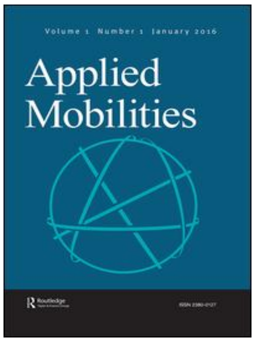

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ARTICLE

What about the people? Developing measures of perceived accessibility from case studies in Germany and the UK

Anna-Lena van der Vlugt[a], Angela Curl[b] and Dirk Wittowsky[a]

[a]ILS – Research Institute for Regional and Urban Development, Research Group Mobilities and Space, Dortmund, Germany; [b]Department of Geography, University of Canterbury, Christchurch, New Zealand

ABSTRACT

As a primary objective in transport planning urban neighbourhood accessibility plays an essential role in the sustainable transformation of cities and their infrastructure. In most studies, accessibility is objectively measured using aggregate travel time or generalised costs as an indicator of the separation of people from places. However, this approach does not reflect perceptions of residents, which ultimately shape mobility decisions and represent the "lived reality" of accessibility. This paper addresses this research gap, adding to a growing evidence base on understanding the relationship between perceived and objective measures of accessibility, and discusses opportunities for incorporating perceptions into measures of accessibility. We offer suggestions for how and why individual perceptions of accessibility differ from objective measures using data from Germany and the UK.

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Perceived accessibility; urban mobility; comparative research; sustainable access

1. Introduction

This paper critiques approaches to measuring accessibility which fail to take into account variations in perceptions of different (groups of) people and argues that a mobilities perspective can strengthen approaches to accessibility measurement. Using a comparative case study approach we seek to develop approaches to measuring perceived accessibility through contributing to understanding of factors which influence individuals' perceptions of accessibility and how these compare to objective measures.

Quality of life in cities depends on how public space can be used by citizens. Accessible and walkable places are characteristic for modern and sustainable cities. Ensuring that places are accessible to populations is also a primary objective of spatial and transport planning (Farrington 2007). As cities face challenges in the context of demographic change, energy transition and climate change, ensuring social and environmental sustainability is an important focus to which accessibility planning can contribute.

Improved accessibility has the potential to address transport related social justice and equity (Pereira, Schwanen, and Banister 2017) through promoting participation in society and to improve health and well-being. Lack of access has been associated with the risk of social exclusion as people are unable to access destinations, such as employment, healthcare, healthy food or education (Preston and Rajé 2007).

CONTACT Anna-Lena van der Vlugt anna-lena.vlugt@ils-research.de

Accessibility is closely linked to mobility, as accessibility has a direct impact on individual mobility behaviour, but the distinction between the two is important. In the literature mobility and accessibility are often used interchangeably even though "[…] mobility is the ability to move whereas accessibility is the ease with which something is reached" (Curl 2013, 5). Ensuring and improving mobility is often the focus of transport planning, for example, by reducing generalised costs, e. g. travel time, accidents or emissions. However, planners often do not take into account the accessibility that this mobility affords (Curl 2013). Therefore, while increased mobility can occur as a result of the transport system only, a focus on accessibility demands greater consideration of the relationships between transport and land use.

Measures of accessibility are typically static, assuming homogeneity of accessibility among people living in one place. Accessibility is often missing from mobilities studies, and, we suggest a mobilities perspective can bring a much-needed critique to accessibility studies, focused on objective measurement. A mobilities perspective draws attention to fluctuations, differences and diversity of accessibility experiences and can be used as a tool to critique "objective" measures (Shaw and Hesse 2010). While Urry and Sheller define mobility as "physical movement" (2006, 212) through different means of transport, Tim Cresswell points out physical movement is only one aspect of mobility and it "[…] says nothing about what these mobilities are made to mean or how they are practised" (2010). Similarly, functional measures of accessibility, typically used in transport planning say nothing about how that accessibility is experienced by people living in the places defined as (in) accessible and measures are static, and assume homogeneity of people in one place.

The calculation of accessibility is mostly based on the shortest-path algorithm in a graph, in which the shortest distances (or effort, cost, travel time) to a facility are determined. Therefore, the needs of the inhabitants, the perception of public space as well as the complex patterns of (social) activities remain unconsidered. Distinct from this engineering focussed approach, the "new mobility paradigm" is influenced by the strong impulses of social aspects (Kaufmann 2002; Hannam, Sheller, and Urry 2006; Sheller and Urry 2006; Cresswell 2010; Kesselring 2014). Mobilities are not only the movement between two places, but are also seen with a wider perspective incorporating experiences and effects on movement (Hannam, Sheller, and Urry 2006; Shaw and Hesse 2010). For example, Edensor (2016) discussed the complex mix of heterogeneous social interactions, materialities, mobilities, imaginaries and social effects in cities. In our paper, we pick up the discussion of "the new mobilities paradigm" and focus on perceived accessibility (subjective indicators and measurement), so that distance is no longer the dominant variable in assessing accessibility, but instead, attention is also paid to the experience of accessibility. Nevertheless, as Hannam, Sheller, and Urry (2006) point out, the basis for the production of mobility is everyday practice. In our paper, we examine the perception of accessibility which influences mobility decisions that belong to the everyday practice of actors. Under the umbrella of action-orientated mobility research, we, therefore, examine perceived accessibility.

Accessibility plays a central role in urban and mobility research but is defined and operationalised in different ways, depending upon the context in which the term is being employed, who is defining it and for what purpose, and the scale at which it is being considered. From a spatial mobility perspective, accessibility can be understood as the "opportunities for interaction" (Hansen 1959, 73) which are impeded by spatial separation.

Accessibility is, therefore, a function of both the transport and land use systems and can prevent this accessibility being realised through virtual or corporeal mobility. When considering corporeal mobility, the distance that needs to be overcome can be influenced by the availability of transport modes or planning of the location of activities. More recent definitions of accessibility have a stronger focus on the individual perspective, such as “the ease with which people can access goods and services” (Social Exclusion Unit 2003). Person-based measures focus on accessibility from the perspective of an individual and are based on the time-space geography of Hägerstrand (1970), accounting for individual time-budgets and locations of individuals’ activities. These definitions of accessibility require the spatial separation of people from places as well as to the capabilities, perceptions and realities of individuals, who must use the transport system to overcome this separation. In planning practice it is harder to apply the individual perspective; therefore, our paper seeks to develop a measure that can be applied.

