Analysis of Methodological Approaches for the Data-Based Mapping of the Service Quality of Public Transport

Name: Teresa Eickels
Affiliation: Chair and Institute of Urban and Transportation Planning (ISB), RWTH Aachen University, Mies-van-der-Rohe-Str. 1, 52074 Aachen, Germany
E-mail: eickels@isb.rwth-aachen.de

Name: Fabian Kühnel
Affiliation: Chair and Institute of Urban and Transportation Planning (ISB), RWTH Aachen University, Mies-van-der-Rohe-Str. 1, 52074 Aachen, Germany
E-mail: kuehnel@isb.rwth-aachen.de

In the public transportation sector in Germany the topic quality gains more importance time and time again. In the current discussions about sustainable mobility and the change of usage of motorized individual traffic, improving the quality of public transportation systems is seen as a solution. Although there is no uniform definition of the term and therefore no standardized evaluation of the public transport supply. Nevertheless, there are multiple publications, which either give recommendations for certain aspects of the term quality or even implement methods for the analysis of the supply regarding selected criteria. A comparison of the publications and methods shows, that fundamental differences in the understanding of the term quality should be removed, different criteria and their development should be implemented and simplified methods in determining the quality should be verified considering the advanced technical possibilities.

Keywords*:* Public transport, reachability analyses, service quality

1. Introduction

In the last years, the topic of the quality of public transport has been subject of discussion. One problem of the discussion is the inconsistent use, or in other words, the inconsistent understanding of the term "quality" as well as no unified understanding concerning the resulting criteria for quality. With DIN EN 13816, first approaches to the description of quality and the respective criteria differentiated into eight categories (availability, accessibility, information, time, customer service, convenience, safety and environmental impacts) were developed. One advantage as well as disadvantage is the fact that there are no limiting values or guidelines stated in the norm, but only potential criteria. This is plausible taking into account the multitude of European countries to which this particular norm applies, which differ in their spatial structures, their socio economics, their political environments, and also in their public transport offering. For Germany, the Public Transport Act states that the authority responsible for the assurance of a sufficient provision of transport service in the public transport sector defines the requirements for the extent and the quality of the transport offer, and its environmental quality [PTA, § 8, Abs. 3]. This determination of responsibility results, inter alia, from the EU regulation 1370/2007. However, there is no definition of the term "quality" or "sufficient" service in the Public Transport Act. Therefore, various people and institutions try to approach the notion of quality and measure it with the help of external data sources, objective or subjective detectable criteria. The newest example of such an approach is the VDV guideline "Traffic development, transport offer and network quality of public transport" [VDV 2019], which should, according to their own statement, serve as a "kit" for a content regulation of the term "sufficient" service [VDV 2019, 6]. Another example is the publication "Service quality and accessibility of public transport" of the Federal Institute for Research on Building, Urban Affairs and Spatial Development [BBSR 2018]. In this publication, different analyses concerning extent and accessibility of public transport serve as a basis for discussion for the determination of a definition of „sufficient service". Accessibility is therefore in this context defined as the access to stops of public transport. Further analyses of parameter of travel expenses and travel budget (difference access vs. accessibility) as they occur in several other publications [cf. Schwarze 2005] are not the focus of this study. The „Public Transport Report 2017" [civity 2017] should also be mentioned, which analyzed the local traffic offering concerning the service quality, the tariff system and the fares of local traffic in comparison to the public parking fees in more than 50 cities. Unlike the BBSR publication, which conducted a nationwide, comprehensive analysis of the service quality as a combination from the quality of service, development and connection, the Public Transport Report focusses on metropolitan areas including collective agreement conditions and design for the users. A comprehensive analysis as a first step, reduced to the aspects of service, development and connection quality is in line with the individual results of the Public Transport Report, which state that the frequency and network density is important and that the fare for the attractiveness is only of secondary interest [ARD 2018].

Due to the great importance of service quality for the attractiveness of public transport, the results of the study by the BBSR as well as the recommendations of the VDV guideline are analyzed, compared and, on the one hand, connected to the results of a study by Brost et al. [2018a] on the topic of methodology comparison of reachability analyses of public transport stops and, on the other hand as an example applied to the data and tested for plausibility.

