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Sufficient access? Activity participation, perceived accessibility and transport-related social exclusion across spatial contexts

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Abstract
Promoting social inclusion through facilitating the participation in social and economic activities is a central goal of land-use and transport planning. This study examines the relationship between activity participation and experiences of transport-related social exclusion across different spatial accessibility levels in the Netherlands. Using perceived accessibility as an indicator of the benefits derived from spatial opportunities, this paper reveals a weak and non-linear connection between activity participation and satisfaction with accessibility, which becomes negligible at higher participation levels. Even when individuals have low engagement levels, they often report high perceived accessibility, indicating voluntary non-participation. In rural areas with limited local opportunities, constrained participation is more prominent, especially for those with limited mobility options. The weak correlations between participation and experienced benefits from accessibility across diverse spatial contexts emphasize the importance of considering perceived accessibility alongside spatial and activity data in normative debates on determining the sufficiency of accessibility.

Keywords Perceived accessibility · Transport equity · Travel behaviour · Transport planning · Rural

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Introduction

The main purpose of the transport system is to facilitate participation in spatially dispersed activities, referred to as accessibility (Geurs and Van Wee 2004; Levine et al. 2019; Miller 2018). Inadequate access to essential services, goods, social networks and other life-enhancing opportunities is associated with processes of social exclusion, as it may hinder participation in the economic, political and social life of the community (Kenyon et al. 2002; Preston and Rajé 2007; Social Exclusion Unit 2003). Consequently, there is increasing advocacy for designing more inclusive transport systems that ensure sufficient access for all (Jeekel 2018; Martens 2017).

Transport and land-use policy aimed at social inclusion requires an understanding of the situations in which people face inadequate access to activities. However, there is a lack of consensus on the accessibility levels necessary for sufficient potential to participate in out-of-home activities, which hampers assessing the experience of transport-related social exclusion (Kamruzzaman et al. 2016; Luz and Portugal 2021). Measuring a person's potential to engage in activities is ultimately elusive, as accessibility varies depending on purpose, time and individual characteristics, including diverse needs, desires and abilities (Vecchio and Martens 2021). Indicators of accessibility based on land-use and transport data, therefore, need to make aggregated assumptions regarding desired activities, modal options and reasonable travel times, which may not reflect how individuals perceive accessibility (Haugen 2011; Páez et al. 2012; Pot et al. 2021; Ryan and Pereira 2021).

As an alternative to measuring potential activity participation, accessibility levels may be inferred directly from data on activity participation (e.g. Kamruzzaman and Hine 2011; Lucas et al. 2016; Páez et al. 2012; Schönfelder and Axhausen 2003). Behaviour, however, is influenced by both choices and constraints related to the opportunities provided by the spatial environment, referred to as spatial accessibility. Low levels of participation may not indicate social exclusion if they result from free choice (Van Wee and Geurs 2011). Conversely, individuals with extensive activity participation might still encounter substantial constraints regarding their desired activity patterns and travel behaviour, potentially leading to experiences of transport-related social exclusion. Both issues challenge the identification of those experiencing transport-related social inclusion.

When assessing the adequacy of spatial accessibility levels for social inclusion, a crucial consideration that arises is the extent to which the opportunities offered by the spatial environment facilitates satisfactory activity participation. This paper examines the link between activity participation and experiences of transport-related social exclusion for different levels of spatial accessibility by using self-reported overall assessments of accessibility, referred to as perceived accessibility, as an indicator. Drawing on data from a self-administered survey distributed across the Netherlands, this paper first presents descriptive statistics on combinations of activity participation levels and perceived accessibility in urban, intermediate and rural areas. Second, multinomial logit models are employed to explore spatial heterogeneity in the relationships between individual characteristics and perceived accessibility at different activity participation levels.

The paper is organised as follows. The next section provides a background on the link between spatial accessibility and the experience of transport-related social exclusion followed by a discussion on the usefulness of evaluating perceived accessibility to assess this link. Section 3 delineates the utilized data and methods, the outcomes of which are subsequently presented and discussed in Sect. 4. Section 5 is dedicated to the conclusions.

Background

Spatial accessibility and transport-related social exclusion

Social exclusion can generally be understood as a process by which individuals are unable to fully participate in activities and relationships considered normal by the majority in society (Burchardt 2000; Luz and Portugal 2021). The concept extends beyond poverty and emphasizes a multidimensional and dynamic understanding of deprivation, shaped by individual factors (e.g. age, disability, gender) and contextual influences (e.g. legislation, cultural norms, decision-making processes) that interact to determine one's possibilities to participate in society (Lucas 2012; Schwanen et al. 2015). Following dissatisfaction with income as the primary indicator for the possibilities a person has, social policy has increasingly emphasized the identification of other factors that enable people to fully participate in society (Sen 1993; Stiglitz et al. 2010; WCED 1987).

The performance of the transport and land-use system is a pivotal factor influencing participation, given the spatial dispersion of economic and social opportunities (Kenyon et al. 2002; Lyons 2003; Social Exclusion Unit 2003). When individuals experience this system to fall short in providing sufficient opportunities for satisfactory participation, they are likely to report limited benefits from spatial accessibility, increasing the risk of transport-related social exclusion. For instance, when no opportunities are available nearby, a person will not be able to participate in any out-of-home activities, resulting in zero experienced benefits from spatial accessibility. This will likely translate into transport-related social exclusion (see Fig. 1). Beyond this minimum, a person can participate in more activities but the relationship between participation potential and experienced benefits will be concave (Martens

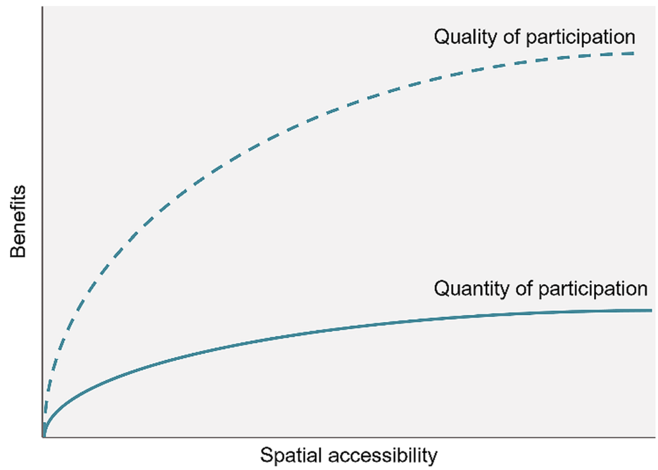

Fig. 1 The relationship between spatial accessibility and the derived benefits in terms of the quantity of activity participation (continuous line) and the quality of activity participation (dashed line) (based on Martens 2006)

2006, 2017). For example, increasing the number of supermarkets will likely not increase the number of grocery shopping trips at the same rate. Accordingly, the link between spatial accessibility and the frequency of participation may only be weak at best (Martens 2017). Recent empirical evidence seems supportive to this hypothesis of diminishing returns, with recent studies only tentatively confirming a positive relationship between spatial accessibility and the frequency of activity participation (Allen and Farber 2020; Cordera et al. 2017; Fransen et al. 2018; Kamruzzaman and Hine 2011).

More than just frequency, the overall derived utility from spatial accessibility is contingent upon the quality of participation, specifically tied to how well the characteristics of opportunities align with individual preferences. This quality-based link between spatial accessibility and experienced benefits (the dashed line in Fig. 1) will be stronger than the quantity-based link (the continuous line in Fig. 1). For example, while an additional supermarket may not necessarily result in more grocery shopping trips, it does increase the probability that people can visit one that better matches their preferences. Note that people may also place value on activities and travel options that are not realized (Bondemark et al. 2021; Geurs et al. 2006). The total benefits from unrealized opportunities will increase with the freedom of choice and thus with spatial accessibility, albeit again with diminishing returns.