Although Geurs and van Wee (2004) distinguish between the term access, taking the person’s perspective into account, and accessibility by using the perspective of the location in the literature the term is not consistently differentiated, so that “[…] accessibility is used for both the perspective of the person and the perspective of the location” (Gather, Kagermeier, and Lanzendorf 2008, 79). We understand accessibility from the person’s perspective, which includes, but is not limited to spatial accessibility typically measured using accessibility metrics.

In most studies, accessibility is objectively measured using aggregate travel time or generalised costs as an indicator of the separation of people from places, for example, through access to different modes of transport, travel time to amenities like work, leisure or shopping, or different infrastructure facilities or public transit stops. However, Rajé points out “there is a gap of experience persons have using the transport system and the […] users’ experiences held by planners and policy-makers” (Rajé 2007).

Such measures of access tend to focus on potential accessibility or the opportunity for interaction (Hansen 1959) given the spatial distribution of people and places, but do not take into the diversity of individual experiences and perceptions of accessibility, which will ultimately influence travel behaviour (Morris, Dumble, and Wigan 1979). Certain population groups, such as older adults may experience longer journey times than suggested by an average objective measure, meaning that objective measures of access are not a good representation of their lived experience of accessibility. The term perceived accessibility is intended to counter this criticism and includes the perceptions of the individual within accessibility measurement. Perceived accessibility describes, therefore, “how easy it is to live a satisfactory life using the transport system” (Lättman, Olsson, and Friman 2016, 258) from the perspective of diverse individuals, rather than assuming homogeneity of accessibility according to spatial location.

1.1. Objectives

In response to recent calls for more research in this area (van Wee 2016), the overarching objective of this paper is to develop an understanding of how perceptions of accessibility relate to measures typically used in planning practice through a comparative research approach in two case studies, UK and Germany. In order to achieve the overall objective we address the following research questions:

- What is the relationship between objective measures and perceived accessibility?
- Which factors are associated with perceptions of accessibility?

With the aim of investigating the relationship between perceived accessibility and other factors, including objective accessibility, we have tested and compared different measurement models in both case studies whereby the second case study builds on the findings of case study one, with the attempt to develop it further and is therefore focused on pedestrians' perceptions of accessibility.

In section two, accessibility and different approaches to measuring it are introduced. Based on the literature of objective and perceived accessibility, especially Geurs and van Wee (2004), we developed a conceptual framework of perceived accessibility (Figure 1). The methodology is presented in section three. Section four highlights the empirical findings of the two case studies. Finally, we compare and discuss our results referring to the research questions and how future accessibility planning could be expanded by integrating subjective perceptions and become more representative of diverse experiences of accessibility.

2. Background

2.1. Measurements of accessibility

In the following section, different measurements of (objective and perceived) accessibility will be defined in order to develop a conceptual framework for perceived accessibility on the basis of the literature. This is the basic framework for the following analyses.

2.1.1. Objective accessibility

Accessibility measures have been developed to support those planning transport or the location of activities, often based on statistical or econometric analyses. Such measures are typically based upon measuring the spatial separation of people from places, usually based upon time, distance or generalised costs and have been classified into infrastructure based, location based, person based and utility based (Geurs and van Wee 2004). Infrastructure-based measures include measures such as frequency of public transport or congestion on the level of service on the transport system. Location-based measures take into account the transport system and spatial distribution of activities, typically resulting in an indicator representing the number of destinations accessible within different time threshold based on cumulative opportunity or gravity measures (Hansen 1959). Besides Geurs and van Wee's classifications, Handy and Niemeier identified three approaches to measuring accessibility which can be classified as follows: "[. . .] cumulative opportunities measures, gravity-based measures, and utility-based measures. All three types incorporate both a transportation element and an activity element, although they differ in the sophistication with which they reflect travel behaviour" (Handy and Niemeier 1997, 1177).

Moving towards accessibility that does not depend on private motorised transport as an objective of sustainable spatial and transport development is causing a lively discussion about the development of pedestrian-friendly neighbourhoods in urban areas (Frank et al. 2006; Rode and Floater 2014). As a central influencing factor on spatial behaviour patterns and decisions, the measurement of objective accessibility with the focus on pedestrian accessibility has increased significantly (Páez, Scott, and Morency 2012). To be mentioned here is the debate about potential pedestrian level access, determined by location factors. This has resulted in a number of measurement methods, like the Walk Score®, Walkability, Neighbourhood Destination Accessibility Index (NDAI) or the Land Use Public Transportation Accessibility Index (LUPTAI) (Frank et al. 2005). However, these methods do not consider perceptions of residents, which, as we have already established ultimately shape mobility decisions.

2.1.2. Perceived accessibility

In contrast to objective metrics, subjective measures seek to, "describe the way people perceive and evaluate conditions around them" (Pacione 1982, 498). Applied to accessibility, this can be understood as "how easy it is to live a satisfactory life using the transport system" (Lättman, Olsson, and Friman 2016, 258). The debate in the current research illustrates that there is a multitude of research approaches on the topic subjective influences on travel behaviour or mobility. Some studies analyse, for example, the relationship between the environment and active travel and try to include both objective and subjective measures. Scheiner (2010) and Scheiner and Holz-Rau (2007) have undertaken studies to explain travel behaviour using both objective environmental characteristics and attitudinal, or perception variables. Van Acker, Mokhtarian, and Witlox (2011) also demonstrated the importance of attitudes in addition to built environment factors in explaining modal choice.

Almost all existing studies show a discrepancy between objective and perceived accessibility (Gebel et al. 2011; Ma and Cao 2017; Maddison et al. 2010). Maddison et al. (2010) found low agreement between self-reported and objectively measured distance to physical activity resources. When predicting behavioural outcomes, such as physical activity, perceptions are often stronger predictors than objective measures (Blacksher and Lovasi 2011). Ma and Cao (2017) point out perceptions act as a mediator between the built environment and travel behaviour, although there are also direct effects. They showed a mismatch between perceived and objective accessibility for driving trips.

