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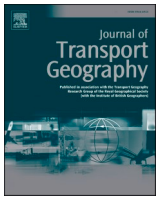

Measuring transport poverty with a mixed-methods approach. A comparative case study of the German cities Berlin and Hamburg

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ABSTRACT

This mixed-methods study examines transport poverty in Berlin and Hamburg, combining GIS-based spatial analysis of public transport (PT) service levels with qualitative interviews of 40 welfare recipients about their transport experiences. The research reveals that low-income residents do not have worse absolute access to PT, but per-capita service is poorer due to high population density. This highlights inequities where crowded transport systems diminish service quality. The interviews also show that high PT fares, before the introduction of the €58 "Deutschlandticket," had been a major barrier, forcing individuals to choose between transport and other essential needs like food and housing. This financial constraint limits mobility, employment, and social interaction. The study's integration of GIS analysis and personal interviews provides a comprehensive view of transport poverty, capturing both systemic issues and individual coping strategies. The findings suggest a typology of seven mobility types among low-income residents, offering policymakers a framework for targeted interventions. Recommendations include fare reductions, improved per-capita services in dense areas, and enhanced support for vulnerable groups to address both systemic inequalities and financial barriers, advancing a transport equity agenda that promotes social inclusion.

1. Introduction

Since the early 2000s, planning tools have been developed to measure and improve spatial accessibility to transport and hence the inclusion of income-poor populations. This has made it possible to identify deficits and derive recommendations for improving transport services (Schwarze, 2015; Social Exclusion Unit, 2003). Only recently have these quantitative studies been supplemented by qualitative approaches that adopt the perspective of people affected by transport poverty, on the assumption that large-scale measures to improve accessibility do not necessarily reflect the needs of those affected (Karner, 2018). In addition, low-income earners are comprised of heterogeneous groups, each with specific requirement profiles (Daubitz, 2013).

Until recently, only few works have connected these two approaches (e.g. Kamruzzaman and Hine, 2012; Shay et al., 2016). We aim to contribute to fill this methodological gap by investigating the accessibility of public transport for low-income populations in the largest two German cities. Based on the belief that the combination yields outcomes greater than the sum of both individual approaches, we have opted for a mixed-methods approach and conducted a socio-spatial analysis. In order to relate the quantitative and the qualitative data collection to each other, we apply the two concepts of objective *action space* and subjective *opportunity space*. We thus integrate a quantitative GIS-based analysis for Berlin and Hamburg and a survey conducted among 40 welfare recipients. This allows us to bridge the analytical distinction between *action space* and *opportunity space*, creating a typology of low-income people that are affected by transport poverty, enabling us to identify seven mobility types.

In section 2 we briefly describe our theoretical starting point that strongly relies on the distinction between actual and imagined mobility and describe previous work that we built on. In Section 3 we explain the methods that we used and how we integrated the qualitative and quantitative results into a typology. In section 4 we describe results (in a slightly different order than section 3 to enhance readability). A discussion in section 5 and a conclusion in section 6 round off the article.

2. Concepts and methods

In our empirical material, we distinguish between actual mobility practices and imaginable mobility (Schwedes et al., 2023). In what

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follows, we will make this distinction by means of two terms: firstly, *action space* encompasses the actual spatial changes of location, which can be compared in their length, duration and frequency (Scheiner, 2018). Secondly, *opportunity space* describes both mobility-related knowledge, capabilities, experiences and assessments, and the desired destinations. This term was coined by Canzler and Knie by defining mobility as "movement in possible spaces", distinguishing it from transport as "movement in concrete spaces" (Canzler and Knie, 1998). Based on the empirical material, our typology extends the concept through a third term: the *desired space* describes the extent to which people are able to consider potential changes of location, which is part of the subjectively perceived space of opportunities. Through a combination of qualitative interviews and the comparative analysis of *action space* and *desired space*, we are able to determine the extent of transport poverty.

It is widely agreed upon in transportation research that mobility is crucial for well-being. The concept of well-being can be described as 'living a good life', which is associated with or synonymous with notions of happiness, life satisfaction and fulfilment (Delbosc, 2012; Vella-Brodrick and Stanley, 2013). This concept has often been adopted and linked to social exclusion particularly in the U.S., the UK, Australia and New Zealand. Most case studies take a social perspective as the main focus of their research (Delbosc and Currie, 2011a; Lucas, 2004; Páez et al., 2009) and many refer to the capability approach taken by Amartya Sen (2009). Currently, there is no universal definition for transport poverty, but the concept is recognized as being of multi-dimensional nature (Lucas, 2012; Lucas et al., 2016). Building on terminology used by Lucas et al. (2016), we derive the following working definition: transport poverty describes a lack of capacity to achieve well-being. This lack can be grounded in a lack of transport options (mobility poverty), a lack of resources to pay for these options (lack of transport affordability), and/or an inaccessibility of services and activities (accessibility poverty). Besides the systemic components such as service frequency or fare, individual traits such as needs, capabilities and affluence play a central role in shaping exclusion. By identifying these traits and developing appropriate strategies, an inclusive mobility-oriented policy can extend *opportunity spaces* – and provide inclusion to those who have less of a choice when it comes to mobility, i.e., ethnic minorities, women, physically-disabled individuals and, as the present paper shows, those on very low incomes.

2.1. The mixed-methods approach

We combined quantitative and qualitative methods to measure transport poverty in Berlin and Hamburg. Our selection of these case areas was motivated by previous literature that describes the distinct socio-spatial concentration of economically marginalised groups in the two largest German cities (e.g. Häußermann et al., 2004; Pohl and Wicher, 2013; Vrenegor, 2014; Holm, 2016).While there is a large body of work advancing GIS-based methodology, only few studies combined GIS-based accessibility with the subjective perceptions of those affected. The latter include the work by Shay et al. (2016), who mapped factors of socio-economic exclusion and supplemented the results with interviews and focus groups to investigate the issue of accessibility for the rural population in North Carolina/USA. Kamruzzaman and Hine (2012) combined the area of *action spaces* of 157 respondents in Northern Ireland with focus groups. Both teams described the benefits of combining quantitative and qualitative approaches as a major methodological gain. In Germany, the project *Social2Mobility* also adopted a mixed-methods approach (Rozynek et al., 2022; Sommer et al., 2024). *Social2Mobility* also addressed transport poverty and inclusion, investigating the town of Ronnenberg in the Hanover region.

Similarly, we recognize the explanatory value in the complementary methods that we applied. Our analysis builds on two approaches to data collection and analysis, which are introduced in sections 2.2 and 2.3. We followed a microscopic approach by qualitatively interviewing low-income urban dwellers, thereby exploring their personal perspective on exclusion, their needs, and their coping strategies. This approach is complemented by a macroscopic one: we applied GIS-based spatial analyses to investigate structural forms of inequity concerning mobility and poverty.

2.2. Qualitative mobility surveys as a means to explore transport poverty

The microscopic approach of our study entailed conducting qualitative interviews with low-income residents of Berlin and Hamburg, in order to gain insight into their subjective experience in terms of potentially being deprived of mobility options. The interviews were complemented by travel diaries, which were inspired by the *Mobilität in Deutschland* survey (MiD). The latest available MiD survey was conducted in 2017 and is comparable to the U.S. National Household Travel Survey (infas et al., 2018). The combination of diaries and qualitative interviews has been used in mobility research primarily to investigate certain groups (Ahrend, 2002; Schneider, 2017), which have been sampled in terms of demographics (children, families or elderly people) rather than their economic situation.