2. Analysis and comparison of methodological approaches to determining accessibility of public transport stops as a quality criterion of service quality of public transport

In connection with the development of the model for site selection for electric charging infrastructure (STELLA) [Brost et al. 2018b] and the in this context developed methods for the comprehensive concretization of the determination of modal split of public transport in connection with the method for the estimation of traffic volume by the Road and Transportation Research Association (FGSV) [2010a], analyses on the accessibility of stops have been carried out in the study by Brost et al. [2018a]. The motivation of the study was the goal of deriving indicators based on objective data sets from comprehensive topic fields such as public transport offer, socio demographics, socio economics, spatial design, and their analyses and connections that enable the separation of the share of public transport in the step of traffic distribution according to traffic modelling. By concretizing the modal split share of one mode of transport (public transport), the other shares are also influenced indirectly. In the specific case of application in the model STELLA, by refining the estimation method of the public transport share, the share of the motorized individual transport is concretized indirectly, which is one of the most crucial basic information and therefore of great importance for the derivation of the (potential) electro mobile traffic share. The basis of the conducted accessibility analyses was the derivation of quality levels for public transport stops differentiated according to the criteria of the mode of transport and the spatial design. The focus of the study is on the comparison of methodological approaches on the one hand with accessibility radii and on the other hand with network analyses. The approach to map accessibility as radii around the examined locations is a common procedure. With the help of routing algorithms and digital maps, it is possible to concretize the simplified method to take, for example, natural obstacles or difficult topographic conditions into account and therefore, improve results [VDV 2019]. In the case study for the model region of VGN, it was shown that an up to 60 % lower territorial coverage of neighboring urban districts was achieved in network analyses of the effectively available road system compared to analyses of reachability radii [Brost et al 2018a]. This study shows that, in the context of the question of service quality of public transport, the selection of a method for analysis should be of particular importance. However, the assumptions made in the preliminary stage are also highly relevant for the results: accessibility distances for the different quality levels are chosen depending on the conducted spatial typification. These distances are based on literature research, in which it became clear that there are no legal regulations, but only recommendations and that they vary depending on source and institution [VÖV 1981] [FGSV 1999] [VDV 2001] [VDV 2019] [STMWI 2018]. All sources have in common that they state specific catchment areas for different spatial categories.

2.1 Spatial differentiation as basis of methods for accessibility analyses

In many cases there is a differentiation of the space on the first level in urban center, medium center, sub-/small center and rural community On the second level, these categories are further distinguished according to their utilization density in “core area”, “high utilization density”, “low utilization density” or “central area” [VDV 2019]. However, no source offered a definition of the terms or a limit value for differentiation in direct context yet. The publication of the VDV from 2019 assigns limit values of utilization density to spatial density levels. The utilization density is specified as residents, employees as well as pupils and students (EAA) per km² [VDV 2019]. This definition can support the application of the recommendations for the catchment areas of stops, but it also raises new questions: The density differentiation “high to very high utilization density”, “medium utilization density” and “low utilization density” do not occur in the terminological differentiation in the recommendations for catchment areas [VDV 2019, 15]. A mere analysis of urban quarters differentiated according to utilization density reveal a similar distribution for Germany and the region of VGN: about two thirds of the areas would be categorized as high or very high density (see Fig. 1). When applying the limit values to the urban quarters in the VGN in combination with central locations, results must be verified (see Fig. 1): even in rural areas, more than half of the districts are categorized as high or very highly dense. This would lead to the derivation that with these recommendations a further distinction according to utilization density could be necessary in rural areas.

