Perceived accessibility revisited: A perspective on change

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The past few months have been an exciting journey, seeking answers on the irrationality of perceived accessibility. Initially, I thought I would be able to unfold the rationale behind experienced levels of accessibility. Soon after starting this thesis, however, I concluded that perceived accessibility is severely bounded by its own rationality. While I have tried to jack up the explanatory power of the models reported in this thesis using various quantitative methods, I cannot say that I fully succeeded in making the concept of perceived accessibility rational. The following comment by Herbert Simon comforted me in times of uncertainty: *"You do not change people's minds by defeating them with logic"* (Simon, 1991)

Still, without the help of others, I don't think I would have gotten this far. Maarten, what started as an interesting bachelor thesis project on Dutch travellers' preferences towards direct itineraries got out of hand really fast. In the meantime, we have worked on and published journal articles, all related to our common interest in travel behaviour and transport policy research. The support you provide during our research projects is very well appreciated! I cannot wait to gain more experience under your supervision in the coming four years because there is still much to discover and learn! Nihit, thank you for your valuable comments and suggestions as well. These thorough and sharp comments on the project proposal and report during our meetings improved this thesis. Marije and Iris, our many interesting discussions on perceived accessibility were very much appreciated, both during our weekly meetings and at the coffee counter. And to all KiM colleagues, for providing (once again) such a welcoming atmosphere at the office. Looking forward to working alongside all of you as colleagues in the research field of transport policy in the coming years.

Summary

Social exclusion refers to the process by which individuals are systematically denied access to opportunities commonly available to others. With more and more people at risk of experiencing social exclusion, there is a pressing need to alleviate situations in which social exclusion lurks. Transport is critical in this, directly affecting individuals' ability to access employment, education, healthcare, and social activities. When transportation systems are inadequate, people can become physically isolated, resulting in (transport-related) social exclusion.

Recent trends show a decline in accessibility levels in the Netherlands, particularly due to cuts in public transport services, rising fares, and the loss of amenities. As a result, around 10% of the Dutch population is estimated to experience lower levels of accessibility. Barriers to reaching destinations may be experienced by those with lower levels of accessibility, limiting the ability to access opportunities such as education and employment and participate in life.

To reduce the chances of accessibility poverty and transport-related social exclusion, efforts have been made to measure individuals' perceived ease of reaching destinations and to identify the factors determining perceived (in)accessibility. However, an essential shortcoming of research on perceived accessibility is that changes in an individual's perceived accessibility and the consequences of these changes on travel, activity participation, and well-being are limitedly explored. Therefore, this thesis aims to '*offer a deeper understanding of determinants and outcomes of perceived accessibility, by accounting for changes in perceived accessibility over time*'.

This objective is addressed through a twofold empirical approach. First, changes in perceived accessibility and the factors driving these changes are analysed. Afterwards, the impacts of perceived accessibility on travel, activity participation, and well-being are empirically explored. The determinants and outcomes of perceived accessibility assessed in this thesis are identified through a literature review.

Concerning the first part of this thesis, trajectories in perceived accessibility over time have been identified by carrying out a longitudinal latent class analysis, after which explanatory factors of these changes are analysed using panel data regression analyses. In this regard, a literature review identified changes in socio-demographic factors (e.g. income, age, travel options), built environment characteristics, and attitudes (e.g. towards travel options and accessibility of residential location) as potential determinants of changes in perceived accessibility. To assess the extent to which these factors explain such transitions, data has been collected in 2020 and 2023 among household members of the Netherlands Mobility Panel (MPN). Fixed and random effects regression models are estimated to effectively disentangle factors causing between-person variations and within-person changes in perceived accessibility.

The main findings of this first part are:

- Most trajectories in perceived accessibility (61% of the sample) remained relatively stable over time. Other trajectories indicate notable transitions, with two clusters (27% of the sample) reporting a decline and a single cluster (12% of the sample) reporting an increase between 2020 and 2023.
- Within-person changes in perceived accessibility are partially explained by changes in distances to nearest amenities (in particular: supermarket, train station, secondary school) for the whole sample.
- Vulnerable groups perceive a change in the distance to the nearest amenities (especially the nearest supermarket) as more substantial. Rural-living individuals, women, older adults, people with a low income, and single-person households seem to experience such changes to a larger extent than the whole sample.
- Still, other factors contribute to changes in perceived accessibility to a larger extent. These are changes in mobility tool ownership, household composition, and the number of times meeting online.
- With respect to between-person variations in perceived accessibility among individuals, socio-demographic characteristics and attitudes rather than built environment characteristics determine such heterogeneity in perceived accessibility.