2.3. Spatial data as an indicator for transport poverty

Quantitative accessibility analyses have long been established in transportation research. The guiding principles date back to the mid-20th century (Hansen, 1959; Ingram, 1971). Since then, many studies have discovered that accessibility encompasses fundamental desirable qualities and is thus appropriate as an element of urban and regional planning, as Levinson and Wu, 2020 point out in their informative summary. The specific application to matters of social (in-)equity saw a peak of international attention in the early 2000s, induced by the British Government's well-known SEU report (Social Exclusion Unit, 2003). Also in the U.S., transit agencies of large conurbations are obliged to assess the consequences of PT-related interventions in the access to mobility of low-income groups, among others (Karner, 2018). In German planning, accessibility is also referred to as a central issue on several administrative levels, e.g. regarding the needs of the elderly. However, few documents apply the concept of access to mobility using concrete indicators, which leaves accessibility planning confined to "a rather informal application" (Peter, 2020, p. 8; own translation).

To account for marginalised groups, accessibility indicators can be complemented by social indicators (e.g. population density, unemployment rate or local purchasing power) to describe disparities, as several researchers have pointed out at a conceptual level (e.g. Kwan, 1998; Preston and Rajé, 2007; Wachs and Kumagai, 1973) and applied in case studies (Chen and Wang, 2020; Da Silva et al., 2022; Fina et al., 2019; Guzman et al., 2017). As exemplified by Delbosc and Currie (2011b), the Gini coefficient and Lorenz curves can be applied to describe inequity in transport accessibility.

3. Methodology: the combination of qualitative interview survey and spatial accessibility analyses

3.1. Qualitative interview survey

The aim of our qualitative approach is to uncover the causes and backgrounds of transport poverty. In particular, the narratives of those affected were analyzed in order to understand processes of exclusion.

3.1.1. Sampling

We aimed at generating a heterogeneous sample, assuming different coping mechanisms depending on, for instance, the composition of the household, the available social network or the level of education (Daubitz, 2011). We started the sampling by selecting six urban areas in Berlin and Hamburg on the basis of three criteria: the local unemployment rate (≥2 standard deviations above average), a mixture of urban types (not just large housing estates), and accessibility of the city centers

by PT (Aberle, 2018). In order to recruit a total of 40 interviewees, social workers were approached, who provided a great deal of support. From November 2018 to June 2019, a total of 29 women and 11 men were interviewed. Despite the explicit request made to social workers to extend their efforts to reach men, the proportion of male interviewees reached only 27.5%, despite men constituting 50% of the total number of welfare recipients (Federal Employment Agency, 2025).

With regard to the highest educational qualification, the group holding an elementary or secondary school certificate accounted for 40 % (Table 1). Due to having a far higher share of people with a low level of education than the national average, our – non-representative – sample is in line with the finding that people with low educational attainment are more affected by poverty (destatis and WZB, 2018; Sozialministerium BW, 2015).

3.1.2. Travel diaries

Each travel diary documented the period of one week. It revealed origin-destination relations for all trips, most of which we could segment into legs and map them as a movement profile for each respondent (Fig. 2). The diary also served as a conversation starter for the qualitative interview. Apart from origins and destinations, the diary addressed difficulties, e.g., whether the interviewee was unable to undertake any trips. If so, these difficulties were discussed in the subsequent interview. The combination of travel diaries and interview transcripts allowed us to assign stories to most destinations as presented in Fig. 2.

3.1.3. Qualitative interviews

The guide for the qualitative interview was based on suggestions presented by Cornelia Helfferich (2009) and was followed dynamically. Its structure made it possible for spontaneous questions to arise. Five major topics were addressed:

1. *Action space*: we started each interview with the prompt "Please report exactly what you experienced today". Our aim was to have the interviewee talk about their everyday life, and thus describe their *action space*. Detailed and control questions followed. Subsequently, we addressed difficulties. The purpose was to investigate barriers that do not necessarily result from poverty but rather arise from – for example – personal fears. If trips not made had nevertheless been recorded, the interviewees were asked to describe these in detail.
2. Mobility biographies: here, incidents that had an influence on current mobility were investigated. In an every-day context, such incidents lead to positive or negative experiences or sometimes facilitate mobility skills. In a larger biographical setting, key events were considered, such as a change of residence, a new job or the death of one's partner.
3. Spatial environment: the accessibility of health care, PT stops and cultural and social facilities in the residential environment were surveyed. This set of questions was based on important destination categories identified from the research literature (Allardt, 1993; Haugen, 2011; infas and DLR, 2010; Nordbakke and Schwanen, 2014; Schwarze, 2015). This part of the interview provided an important contextualization of the spatial analyses (section 4.1), allowing us to compare the subjective assessment of accessibility to the GIS-based results.
4. Costs of mobility: since the financial barrier had been identified in previous research to be a determining factor in everyday mobility, possible strategies were addressed that aim to meet needs despite inadequate financial resources (e.g. economizing in various spheres of life or saving on mobility costs, including illegal strategies).
5. *Opportunity space*: this topic usually formed the conclusion. The focus was on the importance of mobility and on desired trips. When asked about their desired destinations, the interviewees were asked to leave aside their current financial restrictions and to freely formulate possible destinations.

Table 1
Our sample described by educational level.

Highest educational level	count	%
No school-leaving certificate	2	5
Lower secondary leaving certificate	16	40
Intermediate secondary leaving certificate	13	32.5
Advanced technical college qualification or vocational training with Baccalaureate	3	7.5
Higher education entrance qualification, Baccalaureate	6	15
Σ	*40*	*100*

3.2. Spatial accessibility analyses

We compiled spatial datasets at a census district level (100x100m) that comprise different indicators for PT accessibility in Berlin and Hamburg. For a detailed description with equations, we refer to the final report of our research project (Daubitz et al., 2023, section 3.2). The purchasing power indicator as well as information on the population were procured from a data service provider. The indicators can be classified as follows.

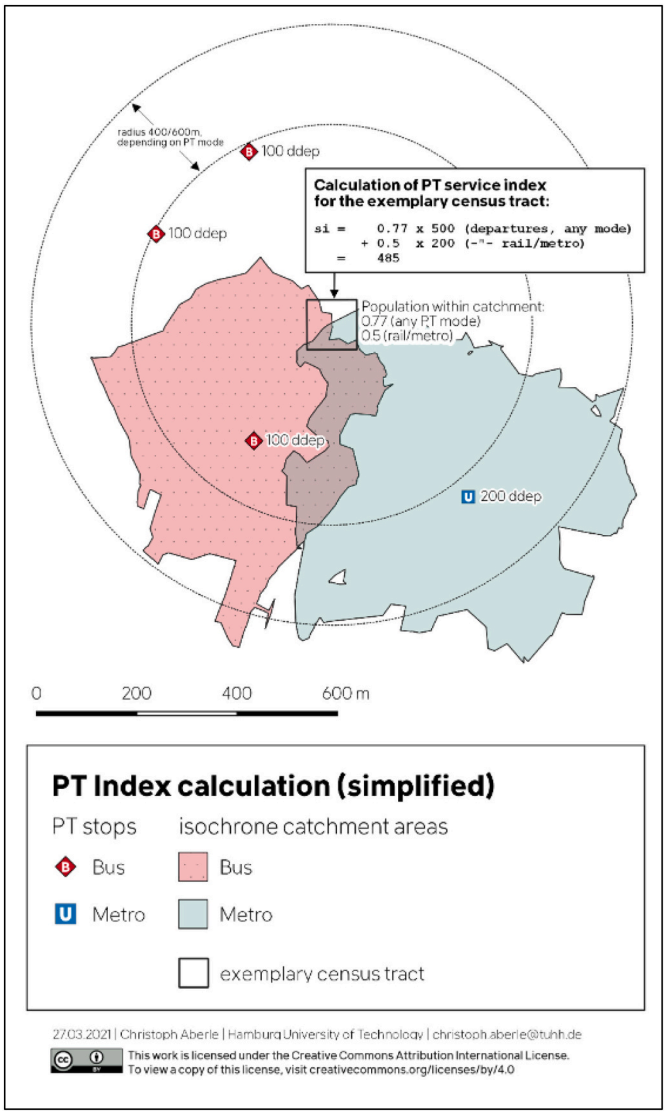
3.2.1. Catchment area

Based on the PT grid and population data, we defined the city-wide number of people that live within catchment areas for the entire PT system or the rail/metro system, respectively. To define catchment areas, real-time isochrones were drawn that correspond to a walking distance of 5–17 min from any stop (following German planning standards; VDV, 2019). The isochrone size was based on the kind of transport mode (rail/metro vs. bus/tram) and on the spatial type of a census district (dense vs. not dense). The intersect area of the isochrone with each district approximated the share of persons that live within the PT catchment, thereby assuming the population to be evenly distributed within each district. A variation of this catchment indicator was calculated for the rail/metro system in order to account for the system's higher quality of service (section 3.2.2).