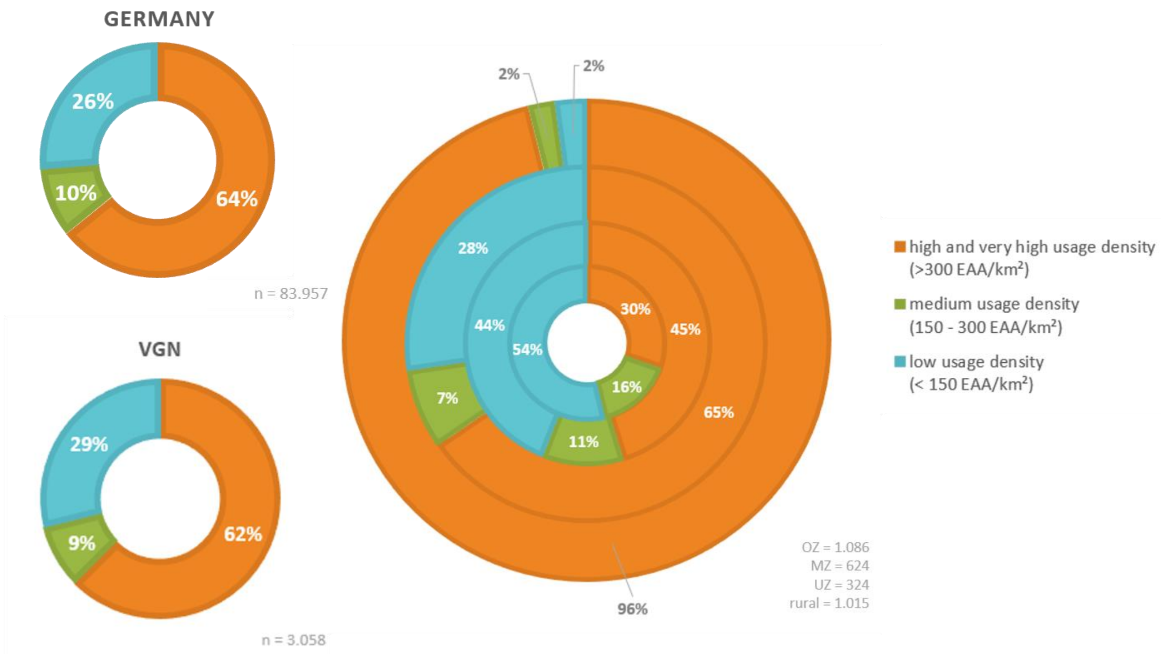

Figure 1. Evaluation of urban quarters according to categories of utilization density following VDV 2019 (urban center outside; rural area inside) [own illustration]

A Validation of the results of this application of the defined utilization densities to a large-scale area is required in future studies. Thereby, the levels of consideration of urban quarters as well as limit values should be assessed.

2.2 Method for determination of catchment areas

In the method, which is the basis for the paper by the BBSR, catchment areas of stops are determined due to public transport and spatial categories following the recommendations for planning and operation of public transport [FGSV 2010b]. For the comprehensive analysis, a uniform accessibility radius of 600m is derived, which results in more than 90% of the population living in these catchment areas of stops [BBSR 2018]. For the derivation of development quality, this result is connected to a criterion of the indicator of service quality, which establishes a minimum offer of around one or two departures per direction and hour between 7am and 5pm. These minimum requirements for the connectivity quality decrease the share of population with access to stops to slightly above 80 % or slightly under 70 % [BBSR 2018]. At this point, three established constraints can be criticized: the minimum frequency of departures, the considered time period (see chapter 2.3), and the selected reachability radius.

The boundary condition of the selected reachability radius, having regard to the results of the comparison of methods by Brost et al. [2018], is at this point reflected upon in more detail. Assuming a beeline distance of 600 m, it has to be assumed that the effective distance to be travelled is longer. In the literature, this is covered by considering the beeline distance plus a detour factor. This can be carried out either specifically for the purpose of the journey [UVEK 2011] or generally, for example using a factor of 1.2 [VDV 2001]. Based on these results from the literature, a generalized calculation with a reachability radius of 600 m would result in an effectively travelled distance of up to 720 m. Instead of this generalized assumption, the here applied method estimated in a first step a reachability radius of 600 m around each stop of the VGN. In a second step, all intersections between the radius and the road system that can be used by pedestrians were identified, from which, in another step, the distance to stops was routed back to the road system (compare Fig. 1).