At higher levels of spatial accessibility, the degree to which accessibility needs, desires and abilities are being met becomes important for evaluating accessibility, rather than solely focusing on sheer participation levels may. A key question in assessing transport-related social exclusion is whether low participation is due to personal choices and, accordingly, still align with accessibility needs and desires (Van Wee and Geurs 2011). Burchardt (2000) emphasizes that individuals are not excluded voluntarily. Social exclusion occurs when individuals, for reasons beyond their control, would like but are unable to participate in certain activities. Low participation rates can coincide with either high or low derived benefits, depending on whether the available opportunities match one's preferences regarding accessibility and travel behaviour. As preferences are more likely to be met in areas with a greater number of opportunities, the probability that low participation rates result from free choice rather than constraints concerning desired activity patterns increases with spatial accessibility. Figure 2 displays a hypothetical cumulative probability function of this relationship between spatial accessibility and the probability that low participation rates are the result of free choice. The actual position of the inflection point and shape of this function depend on the degree to which people can match preferences across spatial accessibility levels, which is linked to processes of residential sorting. If people can to a large extent sort themselves into areas that match their preferences regarding accessibility, the probability that low participation is a result of choice at low levels of spatial accessibility will increase.

Perceived accessibility as an indicator of derived benefits from spatial accessibility

The theoretical argument made in Sect. 2.1 highlights that solely measuring activity participation may not reliably reflect the experienced benefits from spatial accessibility, as it does not indicate the extent to which desired destinations can be reached (Páez et al. 2012; Pucher and Renne 2005). The relevance of individual needs, desires and abilities for derived benefits highlights the need to consider individual heterogeneity when evaluating spatial accessibility. However, measuring the exact level of experienced accessibility is ultimately elusive, as this varies depending on purpose, time and individual characteristics and

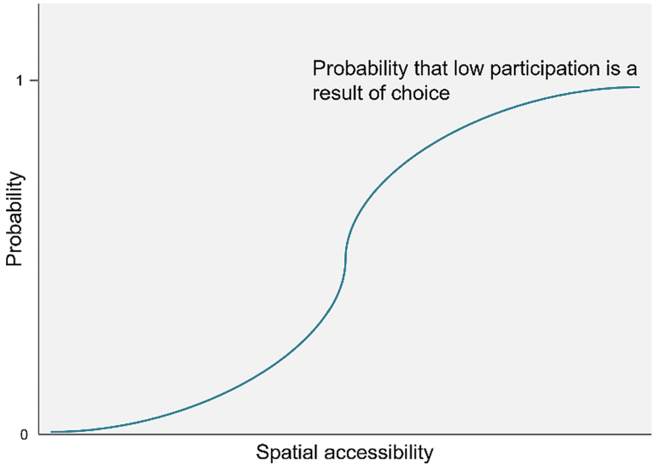

Fig. 2 The hypothetical link between spatial accessibility and the probability that low participation rates are the result of free choice

perceptions (Vecchio and Martens 2021). Therefore, accessibility indicators often rely on group aggregated assumptions regarding needs, desires and abilities (Páez et al. 2012). The aggregated and simplified nature of these measures make that such accessibility indicators may not reflect how accessibility is perceived and, potentially impacting their usefulness as indicators for evaluating the performance of the transport and land-use system (Lättman et al. 2018; Pot et al. 2021; Ryan and Pereira 2021).

An alternative approach to assessing the derived benefits of accessibility involves directly evaluating *"how easy it is to live a satisfactory life with help of the transport system"* using self-reported evaluations of accessibility, referred to as perceived accessibility (Lättman et al. 2016a, p. 36). This involves evaluating the degree to which a specific level of activity participation aligns with accessibility preferences based on one's needs, desires, and abilities, which equates to the derived utility from accessibility. Consequently, lower (higher) participation levels may still correspond with high (low) self-reported levels of perceived accessibility. When individuals report low perceived accessibility, it signals that their preferences are, to some extent, unmet, implying that individuals feel hindered in their activity participation, akin to the experience of transport-related social exclusion.

While the literature on the connection between accessibility indicators based on spatial data and perceived accessibility is expanding (e.g. Curl et al. 2015; Lättman et al. 2018), there has been limited exploration of the link between activity participation and social exclusion through perceived accessibility. Previous research in this regard has relied on qualitative methods with small sample sizes focusing on specific local communities (e.g. Ahern and Hine 2012; Cooper and Vanoutrive 2022; Pot et al. 2020). Such qualitative findings are essential to gain a nuanced understanding of potential causal mechanisms behind social exclusion. Yet, they are less suited for integration in conventional transport policy evaluations. A quantitative approach exploring the conjunctions between spatial accessibility, activity participation, and perceived accessibility bridges the gap between individual qualitative experiences and aggregated spatial accessibility assessments. This may provide a more robust foundation for policy development concerning experiences of transport-related social exclusion.

Data and methods

Survey

This study uses data from a survey conducted in the Netherlands in 2020. The questionnaire covered activity and mobility patterns, preferences and satisfaction regarding accessibility, and individual characteristics. The survey was distributed in three ways. First, 8,500 postal surveys were distributed in rural areas, resulting in 1,619 questionnaires returned (a response rate of 19%). Second, online data collection through promotion in local newspapers and social media yielded an additional 789 responses. Third, the survey was distributed online via the nationally representative Dutch Mobility Panel (MPN) across the country at the end of 2020, yielding 1,254 respondents (a response rate of 90%). It should be noted that respondents from rural areas are overrepresented in the total sample due to the targeted nature of the postal survey. The total sample size amounts to 3,378, after removing the responses that could not be geocoded.

Due to the COVID-19 pandemic, data collection was paused at the end of February 2020 and continued in September 2020, as this was the moment that restrictions on activity patterns were largely lifted in the Netherlands. Respondents were asked to answer questions as if there were no pandemic-related restrictions in place. Analyses comparing survey responses from before and during the pandemic yielded no significant differences in model results, indicating that the break in data collection did not meaningfully affect the results.

Main variables

Perceived accessibility

The 'Perceived Accessibility Scale' (PAC) developed by Lättman et al. (2018) serves as the measure of perceived accessibility. Respondents were asked, *'considering how one travels'*, if *'it is easy to do daily activities'*, someone is *'able to live life as wanted'*, is *'able to do all preferred activities*', and whether *'access to preferred activities is satisfying'* on a seven-point scale ranging from (strongly disagree) to 7 (strongly agree). Self-reported assessments of one's opportunities can be as a solution to the elusiveness of spatial accessibility measurement that accounts for all combinations of spatial factors and individual requirements (Anand and van Hees 2006; Pot et al. 2023b; Van Ootegem and Verhofstadt 2012; Vecchio and Martens 2021). The PAC-scale was specifically designed to capture an overall assessment of accessibility at the individual level, thereby circumventing the need for assumptions regarding individual needs and desires (Lättman et al. 2018).

The PAC-scale captures both the ease of reaching and the relevance of available activities, closely aligning with the conventional interpretation of accessibility as the potential for engaging in desired activities. A principal axis factor analysis confirmed the unidimensionality of the scale by retaining a single factor with an eigenvalue surpassing the threshold of 1 ($\lambda = 2.90$), accounting for 93% of the variance. The scale demonstrated a strong overall item correlation (Cronbach's $\alpha=0.90$), with no enhancement observed upon item deletion, consistent with previous implementations (Lättman et al. 2016b, 2018). The perceived accessibility index (PAC-index) is defined as the average of the four items and serves as the main measure of perceived accessibility in this study with a mean of 5.93, a standard deviation of 1.13 and a strong left skew of −1.64.

Activity participation

Participation in activities was measured by querying respondents about the frequency of travel to various destinations, including work, education, healthcare, shopping, outdoor activities, attending events, and visiting friends and family. A six-point ordinal measurement scale was utilized with the categories (comparable to Adeel et al. 2016; Chan et al. 2019; Nordbakke and Schwanen 2015; Páez and Farber 2012): '*never*'; '*on less than one day in three months*'; '*on one to two days in three months*'; '*on one to three days a month*'; '*on one to three days a week*'; and '*on four days a week or more*'. The lower bound of each category was used as an approximation for the weekly trip count. Aggregating these approximations across all destination types yielded the total number of out-of-home activities per week. Based on this variable, the estimated mean number of out-of-home activities per week is 8.53 with a standard deviation of 4.37 and a moderate right skew of 0.97.

