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Perceived accessibility and residential self-selection in the Netherlands

Felix Johan Pot *, Sierdjan Koster, Taede Tillema

Department of Economic Geography, Faculty of Spatial Sciences, University of Groningen, Landleven 1, 9747 AD Groningen, The Netherlands

A R T I C L E I N F O

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A B S T R A C T

This paper evaluates the role of residential self-selection in the spatial distribution of perceived accessibility in the Netherlands. People may self-select into residential areas that match their preferences regarding participation in out-of-home activities. Differences in the magnitude of opportunities provided by the land use and transport system may, consequently, not accurately mirror perceived accessibility differences, complicating the design of responsive policy. Perceived accessibility was found to be less variable than spatial accessibility, meaning that fewer opportunities do not fully translate into lower perceived accessibility. Expected perceived accessibility differences under random conditions were estimated by comparing residents of distinct spatial accessibility contexts with the same propensity to live in either context, yielding a quasi-experimental setting. Estimates of the expected increments in average perceived accessibility levels as the number of locally available opportunities increases indicate diminishing returns to spatial accessibility. In addition, preference-based residential self-selection was found to further mitigate spatial accessibility differences. Yet despite diminishing returns to spatial accessibility and residential self-selection, perceived accessibility remains lower in rural areas due to limited residential freedom. In addition, the non-linear benefits of spatial accessibility imply that further loss of facilities in rural areas can quickly lead to insufficiency below a certain tipping point. Already, residential self-selection in rural areas strongly relies on access to car mobility, conflicting with environmental and social inclusion accessibility planning objectives. Accessibility-based transport planning, therefore, requires not only a substantive shift away from alleviating car congestion, but also a geographical shift in favour of rural areas.

1. Introduction

Providing access to spatially dispersed opportunities is one of the primary goals of a transport system. Concerns over the sustainability of providing access through promoting mobility by motorized transport have fuelled a debate to shift from mobility-based to accessibility-based transportation planning, which revolves around spatial proximity rather than relieving car congestion (Akse et al., 2021; Handy, 2020; Papa et al., 2016). In this view, people living in rural areas rather than congested urban centres seem to be at a disadvantage regarding participation in out-of-home activities as proximity can overcome the low speeds in urban areas (Levine et al., 2012; Mondschein and Taylor, 2017). An issue arising from this paradigm shift is how to ensure that residents in less dense spatial contexts have adequate access to desired social and economic activities.

However, not only the sheer magnitude of opportunities the environment provides (i.e. spatial accessibility) determines whether accessibility is perceived as sufficient. The well-being impacts of fewer opportunities depend on the extent to which individual activity participation requirements are nevertheless being met (Pot et al., 2021). These individual requirements may, moreover, not be randomly distributed across space. People aim to choose a residential environment that best matches their preferences (Bijker et al., 2012; Rijnks et al., 2018). Residential self-selection based on desired and expected travel behaviour has already been widely identified as a potentially important intermediary factor in the relationship between the physical environment and travel patterns (Bohte et al., 2009; Cao et al., 2009). Studies incorporating travel mode as well as land use attitudes have identified significant self-selection effects in the relationship between the built environment and travel behaviour (e.g. Cao et al., 2010; Cheng et al., 2019; De Vos et al., 2012; Ettema and Nieuwenhuis, 2017; Kajosaari et al., 2019; Lin et al., 2017; Schwanen and Mokhtarian, 2005). The extent to which people can self-select into a neighbourhood that matches their travel attitudes, subsequently, affects satisfaction with travel (Cao and Ettema, 2014; De Vos et al., 2016, 2021; De Vos and Witlox, 2016). However, travel behaviour, in the end, mostly serves as a

* Corresponding author.
E-mail addresses: f.j.pot@rug.nl (F.J. Pot), sierdjan.koster@rug.nl (S. Koster), t.tillema@rug.nl (T. Tillema).

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means to access desired activities. The evaluation of the role of residential self-selection in explaining travel behaviour and satisfaction has not yet expanded to explaining satisfaction with access to activities. This paper aims to fill this gap by evaluating the contribution of residential self-selection to perceived accessibility levels.

Processes of residential self-selection based on accessibility preferences would predict that urban areas attract people with a strong preference for local access to activities, while people living in rural areas would value accessibility less (Van Wee and Geurs, 2011). However, accessibility and travel considerations are only part of the complex trade-off between housing and locational characteristics that determine the overall utility derived from a residential location (Naess, 2014). Therefore, people not only choose where to live based on accessibility preferences. This implies that preferences regarding accessibility may not be fully met and significant residential dissonance regarding accessibility preferences may still be observed, even in the case of a spatial equilibrium in terms of overall residential utility (Rijnks, 2020; Schwanen and Mokhtarian, 2004). The remaining residential dissonance regarding accessibility after self-selection will be reflected in spatial inequalities in perceived accessibility levels. For transport planning to be responsive to the needs, desires and abilities of the people living in a certain area, it is necessary to understand the underlying mechanisms that cause current disparities, or absence thereof, in perceived accessibility between different spatial contexts.

This paper compares differences in perceived accessibility between urban, rural and intermediate spatial accessibility contexts with expected differences in perceived accessibility if the population would be randomly distributed across these residential contexts irrespective of their accessibility requirements. This is done by applying the quasi-experimental method of propensity score matching based on data from a self-administered survey in the Netherlands. This exercise enables estimation of the contribution of residential self-selection effects in observed differences in perceived accessibility as well as identification of which factors determine the extent of self-selection.

The following section presents a theoretical discussion identifying factors that determine the prevalence of residential self-selection on mismatches between spatial and perceived levels of accessibility. This is followed by a conceptual illustration that serves as the basis for the empirical part of this paper of which the data and methodology are introduced in Section 3. The results of the estimation of self-selection effects are presented in Section 4, which are further discussed in Section 5. The final section summarizes the results and discusses the main policy implications of this study.

2. Background

Failing to account for residential self-selection according to accessibility preferences may distort the evaluation of accessibility through looking at the sheer number of opportunities the environment provides. This section explains the hypothesis of residential self-selection after which it identifies the main factors that determine the magnitude of accessibility-based residential self-selection effects on perceived accessibility. This is accompanied by a conceptual illustration in which three extreme scenarios of residential soring are presented: randomly distributed population, the entire population assigned to a residential environmentthat matches their preferences, the entire population assigned to a region that contrasts their preferences (see also Cao and Chatman, 2016).

2.1. Accessibility and spatially non-random requirements

At the root of the possible presence of residential self-selection lies the heterogeneity of people's requirements regarding accessibility. Some may prefer to live close to many activity locations, while others may consider this less of a priority. These requirements are shaped by one's needs and desires regarding activity participation as well as one's ability to travel to those activities.

First, individuals will have different *needs* and *desires*. For example, some may need to have access to educational or healthcare facilities, while for others these are less relevant (Bijker et al., 2012). Also, people will have heterogeneous desires for activity locations reflecting their preferred lifestyles (Ardeshiri and Vij, 2019; Lee et al., 2019; Van Acker et al., 2011). Some want to have access to many cultural facilities while others may value open green space more. Next to activity-related tastes, attitudes may also apply to travel behaviour, such as enjoying travelling by active modes and wanting to live in an area that facilitates access to desired activities on foot (Faber et al., 2021).