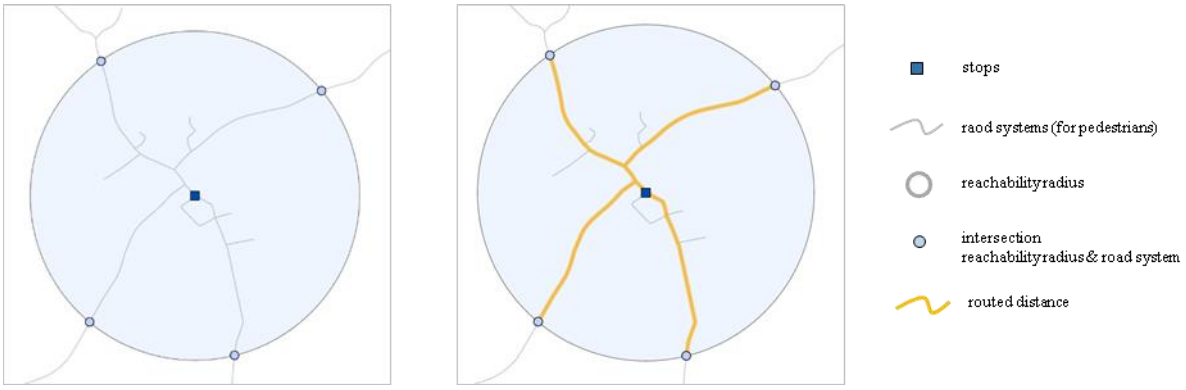

Figure 2. Schematic display of the method for comparing beeline distance and routed distance of a public transport stop [own depiction]

Evaluations for the model region of VGN show, however, that the effectively travelled distance on the road system that can be used by pedestrians [HERE 2017] is on average 896 m. To put less emphasis on potential outliers and spatially special cases, a consideration of the meridian, which is at 779 m (see Fig. 2), can be useful. This shows that the routed distance on the network is longer. With regard to the distance of the first and third quantile (698 m und 896 m), a majority of the intersections resulting from the reachability radius and the road system are located within an access time of nearly 9 minutes up to more than 11 minutes.[1] This exceeds the in the literature recommended 5 to 10 minutes access times for stops [Winter 2005]. If, at this point, the routing for the selected 600 m or 720 m would be determined as the maximum distance to stops, the proportion of the population with access to stops would to some extent decrease significantly, similarly to the results by Brost et al. [2018a].

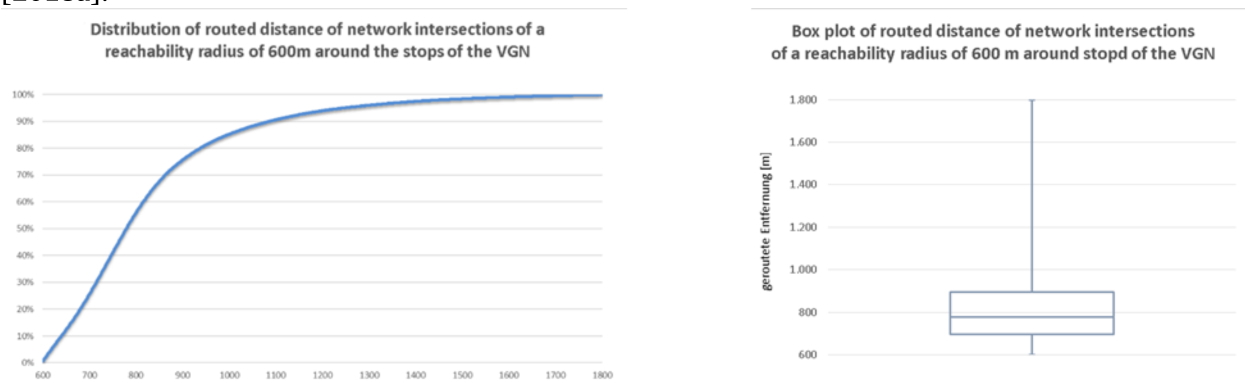

Figure 3. Distribution and box plot of routed distance between network intersections of a reachability radius of 600 m around stops of the VGN [own depiction]

In addition to the presented analysis, further steps should include not only a network analysis with a distance of 720 m, but also a differentiation with regard to the mode of transport (rail

[1] Based on an average speed of 1,34m/s [Weidmann 1992].

transport stations with a recommended distance of 1200 m according to the BBSR study) and the spatial location (urban center, medium center, sub-/small center and rural community).