In the second part, pathways from perceived accessibility to life satisfaction are explored using a twofold structural equation modelling (SEM) approach. First, the direct and indirect effects of perceived accessibility on life satisfaction have been systematically studied using 2020 data from MPN members in a cross-sectional SEM design. The analysis includes travel behaviour and satisfaction, activity participation and satisfaction, and residential satisfaction as mediators. Second, this thesis empirically explores a potential (bi)directional causal link between perceived accessibility and life satisfaction using a longitudinal SEM design. More specifically, a random-intercept cross-lagged panel model has been estimated using data from 2020, 2023, and 2024 on perceived accessibility and life satisfaction among MPN members. In both analyses, confounders are accounted for by including a wide range of personal characteristics.

The main findings of this second part are:

- Perceived accessibility is positively associated with activities such as walking, grocery shopping, and sports participation and negatively associated with health-related activities.
- The strongest correlations have been found between perceived accessibility and satisfaction-related outcomes (travel, activity, residential, and life satisfaction).
- Notably, the correlation between perceived accessibility and life satisfaction is substantially lower than the indirect link mediated through behavioural decisions and satisfaction with these decisions.
- At the within-person level, life satisfaction is more likely to positively change perceived accessibility than the other way around.

Based on these empirical findings, three main lessons for policy can be identified. First, changes in the physical environment are actively accounted for by individuals, especially for vulnerable groups. With the loss of amenities and, inherently, increasing distances to activity locations in the Netherlands, an important policy lesson is to identify the neighbourhoods where vulnerable groups live, monitor the corresponding trends in spatial accessibility, and address the decline in amenities in these neighbourhoods using policy designs. Second, providing individuals with the means to travel might mitigate the loss of a private ownership tool and, in turn, allow individuals to maintain their level of accessibility. In this respect, investments in shared mobility or public transport services such as trains, busses, and demand-responsive transport could be alternatives to mitigate private ownership losses. Last, this thesis did not find within-person effects from perceived accessibility to life satisfaction, suggesting that greater perceived accessibility may not be sufficient to enhance life satisfaction directly. Therefore, improvements in accessibility levels should most likely be part of a broader policy design that addresses (perceived) social inclusion and (subjective) well-being.

Two main lessons for policy have been identified as well. First, this research highlighted a discrepancy between factors causing (between-person) variations in perceived among individuals and those causing (within-person) changes in perceived accessibility. Researchers in the field of transportation research, and in particular those studying perceived accessibility, should actively consider and/or account for these differences in future research. Second, the Perceived Accessibility Scale (PAC) is an often-used measure of perceived accessibility. While using an often applied scale is reasonable and defensible, it remains crucial for researchers to recognise that such a scale may not perfectly isolate the construct of interest. The scale does not exclusively include statements about perceived accessibility; it also asks respondents to rate statements concerning their satisfaction with activities and, more broadly, their general satisfaction with life. This presents a limitation in accurately capturing perceived accessibility as a standalone construct, primarily for research focussing on the influence of perceived accessibility on broader concepts such as travel, activity participation, and well-being, which is the case in this thesis.

While novel findings have been revealed on determinants and outcomes of perceived accessibility in this thesis, this research could still benefit from future research in several directions. Concerning the first part of this thesis, future research could estimate household-level rather than individual fixed effects to account for household-specific factors that remain constant over time. In addition, future research could explore whether a deterioration and an improvement in spatially inferred accessibility levels have a similar effect on changes in perceived accessibility, assess other types of amenities which have not been included in this thesis, or assess the role of moving to new places with different accessibility levels. Measuring individuals' perceived and spatial accessibility simultaneously could also yield novel results. In this thesis, data were collected at other times, with a one-month gap in 2020 and a six-month gap in 2023. This may have resulted in a potential misalignment between when changes in spatial accessibility occurred and when they are reflected in perceived accessibility.