Second, individuals have different *abilities*. Someone who owns and can drive a car might be able to live more remotely while still enjoying similar accessibility as someone living in a more central location. Car ownership, thus, may have an intermediate role in the residential self-selection process (Van Acker and Witlox, 2010; Van de Coevering et al., 2016). Note that these sources (needs, desires and abilities) of accessibility-related residential preferences are interrelated. A person with ill health may have a high need for access to healthcare facilities, may not be able to drive and, consequently, prefer to live in an area where a hospital can be easily reached by public transport.

2.2. Parameters determining the impact of residential self-selection on perceived accessibility

The role of residential self-selection on the spatial distribution of perceived accessibility depends on the extent to which residential self-selection takes place and corresponding effect on perceived accessibility levels. Table 1 hypothesizes three broad factors associated with the prevalence and impact of self-selection on perceived accessibility.

First, the relevance of self-selection in the spatial distribution of perceived accessibility levels will depend on the *distribution of preferences* regarding accessibility among the population. Given a certain budget, the residential choice is a trade-off between many compensable aspects in which accessibility is only part of the equation. Spatial accessibility levels can be traded with other aspects (e.g. dwelling space) to achieve a spatial equilibrium in overall residential utility (Alonso, 1964). It has been suggested that, for many, motives regarding preferred travel behaviour and accessibility are likely only secondary determinants in residential choice (Ettema and Nieuwenhuis, 2017; Faber et al., 2021; Naess, 2014). In Dutch rural areas, it has been found that movers are mainly attracted by dwelling characteristics and the physical and social qualities of the environment (e.g. quietness, scenic beauty, sense of community) rather than access to a wide variety of opportunities while in other areas economic opportunites are more important (Bijker et al., 2012; Elshof et al., 2017; Rijnks et al., 2018). Variation in how important accessibility is for individuals implies varying elasticities of perceived accessibility concerning the opportunities provided by the environment. There will be no differences in perceived accessibility between places with different levels of spatial accessibility if the entire population is inelastic to accessibility, as everyone's preferences would

Table 1
Factors influencing the impact of residential self-selection on perceived accessibility.

Factor		Expected relationship with perceived accessibility
1.	Distribution of preferences	The more people with a strong preference for accessibility, the larger the potential impact of residential self-selection
2.	Variation in spatial accessibility	The greater the variation in spatial accessibility, the larger the potential impact of residential self-selection
3.	Residential freedom	The more free people are to choose to live in an environment that matches their accessibility preferences, the larger the potential impact of residential self-selection

be met in all locations. The more people with strong preferences regarding accessibility, the more people want to select themselves into a residential location based on accessibility characteristics.

Second, there needs to be *variation in spatial accessibility* for residential self-selection to have a role in the spatial distribution of perceived accessibility. Residential self-selection based on accessibility preferences is not possible if spatial accessibility levels are the same in every place. As the variation in spatial accessibility between locations increases, more people could potentially live in an area that closely matches their accessibility preferences. Note that, the law of diminishing returns to new opportunities likely applies here (Pot et al., 2021). For many, the addition of a second alternative to a single activity option likely adds more to a choice set than the addition of a third or fourth alternative. The rate at which returns diminish depends on the elasticity to accessibility. The addition of a third retail outlet will have more value for one with a strong preference for shopping than for someone who enjoys shopping less.

Third, the extent to which people can sort into their preferred location depends on *residential freedom*. The trade-off between various characteristics of the dwelling and the environment when choosing where to live is constrained by financial resources and power relations within households (Ho and Mulley, 2015; Molin et al., 1999; Schwanen and Mokhtarian, 2004). Additionally, constraints are brought about by a potentially limited supply of housing or access to it. Residential self-selection will be less prevalent if many people want to live in dense high-accessibility areas while housing provision in such areas is scarce, unaffordable or heavily regulated (Levine et al., 2005; Lin et al., 2017). Keeping housing supply constant, differences in perceived accessibility between regions with different levels of spatial accessibility may increase with the number of people with high elasticity to accessibility, as more and more people would start to compete with each other for high accessibility locations.

It should be noted that the listing of factors above assumes that residential location choices are made through maximizing expected utility. Yet, it is increasingly acknowledged that changing residence is unlikely to be fully based on rational utility-maximizing principles as it involves a wide and complex set of attributes accompanied by high information requirements and uncertain prospects in terms of experienced utility after a choice is made (Marsh and Gibb, 2011). A specific aspect of this is that comparisons are often made on a few characteristics, usually very distinctive and easily observable, out of a larger set of characteristics that are relevant for eventual residential satisfaction when comparing alternatives (Schkade and Kahneman, 1998). If accessibility-related attributes are part of this subset of considered characteristics, the scale of residential self-selection likely rises. However, these attributes may also be misjudged *ex-ante* leading to a gap between expected and experienced utility derived from accessibility (Chorus and de Jong, 2011).

2.3. Conceptual illustration

This section provides a conceptual illustration of the effect of residential self-selection on the observed correlation between spatial and perceived accessibility. Three simplifying assumptions are made. First, suppose there are two regions of which one is a rural region with low spatial accessibility and the other an urban area with high spatial accessibility. Second, housing supply is assumed to be equal in both these regions. Third, preferences regarding accessibility are dichotomous and evenly distributed among the population. Half of the population has a strong preference for high spatial accessibility. That is, their perceived accessibility is elastic to levels of spatial accessibility, meaning that they will have a high level of perceived accessibility only when living in the urban area. In rural areas, they will have a low level of perceived accessibility. Levels of perceived accessibility of the other half of the population are inelastic to spatial accessibility. This implies that the inelastic half of the population has high perceived accessibility irrespective of living in the rural or urban region.

Fig. 1 shows three extreme scenarios based on these simplifying assumptions mentioned above. First, assume that the population is randomly distributed across the two areas. This means that both areas will have an equal number of people with strong accessibility preferences, as well as people who are not sensitive to accessibility. It follows that, in the urban area, half of the people will have a strong preference for locally available opportunities. Their preferences are met, implying high levels of perceived accessibility. The other half living in the urban area is inelastic to spatial accessibility, implying that also their preferences are met, which results in equally high levels of perceived accessibility. Turning to the rural area, the preference distribution is the same, with half of the people having a strong preference for spatial accessibility and the other half being inelastic. Those who are inelastic will have high levels of perceived accessibility, as their accessibility preferences are met despite living in a rural area. Yet, the preferences of people with a strong preference for accessibility are not met, meaning that they have lower levels of perceived accessibility. It follows that the average level of perceived accessibility μ is lower in the rural area than in the urban area, as only in the urban area everyone's preferences are met.