Based on the assumption that the walking environment is of great importance in terms of perceived accessibility, various studies focus on the comparison of the pedestrians' perceptions of the neighbourhood related to objective measures of accessibility. Tuckel and Milczarski (2015), for example, found out that perceived neighbourhood walkability was more strongly associated with all types of walking (transport, recreational and total walking) than the objective Walkscore. This is also confirmed by Ball et al. (2008) in a comparison of self-reported accessibility with objective GIS-based measures of accessibility to physical activity facilities (such as leisure centres or outdoor space). These studies show that the differences between objective and subjective accessibility occur for various modes of transport. Lotfi and Koohsari (2009) found that those areas objectively measured as most accessible did not match with residents perceptions, due to issues of safety and security.

Given that individual behaviour is likely to be affected by perceptions of accessibility (Ma and Cao 2017; Morris, Dumble, and Wigan 1979), it is important that measures of accessibility can incorporate perceptions and are more behaviourally realistic (see Figure 1: conceptual framework). While such associations have long been recognised, there is still a dearth of research into understanding perceptions of accessibility (van Wee 2016). In many studies, only a weak correlation between objective accessibility and travel behaviour could be determined, e.g. the correlation between the number of footpaths and walking (e.g. Reyer et al. 2014). This is likely to be because the assumptions (e.g. of travel time or individual knowledge) in such measures do not reflect the heterogeneity of populations then they are only a reflection of objective accessibility from planners' perspectives and do not represent the diversity of experience across the population. Therefore, there are unknown components of individual perceptions that cannot be explained with objective data.

2.2. Conceptual framework

On the basis of the literature review, we developed a conceptual framework of perceived accessibility (Figure 1.) to develop a measure of perceived accessibility, building on the components identified by Geurs and van Wee (2004). We integrate perceptions related to the land-use and transport system. For example, the perception of journey time of different transport modes

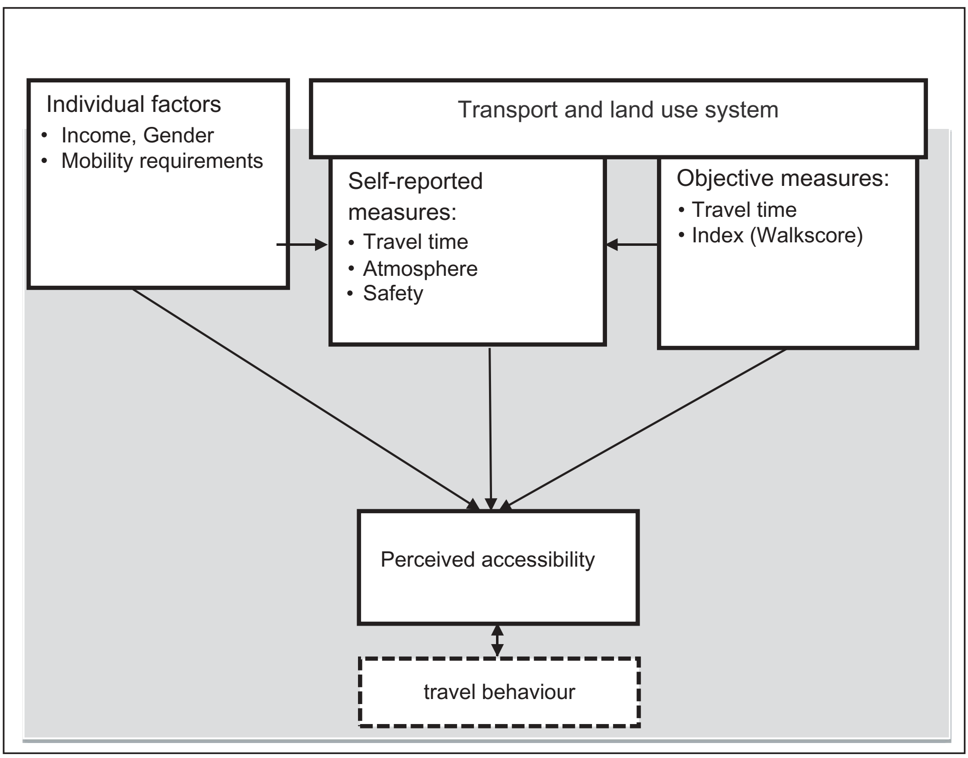

Figure 1. Conceptual framework of perceived accessibility.

is included as well as individual perceptions of neighbourhood atmosphere and safety. Finally, it is assumed that these three components flow into the perceived accessibility.

Referring to the research questions we apply the conceptual framework to identify objective and subjective factors associated with overall perceived neighbourhood accessibility. By doing so we also discuss opportunities for incorporating perceptions into measures of accessibility and offer suggestions for how and why perceptions of accessibility differ from objective measures, through a comparative research approach.

3. Data and methodology

This paper used a comparative research approach from a methodological point of view.

Case study two is to be regarded as a further development of the approach taken in case study one with an adapted focus on walking. Both studies intend to identify indicators that influence perceived accessibility and follow the same methodological approach, but used different measurement items so are not comparable in detail.

Each study used a measure of objective accessibility typically used in urban and transport planning and then develops a measure of perceived accessibility to be compared with objective measures. Based on this, both case studies identify influential indicators of perceived accessibility. The following table shows the contents of the objective and perceived measures of accessibility used in the two case studies.

3.1. Sampling procedure

The first case study was undertaken in Nottingham, UK, in 2010. A postal survey was sent to 2,500 households in selected neighbourhoods, asking questions about perceptions of local accessibility (Table 1). Eight neighbourhoods were selected based on levels of deprivation, level of public transport accessibility and use of non-car modes for travel to work. Households were randomly chosen within selected neighbourhoods using the postcode address file and any adult in the household could complete the survey.

The second case study was carried out in urban neighbourhoods in a small district of Hamburg, Germany, in 2015. In a postal survey 400 households were encouraged to answer questions about their mobility requirements, usual transport modes, their satisfaction with and perceived importance of destinations, time-dependent perceptions of safety, barrier-free environments, cleanliness as well as their mobility and neighbourhood related attitudes. The target groups were families and senior citizens. In order to compare objective and subjective accessibility, two measures were developed.

3.2. Objective accessibility measure

In case study one, the measures of objective accessibility are from a national dataset of accessibility indicators from the UK Department for Transport. These are calculated at output area level (around 300 households) and reported at Super Output Area level (average, 1500 households), as a population-weighted mean of all output areas within the Super Output Area (zone). Measures include the mean journey time to the nearest of each of seven destination types from each super output area (travel time measures), a cumulative measure of the number of each type of destination accessible within given journey time thresholds

Table 1. Description of the case studies.