3.2.2. PT service index

To account for the service level, the catchment indicators were extended to a PT service index by including available departures for each census district. Based on timetable data, we calculated the number of available departures in the surrounding area, including stops located up to 600 m linear distance around the centroid for rail/metro stops and 400 m for bus/tram stops, following municipal planning standards (BWVI, 2018). For tram&bus, an equivalent variable was calculated with a 400 m radius (Map 1). The linear distance served as an approximation, following standards in German PT planning. Furthermore, we calculated per capita departure values for each census district by dividing the daily departures by the population count.

From these catchment and departure indicators, we derived a PT service index. As exemplified by Delbosc and Currie (2011b) for a case in Melbourne, we calculated the product of catchment and departure. An exemplary census district with 77 % catchment by any mode and 500 departures, whereof 200 are rail/metro, would gain an index of 485 (Map 1). This means that rail and metro service is counted twice: once as a part of the overall PT index and once as part of the rail index. By weighting this way, we account for the higher utility that rail and metro offer compared to bus and tram. Although seldom quantified, there's a consensus among German transport planners that rail-based PT offers higher comfort and higher capacity (VDV, 2019). Furthermore, international case studies indicate that rail passengers suffer from lower stress levels and enjoy higher satisfaction than bus passengers (Cantwell et al., 2009; Scherer and Dziekan, 2012; Wener et al., 2005). Assuming that PT departures are subject to a diminishing marginal utility as most goods and services, we extended Alexa Delbosc's indicator by applying the natural logarithm to the departure count of each census district.



Map 1. Simplified illustration of the data generation process and calculation of PT service index. The square represents an exemplary census district, 77 % of which is covered by any PT mode and 50 % of which is covered by rail/metro. These shares are multiplied by the number of vehicle departures within a 400 m/600 m radius, depending on the mode. The PT index of 485 is fictive; the real distributions were logarithmised and have a median of ~6 (Fig. 4).

3.3. Integration by typology

The aim of the analysis was to go beyond the individual level and supplement the typologies that have already been proposed for the group of the income-poor (Daubitz, 2013). As presented by Kelle and Kluge (1999), a typology is understood as the result of a process, in which the interviewees can be divided into groups or types based on various characteristics. It should be noted that each type has as much in common as possible (internal homogeneity) while being distinguished from other groups (external heterogeneity).

In order to obtain a typology, parameters of comparison have to be worked out. We did so by interpreting the interviews and contextualising them in a three-day workshop once all data had been obtained. For each case, we compiled an integrated map that showed the approximate home location as well as the destinations that the respondent had documented in their travel diary (Fig. 2).

The data were compiled in a table in order to group the cases and explore empirical patterns. Firstly, the collection resulted from the categories obtained from the coded interviews. Secondly, relevant characteristics of the individuals were quantified. These include the count of visited destinations, the number of destination categories, the observed *action space* and the narrations that concern imaginable destinations. After spatially linking experiences and perspectives on a map for each respondent, we were able to identify an important comparative dimension by describing the relation between the *action space* and *desired space*. By discussing the data case by case, we were able to distinguish these spaces for each respondent, which helped us to plot the sample on an x/y graph (Fig. 8). With the exception of one respondent from Hamburg (whose travel diary was inconsistent with all patterns), we were able to group the entire sample.

4. Results

We present a summary of the results in the following section. For reasons of comprehensibility we start with the spatial analysis.

4.1. Spatial accessibility analyses

4.1.1. Catchment areas

Concerning the share of people living outside the PT catchment area, respectively, no substantial difference between the average population and social welfare recipients is recognized (Fig. 3). The highest deviation amounts to 1.5 percentage points, describing a higher share of welfare recipients living outside the Hamburg rail system. Indeed, three of Hamburg's large housing developments have not yet been connected to the railway network and have a population of ~27,000 residents (own calculation based on 2018 population data). Acknowledging that many of them only have a low to medium income explains the slightly higher share of people that are not served by PT.

4.1.2. PT service index

In accordance with the MiD national mobility survey (Section 2.2), we separated the PT service index into five classes that represent the quintiles of the purchasing power distribution. i.e., all residents who have less purchasing power than the first quintile were assigned to class 1, and so on (Table 2). These levels do not perfectly match the MiD classes, which are based on a weighted household income not available to us in a census district resolution. Our heuristics, however, do produce a distribution that delivers insights into the distribution of accessibility broken down by purchasing power.

Fig. 4 shows the PT service index as distributed among purchasing power quintiles in Berlin and Hamburg, respectively. It is subdivided by a binary density classification, which followed a quarter-level spatial typology by Matthes (2010) for Hamburg. For Berlin, density was classified by using a map of the regional PT planning agency that demarcates dense areas. As can be clearly seen, all dense areas (dark bars) benefit from an above-average PT service, which in the case of Berlin increases with purchasing power. In Hamburg, districts with the lowest purchasing power actually have the highest level of PT service. On the contrary, non-dense areas of Berlin and Hamburg (light bars) are characterised by a below-average PT service index. With the exception of the wealthiest

Table 2
Purchasing power (Pp), as distributed by quintiles. To be read as follows: 32 % of Berlin population have an average yearly Pp of less than 17,600 EUR. This value represents the first quintile of the Pp distribution.

	Berlin		Hamburg	
Pp quintile	*Pp (kEUR)*	*Population (%)*	*Pp (kEUR)*	*Population (%)*
1	< 17.6	32	< 20.7	33
2	< 19.9	22	< 23.5	21
3	< 22	16	< 26.6	16
4	< 24.9	14	< 31.3	15
5	≥ 24.9	13	≥ 31.3	12

quintile in Berlin, the PT index decreases with growing purchasing power.

This picture, however, changes when taking population into account: divided by population density of each census district, the PT service index plummets far below average (Fig. 5). Especially the large housing developments of Berlin and Hamburg, which are characterised by low purchasing power, have a PT service that does not match the high population density.

This is evident in both cities. In Berlin, there is a particularly salient difference between dense and non-dense areas (dark/light bars). This is due to a more concentrated population in dense areas in Berlin,[1] leaving a larger share of sparsely-populated districts, which increases their per capita PT index (since population is the denominator of the index equation).

Although they are provided with an above-average absolute PT service in terms of well-distributed stops and high departure numbers, as these results indicate, people in low-income areas are substantially less well-provided for when considering per-capita service. As previous results of ours show, this finding corresponds with the subjective impression of low-income interviewees who see themselves as worse-off as a result of crowded buses in their district (Daubitz and Aberle, 2020; notably before the Covid-19 pandemic). The Lorenz distributions in Fig. 6 support this finding: while not providing the reason for inequity, they indicate that access to bus transport is only slightly more equitable than access to private cars. Access to rail is distributed least equitably.