2.3 Analyses of departure density in the context of service quality of public transport

Similarly, to the topic of definition of quality of accessibility of stops, there are no mandatory guidelines for authorities for the departure density or the frequency of departures at each stop. The paper by the BBSR states a minimum offer of 20 or 40 departures per day for the determination of service quality at bus stops and stops for the special call and collect services. Converted to the considered time period from 7am until 5 pm, this results in one or two departures per direction and hour at each stop [BBSR 2018, 9f]. This corresponds to 30 to 60 minutes cycle without a differentiation between periods of regular traffic intensity[2], periods of low traffic intensity[3] or rush hours[4]. These selected framing conditions can be analyzed in more detail regarding two aspects: the considered period of time and the chosen minimum number of departures. With regard to the considered time period, it becomes clear that, considering the MiD 2008 as well as the MiD 2017, the traffic volume peaks between 3 and 6 pm [infas, DLR 2010] or between 3 and 7 pm [infas et al. 2018] in the course of the day, which is among other factors due to the return journey of the commuters. So, by restricting the analyzed time period for the determination of service quality of public transport to the time between 7 am and 5 pm, the offer for a large proportion of regular trips, for example the way back after work after 5 pm, is not taken into account in the quality assessment of the offer. From a user perspective, the public transport offer can only have a certain quality if he or she can use it for his planned journey. A good offer for the way to work, but a lack of a similar offer for the way back home results in an overall as insufficient regarded service.

[2] Periods of regular traffic intensity are the periods in which the trip purposes purchase, errand, and shopping are dominant. It is the time between rush hours in the week, and shop opening hours on Saturdays.

[3] Periods of low traffic intensity are the periods with low transport demand, in which the trip purposes leisure and living dominate. There are no consistent definitions for the temporal delimitation. Usually, they start after 8pm or 10pm during the week, after the periods of regular traffic intensity on Saturdays, on Sundays and bank holidays, and end before the rush hour in the morning (with breaks at the end or start of business hour).

[4] Rush hours are the periods of highest traffic intensity in which the trip purposes work and school dominant. There are no detailed definitions of this time period, usually they occur from Monday to Friday between 6 and 9 am or between 4 and 7 pm.

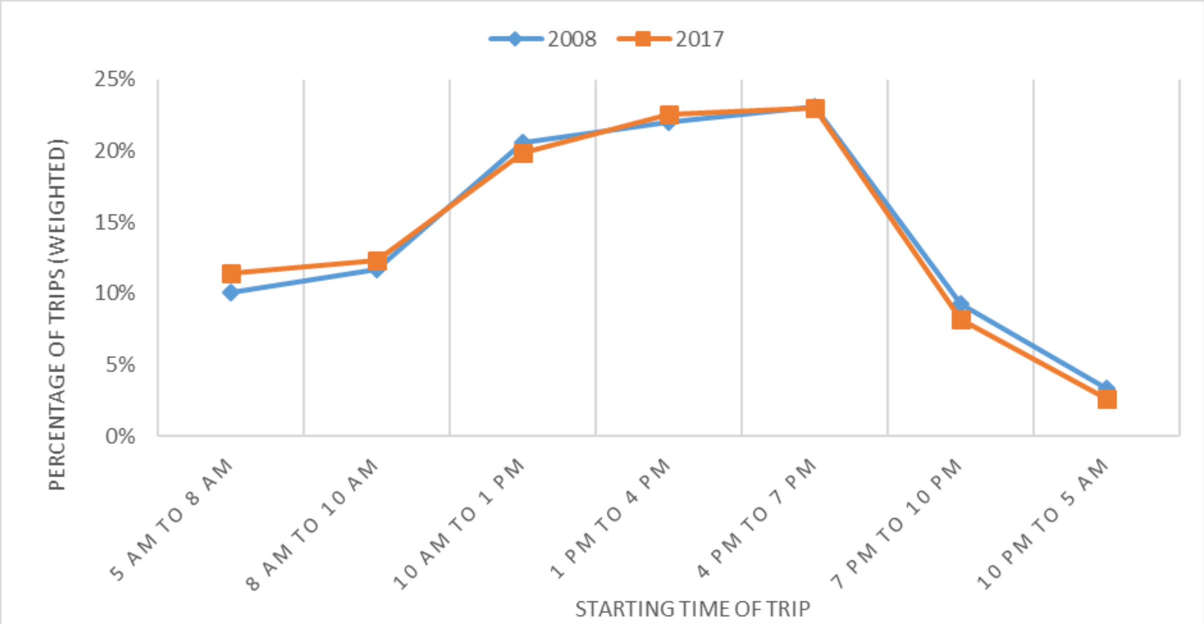

Figure 4. Distribution of launch times of weighted trips from MiD 2008 and MiD 2017 [own illustration following infas, DLR 2010 und infas et al. 2018]

For the VGN, two time periods that could potentially be analyzed are compared, namely 7am until 7pm – based on selected boundary conditions from the BBSR paper – or 6am until 7pm – based on the evaluation of the studies mobility in Germany 2007/2018 (compare Tab. 1). In doing so, the continuous transport offer at the stops has been examined. The comparison reveals that the expansion of the time period by 3 hours decreases the number of stops with a high departure frequency slightly. The slight deterioration can be observed for bus, or tram and train. The underground, however, shows a consistent offer of departures of this transport mode for both considered time periods. It can also be seen that the underground departs every 15 minutes minimum.