Only in this scenario, the observed difference (OBE) in perceived accessibility between the urban and rural environments, $\mu_u - \mu_r$ can be interpreted as the average treatment effect (ATE) of living in an urban area on perceived accessibility, as it follows from a randomized situation. The size of the ATE depends on the number of people with strong accessibility preferences and the elasticity of perceived accessibility to spatial accessibility of this group (see Section 2.2). Furthermore, the actual difference in spatial accessibility between the two regions matters. Even if the difference in spatial accessibility is small (large), the ATE can be large (small) if the elasticity to spatial accessibility of the rural dissonants (i.e. the people living in a rural area with accessibility preferences) is high (low).

In the second scenario, the entire population is assinged to the region that best matches their accessibility-related preferences. All people with strong preferences for accessibility now live in the urban area, while the inelastic half of the population resides in the rural area. Compared to the randomized scenatio, those with strong accessibility preferences in the rural area have moved out to the urban area and are swapped with those living in the urban area without these preferences. In the urban area, perceived accessibility remains high because, just as in the random scenario, everyone's preferences are met. Following their insensitivity to spatial accessibility, everyone living in the rural area perceives accessibility equally high as those with strong preferences living urban area. It follows that the OBE in the matched scenario, $\mu_{mu} - \mu_{mr}$, equals zero and, therefore, is smaller than the ATE as defined in the random scenario.

In the final scenario, the whole population is unmatched, which means that all individuals with a strong preference for accessibility live in the rural area and all inelastic individuals live in the urban area. As a result, perceived accessibility remains just as high in the urban area because the preferences of those that are inelastic remain to be met. However, in the rural area, average perceived accessibility is lower than in the random and matched scenarios, as now no one's preferences in this region are met. This means that in this fully unmatched scenario, the OBE, $\mu_{uu} - \mu_{ur}$, is larger than the ATE.

The assumptions for the three scenarios described above are, of course, highly artificial and simplifying. However, the main implications resulting from this illustration remain when these assumptions are relaxed. The OBE will only be equal to the ATE when accessibility preferences are uncorrelated with spatial accessibility levels. Whether an observed difference in perceived accessibility is meaningful in such a scenario depends on the absolute levels of spatial accessibility and the associated elasticity with perceived accessibility. Furthermore, the more residential self-selection occurs, the more the OBE approaches zero. The rate at which this occurs depends on the elasticity of perceived

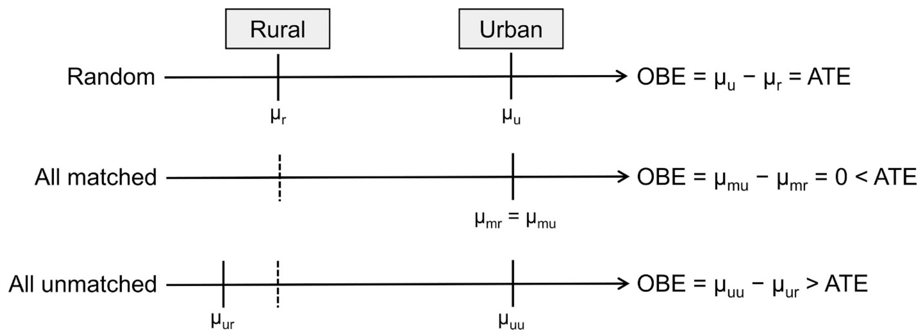

Fig. 1. Conceptual model of the impact of residential self-selection on perceived accessibility.

accessibility concerning spatial accessibility.

3. Data and methods

From here onwards, the conceptualization of Section 2 will be applied to real-world data. Drawing on a survey conducted in the Netherlands, the spatial distribution of perceived accessibility is evaluated. Subsequently, the contribution of residential self-selection to differences in perceived accessibility between residential contexts with different levels of spatial accessibility is evaluated by comparing observed differences with estimated average treatment effects when the population would be randomly distributed.

3.1. Data

3.1.1. Survey

This study uses data from a self-administered survey conducted in the Netherlands in 2020. The questionnaire covered activity and mobility patterns, accessibility preferences and satisfaction, and individual characteristics. The survey was distributed in three ways. First, 8500 postal surveys were distributed in rural areas. A total of 1619 questionnaires were returned, resulting in a response rate of 19%. Second, online data collection through promotion in local newspapers and social media yielded another 789 responses. Third, the survey was distributed online via the Dutch Mobility Panel (Mobiliteitspanel Nederland, MPN) across the country at the end of 2020, yielding 1254 respondents (a response rate of 90%). The total sample size amounts to 3378, 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 least present in the Netherlands. Respondents were asked to answer questions as if there were no restrictions regarding the pandemic. Using survey responses from before and during the pandemic yielded no significant differences in model results, suggesting that this break did not affect the results in a meaningful way.

3.1.2. Perceived accessibility

Perceived accessibility is measured using the 'Perceived Accessibility Scale' (PAC) developed by (Lättman et al., 2018). The respondents were asked to indicate on a seven-point scale (ranging from 1 = strongly disagree to 7 = strongly agree) the extent to which, considering how one travels, '*it is easy to do daily activities*', someone is '*able to live life as wanted*', someone is '*able to do all preferred activities*, and whether '*access to preferred activities is satisfying*'. A principal axis factor analysis confirmed the unidimensionality of the scale by retaining one factor explaining 93% of the variance (Eigenvalue $\lambda = 2.90$) with satisfying overall item reliability (Cronbach's $\alpha = 0.90$) with no improvement for item deletion, which is in line with earlier applications (Lättman et al., 2016, 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.

3.1.3. Spatial accessibility

In keeping with the conceptual illustration of Section 2.3, respondents are categorized into residential contexts based on spatial accessibility levels. For each individual in the sample, a spatial accessibility indicator is calculated reflecting the magnitude of opportunities from their home location. Spatial accessibility is assumed to be 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 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 an activity location has a diminishing influence on spatial accessibility as the distance increases. Activity locations are obtained from the Dutch establishment register LISA, which contains location coordinates, the number of jobs and the SBI sectoral definition of each firm. The sectors used to calculate spatial accessibility comprise groceries, education, healthcare, retail, cultural, hospitality and sporting facilities. The resistance function is formulated as $f(d_{ij}) = \exp(-\beta d_{ij})$ with a decay parameter β of 0.5, corresponding to a distance threshold of about 5 km, which is assumed as an upper limit for the use of active modes and corresponds with earlier operationalizations of local accessibility (Silva and Altieri, 2022; Wiersma et al., 2016).

Three residential contexts were identified based on a K-means cluster analysis of this spatial accessibility indicator: urban, rural and intermediate. A silhouette analysis identified this optimal number of clusters (see Fig. A1). This classification was robust to values of β between 0.25 and 1.5. Fig. 2 maps the spatial distribution of all respondents and their respective residential categories.

3.2. Descriptive statistics

The urban, intermediate and rural groups resulting from the cluster analysis described in Section 3.1.3 show significant differences in spatial accessibility and distances to public transport (Table 2). There are also significant differences in perceived accessibility between these residential contexts. However, these differences appear to only apply to rural areas and are less pronounced than those of the spatial characteristics when comparing the F-statistics (see also Fig. 3).