4.2. Qualitative interview survey

In the interviews, the two topics *costs of mobility* and *opportunity space* proved to be central to the description of transport poverty:

4.2.1. Costs of mobility

Fig. 7 summarizes the interview results regarding the central phenomenon of the *financial barrier*. The chart was created using the axial coding paradigm of grounded theory (Strauss and Corbin, 1997).

In all interviews, the financial barrier was addressed. Most of the interviewees had to cover their monthly expenses with a welfare allowance of about €432 or less, which was the standard rate throughout the survey period. Their mobility needs are usually met at the expense of other needs, such as food or clothing. For some respondents, for instance, the pursuit of discounts at retail stores determines their everyday mobility. The motive of permanent price comparison was repeatedly reported by interviewees. As stated by the father of a family in Hamburg:

"Yes, because [supermarket A] is much cheaper. And there are usually special offers from 5 p.m. onwards. Vegetables are cheaper and [available] in bulk [...] For example, [supermarket B] is expensive. And [at supermarket A] it's much cheaper, that's why I travel there." (P17:11).[2]

In general, strategies for coping with the financial barrier are type-dependent, referring to the seven mobility types presented in section 4.2.3. In families, for instance, life is usually organized around the needs of the children. One mother pointed out that she cannot afford the social ticket for Berlin due to other priorities:

"Well, the money is not enough to buy my ticket [...] So these €27.50 can probably be covered by my [welfare allowance], but I'd rather spend it on food for my child instead of getting a ticket. [...]. Exactly, it just wasn't enough for me to make ends meet." (P4:7–9).

Especially when it comes to visiting leisure facilities, the entrance fees are considered and can prevent interviewees from travelling to the destination in question. Factoring in the on-site costs is very common among low-income families, who develop strategies to organize excursions for their children:

"This is everyday life. This is exactly how we live our everyday lives. Because with many children and little money you are just required to look for cheap alternatives for leisure activities. We went to the wildlife park on Sunday. There is the Klövensteen forest in Hamburg-Rissen. It's always worth a trip to see animals in the wild, so to speak, and to pay no entrance fee." (P40:1).

Balancing and reallocating the budget are common to all the people interviewed. In general, the social welfare allowances are not consumed uniformly in the month for which they are intended. The fixed budgets (e.g. for clothing or transport; Fig. 1) are very inflexible and do not correspond to the mobility or other requirements of low-income households.

In 2017, the City of Berlin adjusted the PT fare to ameliorate transport poverty: to bring it into line with the welfare allowance, the government lowered the price of the "Sozialticket" (valid for the entire urban area without a time limit) from €36 to €27.50. The Berlin interviewees viewed this positively but did not report a change in transport behaviour. As one Berlin interviewee put it:

"That's, well, almost 10 euros more each month. And in the world of 'Hartz IV' [= name of the welfare program], ten euros a month means a lot. […] If you have a tenner more at your disposal, there is a little bit more breathing space." (P9:25).

The Hamburg interviewees considered the local fare system as a barrier. In general, the situation for low-income PT users was much more difficult – it should be noted that we describe the 2019 situation before the introduction of the "Deutschlandticket".[3] An unrestricted monthly pass was too expensive (€90.20 regular, €69.20 with a subscription; social discount already taken into account) and was therefore only used by a few interviewees. The restricted pass was not valid during rush hours on workdays, so that an additional single ticket had to be purchased. The risk of being penalized (e.g. due to a delay in the means of transport) compelled those affected to constantly schedule their mobility, which they perceived as discriminatory:

"I always have to check: How do I get where? When do I have to get off the bus so that I don't end up in the 4 p.m. time slot [when my ticket is no longer valid]? That would be the very first thing to think of, because you feel discriminated against, to be honest. Nothing but ballast: ballast that has to stay away because that's when the decent people take the bus and train. So we have to make ourselves scarce, and quickly." (P24:96)

Thus, when trying to foster inclusion, a restricted ticket does not seem to be an adequate solution, since the requirements of those on low incomes do not match the given time-frame. In addition to doctor's appointments, for instance, drop-off and pick-up routes for children are incompatible with the conditions for the ticket.

The school ticket also constituted a burden for low-income households. A ticket for a school child including a social discount cost €28.90 per month (€19.70 for a subscription). In an interview, a single parent in Hamburg described how she made ends meet by taking her children to school on foot:

"You can't make them walk two kilometres every morning. That's what I did with my older girl, for example, when she was in third grade. I

[1] In Hamburg, 68 % of the population live in 49 % of the populated census districts. In Berlin, it is 79 % of the population within only 47 % of the districts. Own elaboration based on a population dataset by infas360 dating from 12/2018.

[2] P17:11 = the 11th coded text segment of primary source 17, i.e. interview 17.

[3] Since May 2023, the "Deutschlandticket" has been in place, offering a national flat-fare for €58/month (until 2024: €49/month). Welfare recipients in Hamburg are entitled to a reduced national ticket for €22.50/month and a free one for each child. Berlin has offered a regional social fare of €9/month that is valid in the Berlin AB zones and that will be raised to €19/month by April (SenASGIVA 2025). When we collected our data in 2019, none of these interventions were foreseeable. For a discussion of recent transport policy in this context, see Aberle (2025a, 2025b).