Table 1. Differentiation of stops according to their departures per hour in comparison of two selected time slices [own illustration following VGN 2019]

Departure/Hour	Cycle	Bus/Tram[1]		Train[2]		Underground[3]	
		7am-5pm	6am-7pm	7am-5pm	6am-7pm	7am-5pm	6am-7pm
≥ 1	60 Min	20.5 %	19.4%	85.2%	83.0%	98.0%	98.0%
≥ 2	30 Min	13.6 %	12.9%	46.3%	45.9%	98.0%	98.0%
≥ 3	20 Min	7.9 %	7.3%	38.9%	38.9%	98.0%	98.0%
≥ 4	15 Min	5.3%	5.1%	18.3%	17.9%	98.0%	98.0%
≥ 6	10 Min	1.9%	1.8%	6.6%	6.6%	96.0%	96.0%
≥ 12	5 Min	0.3%	0.3%	1.8%	1.8%	15.2%	15.2%

[1] n = 16.041 | [2] n = 229 | [3] n = 99

The recommended transport offer in periods of regular traffic intensity from the VDV publication can be used as a comparative value for an average cycle, in which such a cycle would correspond to the quality level C or lower.

With regard to the minimum offer of one or two departures per stop per hour from the BBSR paper, a comparative value from the VDV publication, namely a quality level, can be used

[VDV 2019, 21]. These quality levels are only stated for periods with regular or low traffic intensity. A classification of the offered cycles during rush hours into quality levels is not presented in the VDV paper. Furthermore, there is no distinction between transport modes, so that a high rate of bus departures corresponds to the same quality as a high rate of underground departures. To what extent this holds true with regard to transport speed, capacities and operating range should be taken into account when using this evaluation system. Assuming that the considered period of analysis by the BBSR is rather a period with regular traffic intensity than a period with low traffic intensity, the cycle of 30 to 60 minutes analyzed in the BBSR paper would correspond to a quality level of C or lower *[VDV 2019, 21]*. According to the definition, this transport offer is recommended for areas with low demand potential (peripheral regions of urban and medium centers, sub-/small centers, rurally structured areas). However, in the nationwide consideration by the BBSR, areas with medium or high utilization density have also been included, which have been valued with the same minimum offer.

3. Conclusion and outlook

The literature research as well as the above presented detailed analyses of three methodological approaches for determining the public transport service quality show that the absence of concrete guidelines result in different interpretations and executions of the recommendations for quality criteria for public transport. The recent publication of the VDV, which deals with this exact topic, is a first indicator for approaching answers to the question of the meaning of the recommendations stated in different publications in terms of concrete guidelines and limit values of specific data sets. Nevertheless, it becomes clear that despite more detailed assessments of the topic, there are still definitions gaps or ambiguities due to incomplete representation of individual criteria or use of inconsistent terms. Further analyses show that it must be examined whether simplified approaches, for example in the case of accessibility, are useful for other applications or if they need to be refined with regard to modern technological possibilities. The validation regarding modern, more comprehensive technological possibilities as well as modern, broader available data sets should be carried out for all methods that are implemented for the examination of relevant quality criteria.
In the case of reachability analyses, this implies that the use of reachability radii is useful as a first approach in initial analyses. When carrying out more detailed analyses regarding the question of the service quality, the implementation of routing algorithms and network analyses should be considered in order to get more precise results. Major differences occur for example for barriers in the spatial structure like railway lines that can only be crossed at certain points (potentially outside of the radius), which does not have an impact in an exclusively laminar treatment of the reachability radius due to methodological reasons which results in an overestimation of the covered area. The topic of the assessment of service quality in the public transport sector is given currency by the two recent publications, which could lead to a discussion about methodological approaches and missing concrete guidelines and limit values in expert groups resulting in positive development. The paper of the BBSR also aims at this goal, offering a discussion basis for debates on appropriateness and necessity of service quality of public transport with its chosen methods and limit values in the form of a first comprehensive approach for Germany *[BBSR 2018]*.

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