Lower levels of spatial accessibility may not fully translate into lower perceived accessibility due to spatially heterogeneous requirements regarding accessibility following residential self-selection. The individual characteristics included in this study gauge people's needs and abilities regarding activity participation, which determines the preferred level of spatial accessibility (see Dijst et al., 2023; Mokhtarian and Cao, 2008). The sociodemographic variables included in this study comprise gender, age, education level, net income, employment status, household size, car ownership and the presence of a disability that

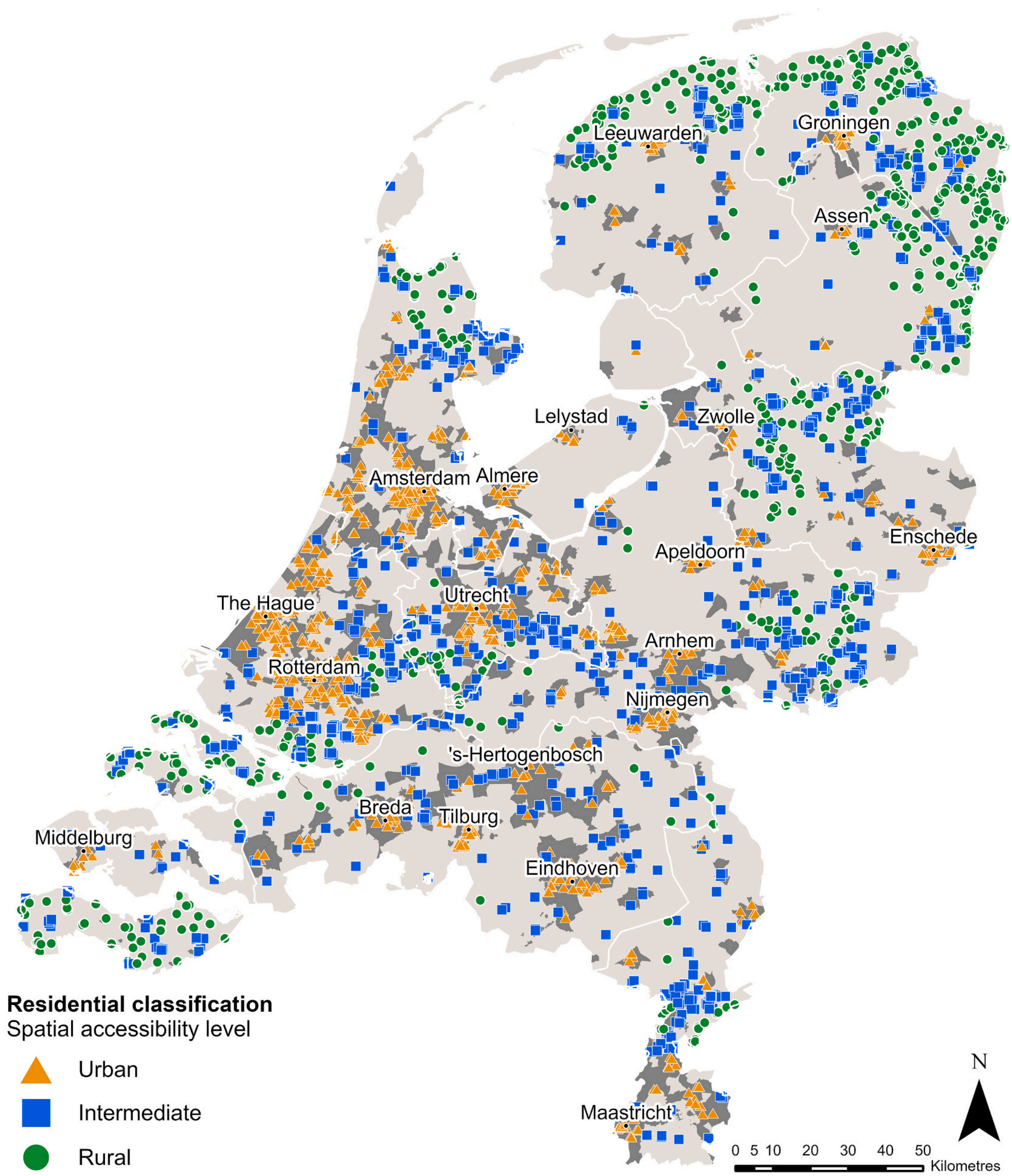

Fig. 2. Residential classification of respondents.

hinders travel behaviour in any way. The attitudes measured comprise the desire for proximity to activities, the preference for the availability of public transport, prioritization of dwelling characteristics over the living environment and transport mode attitudes.

There are some significant differences across the spatial accessibility categories regarding sociodemographic characteristics (see Table 2). The average age declines with spatial accessibility, which potentially reflects declining desires concerning accessibility in later life. Larger household sizes in intermediate and rural areas may reflect lifestyles and the need for space. Car ownership is higher in rural and intermediate areas than in urban areas. This may reflect both a coping mechanism to deal with lower levels of accessibility and a selection mechanism, as people with access to a car can more easily live further away from urban centres. Individuals with a low level of education, who are on lower incomes or who have some form of mental or physical condition that hinders them during travel are not overrepresented in any spatial accessibility category.

Attitudes related to activity locations are also significantly different across groups. The ‘pro proximity’ factor is based on statements reflecting land use preferences for local access to opportunities (see Table A1). This score reflects the desire for the spatial proximity of opportunities and is on average lower in rural areas than in intermediate and urban areas. Attitudes to various transport modes are measured by asking respondents whether the following positive aspects characterize a certain mode (1 = *yes*, 0 = *no*): comfortable, relaxing, time-saving, flexible, safe, and enjoyable. Following De Vos (2018), the sum of these six evaluations (ranging from 0 – 6) is used as a measure of a positive attitude towards a certain mode. These summed attitude variables are then entered in a factor analysis, retaining three factors: ‘pro private motorized’, ‘pro public transport’, and ‘pro active modes’ (see Table A2). Compared to urban areas, attitudes to private motorized transport are more positive in rural areas, while attitudes to public transport, albeit to a lesser extent, display an opposite picture. Accordingly, the preference to live near a public transport stop is most prominent in urban areas. Giving priority to the dwelling rather than the living environment is not significantly different across spatial