	Case study one	Case study two
Calculation of objective measure	Calculated at the zonal level. Only participant's zones were recorded. Open to ecological fallacy and MAUP.	Improves on case study one by calculating a bespoke objective measure for each participant on a GRID level
	Mean journey time to the nearest of each of seven destination types from each super output area	Distance to the nearest of each of eight destinations
Calculation of perceived accessibility measure	Not mode specific	Exploratory factor analysis focus on walking
Included Item 1	Ease of getting to places I need to get to	I can achieve anything in my living environment.
Included Item 2	Range of local facilities available to meet my needs	In my living environment I can do all my everyday walks well on foot
Included Item 3	Accessibility of places I need to get to on a regular basis	Satisfaction with the pedestrian accessibility of services of general interest
Covariates included in the regression models	Multivariate regression model not mode specific	Multivariate regression model focus on walking
	Objective JT Accessibility	Number of walks per day
	Subjective JT Accessibility	People with mobility restrictions
	Socio-demographics	Socio-demographics
	Car Availability	Private car use
	Attitude towards walking	Satisfaction access with all transport modes
	Attitude towards PT	Atmosphere
	Attitude towards car	Barrier-free environment
	Overall satisfaction with destinations	Safety after dark
	Rating of choice destinations	Cleanliness
	Overall time satisfaction	
Investigation level	Macro	Micro
Investigation area	UK	Germany
Sample size	286	358

(15–60 minutes depending on destination type) (origin indicators) and the population within a given time threshold each destination type (destination indicators). In this analysis, the main purpose was to control for objective journey time accessibility in the model. A composite indicator of public transport journey time to all seven destination types was created, weighting each destination equally. The zone (super output area) in which a respondent lived was then categorised as above or below average accessibility, with those above being coded "accessible" and below "inaccessible". This is a coarse measure designed to indicate whether an area was generally accessible or not, to ensure that the model of perceived accessibility did control for measured accessibility across a range of destination types.

Case study two improves on case study one by calculating a bespoke objective measure, a walkscore, for each participant in the investigation area. The objective accessibility is determined by calculating an individual walkscore for each participant in the investigation area. The approach approximated the Walk Score® (2018) but uses an idealised decay (not step) function. It is based on the calculation by Reyer et al. where they "[. . .] follow the original Walk Score approach as closely as possible" (Reyer et al. 2014, 5854). Based on residential locations, the distance to the nearest destination of each type is calculated. The residential location was aggregated to a 100x100 meter grid. This aggregation level allows calculation of very detailed measures of objective accessibility for the interviewees. As the objective measure the walkscore in the investigation areas have a range of values between 80–100 points. When you take the measurement of the typical Walk Score® into account, the objective accessibility is between the highest categories "very walkable" and "walkers paradise", explained by the urban structure of the investigation areas. Despite low variance, the following figure shows the differences in accessibility based on the walkscore in the investigation area (Figure 2).

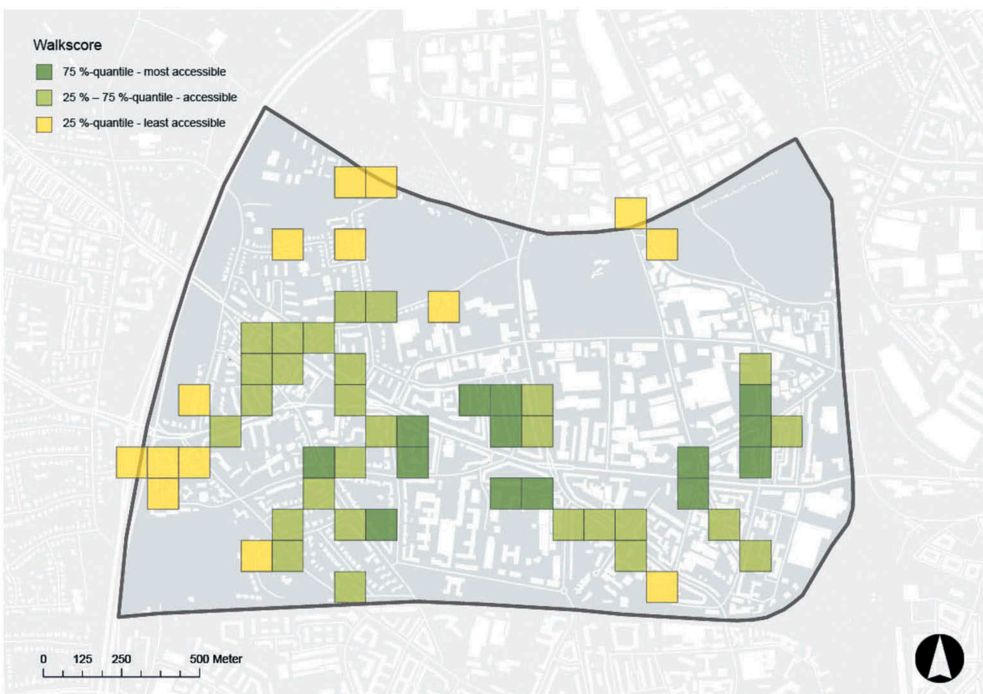

Figure 2. Walkscore of the investigation area in Hamburg, Germany.

3.3. Perceived accessibility measures

The dependent variable, perceived accessibility, in each study is developed from a similar conceptual understanding, but the independent variables are heterogeneous.

Perceived accessibility is calculated by using the mean scores of three items in each case study, measured on a 5-point Likert-type scale. In case study one, the purpose was to develop a non-destination and non-specific measure. The measure of perceived accessibility is based on three survey items measured on a 5-point Likert-type scale:

- Ease of getting to places I need to get to ($\bar{x}$ = 4.02, sd = 0.993)
- Range of local facilities available to meet my needs ($\bar{x}$ = 3.83, sd = 0.975)
- Accessibility of places I need to get to on a regular basis ($\bar{x}$ = 4.18, sd = 0.976)

There was a high level of agreement among these items (α = 0.739) and they were combined to give a measure of perceived accessibility.