It is important to highlight that, due to the use of lower bounds and the exclusion of multiple trips on the same day, the estimated frequency is conservative in comparison to results typically observed in travel surveys. However, this potential underestimation is consistent across groups and is unlikely to undermine the study's objectives, given the focus on evaluating relative participation differences across groups and accessibility levels, rather than scrutinizing absolute participation levels. The lack of precision of this measure of activity participation due to the use of an ordinal scale should also not compromise the objectives of this study, as this paper seeks to identify general patterns between participation and perceived accessibility, rather than establishing precise thresholds for activity participation. Moreover, the measure demonstrates robustness in comparisons with other indicators. Comparison of the measure used in this paper with an index from Nordbakke and Schwanen (2015), where the values of the ordinal scale (ranging from 1 to 6) for each participant were summed for each activity type and then divided by seven (the number of destination types), yielded a correlation coefficient of 0.79.

Spatial accessibility

Respondents are categorized into residential contexts based on spatial accessibility. For each individual, a spatial accessibility indicator is calculated reflecting the magnitude of locally available opportunities from their home location. Compared to more commonly employed classifications in policy practice, which often rely on population density and are defined at higher spatial scales, this approach, using the number of local opportunities at the individual level, maintains a more explicit substantive connection to the key outcome variables of activity participation and perceived accessibility.

This research fundamentally aims to elucidate the potential disjunction between spatial factors and individually experienced accessibility. Consequently, the spatial accessibility indicator exclusively incorporates information on the land-use and transport system, intentionally omitting individual characteristics such as mode availability. This approach minimizes the need to make assumptions about the diverse needs, desires, and abilities of individuals. Spatial accessibility is operationalized as a function of the number and size of activity locations weighted by the distance to these locations: $ACC_i = \sum_j O_j f\,(d_{ij})$, where ACC_i represents spatial accessibility from an individual's self-reported home street location i, O_j represents the magnitude of opportunities provided at activity location j, proxied by the number of jobs provided by the establishment, and $f\,(d_{ij})$ represents a resistance function of road distance d_{ij} in kilometres, which entails that opportunities have a diminishing influence on spatial accessibility as distances increase. The distance resistance function requires some assumption on travel abilities of the population and is formulated as $f\,(d_{ij}) = \exp(-\beta d_{ij})$ with a decay parameter β of 0.5. This corresponds to a distance threshold of about 5 km, widely considered the upper limit for engaging in active modes like walking and cycling, which are nearly universally available with minimal barriers (Silva and Altieri 2022; Wiersma et al. 2016).

Opportunity locations are obtained from the Dutch establishment register LISA, which contains location coordinates, the number of jobs and a sectoral categorization of each firm (LISA 2020). The sectors relevant for accessibility are informed by earlier studies and comprise supermarkets, education, healthcare, retail, cultural, hospitality and sporting facilities (Christiaanse 2020; Kolodinsky et al. 2013; Rijnks 2020). Calculations have been made in ArcGIS using the NWB (Nationaal Wegenbestand) road dataset made available by the Dutch executive agency for national infrastructure Rijkswaterstaat.

Three residential contexts were identified by applying K-means clustering and a silhouette analysis on this spatial accessibility indicator: urban, intermediate and rural. This classification was robust to values of β between 0.25 and 1.5, suggesting that variations in this behavioural assumption do not exert a significant influence on the study's results. Furthermore, the classification exhibited substantial concurrence with the urbanization classifications employed by Statistics Netherlands (2022) and Eurostat (2020), as indicated by Cramér's V measures of association (ranging from 0 to 1) amounting to 0.76 and 0.60, respectively. Figure 3 maps the spatial distribution of all respondents and their respective residential categories.

Covariates

Sociodemographic variables in the questionnaire include gender; age; education (*low*=primary or prevocational, *medium*=higher secondary or vocational, *high*=university); household monthly net income (*low* = < €2,000, *medium* = €2,000 - €4,000, *high* = ≥ €4,000); employment status (employed/full-time education, retired or unemployed/out of workforce); household size (number of people); the presence of children under 18 years of age in the household (dummy).

The variables that explicitly relate to accessibility include the number of cars, bikes and e-bikes per household member; a dummy related to the degree of social support (stated that getting a lift by car from someone is easy); having a public transport subscription of any form (e.g. student free-travel card, paid subscription for a certain route, discount card) (dummy); having a good internet connection (dummy), which may allow to efficiently plan or substitute activities that require travel; and having some form of physical and/or mental condition that limits travel behaviour (dummy). Furthermore, a factor analysis out of seven

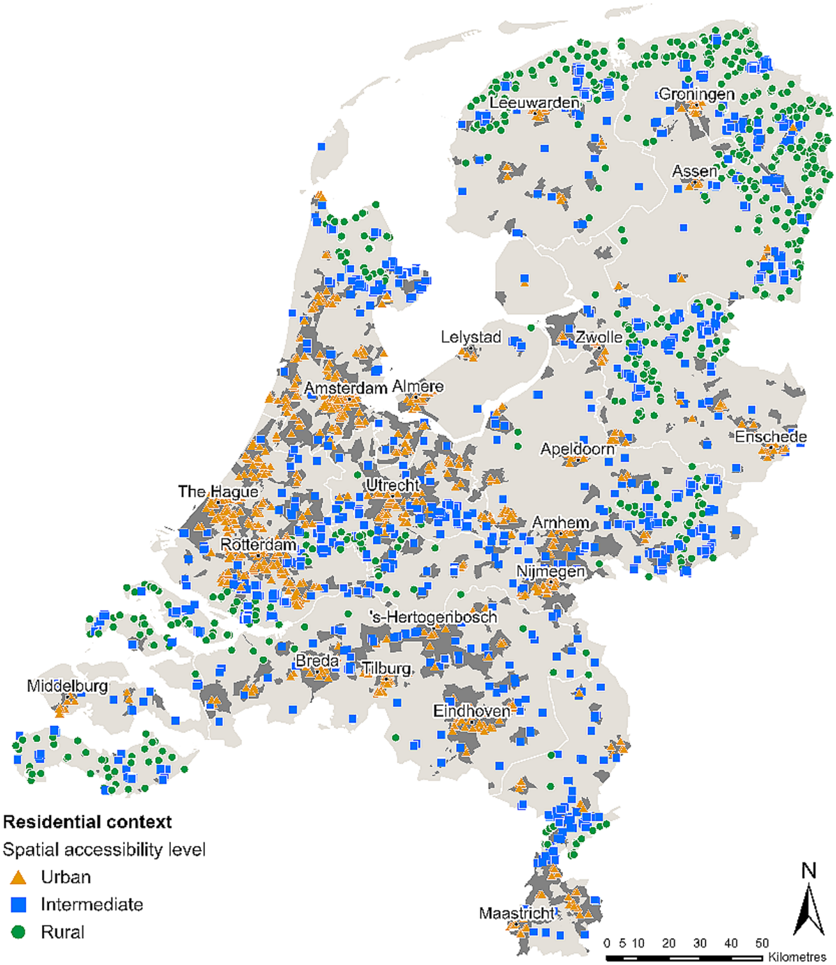

Fig. 3 Residential classification of respondents

statements regarding accessibility desires resulted in a 'pro proximity' factor reflecting the level of desired local accessibility, to capture preferences regarding proximity more explicitly (see Table A1).

Travel mode use frequency was measured on a seven-point ordinal scale, similar to the measure of activity participation. To estimate the total number of weekly trips per mode, the lower bounds of the response categories were summed. Subsequently, the shares of the car (both as the driver and as a passenger), public transport (bus, tram, metro, demand responsive transport, and train) and active modes (bike, e-bike and walking) in total mode use were derived. Finally, a dummy variable that asks whether an individual often shops online indicates a degree of substitution of physical travel to activity locations.