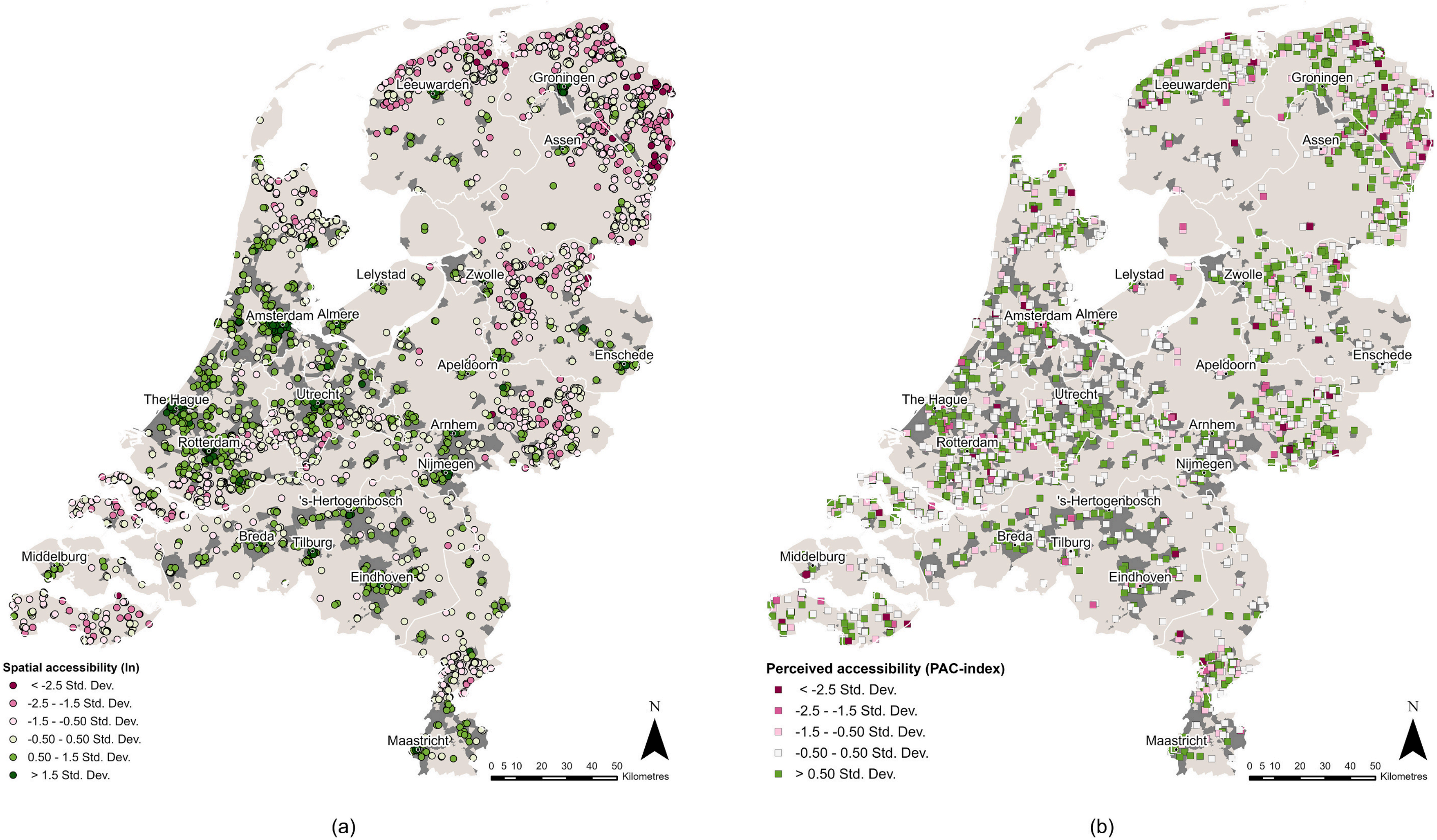

Fig. 3. Spatial distribution of (a) spatial accessibility and (b) perceived accessibility.

Table 2
Sample characteristics.

Variables	Total	Urban	Intermediate	Rural	Group differences
Number of observations	3378	872	1596	910	
Spatial characteristics					
Spatial accessibility (ln*ACC*)	5.22	6.94	5.33	3.37	$F_{[2,3375]} = 5049.6^{***}$
Distance to the nearest public transport stop (km)	0.57	0.34	0.53	0.87	$F_{[2,3375]} = 174.1^{***}$
Distance to the nearest train station (km)	8.46	4.64	7.74	13.5	$F_{[2,3374]} = 196.8^{***}$
Perceived accessibility					
PAC-index	5.93	6.01	5.97	5.79	$F_{[2,3180]} = 9.49^{***}$
Sociodemographic characteristics					
Gender (ref. male)	53%	52%	52%	54%	$\chi^2_{[2]} = 1.04$
Age	54.5	49.8	56.2	56.4	$F_{[2,3323]} = 43.0^{***}$
Low education (dummy)	27%	25%	27%	29%	$\chi^2_{[2]} = 3.71$
Low household monthly net income (< €2000)	25%	28%	24%	25%	$\chi^2_{[2]} = 3.21$
Paid employment (dummy)	53%	54%	51%	53%	$\chi^2_{[2]} = 2.87$
Household size	2.27	2.00	2.34	2.42	$F_{[2,3329]} = 29.2^{***}$
Number of cars in household	1.34	1.01	1.33	1.47	$F_{[2,3230]} = 122.8^{***}$
Disability (dummy)	21%	21%	20%	22%	$\chi^2_{[2]} = 0.62$
Attitudes					
Pro proximity factor	−0.01	0.13	0.10	−0.31	$F_{[2,2925]} = 64.0^{***}$
Want public transport within walking distance (dummy)	53%	65%	53%	44%	$\chi^2_{[2]} = 68.0^{***}$
Dwelling more important than environment (dummy)	39%	40%	39%	38%	$\chi^2_{[2]} = 0.65$
Pro private motorized modes factor	−0.02	−0.21	−7.1E-4	0.10	$F_{[2,3249]} = 37.1^{***}$
Pro public transport factor	−0.01	0.06	−0.01	−0.07	$F_{[2,3251]} = 5.64^{***}$
Pro active modes factor	−0.01	−0.02	0.01	3.7E-3	$F_{[2,3249]} = 0.22$

$^{*}p < 0.1$ $^{**}p < 0.05$ $^{***}p < 0.01$.

accessibility levels.

The next section introduces the estimation of the ATE, which reflects the effect of living in a residential context with higher spatial accessibility on perceived accessibility while controlling for individual characteristics that influence residential choice. This allows for unveiling the relative effect of residential self-selection on differences in perceived accessibility between the considered residential contexts (i.e. urban, rural and intermediate areas).

3.3. Estimation of treatment effects

It is not possible to interpret the difference in perceived accessibility between different levels of spatial accessibility as a pure effect of the built environment (i.e. the ATE, see Section 2.3). The association between spatial accessibility and perceived accessibility may be blurred by residential self-selection, entailing that needs, desires and abilities regarding accessibility are different across spatial accessibility contexts (see Table 2). Moreover, it is not possible to observe perceived accessibility of the same individual in different residential contexts, as one can only live in one place at a time. Nevertheless, it is possible to compare individuals with similar accessibility requirements living in different spatial accessibility contexts, yielding a quasi-experimental research design. The average difference in perceived accessibility between individuals that have the same likelihood of living in either spatial context can, therefore, be interpreted as an estimate of the pure effect of spatial accessibility on perceived accessibility. Accordingly, the contribution of residential self-selection to observed differences in perceived accessibility can be derived.