Building on this, in case study two destination and mode-specific items were added to the overall measure. With the intention to create a measurement of perceived accessibility, based on Lättman's PAC (Lättman, Olsson, and Friman 2016), an explorative factor analysis was used to determine perceived accessibility factors based on attitudinal statements and satisfaction assessments to different destinations (see Table 2). Accordingly, a measure of perceived accessibility was calculated based on the mean of three items, two of them measured on a 5-point Likert Scale. The third item consists of the mean values of 14 questions[1] on satisfaction with the pedestrian accessibility of facilities of general interest, also each calculated on a 5-point Likert Scale. The descriptives, correlations and factor loadings are shown in the following table: the factor explains 65.89% of the variance. Furthermore, a Cronbach's Alpha analysis also showed satisfactory overall item correlations (α = .72).

Table 2. Mean, Correlations, Standard deviation, change in Cronbach's alpha for three items, Factor loadings of the factor analysis.

Item	1	2	M	SD	α if item deleted	Perceived Accessibility (factor loading)
I can achieve anything in my living environment	–	–	3.54	1.12	.536	.851
In my living environment I can do all my everyday walks well on foot	.510**		3.61	1.21	.661	.782
Satisfaction with the pedestrian accessibility of services of general interest[a]	.540**	.412**	3.75	.78	.668	.801
Eigenvalue						1.977
% of variance						65.89

*correlation significant at $p < 0.05$, **correlation significant at $p < 0.01$

Satisfaction with the walking accessibility to small grocery stores, supermarkets, drugstores, hairdressers, post offices, banks, pharmacies, doctors, cafés, green spaces, leisure facilities, sports facilities, day care centres, schools.

3.4. Analytical approach

In both examples, factors related to perceptions of accessibility are identified using regression models. Accordingly, the analysis approach allows the comparison of two different investigation areas and compares and contrasts results with regard to the influencing factors that determine the perception of accessibility in different contexts. This makes it possible to develop approaches that show possibilities of how perceptions can be integrated into measures of accessibility in different countries.

As outlined in the conceptual framework (Figure 1) perceived accessibility is a function of the accessibility of the built environment as objectively measured using travel time indicators of accessibility and how individuals rate different aspects of their own daily accessibility.

In case study one, the model includes an indicator of objectively measured travel time accessibility as a control, in order to identify, factors, additional to objective accessibility which influences perceived accessibility. A binary indicator of self-reported journey times is included to show the importance of self-reported journey times as well as measured journey time. This measure was calculated similarly to the objective measure. Self-reported journey times to a range of destinations were averaged and then respondents split into more or less accessible based on the median split. This is by necessity simplistic as there is collinearity between access to different destinations and it becomes complicated to include all destinations separately. Although separate analyses by destination and by mode have previously been reported (Curl 2013) the purpose here is to focus on overall accessibility that is not specific to particular modes or destinations and this requires some simplification of predictor variables. Additionally, we include socio-demographic variables of age, gender and access to a car.

Finally, variables indicating attitudes towards different modes of transport (walking, public transport and car) are included in addition to satisfaction with attributes of accessibility including available destinations, choice of destinations, satisfaction with the time taken. These were measured on a 5-point Likert-type scale.

In case study two, we estimate perceived accessibility using a regression model. t-tests for independent samples were carried out as a first step. To test differences in perceptions according to sociodemographic and subjective factors, further independent one-way ANOVAs were calculated. The subjective factors are, for example, the satisfaction with access with all transport modes, a barrier-free environment, which includes consideration of kerb lowering, crossing aids, the availability of public toilets and the general condition of roads and pavements as well as the topics of safety, cleanliness and atmosphere. In the next step, a multivariate regression analysis is used to examine the interrelated effects of the tested variables with a focus on pedestrians. Figure 3 illustrates the input variables of the perceived accessibility model. We calculated two models. In the first model, the items refer exclusively to individual perceptions and evaluations. In the second model, an item was integrated for realised behaviour in order to be able to analyse the interactions with realised behaviour. The analysis is described in further detail in the following section (4.3).

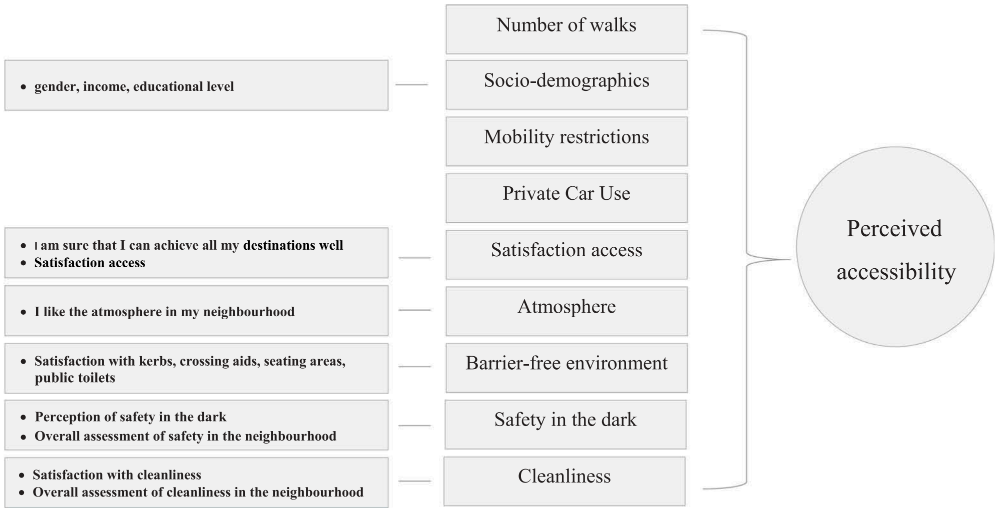

Figure 3. Measuring model of perceived accessibility.

4. Empirical findings

Results are presented in three sections. First, we present the descriptive results for each study and then referring to the research questions we analyse the relationship between objective and perceived accessibility and explore factors associated with overall perceptions of accessibility in each case study.

4.1. Sample characteristics

The sample of case study one is characterised by a mean age of 54.8 years, women are slightly overrepresented and car ownership is about 47%. Almost half of those surveyed are pensioners, are well educated and have household income between 15,000 and 30,000GBP per year (Table 3).

In case study two, the size of the household is typically much larger among the families than among the seniors. Similar to case study one, women are slightly overrepresented in both target groups. Families are more highly educated and have a higher income. The employment status of the families is divided into full- and part-time, with 89% of the senior citizens being retired.