Analytical strategy

Grouping

Classification into groups based on perceived accessibility and the level of activity participation serves as a basis for identifying how individual factors determine the correspondence between these variables. Respondents were classified into two categories regarding perceived accessibility. Those who scored lower than 4.5 on the PAC-index are labelled as 'low perceived accessibility' as they have, on average, responded negatively to the questions on the PAC scale (i.e. '*neutral'* at best). Others were labelled as reporting 'high perceived accessibility'. This binary approach aligns with the social policy interest of accommodating the group that experiences insufficient accessibility rather than improving accessibility for those who are already satisfied. The cut-off is set at 'neutral' to provide an upper-bound estimate for the count of individuals confronting challenges. This approach facilitates capturing the potential diversity in groups experiencing issues across different spatial contexts.

It is less straightforward to set thresholds for what levels can be considered low or high in the absence of a qualitative interpretation of activity participation frequency. The current policy discourse suggests that sufficient accessibility entails everyone should have the ability to reach and take part in activities considered 'normal' or 'acceptable' to that society, where people falling below a certain threshold may be at risk of social exclusion (Farrington 2007). In this study, the median level of activity participation is used to define what could be considered normal. Utilizing the midpoint as a threshold, rather than adopting a philosophically rooted definition of what constitutes a sufficient level of activity participation, aligns with the study's aim to inform the policy debate regarding the determination of sufficient accessibility. Accordingly, respondents with below-median levels of activity participation (Med = 8.53) are classified as 'low participation' and those with above-median levels as 'high participation'. It is noteworthy that a categorization into three participation levels yielded similar patterns in terms of group composition (Cramér's $V = 0.81$), but the groups were too small to yield meaningful results in multivariate analyses. Moreover, a categorization splitting the sample at the median following the activity participation index from Nordbakke and Schwanen (2015) (see Sect. 3.2.2) also yielded a similar classification ($\phi = 0.63$).

Statistical analysis

Descriptive analyses present group membership shares for the three considered residential contexts. This allows for comparing the strength of the link between activity participation and perceived accessibility at different levels of spatial accessibility and, thus, varying degrees of freedom of choice.

Multivariate analyses were conducted on the entire sample and subgroups representing urban, intermediate, and rural spatial accessibility contexts. These analyses aimed to explore the spatial heterogeneity in the relationships between individual covariates and belonging to groups with low or high activity participation in conjunction with low or high perceived accessibility (as defined in Sect. 3.3.1). Binary logistic regression models could predict group membership probabilities compared to the rest of the sample. However, this approach would not clarify whether a covariate's effect is due to its link with participation frequency or perceived accessibility. To address this, a multinomial logit (MNL) approach was employed, allowing simultaneous comparisons of group membership to other groups. The MNL assumes the absence of conceptual overlap between response categories (independence of irrelevant alternatives, IIA). In this case, even though individuals shared participation or perceived accessibility levels with other groups, this independence assumption is met. Importantly, perceived accessibility is not conceptually a subcategory of activity participation. Moreover, the analysis incorporates factors determining activity participation frequency, effectively mitigating shared unobserved group characteristics and preventing correlated error terms, as confirmed by insignificant Hausman specification tests.

Results and discussion

Associations between activity participation and perceived accessibility

Table 1 presents the main summary statistics on perceived accessibility and activity behaviour. Overall, 9.4% of the respondents report low levels of accessibility. Mean spatial accessibility levels increase incrementally from rural to intermediate and urban areas. Yet, there are no significant differences concerning weekly activity participation across these residential categories. The absence of an increase in activity participation with spatial accessibility may be explained by the relatively high absolute levels of accessibility in the Netherlands, including its rural areas, and there are likely diminishing returns to spatial accessibility concerning activity participation (Allen and Farber 2020; Martens 2017). However, the ways activities are reached vary with the level of spatial accessibility. In line with national statistics (Statistics Netherlands 2020), car use is higher in low spatial accessibility contexts while the share of trips made by public transport, bicycle or walking increases with spatial accessibility. The percentage of people who frequently shop online is lowest in intermediate areas and highest in urban areas.

The proportion of individuals with low perceived accessibility is comparable in urban and intermediate regions, both standing at 8.5% and 8.4%, respectively ($p=0.91$). These similar values could suggest that accessibility preferences are equally met across these two

Table 1 Main accessibility and activity behaviour summary statistics

Variables	Total	Urban	Intermediate	Rural	Group differences
Number of observations	3,378	872	1,596	910	
Spatial accessibility					
Mean spatial accessibility (ln*ACC*)	6.34	8.08	6.35	4.86	$F_{[2,3375]}=8{,}196.6$***
Activity behaviour					
Mean of the estimated total number of weekly out-of-home activities	8.64	8.75	8.55	8.70	$F_{[2,3066]}=0.69$
Share of car trips	42.2%	30.9%	41.9%	59.9%	$\chi^2_{[2]}=295.5$***
Share of public transport trips	4.6%	6.4%	3.9%	3.3%	$\chi^2_{[2]}=38.3$***
Share of active mode trips	51.2%	59.8%	52.3%	41.5%	$\chi^2_{[2]}=202.9$***
Share of people that frequently shop online	42.6%	46.6%	40.3%	42.7%	$\chi^2_{[2]}=8.10$**
Perceived accessibility					
Share of people with low perceived accessibility (PAC-index < 4.5)	9.4%	8.5%	8.4%	12.4%	$\chi^2_{[2]}= 11.9$***

** $p<0.05$, ***$p<0.01$

categories of spatial accessibility. Yet, the group of people reporting low perceived accessibility is significantly larger in rural areas (12.4%) compared to intermediate ($p<0.01$) and urban areas ($p=0.01$). This disparity suggests that individuals in rural areas may encounter greater limitations in participating in desired activities in contrast to those residing in urban and intermediate accessibility areas.

This observation is substantiated by the graphical representation of the percentage of individuals reporting both low participation rates and low perceived accessibility across different spatial accessibility levels (Fig. 4). The percentage of individuals facing both low participation rates and perceiving this as unsatisfactory decreases until approximately the third quantile (30th percentile) of spatial accessibility. This point coincides with the 'rural' category, which encompasses values of spatial accessibility up to the 27th percentile.

Figure 5 illustrates a negative but non-linear link between activity participation and the share of people reporting low levels of perceived accessibility. The graph reveals that the share of respondents with low perceived accessibility is highest among those who participate in less than two activities per week (30.8%). As the number of activities undertaken increases, this share gradually decreases before stabilizing around median levels of activity participation at about 8%. Remarkably, even at the lowest level of activity participation (less than two activities per week), most report high levels of perceived accessibility (69.2%). Conversely, at high levels of participation, at least 8% of the respondents remain to report low levels of perceived accessibility. This non-linear relationship indicates that there might be a threshold value of participation beyond which additional participation does not result in higher experienced utility.