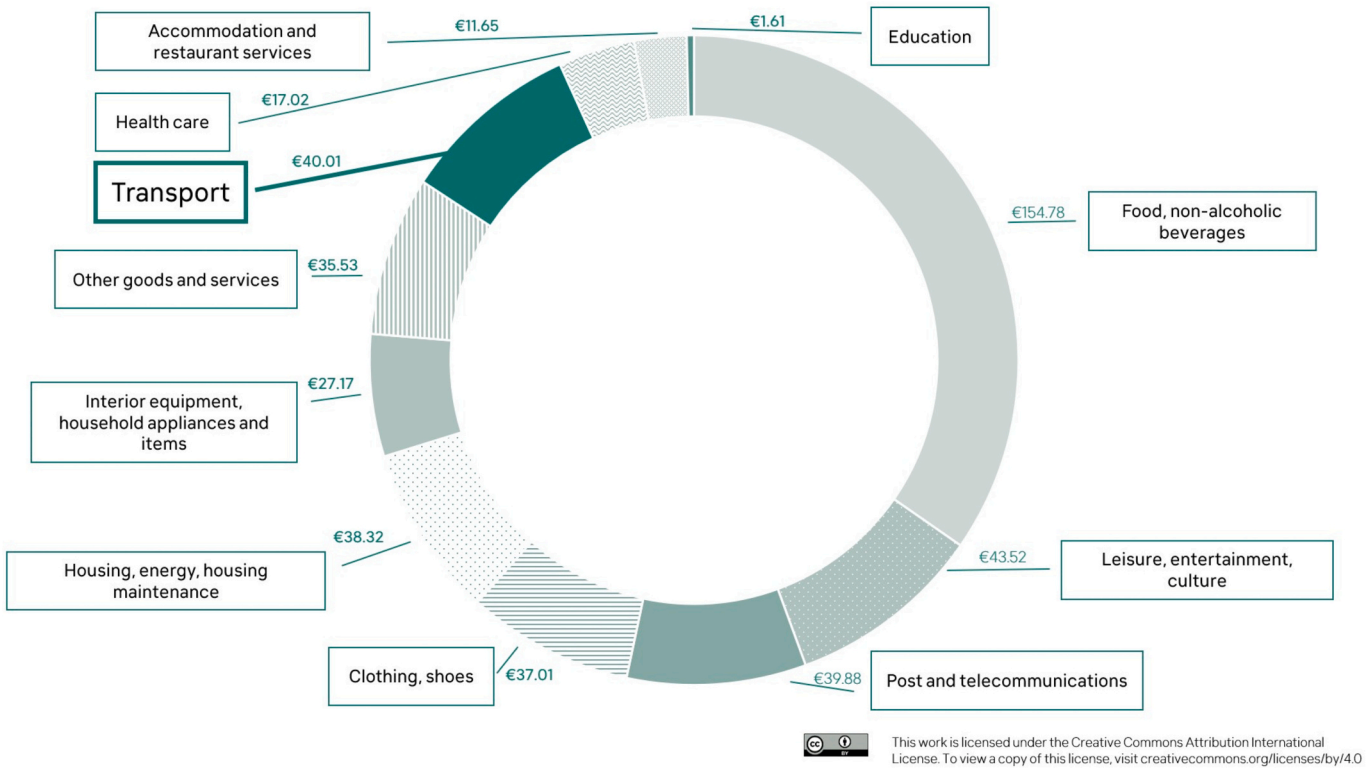


Fig. 1. Composition of the monthly 'Hartz IV' welfare allowance during our survey period, as paid out each month (since 2023 the allowance has been called 'Bürgergeld'). Based on Rudzio (2020). An inflation surcharge has been added to the 2018 baseline data, resulting in a total budget of €446. We present the allowance here to provide some context on German social policy and its impact on transport behaviour.

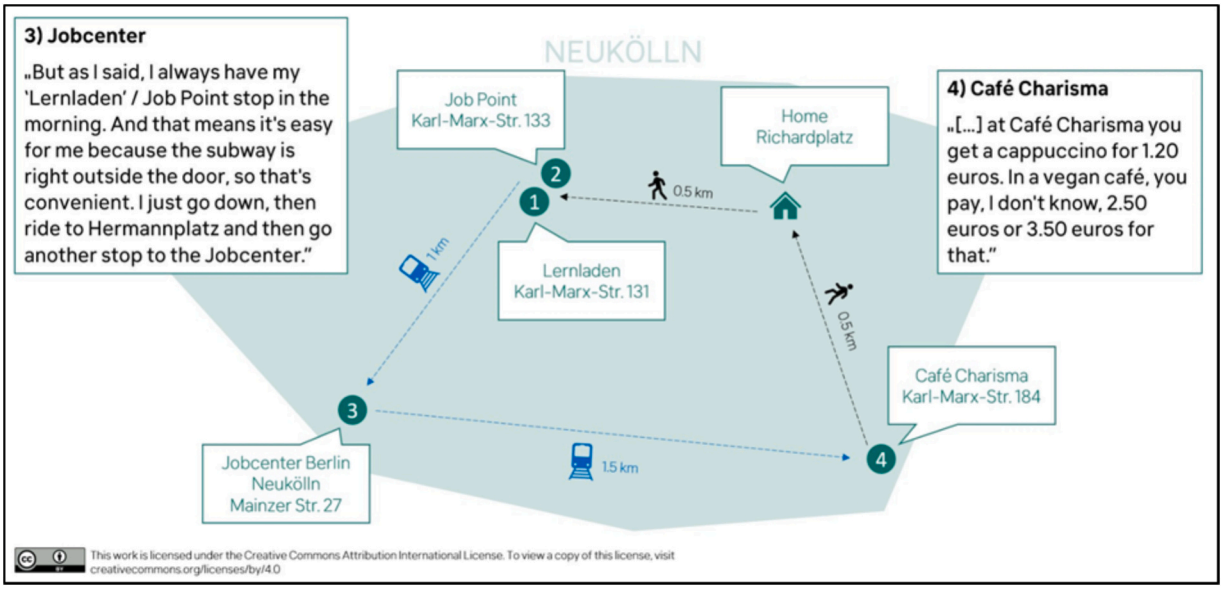


Fig. 2. Exemplary action space of a Berlin-based interviewee, illustrated as an abstract map and complemented by interview quotes. The home location was altered for privacy reasons.

walked with her for a year and a half, that was 1.7 kilometres every morning, with three children, A [restricted monthly pass] was not useful at all, because she has to be at school at eight." (P37:23).

Mobility as a Service schemes such as bicycle rental systems, if available at all, were not used because of the financial barrier, as a Berlin interviewee reported:

"[T]here are these [brand] rental bikes. And then you can register for these bikes via this [brand] app, but then you still somehow pay four euros an hour or something. But you don't find them everywhere just like that. Here in our district, we have looked, [they are] actually not [to be found] at all […] [I] find that quite expensive." (P4:158).

4.2.2. *Limited opportunity spaces*

For the different characteristics of the *opportunity spaces*, we could aggregate the coded interview transcripts into five central determinants:

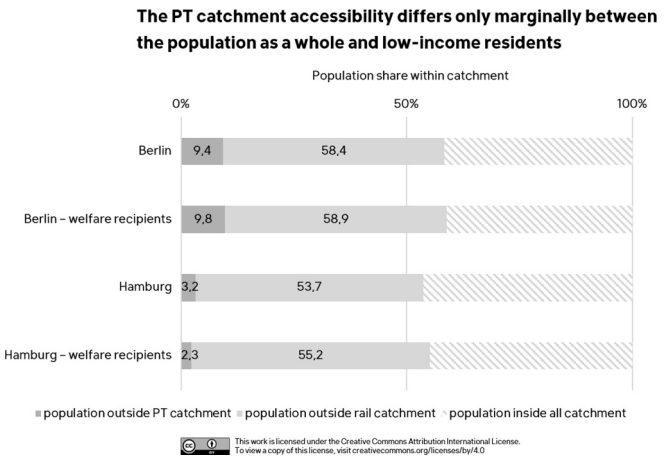


Fig. 3. Share of residents in Berlin and Hamburg that are not served by public transport, in percent. The values are cumulated, i.e., residents not served at all (dark) are included in the group of residents not served by rail & metro (light).

1. Imaginable mobility: the respondents differ in terms of their desired destinations. Some of our interviewees were not able to name concrete desired destinations. Some of them only named destinations that were part of their everyday *action space*, which in turn was often limited to their immediate living environment. Destinations that went beyond this remained largely unimaginable. On the other hand, there are those whose desired destinations go far beyond the *action space* and they suffer most from their limited mobility.
2. Importance of mobility: for those with many desired destinations, mobility is highly relevant. It is associated with freedom and inclusion and they cut back on other needs in order to be mobile. Those who place a low value on mobility spend little money on it. For example, they refrain from purchasing a social ticket, even an inexpensive one (see section 4.2.1).
3. Social network: everyday mobility differs according to the extent of social relationships. For respondents with many relationships, many more trips are necessary or desired.
4. Skills and knowledge: Interviewees who have mobility-related skills (e.g. cycling) and knowledge (e.g. using mobility portals) find it easier to name many desired destinations. Lack of availability is perceived as an insurmountable barrier (e.g. bicycle in need of repair or stolen).
5. Individual needs: respondents with specific interests or hobbies want to and do use the entire urban space. Personal barriers are also the reason why trips are not undertaken or certain means of transport are not used. These personal barriers include not only physical but also psychological limitations. In general, most of the interviewees are confronted with various problems and therefore describe several personal barriers.

The loss of a job, a divorce or the death of family members are traumatic life events that have fundamentally changed mobility for some of the interviewees. These ruptures in their lives were mostly followed by the loss of their car, or a general withdrawal from social life.

Particularly respondents who grew up in poor families describe a childhood or adolescence in which their mobility options were already limited. When asked about his lack of a driver's license, a Berlin respondent replied:

"I would have liked to [get a license] if the opportunity had been there. But my parents unfortunately also live on [social welfare]. So [we couldn't afford it and] there was no other way." (P4:119).