4.2. Case study one: perceived and objective accessibility in Nottingham, UK

Referring to the research questions in the first stage of the regression model (not shown), only journey time accessibility was included as a predictor. Both objective ($t = 0.179$, $p < 0.01$) and subjective journey time ($t = 0.213$, $p < 0.01$) accessibility were significantly associated with overall perceived accessibility. However, once demographic and attitudinal variables are added the strength of the relationship for journey time becomes weaker and non-significant.

Table 3. Sample demographics.

	Case Study 1	Case study 2: Families	Case study 2: Seniors
Mean Age	54.8	40.2	74.7
Mean Household size	2.2	3.3	1.6
Gender			
Male	41%	42.10%	36.30%
Female	59%	57.90%	63.70%
Households with dependent children	22%	97.70%	0.00%
Car ownership			
No car	22%	39.70%	49.00%
1+ car	79%	60.30%	51.00%
Employment status			
Employed full time	27%	41.20%	4.70%
Retired	41%	0.80%	89.20%
Other	32%	58%	6.1%
Education			
First or higher degree	37%		
Post-16 (A-level/Abitur and higher)	19%	87.00% (inc degree)	36.30% (inc degree)
Secondary school	26%	11.5%	62.8%
None	18%	1.5%	1.0%
Income per year			
<15,000GBP	30%		
<30,000GBP	33%		
<45,000GBP	18%		
<60,000GBP	10%		
<75,000GBP	4%		
<12,000€		1.6%	9.9%
<24,000€		7.1%	39.1%
<48,000€		42.1%	39.6%
<72,000€		41.3%	9.9%
≥72,000€		7.9%	1.5%

In the final model (Table 4), perceptions of accessibility become poorer with age, which might be expected, as, controlling for journey times, it would be expected that older people may face more challenges in accessibility than other age groups. Remembering that distance from facilities is already accounted for by controlling for journey time, it is interesting that those who have a favourable attitude towards public transport have a better overall perception of accessibility. This may be because they are more aware of the availability of public transport. Satisfaction with the time taken to reach destinations was more important than the

Table 4. Factors associated with overall perceived accessibility (case study one).

Predictors	*Overall Perceived Accessibility (n = 286)*
r^2	*.398*
F	*16.490*
Objective JT Accessibility	.055
Subjective JT Accessibility	.017
Age	−.120*
Gender	.054
Car Availability	.107*
Attitude towards walking	.074
Attitude towards PT	.310**
Attitude towards car	−.004
Overall satisfaction with destinations	.099^
Rating of choice destinations	.177**
Overall time satisfaction	.191**

*variable significant at $p < 0.05$, **variable significant at $p < 0.01$, ^variable approaches significance ($p < 0.1$)

actual measured time taken which suggests that people may have different thresholds of ″acceptable″ travel times, influencing how they perceive access in the local area. The perceived range and satisfaction with destinations was also important, lending support to accessibility measures which consider the cumulative opportunity and the range of accessible destinations, rather than the nearest destination only. These results suggest that after accounting for spatial separation, socio-demographic variables and attitudinal factors are important in shaping people's perceptions of accessibility.

4.3. *Case study two: perceived and objective accessibility in Hamburg, Germany*

Referring to the research question one (relationship between objective and subjective accessibility) a Pearson correlation with an $r = .031$ ($p = 0.652$) considered a weak and non-significant correlation between objectively measured accessibility and perceived accessibility.

In order to answer the second research question (influencing factors of perceived accessibility), bivariate tests show that most of the sociodemographic factors do not show a significant relationship with perceived accessibility (see Figure 4). By calculating an independent one-way ANOVA, income revealed a significant association $F(2, 350) = 3.87$ ($p = .022$). Due to variance equality in the groups (Levene $p = .097$), a Bonferroni revealed significant differences between the middle- and high-income groups ($p = .022$) (0.29, 95% – CI [0.03, 0.55]). Furthermore, disability shows a significant difference in perceived accessibility, calculated by an independent t-test $t (343) = 3.21$ ($p <0.01$).

To test differences in perceptions according to subjective factors, further independent one-way ANOVAs were calculated. The subjective factors are, the level of satisfaction with access with all transport modes, a barrier-free environment, which includes consideration of kerb lowering, crossing aids, the availability of public toilets and the general condition of roads and pavements as well as the topics of safety, cleanliness and atmosphere (see Figure 5). The analysis of variance revealed a difference which approaches significance between satisfaction with access $F(2,350) = 10.86$, $p <.001$ as well as a difference between barrier-free environment $F(2,334) = 8.52$, $p <.001$ and atmosphere $F(2, 350) = 13.74$, $p <.001$. A Bonferroni test for variance equality in the groups (Levene $p = .077$) between dissatisfied and satisfied respondents in relation to the satisfaction with the perceived access show a significant difference ($p = .022$) (0.52, 95% – CI [−1.18, −.35]). The topics of safety and cleanliness show no significant differences in relation to perceived accessibility.

As the next step a multivariate regression analysis is used to examine the interrelated effects of the tested variables. Table 5 list the results for estimating the parameters of perceived accessibility.

We calculated two models. In the first model, the items refer exclusively to individual perceptions and evaluations. In the second model, an item was integrated for the realised behaviour in order to be able to analyse the interactions with the realised behaviour. In both models, the largest positive effect can be observed by the overall satisfaction access, including all transport modes, and atmosphere. Similar to car availability, gender, a barrier-free environment and safety are positive factors. Females perceive their accessibility better than males. The lack of a barrier-free environment induces reduced perceptions of accessibility. Therefore, it is not surprising that a positive effect of a barrier-free environment is associated with a better perception of accessibility.

