinien für integrierte Netzgestaltung. Köln, 2008.

Laws R., 2009. Evaluating publicly funded DRT schemes in England and Wales, PhD Thesis, Loughborough University, Loughborough

Sommer, C.; Schäfer, F.; Löcker, G., 2016. ÖPNV strukturiert planen. Leitfaden zur ÖPNV-Planung in ländlichen Räumen liegt vor. Der Nahverkehr 10/2016. S. 40 - 45.

Viergutz, K., Brinkmann, F., 2018. Demand Analysis and Willingness to Use of Passengers of Flexible Mobility Concepts. European Transport Conference, Barcelona.