It is evident that the *opportunity spaces* are highly individualized among the 40 respondents. This also means that, in addition to measures to remove financial barriers and the provision of an appropriate infrastructure, individual interventions are required in order to expand opportunities.

4.2.3. *Seven types of urban transport poverty*

Our typology integration yielded seven types that are depicted in Fig. 8:

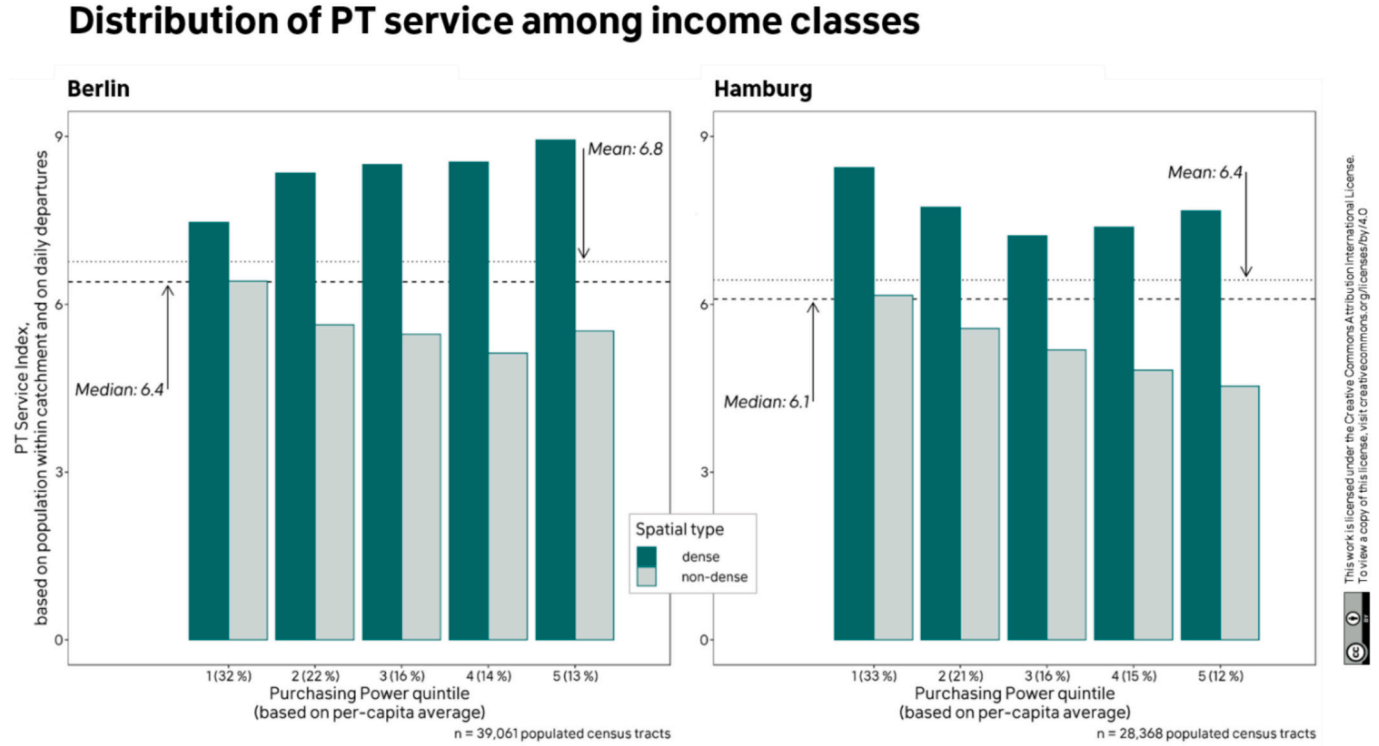


Fig. 4. Variation of average PT index per census district by purchasing power quintiles. The dark bars indicate values for dense areas, the light bars indicate values for non-dense areas. The classes are split along purchasing power quintile values.

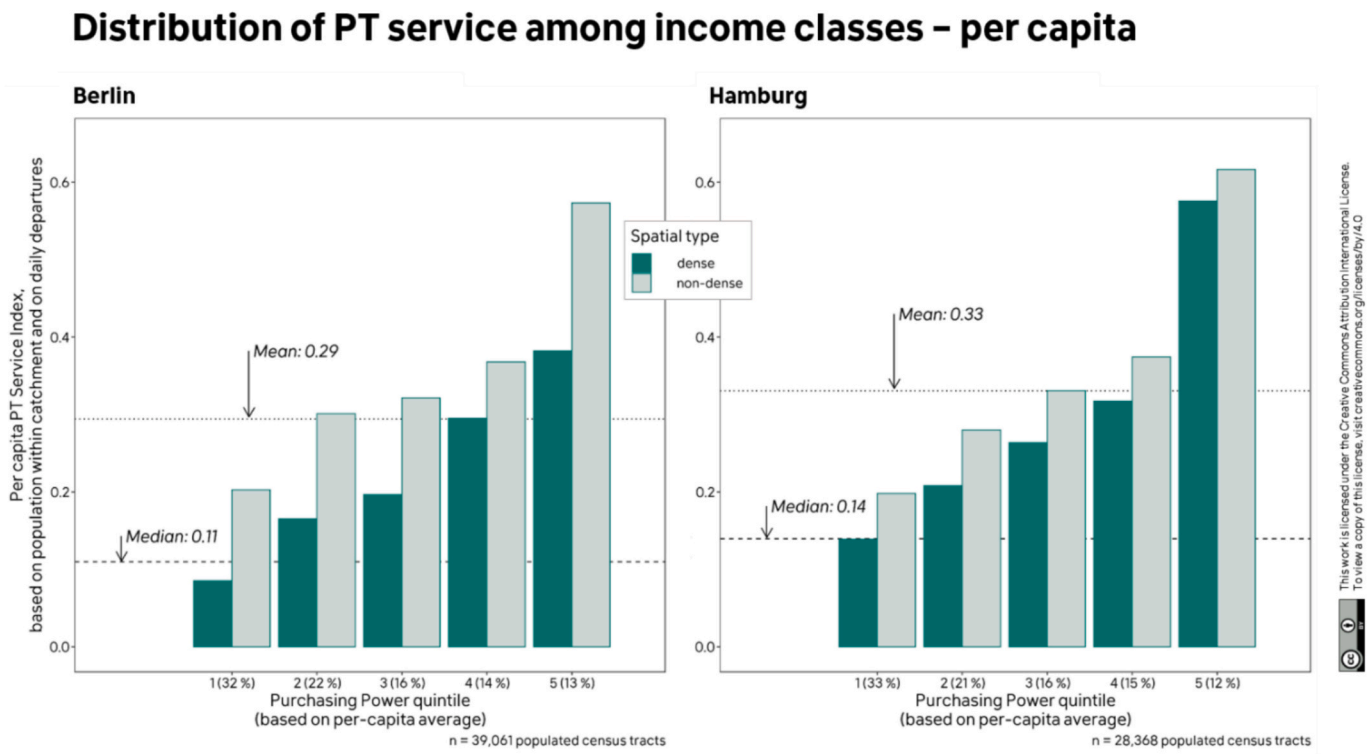


Fig. 5. Variation of average PT index per capita by purchasing power quintiles. The dark bars indicate values for dense areas, the light bars indicate values for non-dense areas. The classes are split along purchasing power quintile values.