Figure 6 displays the link between participation and low perceived accessibility across different residential contexts. The graphs illustrate that the relationship between the frequency of participation and the proportion of people with low perceived accessibility

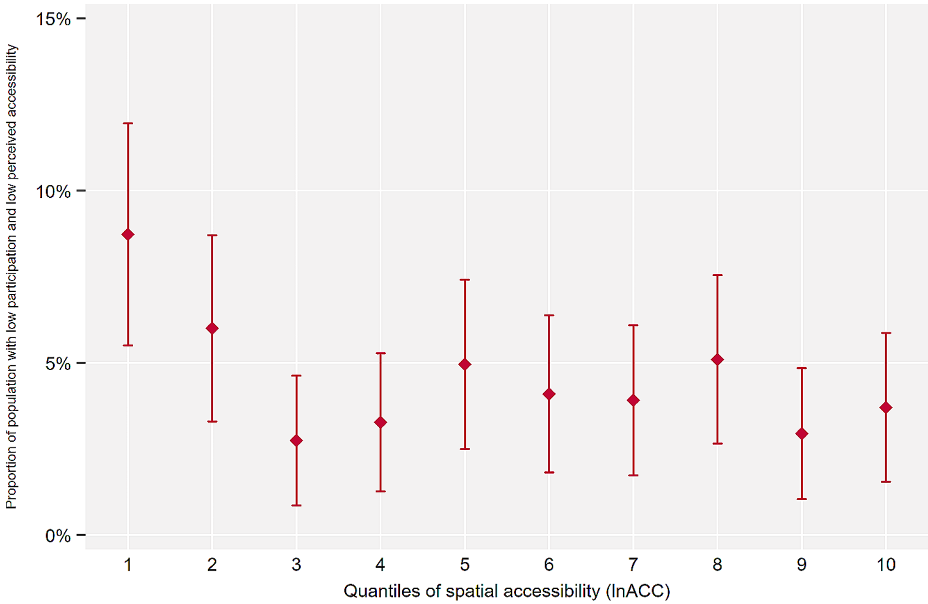

Fig. 4 Spatial accessibility and percentage of individuals reporting both low participation rates and low perceived accessibility (with 95% CI)

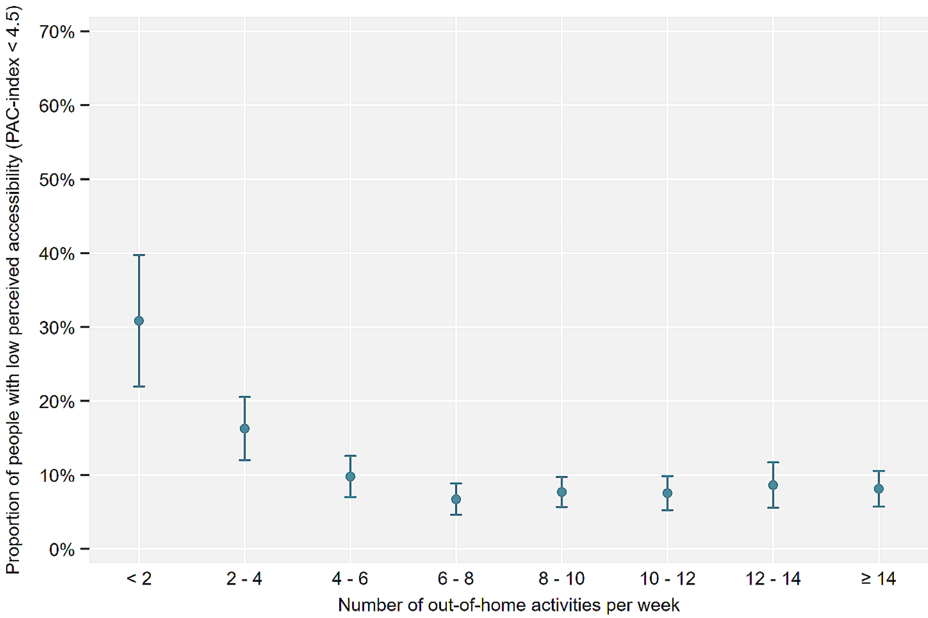

Fig. 5 Activity participation and share of people with low perceived accessibility (with 95% CI)

continues to persist over higher levels of activity participation at lower levels of spatial accessibility, although the link also becomes non-existent for rural areas beyond median levels of participation. Also, the proportion of people with low perceived accessibility at higher participation levels stabilizes at a higher level in rural areas compared to intermediate and urban areas. This observation aligns with the hypothesis that low levels of participation are more indicative of transport-related social exclusion in rural areas. In environments with higher spatial accessibility levels, there is a higher likelihood that accessibility preferences can be met. Therefore, engaging in fewer activities is more likely to be the result of choice than in rural contexts, where people may face more accessibility constraints (see Fig. 2).

Cross tabulations presented in Table 2 confirm a significant but generally low association between activity participation and the utility derived as measured by perceived accessibility ($\chi^2_{[2]}$= 5.70, p=0.02, measure of association ϕ=0.04). The vast majority of people report high perceived accessibility (PAC-index≥4.5) irrespective of the number of activities. Nevertheless, the share of people with low perceived accessibility is slightly higher among those with low participation levels (i.e. below-median) (11%) than among those with high levels of activity participation (8%). This difference is most pronounced in rural areas (15% vs. 10%), to a lesser extent in intermediate areas (10% vs. 7%) and not significant in urban areas (9% vs. 8%). The groups in Table 2 serve as the basis for the multivariate analyses of which the next section presents the results.

Factors predicting combinations of activity participation and perceived accessibility

This section examines how individual factors are associated with combinations of levels of activity participation and perceived accessibility in different spatial accessibility contexts.

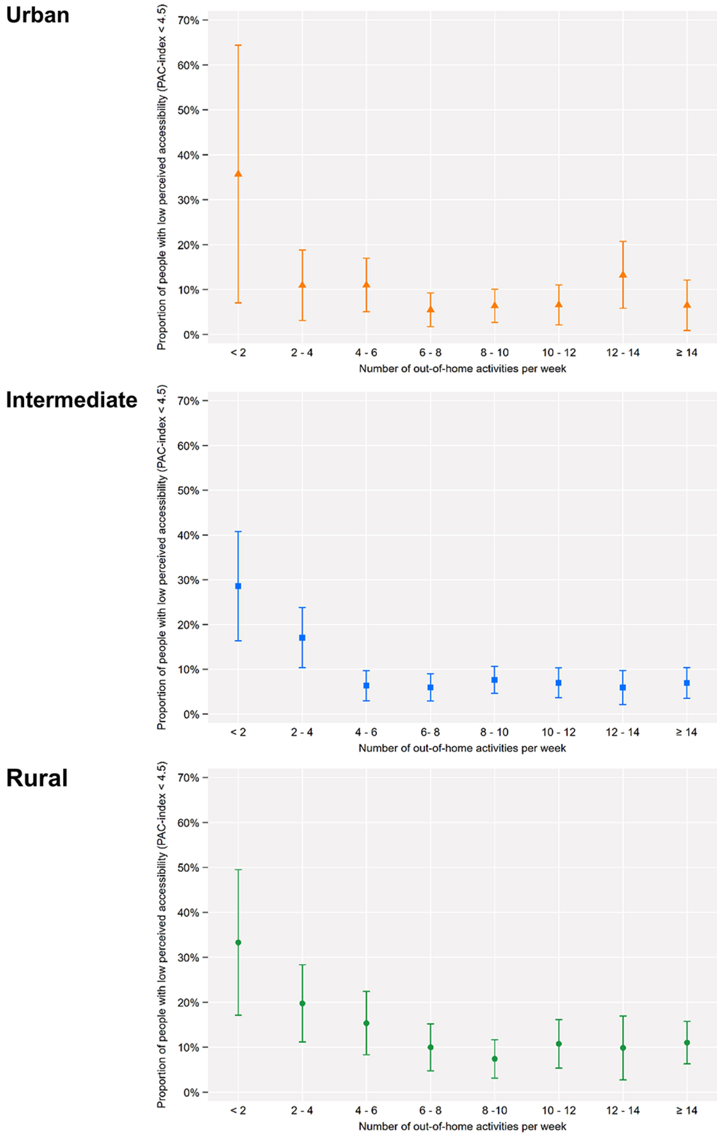

Fig. 6 Activity participation and proportion of people with low perceived accessibility (with 95% CI) for urban, intermediate and rural spatial accessibility contexts

The analysis utilizes a MNL regression approach, with respondents demonstrating high activity participation combined with high perceived accessibility serving as the reference category. For each covariate, relative risk ratios larger than 1 indicate a higher probability of belonging to another category (i.e. high participation but low perceived accessibility, low participation with low perceived accessibility, or low participation but high perceived accessibility). Table 3 presents the results for the total sample. Tables 4, 5 and 6 present the results for subsamples of urban, intermediate and rural spatial accessibility contexts, respectively.