Matching individuals living in different spatial accessibility contexts is done based on the propensity score. The propensity score is the probability that an individual receives 'treatment' (e.g. living in an urban area instead of a rural area), conditional on the individual covariates listed in Table 2 (e.g. car ownership) (Rosenbaum and Rubin, 1983). Two individuals living in different residential contexts with similar propensity scores, therefore, have similar probabilities to live in either residential context. Accordingly, the difference in perceived accessibility between these two individuals can be attributed to the residential context, as other relevant individual covariates are assumed to be controlled for. The propensity scores are estimated through logistic regression models. It would statistically be most efficient to estimate a multinomial logit model since there are three residential contexts under consideration (i.e. urban, rural and intermediate). However, Lechner (2001) argues that the estimation of multiple binary models is a more robust approach because misspecification in comparing one pair of residential contexts does not compromise all other comparisons, as would be the case in the multinomial setting. Since the number of binary models to be estimated for this research is manageable, propensity scores are estimated by separate binary logistic regression models (Eq. 1) for all three comparisons of residential environments (i.e. urban vs intermediate; urban vs rural; and intermediate vs rural):

$$p\left(\vec{x}_i\right) = Pr\left(T_i = 1|\vec{x}_i\right) = \frac{exp(\beta_0 + \sum \beta_n x_{ni} + \varepsilon_i)}{1 + exp(\beta_0 + \sum \beta_n x_{ni} + \varepsilon_i)} \quad (1)$$

where $p\left(\vec{x}_i\right)$ is the propensity score of individual i which is equal to $Pr\left(T = 1|\vec{x}_i\right)$, being the probability of an individual receiving a treatment T (1 = *treated*) conditional on the vector $\vec{x}_i$ of individual sociodemographic characteristics and attitudes (see Table 2).

Individuals with similar propensity scores (i.e. a similar probability to live in either residential context) are, subsequently, matched. The expected average difference between individuals with similar propensity scores in the treatment and control area (e.g. urban vs rural) serves as an estimate of the ATE of living in the treatment area on perceived accessibility (Eq. 2):

$$\text{ATE} = \text{E}(\Delta|p(\vec{x}), T = 1) = \text{E}(y_1|p(\vec{x}), T = 1) - \text{E}(y_0|p(\vec{x}), T = 0) \quad (2)$$

The difference between the OBE and the ATE can be interpreted as a residential self-selection effect (RSE). That is, the reduction or the increase in the difference between perceived accessibility in two development types due to residential self-selection based on needs, desires and abilities.

4. Estimation results

4.1. Matching

The estimation results for the propensity scores (Eq. 1) are presented

Table 3
Odds ratios for residential context.

	Urban (ref. intermediate)		Urban (ref. rural)		Intermediate (ref. rural)	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Sociodemographic characteristics						
Gender (female)	0.864	[0.687–1.088]	0.769*	[0.582–1.017]	0.836	[0.670–1.042]
Age	0.970***	[0.963–0.977]	0.961***	[0.952–0.971]	0.989**	[0.981–0.997]
Low education (dummy)	1.012	[0.766–1.337]	0.949	[0.676–1.333]	0.921	[0.705–1.203]
Low household monthly net income (< €2000)	0.673***	[0.501–0.902]	0.524***	[0.367–0.748]	0.727**	[0.545–0.970]
Paid employment (dummy)	1.225	[0.934–1.607]	1.346*	[0.972–1.865]	1.081	[0.834–1.402]
Household size	0.740***	[0.662–0.828]	0.779***	[0.680–0.894]	1.006	[0.906–1.116]
Number of cars in household	0.528***	[0.429–0.650]	0.336***	[0.261–0.432]	0.658***	[0.443–0.782]
Disability (dummy)	0.915	[0.676–1.237]	1.056	[0.731–1.525]	1.080	[0.809–1.442]
Attitudes						
Pro proximity factor	1.050	[0.913–1.207]	1.606***	[1.363–1.891]	1.585***	[1.400–1.795]
Want public transport within walking distance (dummy)	1.470***	[1.146–1.887]	1.620***	[1.199–2.188]	1.057	[0.834–1.339]
Dwelling more important (dummy)	1.093	[0.871–1.372]	1.071	[0.812–1.413]	0.996	[0.802–1.238]
Pro private motorized modes factor	0.624***	[0.527–0.739]	0.612***	[0.500–0.750]	0.906	[0.776–1.058]
Pro public transport factor	0.923	[0.800–1.064]	0.866	[0.725–1.035]	0.986	[0.863–1.125]
Pro active modes factor	0.952	[0.820–1.106]	0.844*	[0.705–1.010]	0.928	[0.811–1.062]
Constant	9.332***	[4.778–18.23]	49.65***	[20.99–117.4]	6.753***	[3.274–13.93]
Number of observations	1606		1187		1617	
Log-likelihood	-938.8		−643.8		−1011.2	
Pseudo *R*-squared	0.110		0.218		0.051	

*p < 0.1 **p < 0.05 ***p < 0.01.

in Table 3. Non-significant factors are retained in the models, as the main goal was to predict propensity scores rather than testing hypotheses regarding these factors. The significance of the odds ratios can, nevertheless, be used to reveal which self-selection mechanisms are most important between different levels of spatial accessibility. In line with the descriptive statistics (see Table 2), car ownership decreases with spatial accessibility reflecting a coping mechanism for low accessibility levels or self-selection in more remote areas when a car is available. Age is also negatively associated with high levels of spatial accessibility, potentially reflecting lower desires or prioritization regarding living near a large variety of opportunities. Income is associated with a greater likelihood of living in a more urbanized area, which may indicate that people with higher incomes have more freedom to live in a more urban area if they so desire since housing costs are usually higher in cities.

Many variables display varying effect sizes and significance levels across models, indicating that selection mechanisms are not equal between urban, intermediate and rural spatial contexts. Stated preferences concerning locally available activity locations (i.e. the 'pro proximity' factor) do matter for residential location choice, however only when compared to rural areas. A preference for proximity to activity locations does not significantly affect the choice of an urban over an intermediate environment. This potentially reflects diminishing returns to the number of available opportunities. Intermediate areas seem to already provide high levels of accessibility for most, making higher preferences concerning accessibility not a dominant factor in choosing an urban area over a living environment with an intermediate level of spatial accessibility. Factors that are specifically important for the choice of an urban area over an intermediate area relate to preferred travel behaviour rather than the availability of opportunities such as the desire to live near a public transport stop and relatively negative attitudes towards private motorized transport (e.g. the car).

The next step in the analysis is to match individuals living in different residential contexts with similar probability to live in either context based on the estimated propensity scores. Observations were matched in STATA 17 using the 'PSMATCH2' command. Radius matching with a calliper of 0.01 was applied. This entails that an individual in a treatment area is matched with all observations in the control area whose propensity scores are within 0.01 of the propensity score of the treatment observation. Observations in the control area were allowed to be used in multiple comparisons to take advantage of oversampling. Standard differences of the matching variables are used to check whether the covariates are sufficiently balanced after matching (D'Agostino, 1998): $\delta = \frac{100*(\bar{x}_{T=1}-\bar{x}_{T=0})}{\sqrt{\frac{s^2_{T=1}+s^2_{T=0}}{2}}}$, where $\bar{x}_{T=1}$ and $s^2_{T=1}$ are the mean and variance of a covariate for the treatment group, respectively; and $\bar{x}_{T=0}$ and $s^2_{T=0}$ are the mean and variance of a covariate for the control group, respectively. As a rule of thumb, a standard difference of $|\delta| \leq 10$ is considered acceptable (Oakes and Johnson, 2006). After matching, the standard differences of all variables fell below this acceptable level (see Table A3). Therefore, the matched treatment and control groups are comparable in terms of their characteristics that are considered to be relevant for assessing accessibility-based self-selection effects.