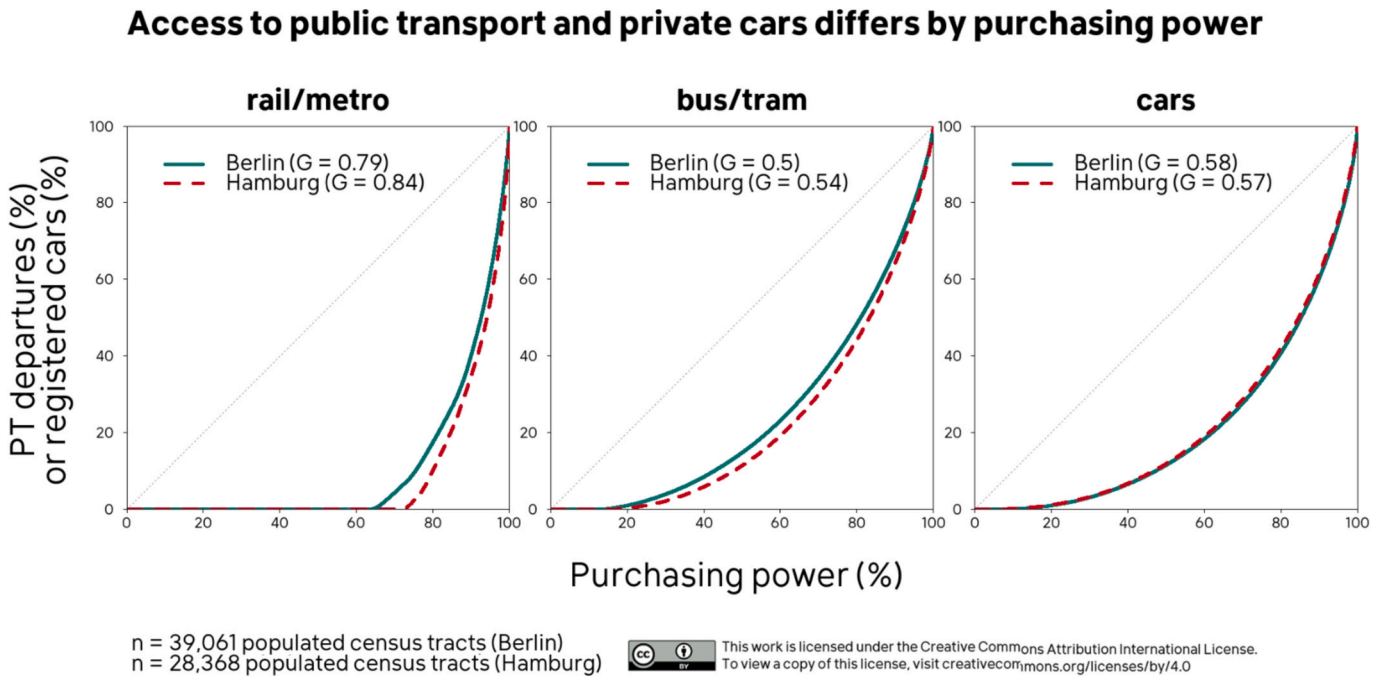


Fig. 6. Lorenz curves and Gini coefficients for public transport services and private car ownership in Berlin and Hamburg. As depicted in the left plot, rail and metro are by far the most unequally accessible: In Hamburg, the population with 75 % of purchasing power are not within reach of any rail or metro service. Overall, public transport accessibility is more evenly distributed in Berlin than in Hamburg.

(1) *The Residential Environment-Bound,* where people have close ties to their place of residence, but are as a result unable to name any specific desired destinations beyond that environment.
(2) *The Experience-Hungry* know about the possibilities that a larger budget could open up for them. Despite their financial situation, they try to undertake as many activities as possible, which leads to a great desire for movement throughout the city.
(3) *The Family Professionals* also have a great need for mobility, which is derived from care activities. They use the urban space intensively in order to provide their children with a variety of offerings.

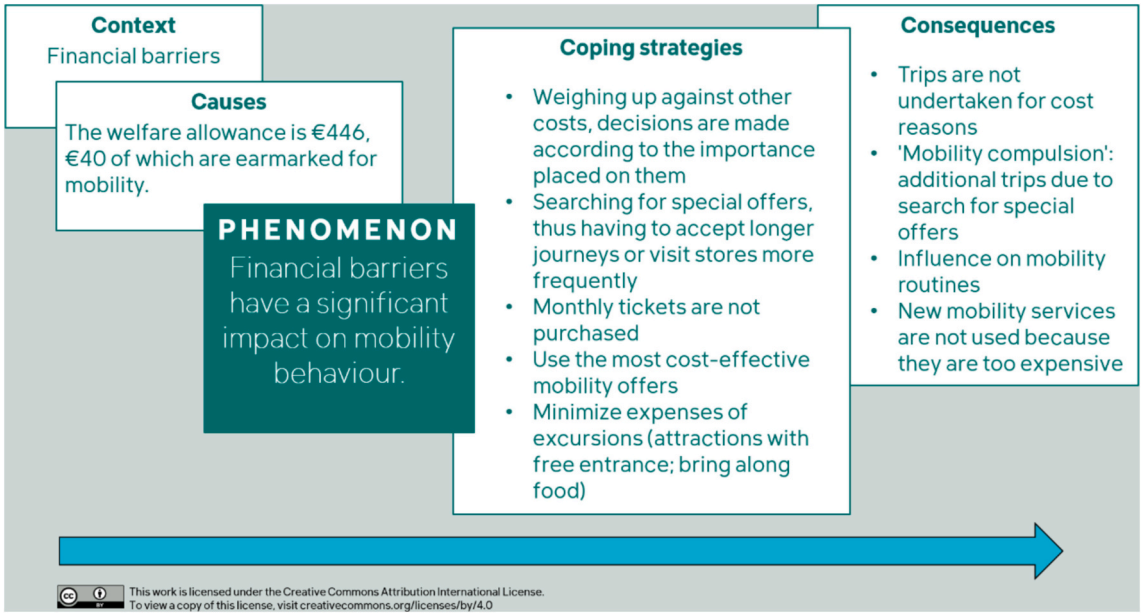


Fig. 7. Interview results summary regarding the financial barrier. The phenomenon emerged from a causal condition and is part of a context (income poverty). It is accompanied by coping strategies. These lead to consequences for everyday mobility.

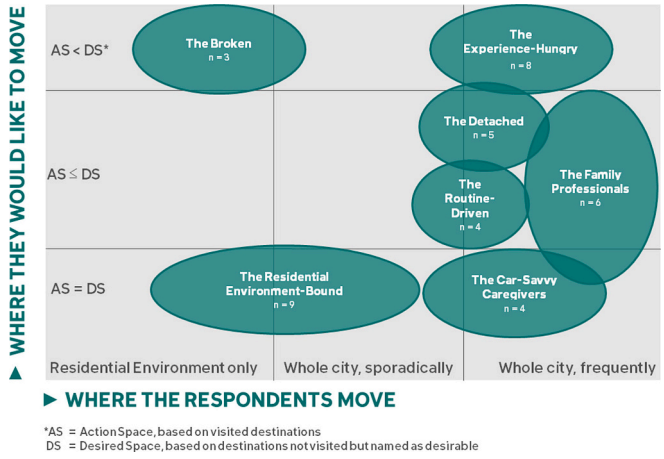


Fig. 8. Seven types of urban transport poverty in Berlin and Hamburg, as plotted along their action space (x-axis) and desired space (y-axis). The figure was inspired by the "Sinus-Milieus" that have been used to describe the German society since the 1980s. Sinus' current typology distinguishes ten milieus that were mapped along their basic values and their social status (Borgstedt and Calmbach, 2023). Note that the types only sum up to $n = 39$, as one person could not be assigned to a type based on their reported behaviour.