Table 2 Cross tabulations of activity participation and perceived accessibility across residential typology

		Low participation	High participation	χ^2	ϕ
Total	Low perceived accessibility	173 (11%)	126 (8%)	5.70**	0.04
	High perceived accessibility	1,459 (89%)	1,424 (92%)		
Urban	Low perceived accessibility	35 (9%)	32 (8%)	0.02	0.01
	High perceived accessibility	368 (91%)	350 (92%)		
Intermediate	Low perceived accessibility	71 (10%)	48 (7%)	3.03*	0.05
	High perceived accessibility	673 (91%)	638 (93%)		
Rural	Low perceived accessibility	61 (15%)	39 (10%)	4.52**	0.08
	High perceived accessibility	348 (85%)	353 (90%)		

Column percentages in parentheses. $\varphi = \sqrt{\frac{\chi^2}{N}}$, *$p<0.1$, **$p<0.05$

Sociodemographic characteristics and attitudes

Individual needs, desires and abilities regarding access to activities determine how a given level of activity participation is associated with perceived accessibility. Concerning the pro proximity factor that aims to measure these preferences directly, it is unsurprising to see that a strong preference for local access to many activities decreases the probability to be satisfied with low participation levels. Moreover, people with a strong preference for proximity are more likely to perceive accessibility as low in rural areas, even if they are able to maintain high levels of activity participation. This underlines that high levels of participation can still coincide with experienced constraints regarding activity participation, particularly in areas with fewer opportunities.

Among the sociodemographic factors that attempt to reflect accessibility needs, desires and abilities, the constraining effect of fewer opportunities in rural areas on perceived accessibility also emerges. Having a disability that limits travel was not unambiguously related to lower levels of participation in any spatial context, but it was nevertheless more strongly associated with low perceived accessibility outside urban areas, even at high levels of participation. Furthermore, being in a large household may decrease the number of trips (see also Fransen et al. 2018), but may still coincide with high perceived accessibility, particularly in more urbanized areas where there are more locally available opportunities.

Employment status, as a defining factor of one's activity patterns, is intrinsically linked with activity participation levels. Compared to employed people and students, those not having a job and having corresponding low levels of participation more often reported low perceived accessibility levels across all residential contexts. Linked to employment status, having a low income has a somewhat ambiguous effect. Lower incomes may correspond to lower levels of participation but with high satisfaction, except in urban areas where low participation seems to be more often associated with low perceived accessibility. Pensioners also generally participate less in general, but this is particularly associated with low perceived accessibility only in rural areas. In contexts with higher spatial accessibility, retirees are more likely to participate less than employed people voluntarily, without experiencing limitations. This pattern partly resembles the effects of age, as older people are generally more likely to participate less but still be satisfied (Ziegler and Schwanen 2011), except in urban areas where older people maintain high participation levels but to a lower degree of satisfaction. For these groups, processes of preference adjustment may explain that low activity participation can still be combined with high perceived accessibility in disadvan-

Table 3 MNL results for total sample

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Sociodemographics and attitudes						
Gender (ref. male)	0.964	[0.550 1.690]	0.527**	[0.289 0.962]	1.013	[0.801 1.282]
Age	1.007	[0.899 1.127]	0.976	[0.872 1.093]	0.963	[0.920 1.007]
Age-squared	1.000	[0.998 1.001]	1.001	[1.000 1.002]	1.001**	[1.000 1.001]
Education level (ref. medium)						
- Low	0.667	[0.302 1.474]	0.629	[0.285 1.388]	0.855	[0.620 1.179]
- High	0.689	[0.368 1.291]	1.286	[0.653 2.533]	0.841	[0.643 1.100]
Household monthly net income (ref. medium)						
- Low	2.065*	[0.996 4.283]	0.931	[0.448 1.934]	1.608***	[1.167 2.217]
- High	1.447	[0.715 2.930]	0.280**	[0.101 0.780]	0.832	[0.630 1.101]
Working situation (ref. employed/student)						
- Unemployed / out of the workforce	1.535	[0.639 3.685]	10.98***	[4.730 25.48]	3.771***	[2.544 5.591]
- Retired	2.304	[0.625 8.489]	3.194**	[1.112 9.176]	4.044***	[2.601 6.288]
Household size	0.741	[0.513 1.069]	0.994	[0.662 1.492]	1.161**	[1.004 1.342]
Children (dummy)	2.872**	[1.131 7.294]	1.588	[0.481 5.245]	0.905	[0.611 1.340]
Disability (dummy)	5.413***	[2.841 10.31]	6.224***	[3.278 11.82]	1.220	[0.868 1.714]
Pro proximity factor	1.151	[0.824 1.607]	0.777	[0.572 1.055]	0.743***	[0.651 0.848]
Mobility means						
Cars per household member	0.589	[0.264 1.315]	0.402**	[0.171 0.946]	0.732*	[0.514 1.043]
Bikes per household member	1.371	[0.939 2.003]	0.667*	[0.415 1.073]	1.061	[0.890 1.264]
E-bikes per household member	0.904	[0.450 1.819]	0.481*	[0.228 1.013]	0.905	[0.684 1.198]
Social network (dummy)	1.000	[0.523 1.912]	0.389**	[0.174 0.871]	1.085	[0.836 1.408]
PT subscription (dummy)	0.600	[0.286 1.260]	0.957	[0.483 1.894]	0.842	[0.622 1.139]
Good internet connection (dummy)	0.364***	[0.182 0.726]	0.262***	[0.130 0.528]	0.973	[0.655 1.445]
Travel behaviour						
Share PT in total trips (%)	3.846	[0.345 42.84]	2.174	[0.152 31.10]	0.635	[0.163 2.478]
Share active modes in total trips (%)	0.755	[0.239 2.390]	1.106	[0.358 3.415]	0.839	[0.507 1.387]

Table 3 (continued)

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Online shopper (dummy)	1.231	[0.696 2.177]	2.303***	[1.251 4.241]	1.423***	[1.118 1.811]
Constant	0.198	[0.010 4.072]	0.093	[0.003 3.379]	0.548	[0.146 2.053]
Number of observations	1,671					
LR-χ^2	555.7***					
Log-likelihood	-1,336.2					
Pseudo R-squared	0.172					

*$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 4 MNL results for urban areas

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Sociodemographics and attitudes						
Gender (ref. male)	1.045	[0.333 3.275]	1.435	[0.268 7.685]	0.955	[0.581 1.570]
Age	1.600**	[1.029 2.487]	0.963	[0.666 1.393]	0.943	[0.854 1.041]
Age-squared	0.994**	[0.989 1.000]	1.001	[0.998 1.004]	1.001*	[1.000 1.002]
Education level (ref. medium)						
- low	0.951	[0.148 6.113]	0.031	[0.001 0.742]	0.595	[0.298 1.188]
- high	0.501	[0.134 1.871]	1.244	[0.218 7.089]	1.341	[0.745 2.416]
Household monthly net income (ref. medium)						
- low	1.443	[0.282 7.387]	0.416**	[0.052 3.334]	1.621	[0.829 3.166]
- high	1.474*	[0.361 6.018]	2.038	[0.140 29.61]	0.607	[0.320 1.151]
Working situation (ref. employed/student)						
- unemployed / out of the workforce	1.806	[0.264 12.332]	124.3***	[8.988 1.71E3]	5.226***	[2.216 12.33]
- retired	78.60*	[0.586 10.5E3]	5.302	[0.247 113.9]	2.728*	[0.887 8.383]
Household size	1.313	[0.570 3.026]	0.591	[0.081 4.298]	1.672***	[1.195 2.339]
Children (dummy)	1.626	[0.187 14.16]	2.897	[0.038 219.0]	0.423*	[0.167 1.071]
Disability (dummy)	2.360	[0.501 11.13]	6.359*	[0.906 44.61]	1.112	[0.540 2.289]
Pro proximity factor	0.967	[0.437 2.139]	1.627	[0.490 5.404]	0.716**	[0.520 0.985]
Mobility means						
Cars per household member	0.913	[0.166 5.006]	0.701	[0.078 6.334]	0.574	[0.277 1.192]
Bikes per household member	1.248	[0.577 2.698]	0.550	[0.156 1.944]	1.038	[0.731 1.473]
E-bikes per household member	1.202	[0.291 4.960]	0.475	[0.051 4.447]	1.065	[0.611 1.855]
Social network (dummy)	1.813	[0.502 6.540]	0.830	[0.106 6.515]	0.981	[0.564 1.706]
PT subscription (dummy)	2.260	[0.517 9.871]	1.535	[0.244 9.651]	0.570*	[0.310 1.048]
Good internet connection (dummy)	0.216*	[0.040 1.150]	0.293	[0.016 5.233]	0.773	[0.253 2.367]
Travel behaviour						
Share PT in total trips (%)	0.222	[0.002 22.51]	1.408	[0.006 319.5]	1.160	[0.113 11.97]
Share active modes in total trips (%)	0.180	[0.013 2.579]	0.020**	[0.001 0.614]	0.981	[0.283 3.396]