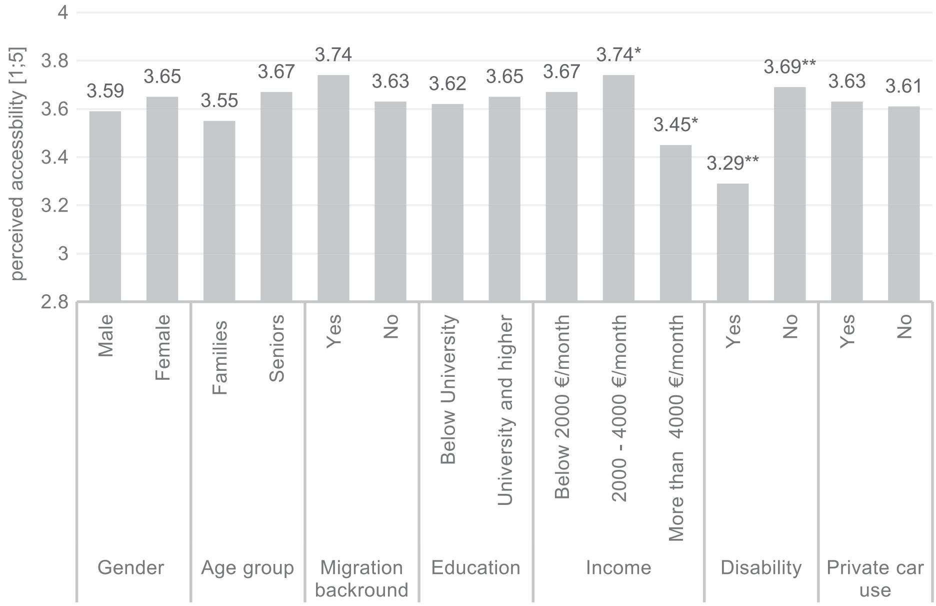

Figure 4. Overview of differences in perceived accessibility. *variable significant at $p < 0.05$, **variable significant at $p < 0.01$.

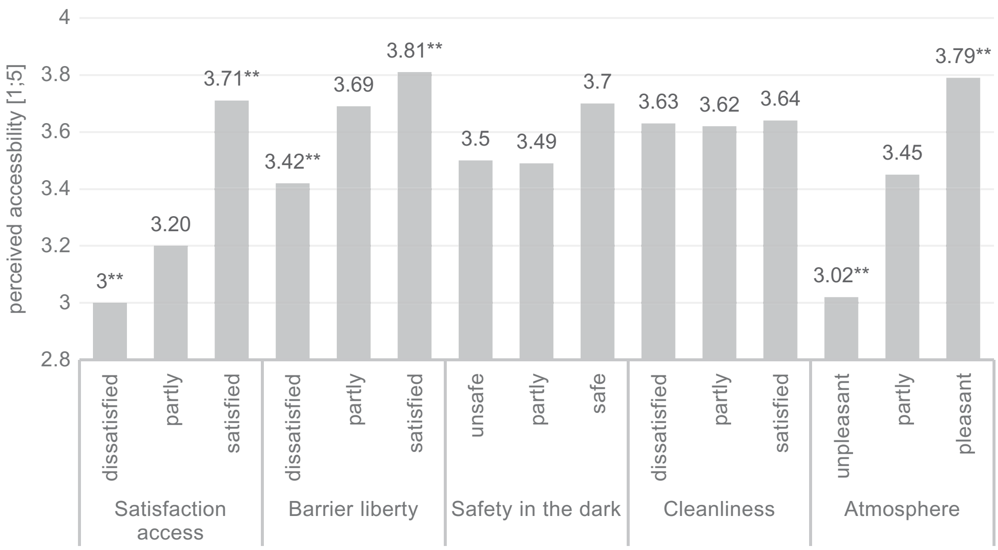

Figure 5. Overview of difference in perceived accessibility according to subjective factors. *variable significant at $p < 0.05$, **variable significant at $p < 0.01$.

As a variable with a high significance, the atmosphere is highlighted in the regression model as a topic for explaining perceived accessibility. The fact that age has no significant effect could be due to the fact that most people lived in the neighbourhood for a long time and do not change their perceptions of the accessibility of the environment, despite changes in personal mobility. Income has a negative and a strongly

Table 5. Factors associated with overall perceived accessibility (case study two).

	Perceived Accessibility Model (n = 358)	*Perceived Accessibility plus Behaviour- Model (n = 358)*
	R^2 = .35	R^2 = .38
	F = 12.974	F = 12.684
	B	B
(Constant)	.362	.402
Number of walks per day		.125**
Target group (reference: seniors)		
Target group	.021	.033
Gender (reference: male)		
Gender	.158^	.118
Income (reference: under 2000€)		
Income 2000–4000€	−.205^	−.190^
Income over 4000€	−.449**	−.447**
Education (reference: under university degree)		
Education university degree	.071	.095
People with mobility restrictions (reference: no)		
People with mobility restrictions	−.293*	−.191
Satisfaction access with all transport modes	.404**	.434**
Private car use (reference: no private car use)		
Private car use	.032	.022
Atmosphere	.286**	.250**
Barrier-free environment	.175**	.141*
Safety after dark	.106*	.057
Cleanliness	−.133*	−.083

*variable significant at $p < 0.05$, **variable significant at $p < 0.01$, ^variable approaches significance ($p < 0.1$).

significant effect, indicating that the perception of accessibility becomes significantly worse with rising incomes. Not surprisingly, there is a very strong positive effect of general satisfaction with the availability of destinations on the perception of accessibility. The more satisfied one is with the availability of destinations, the better the accessibility is evaluated. Car availability has only a weakly positive (non-significant) influence, in contrast to the usual assumption that there is a high correlation between car availability and accessibility. In an urban neighbourhood with a very good offer of public transport, the car is no longer as important for mobility in the neighbourhood. The regression model shows that the sense of security after dark has a highly significant effect on the perception of accessibility. Although perceived safety seems to have only a very weak influence with a small effect, the significance cannot be neglected. Topics such as street lighting, manageability and social control have a certain importance for practical planning in relation to crime prevention measures. Such measures are not new and have already been analysed by several studies. Painter (1996), for example, found that the measure of street lightning significantly improves the perception of security and "[…] increase pedestrian street use after dark" (Painter 1996, 193). In addition, the aspect of a barrier-free environment has a significant effect on perceived accessibility with regard to sustainable neighbourhood development in line with age. The perceived atmosphere and the feeling of well-being are positively associated with the perception of accessibility. Contrary to expectations, perceived cleanliness has a significantly negative effect on perceived accessibility. This circumstance can only be explained by the fact that higher accessibility requires a higher understanding of the environment and also a higher awareness of things like cleanliness. In the second model, the basic model is extended by the objective parameter number of walks per day. It should be noted that there is a dependency between what is done in the neighbourhood and the perceived accessibility. The more walks an individual makes, the more positive is the perception of accessibility.

The results of the regression analysis, therefore, made it clear that accessibility is more complex than it can be described with objective accessibility parameters. The topics of security, a barrier-free environment and place-making must, therefore, become the subject of the planning discussion in order to be able to design future accessibility planning in a target-group-specific and sustainable manner.