(4) *The Detached* express a strong need for distance to others. They usually have strong opinions and are hardly open to change. They perceive themselves as marginalised, for example by high fares, sometimes interpreting the situation as self-imposed exclusion.
(5) *The Routine-Driven* are established in their poverty and apply active coping strategies to deal with everyday life. They have developed routines such as collecting bottles, which in turn shape their mobility routines. They are open to changes that promise financial relief or improvements in routines, for example new mobility offerings.
(6) *The Broken* are characterised by a disruption in their lives, such as the loss of close relatives in an accident. Their *action space* is largely limited to the immediate living environment. Their everyday life is structured and uniform.
(7) *The Car-Savvy Caregivers* are women (some of whom have a migration history) who live in larger families. Their needs are similar to those of the Family Professionals, with the special feature that they have easy access to a car. The car is used intensively and all over the city to run family-related errands, such as fetch and delivery services. Accordingly, everyday mobility is strongly influenced by individual transport.

5. Discussion

People in lower-income residential areas of Berlin and Hamburg have a structurally higher public transport service level as measured by the PT index. On a per capita basis, however, the service falls far behind the level of more affluent areas. These results fit in with a range of evidence on the relationship between income poverty and spatial accessibility. Several researchers emphasize the lack of accessibility that perpetuates unemployment and exclusion (Ihlanfeldt, 1993; Preston et al., 1998; Shen, 2000). In contrast, other researchers report that low-income populations often have a distinctly high accessibility as they did not take part in suburbanisation and remained in the central cities, where activities are easily accessible. However, this locational advantage is thwarted for households without an available car (Grengs, 2015; Karner and Golub, 2015). In our cases, access to a car is not as relevant as in the U.S. with their distinct car culture and settlement structure. Instead, we argue, it is not a lack of PT accessibility but a lack of financial resources that shapes transport poverty of low-income earners in Berlin and Hamburg. Echoing the framework by Lucas et al. (2016), we describe our respondents not as mobility poor; they rather suffer from a lack of transport affordability. Indeed, neither the spatial analyses nor the interviews point towards a lack of basic PT service. As described, respondents occasionally complained about crowded vehicles. A larger dissatisfaction, however, was attributed to a fare system that they perceived as too expensive and cumbersome.

As Karner (2018) points out, measuring PT service level is not enough to assess equity impacts of transport policy. Existing methods to

analyse service equity (i.e. the Federal Transit Administration standards) are not sufficient to describe the accessibility deficits of poor populations. Hence, by complementing our spatial analyses with a qualitative survey, we follow Karner's recommendation of combining multiple measures to gain "meaningful [results] for the populations the analysis is meant to protect" (p. 31).

Of course, our results are subject to some caveats, such as an implicit bias towards railway/metro that the PT index embodies by counting rail departures twice. In German planning there is a distinct hierarchy between the modes. One may argue, however, that a local bus system may be better at at meeting the needs of low-income urban dwellers than a commuter railway line (Bae and Mayeres, 2005; Cervero, 1990). Moreover, due to limited data availability we count each departure similarly, regardless whether it is a 60 seat standard bus or an 850 seat commuter train.

Regarding the interviews, our realised sample is small and geographically limited ($n = 40$ in Berlin and Hamburg). As a result, our findings are certainly limited to welfare recipients in the two largest German cities. For example, the risk group 'low-income forced car owners outside a major city' identified by Stark et al. (2023) for Germany (five years after the end of our survey) is not represented. The qualitative approach aimed at reflecting the interviewees' subjective perceptions as accurately as possible and to compare them with their observed mobility. Despite not being representative in a statistical sense, the reported stories represent experiences that are shared by many people on low incomes.

Since comparable mixed-methods cases are scarce, especially in the field of mobility research, we developed our methodology based on the few published cases that combine qualitative and GIS data (section 2.1). The research process of constant questioning and analyzing meant that some steps were, in retrospect, unsuccessful. Some quantitative information was more important to the qualitative analysis than others. For example, in the process of interpretation, quantitative data on the level of PT service frequency within neighborhoods became relevant in conjunction with the qualitative material. However, quantitative data on local purchasing power were hardly relevant to respondents.

When supplementing our interview material with the 40 travel diaries, the reconstruction of everyday mobility from the transcripts resembled detective work and in some cases required a great deal of effort. A stronger integration of geographical methods into the interview process could alleviate this reconstruction. However, it is important to ensure that the narrative element of qualitative interviews is not diminished, for example by reducing the mobility survey to a standardized questionnaire.

The basic premise of our mixed-methods approach is the combination of different data. In order to produce a synthesis, it is crucial to develop a common understanding of the different scopes (and limitations) of qualitative and quantitative methods and how they can be combined in an exploratory and creative process. The interpreters must therefore be able to carry out this process together. In our study, we achieved this synthesis in several intensive evaluation workshops. It should not be concealed that this was not always easy, as the interpreters were bound by their different methodological approaches. Nevertheless, we consider our methodological approach to be beneficial and we see the described caveats as an invitation to future researchers to further refine the multi-method methodology by applying it to other case studies.

6. Conclusion

In this paper we have presented a multi-method investigation of transport poverty in Germany's two largest cities, combining spatial analyses with an interview survey among 40 welfare recipients.

As the results of the spatial analyses indicate, at first glance objective access to mobility is not structurally worse for low-income city-dwellers in Berlin and Hamburg: the distinction *poor* vs. *rich* seems not to be decisive when it comes to the provision of PT as measured by service level per census district. The key distinction and dividing line regarding access to PT seems rather to be *dense* vs. *non-dense*. Alongside density, however, affluence comes into play again: obviously, low-income people are more likely to live in densely-populated areas, as simple regressions of the purchasing power datasets show (as does common knowledge). Hence, there is no avoiding the conclusion that low-income people are subject to a deficit of per capita PT service. While not revealing the reason for the inequity, the Lorenz curves indicate that the accessibility of PT is far from evenly distributed and only slightly more equitable than access to private cars. Rail accessibility, which is widely considered as more valuable, is distributed least equitably.

We can confirm the finding that the fare is a key factor as a driver and hallmark of transport poverty. Three years prior to the introduction of the subsidized "Deutschlandticket"[5], most of the interviewees were strongly limited in their daily mobility by financial restrictions. Potential policy interventions entail, but are not limited to, adaptations in system design, e.g. improving financial affordability and simplicity. In addition, focusing on the *opportunity space*, with an emphasis on individual empowerment to equip those who suffer from transport poverty with capabilities to extend their imaginable mobility. We therefore constructed a typology of low-income people with seven mobility types, facilitating offerings that are target group-specific.

In the combination of GIS-based analyses and qualitative interview results, we see the capital advantage of our mixed-methods approach: everyday mobility is complex and characterised by constraints, subjective perceptions of mobility and spaces, mobility biographies, mobility demands, and social self-perceptions. In order to grasp this heterogeneity and to derive appropriate recommendations, macro- and micro-perspective approaches are appropriate. The macroscopic approach, represented by spatial analyses, has explored general patterns. The microscopic approach, represented by qualitative interviews with low-income people, has focused on the investigation of 'fine structures' of individual mobility behaviour. It is the strong interlocking of these approaches that determines the quality of the presented results.

The two heuristic concepts of *action space* and *opportunity space* have proved methodologically useful in combining the microscopic with the macroscopic perspective. In this way, we were able to relate the qualitative and quantitative data and combine them in the typology of low-income populations. Hence, we were able to show that a successful combination of different approaches constitutes a significant step forward. By integrating qualitative and quantitative data, planners can not only significantly enhance access to mobility in urban areas, but, more generally, pursue an inclusive transport agenda – which first and foremost serves those who have long been disadvantaged.

CRediT authorship contribution statement

Christoph Aberle: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stephan Daubitz:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization, Funding acquisition. **Oliver Schwedes:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition. **Carsten Gertz:** Supervision, Project administration, Funding acquisition, Conceptualization.

Data availability

Data will be made available on request.

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