Table 4 (continued)

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Online shopper (dummy)	0.779	[0.241 2.517]	3.135	[0.643 15.28]	1.811**	[1.071 3.063]
Constant	0.000	[0.000 0.576]	0.099	[0.000 8,871.5]	0.484	[0.026 9.115]
Number of observations	393					
LR-χ^2	177.95***					
Log-likelihood	-285.53					
Pseudo R-squared	0.238					

*$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 5 MNL results for intermediate areas

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Sociodemographics and attitudes						
Gender (ref. male)	0.499	[0.187 1.330]	0.413*	[0.145 1.175]	1.239	[0.860 1.785]
Age	0.963	[0.810 1.144]	0.954	[0.785 1.159]	0.953	[0.890 1.019]
Age-squared	1.000	[0.998 1.002]	1.001	[0.999 1.003]	1.001*	[1.000 1.001]
Education level (ref. medium)						
- low	0.992	[0.279 3.528]	0.265**	[0.071 0.991]	0.796	[0.488 1.297]
- high	0.594	[0.198 1.783]	1.018	[0.362 2.865]	0.947	[0.630 1.422]
Household monthly net income (ref. medium)						
- low	2.207	[0.594 8.195]	0.893	[0.263 3.031]	1.727**	[1.056 2.824]
- high	1.995	[0.602 6.609]	0.099**	[0.012 0.819]	0.737	[0.484 1.123]
Working situation (ref. employed/student)						
- unemployed / out of the workforce	3.603*	[0.835 15.55]	8.065***	[2.058 31.61]	5.100***	[2.715 9.580]
- retired	0.979	[0.097 9.920]	1.439	[0.285 7.263]	5.045***	[2.564 9.926]
Household size	0.679	[0.354 1.302]	1.111	[0.590 2.091]	1.248*	[0.999 1.558]
Children (dummy)	2.136	[0.467 9.773]	1.221	[0.189 7.896]	0.940	[0.534 1.657]
Disability (dummy)	5.071***	[1.609 15.99]	5.406***	[2.060 14.19]	1.052	[0.635 1.741]
Pro proximity factor	1.039	[0.585 1.846]	0.689	[0.398 1.192]	0.716***	[0.581 0.882]
Mobility means						
Cars per household member	0.649	[0.162 2.601]	0.232**	[0.056 0.963]	1.070	[0.604 1.895]
Bikes per household member	1.917*	[0.996 3.687]	0.674	[0.315 1.440]	1.072	[0.808 1.422]
E-bikes per household member	0.903	[0.260 3.131]	0.348*	[0.102 1.189]	0.938	[0.609 1.444]
Social network (dummy)	1.629	[0.592 4.484]	0.495	[0.150 1.633]	1.017	[0.680 1.522]
PT subscription (dummy)	0.602	[0.160 2.261]	0.665	[0.207 2.140]	1.015	[0.645 1.597]
Good internet connection (dummy)	0.297*	[0.084 1.050]	0.432	[0.122 1.527]	1.139	[0.572 2.266]
Travel behaviour						
Share PT in total trips (%)	6.112	[0.109 342.6]	1.865	[0.027 127.1]	0.441	[0.055 3.564]
Share active modes in total trips (%)	0.386	[0.055 2.686]	3.337	[0.485 22.97]	0.513*	[0.238 1.108]

Table 5 (continued)

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Online shopper (dummy)	1.065	[0.407 2.790]	2.116	[0.795 5.631]	1.154	[0.802 1.660]
Constant	0.844	[0.006 126.9]	0.077	[0.000 52.08]	0.571	[0.077 4.244]
Number of observations	741					
LR-χ^2	260.1***					
Log-likelihood	-576.25					
Pseudo R-squared	0.184					

*$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 6 MNL results for rural areas

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Sociodemographics and attitudes						
Gender (ref. male)	2.220	[0.628 7.849]	0.330*	[0.097 1.125]	1.010	[0.631 1.618]
Age	0.989	[0.789 1.239]	1.025	[0.821 1.279]	0.975	[0.873 1.088]
Age-squared	1.000	[0.998 1.003]	1.000	[0.998 1.002]	1.000	[0.999 1.002]
Education level (ref. medium)						
- low	1.063	[0.210 5.378]	4.381*	[0.769 24.96]	1.344	[0.697 2.594]
- high	0.695	[0.185 2.609]	2.950	[0.554 15.69]	0.685	[0.396 1.185]
Household monthly net income (ref. medium)						
- low	1.189	[0.271 5.211]	0.946	[0.237 3.785]	1.491	[0.772 2.880]
- high	1.062	[0.199 5.651]	0.738	[0.114 4.797]	1.405	[0.795 2.482]
Working situation (ref. employed/student)						
- unemployed / out of the workforce	0.678	[0.095 4.866]	13.50***	[2.699 67.50]	2.865***	[1.306 6.287]
- retired	1.703	[0.191 15.16]	13.49**	[1.888 96.45]	4.854***	[2.149 10.97]
Household size	0.760	[0.358 1.611]	0.464*	[0.189 1.139]	0.863	[0.624 1.193]
Children (dummy)	3.296	[0.528 20.57]	3.671	[0.405 33.24]	1.059	[0.466 2.408]
Disability (dummy)	11.40***	[3.201 40.59]	9.744***	[2.586 36.72]	1.456	[0.720 2.944]
Pro proximity factor	2.150**	[1.086 4.259]	0.750	[0.433 1.300]	0.738**	[0.577 0.943]
Mobility means						
Cars per household member	0.730	[0.090 5.896]	0.138**	[0.016 1.153]	0.421**	[0.191 0.928]
Bikes per household member	0.804	[0.300 2.160]	0.436	[0.160 1.187]	1.093	[0.764 1.565]
E-bikes per household member	0.573	[0.110 2.974]	0.324	[0.071 1.485]	0.896	[0.496 1.619]
Social network (dummy)	0.162	[0.018 1.488]	0.105**	[0.012 0.895]	1.213	[0.714 2.062]
PT subscription (dummy)	0.285	[0.043 1.896]	2.361	[0.588 9.477]	1.019	[0.509 2.037]
Good internet connection (dummy)	0.384	[0.111 1.330]	0.166***	[0.049 0.564]	0.758	[0.414 1.390]
Travel behaviour						
Share PT in total trips (%)	4.776**	[1.304 1.75E3]	2.898	[0.002 3.806]	0.209	[0.004 11.68]
Share active modes in total trips (%)	1.567	[0.120 20.52]	1.392	[0.146 13.30]	0.802	[0.296 2.178]

Table 6 (continued)

Ref. High participation and high perceived accessibility	High participation Low perceived accessibility		Low participation Low perceived accessibility		Low participation High perceived accessibility	
	Relative risk ratio	95% CI	Relative risk ratio	95% CI	Relative risk ratio	95% CI
Online shopper (dummy)	0.931	[0.269 3.225]	3.515**	[1.016 12.16]	1.673**	[1.026 2.728]
Constant	0.141	[0.000 71.07]	0.422	[0.001 343.5]	1.190	[0.053 26.64]
Number of observations	444					
LR-χ^2	203.3***					
Log-likelihood	-342.09					
Pseudo R-squared	0.229					

*$p<0.1$, **$p<0.05$, ***$p<0.01$

taged spatial contexts, whereas in urban areas this might be less the case (De Vos and Singleton 2020; Van Wee 2021).