4.2. Treatment effects

Table 4 presents the estimated treatment effects for all combinations of residential categories (i.e. urban, intermediate and rural). The first two columns denote which residential categories are defined as the treatment and control groups. The third column shows the average difference in spatial accessibility in natural logs between respondents in the treatment and control groups. The fourth and fifth columns denote the level of perceived accessibility in the treatment group and the observed difference (OBE) with the control group, respectively. Note that, the observed differences in spatial and perceived accessibility are slightly different than as presented in Table 2, as some cases that could not be matched with someone in the control group were dropped from the analysis. The sixth column presents the results of the average treatment effect (ATE) calculations (Eq. 2), which represents the expected difference in perceived accessibility if respondents would be randomly distributed across the treatment and control residential environments. The seventh column displays the residential self-selection effect (RSE), reflecting how much the average difference in perceived accessibility between the treatment and control groups has decreased after self-selection and is derived by subtracting the expected difference under random conditions (ATE) from the difference that is observed (OBE). The eighth column presents the ratio of the RSE to the ATE, which can be interpreted as the percentage of the difference in perceived accessibility that is reduced due to residential self-selection.

The expected difference in perceived accessibility without residential self-selection is largest for urban areas compared to rural areas (Column 6, ATE = 0.450). This was to be expected as these two categories also yield the largest average difference in spatial accessibility (Column 3). Yet, the ATE is not linearly related to differences in spatial

Table 4
Average treatment effects of residential location on perceived accessibility.

Pair	(1) Treatment	(2) Control	(3) $\Delta \ln ACC$	(4) $PAC_{T=1}$	(5) OBE	(6) ATE	(7) RSE	(8) RSE/ATE
1.	Urban	Intermediate	1.61	6.055	0.021 (0.053)	0.131	−0.110	84.0%
2.	Intermediate	Rural	1.96	6.034	0.152 (0.057)***	0.279	−0.127	45.5%
3.	Urban	Rural	3.57	6.055	0.173 (0.064)***	0.450	−0.277	61.6%

***$p < 0.01$.

accessibility. The ATE of living in an urban area compared to an intermediate area (0.131) is smaller than the ATE between intermediate and rural areas (0.279), although the increment in spatial accessibility is larger. This signifies diminishing marginal returns to spatial accessibility and implies that an increase in the number of opportunities provided has less of an impact on perceived accessibility at higher absolute levels of spatial accessibility.

For all comparisons of spatial accessibility categories, it holds that the observed differences in perceived accessibility (Column 5) are smaller than what would be expected if no residential self-selection had occurred (Column 6). This can be interpreted as evidence for residential self-selection in the direction of the matched scenario in Fig. 1. In absolute terms, residential self-selection effects are the largest between urban and rural areas (Column 7, RSE = −0.277). Comparing the size of the RSE to the ATE yields that the average difference in perceived accessibility between people living in urban and rural spatial accessibility contexts is 61.6% smaller than expected without residential self-selection (Column 8).

5. Discussion

The main result of this paper is that low levels of spatial accessibility do not fully translate into lower levels of perceived accessibility due to diminishing returns and residential self-selection. This means that differences in perceived accessibility between urban and rural areas are not as large as differences in spatial accessibility might suggest, as people living in rural areas are less sensitive to spatial accessibility. Indeed, people living in rural areas reported valuing local access to activities less than those living in urban areas.

However, a major factor compensating for the lack of local access to opportunities appears to be car mobility, signalling strong car dependence in rural areas (Carroll et al., 2021; Gray, 2001). Dependency on the car in rural areas may not be problematic for many. However, it can create an additional barrier for people who have little or no access to a car to access opportunities. Provided that residential freedom is always to some extent limited, the existence of such an additional barrier to activity participation means that more people will likely have difficulties in meeting their accessibility-related preferences in rural areas compared to their urban counterparts. Being on a low income was negatively associated with living in an area with higher levels of spatial accessibility, indicating that limited residential freedom is indeed a mechanism limiting residential self-selection, which leads to significantly lower observed levels of perceived accessibility in rural areas compared to urban areas. The non-linear benefits of spatial accessibility imply that a decline in local access to opportunities in rural areas can quickly lead to insufficiency below a certain tipping point. It is still an unanswered question whether lower levels of perceived accessibility still reflect sufficient levels of accessibility. Such a sufficiency threshold will inevitably be, to some extent, arbitrary (Martens, 2017). Nevertheless, this political puzzle may be partially solved by further empirical analyses of perceived accessibility in rural areas, as a sufficiency standard arguably cannot be set without knowledge of the consequences of low levels of accessibility on the perceived freedom to participate.

There are some limitations to the use of propensity score matching to estimate the role of residential self-selection in perceived accessibility. First, only observed factors that may influence residential location could be considered. If residential self-selection effects result from other unobserved preferences, propensity scores are unable to address this hidden bias. Second, the cross-sectional design of this study does not reveal whether self-selection effects are the result of deliberate sorting or coping behaviour afterwards. This means that it is not clear whether people owning a car voluntarily self-select into low accessibility areas or cope with low spatial accessibility afterwards, which would potentially reflect a situation of forced car ownership (Curl et al., 2018). Similarly, it is not clear whether attitudes related to accessibility are a determinant of residential choice or a result of behaviour after a place to live has been chosen (De Vos and Singleton, 2020; Van Wee et al., 2019). Evidence is accumulating that travel mode attitudes rather follow behaviour than the other way around (e.g. Kroesen et al., 2017). It is, however, not clear whether this also holds for preferences regarding the volume of opportunities that can be accessed. People may adapt their expectations over time amidst low levels of accessibility in rural areas. This would mean that the differences in perceived accessibility found in this paper reflect short-term disequilibria. That having said, people may only adapt their travel preferences, while keeping accessibility aspirations constant. These aspirations are possibly linked to local norms, as people assess their level of accessibility by what is considered ‘normal’ in their environment (Pot et al., 2020; Van Wee, 2021). Therefore, it can be hypothesized that the disadvantaged group may still aspire to attain high levels of accessibility and remain to report low levels of perceived accessibility in a region with large inequalities in accessibility (e.g. car vs. non car owners in rural areas). Longitudinal analyses of perceived accessibility may enable testing such hypotheses.

6. Conclusion

This paper has evaluated the spatial distribution of perceived accessibility in the Netherlands. Perceived accessibility was found to be considerably less variable compared to the number of opportunities offered by the land use and transport system. This indicates that lower spatial accessibility levels in rural areas do not fully translate into lower levels of perceived accessibility. As part of the explanation for this pattern, it was hypothesized that people may self-select into different contexts regarding spatial accessibility, following individual heterogeneity in needs, desires and abilities concerning accessibility.