5. Comparison and discussion

Our research has tested and compared different measurement models in two case studies, with the aim of investigating the relationship between perceived accessibility and other factors, including objective accessibility. Building a mobilities perspective into accessibility measurement, we consider how experiences and perceptions of accessibility relate to typical accessibility measurement. We suggest extending traditional time or distance-based calculations by considering other barriers and safety concerns.

By using a comparative research approach, case study two is to be regarded as a further development of the approach taken in case study one with an adapted focus. First, objective accessibility was calculated in both case studies. The perceived accessibility measure in the UK and Germany used a similar methodology and is developed on the basis of an exploratory factor analysis. High-level agreements among the items in case study one (α = .73) and case study two (α = .72) resulted in two stable measures of perceived accessibility. Based on this, both case studies identify and compare factors which are important for perceived accessibility.

5.1. Relationship between objective measures and perceived accessibility

The results show that objective measures of accessibility did not have a significant association with perceived measures of accessibility once other individual factors are accounted for. The correlation in case study two shows a weak non-significant effect. However, the explanatory content of the objective measure varied, which is described below.

To explore the factors that explain variation in perceived accessibility, multiple regression models were used in both case studies. The overall model fit is also similar in both case studies (case study one: r^2 =.398; case study two: r^2 = .344). In case study one, when only journey time measures are included, both, objective and self-reported journey time are significantly associated with perceived overall accessibility. This means individuals who report shorter journey times to destinations and those who live in more accessible neighbourhoods have a more positive perception of accessibility. However, these become non-significant once other factors are included in the model. Case study two shows that perceived accessibility is positively influenced by the frequency of walking in the neighbourhood. This means that there is an association between perceived accessibility and behaviour. The second model was focussed on pedestrian accessibility. This decision was justified on the assumption that the local neighbourhood, accessible by walking would play an important role with regard to perceived accessibility. In consequence, the second perceived accessibility measure includes mode-specific items, focused on pedestrian's perceptions.

5.2. Perceived accessibility and its influencing factors

The comparison of both case studies shows the variety of factors associated with perceived accessibility. As one main similarity, in both case studies satisfaction with the destination (case study one) and visiting destinations (case study two) has a significant association with perceived accessibility. In the perceived accessibility measure of case study two, age and car availability has no significant effect. This is in contrast to case study one, where age and car availability are significant.

As already indicated, the second case study builds on the findings of case study one, with the attempt to develop it further and is therefore focused on pedestrians' perceptions of accessibility. This could be the reason that the car availability in case study two has no significant effect. In addition to age, already shown to be important in model one, income had a highly significant negative effect in model two. With increasing income accessibility is perceived to be worse. People with higher incomes may have higher expectations for more sustainable mobility behaviour and therefore perceived accessibility is evaluated more critically than by persons with lower incomes. Furthermore, perceptions of security after dark and atmosphere in the neighbourhood were associated with perceived accessibility. Relating to pedestrians perceptions of accessibility, a barrier-free environment has a strong association with pedestrian perceptions of accessibility. This topic is not always considered in terms of planning, but from a social science perspective, it points to the debate on mobility management in course of sustainable district development.

5.3. Implications for transport planning

Short distances to amenities, high accessibility and walkable and bikeable places are characteristic of modern cities. Thus, the transformation process of mobility includes a mixture of technical, economic and social innovations. This paper has shown that accessibility is more complex than traditional approaches for modelling accessibility would suggest. In land use and transport planning accessibility is generally measured by travel time or generalised costs. However, this approach does not reflect perceptions of residents, which ultimately make mobility decisions and trips on the transport network. A mobilities perspective, recognising diverse experiences of accessibility and drawing attention to such complexity can provide a strong basis for developing accessibility metrics which can account for this diversity of experiences.

This paper shows the importance of evaluating perceived accessibility as part of a complementary monitoring process, in addition to modelling objective accessibility. The objective is to combine approaches of transport modelling and perceived accessibility with research on perceptions of accessibility. This is important because there are unexplained effects in the explanation of the mobility behaviour by objective parameters such as the walkscore or accessibility metrics. It was found that there is only a very weak correlation between objectively measured accessibility and perceived accessibility. First of all individual perceptions of urban space and the quality of mobility services have an important influence. This was confirmed in both case studies. Individuals' perceptions and experiences of urban accessibility are more complex than can be covered by objective accessibility indicators. Both case studies showed variation in perceptions of accessibility according to socio-demographic factors. Furthermore, it became clear that factors such as mobility restrictions, a barrier-free environment, atmosphere, security have significant associations with the perception of accessibility. The creation of attractive public space, for example, barrier-free design of footpaths, as well as measures of crime prevention should be part of accessibility planning in order to be able to address these factors which influence perceived accessibility, and therefore travel behaviour, and ultimately to sustainably promote the goal of improved accessibility and thus social inclusion.

5.4. *Future research and applications*

As the Scientific Advisory Council for Global Environmental Issues of the German Federal Government also demands, cities with good accessibility that have a high level of neighbourhood facilities should be sought, alongside pedestrian and bicycle-friendly environments, which have a high level of safety and are accessible to all social groups (German Advisory Council on Gobal Change 2016). This also includes the identification of aspects of urban environments which are important for supporting residents' perceptions of accessibility and could support sustainable travel behaviours through using the design of urban space to improve accessibility, according to individuals' perceptions and needs. Therefore, indicators of perceived behaviour perception should be integrated into gravity or discrete choice models.

More detailed research is necessary to integrate perceptions of different target groups into objective measurement models. For example, it would be possible to reduce the speed of travel in a senior-specific model, to integrate elements of the barrier-free environment or to give greater weight to the travel time. With regard to safety aspects, it is also possible to incorporate perceived areas of anxiety into the analyses by weighting routes by some measure of attractiveness. However, the aim is not only to supplement these aspects, but also to produce results that are quickly understandable for planning practice in order to ensure that implementation can follow. The aim is to incorporate new knowledge on perceived behaviour and its potential impacts on the transport sector, and make this knowledge usable in a quantitative way.

Note

1. Satisfaction with the walking accessibility to small grocery stores, supermarkets, drugstores, hairdressers, post offices, banks, pharmacies, doctors, cafés, green spaces, leisure facilities, sports facilities, day care centres, schools.

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ORCID

Angela Curl http://orcid.org/0000-0002-8325-190X

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