Processes of preference adjustment may also be linked to the observation that women are less likely to display low perceived accessibility combined with low participation than men, particularly in lower spatial accessibility contexts. Women often have complex travel patterns involving relatively many personal and childcare trips combined with less car use, which can put pressure on women's time budgets and potentially constrain their desired activity patterns (Scheiner and Holz-Rau 2017). However, despite these challenges, women may adapt their preferences and travel behavior to maintain higher perceived accessibility levels compared to men. At the same time, having children in the household, corresponding with potential greater travel complexities, is nevertheless more often associated with low satisfaction, despite potential preference adjustment processes.

Mobility means and travel behaviour

Turning to mobility means, car ownership is notably associated with high participation and high perceived accessibility, particularly outside urban areas. The role of motorized modes in maintaining activity patterns and accessibility is likely linked to larger distances to activity locations in combination with limited public transport options outside urban centres. A similar, albeit tentative, effect can be observed for e-bikes, however only in intermediate spatial accessibility contexts, where distances may still be manageable for cycling. Furthermore, the social network can help prevent involuntary low participation, particularly in rural areas, by providing assistance for individuals unable to travel alone.

Having a good internet connection also helps prevent low levels of perceived accessibility, possibly due to its role in substituting or organizing travel more efficiently (Lavieri et al. 2018). People who shop online more often do indeed have lower participation rates, but this is more often associated with low perceived accessibility, especially in rural areas. This suggests that replacing activities with online alternatives may be a strategy to compensate for undesirable low accessibility levels rather than a preferred way to reach activities.

This underlines that not only the frequency of participation but also the ways activities are accessed matter. A greater reliance on public transport trips is strongly associated with the likelihood of perceiving low accessibility in rural areas, despite high levels of participation. This indicates that frequent users of public transport are more likely to be captives in rural areas than their urban counterparts. In urban areas, there is likely more scope for using active modes to reach desired activities. This is tentatively supported by the model results, indicating that a higher share of active mode use is associated with a reduced likelihood of experiencing involuntarily low participation levels in urban areas.

Conclusions

Low levels of access to spatially dispersed economic and social opportunities may result in lower levels of activity participation and contribute to processes of social exclusion. However, low levels of participation can stem from both voluntary choice and involuntarily faced constraints. Particularly beyond very low levels of spatial accessibility, the experience of transport-related social exclusion is likely to be related not only to the frequency of participation, but rather to the extent to which participation in activities meets one's needs and desires. This paper has aimed to examine how individual factors moderate the link between the frequency of activity participation and the experience of transport-related social exclusion, as measured by perceived accessibility, across different levels of spatial accessibility, drawing from a survey conducted in the Netherlands.

There were no differences in the frequency of activity participation across levels of spatial accessibility. This is consistent with previous hypotheses and evidence that a higher number of opportunities is not proportionally related to more participation (Allen and Farber 2020; Cordera et al. 2017; Fransen et al. 2018; Kamruzzaman and Hine 2011). Furthermore, this study found that the marginal utility of increased activity participation is lower at higher spatial accessibility levels, as preferences become more likely to be already sufficiently met (Martens 2006). Only at the lowest levels of spatial accessibility (i.e. in rural areas), low participation levels more often coincided with less satisfaction with accessibility compared to intermediate and urban areas. Moreover, the percentage of dissatisfied people decreases to a lesser extent at higher participation rates and stabilizes at a higher level in rural areas than in urban or intermediate spatial accessibility contexts. Low levels of participation may therefore be more indicative of involuntarily faced constraints in rural areas than in environments with higher spatial accessibility levels in which the probability that preferences can be met is higher.

This paper has provided an initial empirical basis regarding which individual factors moderate the relationships between spatial accessibility, activity participation and derived benefits. It highlights that some groups that participate in significantly fewer activities may not feel constrained (e.g. those with a less strong preference for local access to activities). However, particularly in areas with lower spatial accessibility levels, people with less mobility potential seem to feel more constrained, leading to low participation more often combined with low perceived accessibility (e.g. pensioners, people without access to a car). Furthermore, online alternatives to remote activity locations may be more often part of a coping strategy to compensate for low accessibility in rural areas than being viewed as perfect substitutes for physical participation. Additionally, certain groups do on average not participate less, but may nevertheless feel constrained. This is especially evident in rural areas for those with stronger preferences for proximity to activities and those relying heavily on public transport. Finally, some variables are associated with experienced constraints regardless of participation level, such as having a disability or lacking access to the internet, particularly in rural areas.

Further research is needed to determine the robustness of the identified relationships between the covariates included in this study, activity participation and perceived accessibility are. The cross-sectional nature of the data used in this study precludes detailed causal inference. Longitudinal research can identify how preferences, activity patterns and perceived accessibility evolve over time, shedding light on the extent of adaptation. Certain groups often considered disadvantaged concerning accessibility, such as women and those with low incomes, low participation did less often coincide with low perceived accessibility, which might be a sign of preference adaptation (De Vos and Singleton 2020). In particular, qualitative research focusing on the population segments identified in this study could provide deeper insights into the mechanisms shaping perceived accessibility (see e.g. Pot et al. 2020).

The general picture that emerges is that, for the majority of the Dutch population, potential activity participation requirements are fulfilled across all spatial contexts. Even at the lowest levels of activity participation in low spatial accessibility contexts, most report high levels of perceived accessibility, indicating a high degree of voluntary non-participation. The relatively dense context of the Netherlands and residential self-selection may explain that the spatial context generally meets most accessibility needs (see Pot et al. 2023a). Nevertheless, low participation rates more frequently align with low perceived accessibility in rural areas due to transport disadvantages. This highlights that there are diminishing returns to spatial accessibility both in terms of participation frequency and in terms of derived benefits.

Diminishing benefits from increased participation potential suggest that increasing spatial accessibility in already dense urban contexts might yield relatively little improvements regarding social inclusion. At the same time, decreasing levels of spatial accessibility following facility closures in rural areas can, below a certain tipping point, quickly lead to insufficiency and experiences of social exclusion for larger population segments. Effective and efficient transport and spatial policy should explicitly address this notion of diminishing returns when determining the expected benefits regarding activity participation facilitated by an intervention. At which level of spatial accessibility the tipping point of sufficiency lies depends on individual accessibility requirements in a certain location, which is linked to processes of residential sorting (Pot et al. 2023a). The observed low correlations among spatial accessibility, activity participation, and the derived benefits from access to opportunities highlight the significance of analyzing perceived accessibility. Such analyses offer valuable insights that complement spatial and activity participation data, enriching the normative debate surrounding the overall adequacy of accessibility in a certain place.

Appendix

Table A1 Factor analysis on requirements regarding local access to facilities

Construct	Factor loading	α if item deleted
Pro proximity factor (α = 0.75, λ = 2.45 KMO = 0.75)		
I want to live near a lot of shops	0.63	0.71
I want to live near a supermarket	0.72	0.71
I want to live near healthcare facilities	0.66	0.72
I want to live near cultural/leisure facilities	0.57	0.72
I want to live near sporting facilities	0.52	0.74
I want to live near educational facilities	0.49	0.74
I want to live close to a city centre	0.51	0.73

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Data availability Anonymized data that support the findings of this study are available on request from the corresponding author, F.J. Pot. The data are not publicly available due to information that could compromise the privacy of research participants.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval The survey conducted in this study was approved by the Ethical Committee of the Faculty of Spatial Sciences of the University of Groningen in accordance with The Netherlands Code of Conduct for Scientific Practice.

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