The assessment of self-selection effects comprised comparing differences in perceived accessibility between urban, rural and intermediate spatial accessibility contexts with expected differences in perceived accessibility if the population would be randomly distributed across these residential contexts irrespective of their accessibility requirements. Propensity score matching allowed for estimating expected differences in perceived accessibility by comparing perceived accessibility levels of people living in different spatial accessibility contexts while having the same probability of living in either context based on variables reflecting accessibility requirements.

The analysis has confirmed that preference-based residential self-selection can make up for differences in spatial accessibility levels. Between urban and rural regions, the difference in perceived accessibility is 61.6% smaller than in a situation in which no self-selection had occurred. People living in rural areas appear to have lower expectations of local accessibility compared to those living in urban and intermediate environments and can generally cope with lower availability of local opportunities through car mobility. The role of self-selection in mitigating spatial accessibility differences was found to decrease between higher accessibility contexts due to diminishing returns to the number of available opportunities. The need to self-select based on accessibility-related preferences declines if two residential contexts already provide relatively high accessibility levels, as most preferences can be met in either context. Indeed, the expected increments in perceived accessibility between urbanity levels, while controlling for residential self-selection, signify diminishing returns.

Yet, the presence of diminishing returns to spatial accessibility and residential self-selection does not imply that transport planning faces fewer challenges in ensuring sufficient accessibility in rural areas. People living in rural areas who are, nevertheless, satisfied with accessibility strongly rely on the car. This signifies that access to opportunities for rural residents is strongly dependent on the functioning of the transport system and, therefore, is arguably more reliant on interventions in the transport domain than in cities. Moreover, residential self-selection is not complete due to income-related limited residential freedom. Promoting self-selection may allow people who live in rural areas to more easily choose to live in an urban area if they desire higher spatial accessibility levels. In the short run, this would result in a better match between the spatial context and individual requirements regarding accessibility. But in the long run, lower demand could amplify a vicious cycle of declining local services, with detrimental impacts on liveability, which would make even more people want to leave increasingly car-dependent rural areas. The non-linear effects of spatial accessibility on perceived accessibility imply that further loss of facilities in rural areas can quickly lead to insufficiency below a certain tipping point. Relying on and promoting self-selection could, therefore, be at odds with societal goals related to designing more inclusive and sustainable access to activities.

Paradoxically, accessibility-based planning aimed at reducing car use has gained particular momentum in very dense cities (Akse et al., 2021). Arguably, the negative environmental externalities of automobile-oriented planning are most visible in cities. Yet, sustaining accessibility while limiting car mobility and promoting a more sustainable transport system will be especially challenging in rural areas, as active mode use is less feasible due to larger distances and public transport alternatives are currently not likely to match the accessibility offered by the car due to low demand (Ao et al., 2019). The shift from mobility-based towards developing accessibility-based planning strategies should, therefore, not only entail a substantive move away from promoting free-flow car mobility. It should also entail a geographical shift towards rural areas to ensure sufficient accessibility for all.

CRediT authorship contribution statement

Felix Johan Pot: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Sierdjan Koster:** Writing – review & editing. **Taede Tillema:** Writing – review & editing.

Data availability

The data that has been used is confidential.

Appendix A. Appendix

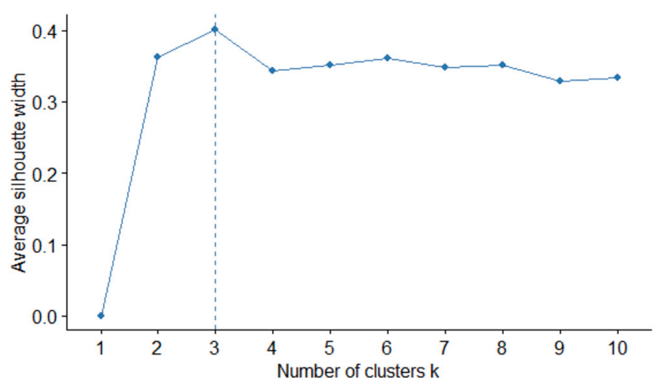

Fig. A1. Optimal number of spatial accessibility clusters.

Table A1
Proximity factor analysis.

Construct	Factor loading	α if item deleted
Pro proximity (α = 0.74, λ = 2.18 KMO = 0.75)		
I want to live near a lot of shops	0.65	0.68
I want to live near a supermarket	0.72	0.69
I want to live near healthcare facilities	0.63	0.70
I want to live near cultural/leisure facilities	0.60	0.69
I want to live near sporting facilities	0.42	0.74
I want to live close to a city centre	0.57	0.71

Notes: Principal axis factoring. λ is factor's eigenvalue. KMO denotes Kaiser-Meyer-Olkin measure of sampling adequacy.

Table A2
Pattern matrix for mode attitudes.

Construct	Private motorized	Public	Active
Attitude to car (as driver)	**0.67**	0.03	0.33
Attitude to car (as passenger)	**0.60**	0.17	0.28
Attitude to e-bike	**0.32**	0.13	0.01
Attitude to bus	0.01	**0.77**	0.13
Attitude to train	0.10	**0.75**	0.24
Attitude to bike	0.13	0.18	**0.76**
Attitude to walking	0.20	0.21	**0.68**

Notes: Principal axis factoring with oblique rotation. KMO = 0.71. Factor loadings above 0.3 in bold.

Table A3
Mean values and standard differences of observed covariates after matching.

	(1)			(2)			(3)		
	Urban	Intermediate	δ	Urban	Rural	δ	Intermediate	Rural	δ
Sociodemographic characteristics									
Gender (female)	0.51	0.51	−0.7	0.51	0.48	4.9	0.49	0.49	1.4
Age	50.3	50.3	0.2	50.9	51.2	−1.9	55.1	55.4	−1.8
Low education (dummy)	0.23	0.22	2.5	0.23	0.26	−7.1	0.23	0.24	−0.9
Low income (< €2000)	0.25	0.26	−1.8	0.25	0.29	−9.5	0.21	0.21	0.5
Employed (dummy)	0.56	0.56	1.5	0.56	0.59	−6.8	0.55	0.55	0.3
Household size	1.96	1.97	−0.5	1.98	1.98	0.1	2.33	2.29	3.7
Number of cars	1.05	1.05	−0.2	1.06	1.07	−1.1	1.38	1.39	−0.9
Disability (dummy)	0.19	0.22	−8.7	0.19	0.20	−1.6	0.19	0.19	1.1
Attitudes									
Pro proximity factor	0.14	0.13	0.7	0.12	0.17	−5.8	0.05	0.06	−0.8
Want PT within walking distance (dummy)	0.64	0.64	−0.4	0.63	0.63	0.6	0.52	0.52	−0.9
Dwelling more important (dummy)	0.39	0.42	−5.1	0.38	0.37	0.4	0.39	0.38	0.7
Pro private motorized modes factor	−0.18	−0.19	1.6	−0.18	−0.20	3.3	0.07	0.04	3.6
Pro public transport factor	0.09	0.09	0.2	0.07	0.10	−4.5	0.01	0.01	−0.3
Pro active modes factor	0.03	4.6E-3	3.2	0.04	0.01	2.7	0.06	0.09	−3.3

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