For the second part of this thesis, an interesting direction for future research would be to examine other bidirectional effects between perceived accessibility and its outcomes. In this thesis, only the reciprocal causal link between perceived accessibility and life satisfaction has been explored. Moreover, additional mediating pathways from perceived accessibility to life satisfaction could also be explored.

Concerning the overall design of this thesis, two avenues for future research have been identified as well. First, future research could study the role of adaptive preferences in changing perceived accessibility in more detail. Individuals experiencing lower levels of accessibility may accept their situation and, in turn, positively re-evaluate their perceived accessibility. Conversely, those individuals experiencing the highest levels of accessibility may develop higher expectations, leading to a negative reassessment of their perceived accessibility. Quantitative methods (e.g. latent transition modelling) and qualitative methods (e.g. focus group discussions, interviews) could shed more light on this potential role. Second, this thesis was conducted in the Netherlands, and data was collected there. Little is known about changes in perceived accessibility and the factors causing such changes in different geographical and/or cultural contexts, which could provide novel insights on within-person transitions in perceived accessibility.

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1

Introduction

1.1. Background

Over the past decade, the ease of reaching destinations and/or activities has significantly declined in the Netherlands. This decline in accessibility is linked to several societal trends and governmental decisions, such as the less prominent role of the Dutch public transport system in recent years (PBL, 2023). Between 2018 and 2023, bus stops decreased by 7%, dropping from 22,100 to 20,600 (NOS, 2023). As a result, around 70 villages no longer have any bus stops. (NOS, 2023). Additionally, public transport services have become increasingly concentrated in urban centres and are limited during off-peak hours and weekends (PBL, 2023). These changes limit people's ability to reach amenities and activity locations, especially those who rely solely on public transport and lack alternative means to travel. Overall, nearly 12% of the Dutch population is estimated to experience lower accessibility (Moleman and Kroesen, 2025a), and this number is expected to rise further.

However, accessibility to places is essential for individuals to fully participate in life. Ideally, the transport system should enable people to reach destinations and engage in activities (Miller, 2018). When these accessibility levels decrease, individuals may face economic and social consequences. A substantial body of research has demonstrated that poor accessibility negatively affects employment, health, and education and contributes to social exclusion (e.g. Social Exclusion Unit, 2003; Lucas, 2012; Bastiaanssen and Martens, 2013).

With an estimated 2.5 billion people at risk of experiencing social exclusion (Cuesta et al., 2024) and thus unable to fully participate in life (United Nations, 2016), more research has been conducted on the nexus between social exclusion and transport. As underscored by the United

Nations (2016), barriers individuals encounter when accessing life-enhancing opportunities (e.g. employment, education, healthcare) should be alleviated to reduce the chances of experiencing social exclusion. For this, transport planning has shifted from mobility to accessibility (e.g. Banister, 2008; Miller, 2018; Handy, 2023), which has led to approaches focusing on ensuring sufficient access for all.

Still, challenges to the concept of accessibility persist. For one, various definitions and measures are proposed to study accessibility, resulting in the fragmentation of theoretical foundations (Miller, 2018). In its simplest form, accessibility refers to 'the ease of reaching destinations' (e.g. Boisjoly & El-Geneidy, 2017, p.38). Still, consensus on how to define accessibility remains limited. Additionally, different measures and study designs have been employed in various studies and contexts (Miller, 2018), which reduces the ability to compare study findings. Luz (2021), for instance, reviewed 24 accessibility measures in the context of transport-related social exclusion, highlighting the diversity of measures used to assess and quantify accessibility levels.

Adding to this, the subjective nature of accessibility challenges researchers to observe differences in accessibility levels between individuals living in the same geographical area (Miller, 2018). Conventional evaluations of accessibility apply indicators inferred from spatial data, relying upon aggregated assumptions on how individuals experience their level of accessibility (Ryan and Pereira, 2021; Vecchio and Martens, 2021). In other words, accessibility evaluations assume that individuals living in similar residential locations experience the same level of accessibility, which is calculated based on spatial data. Therefore, these spatial accessibility indicators most likely overlook the heterogeneity in the needs, desires, and abilities of individuals that shape their perceived levels of accessibility (Pot et al., 2023). To illustrate this point, Fig. 1.1. highlights the variation in experienced levels of accessibility for individuals with a similar number of amenities within 5 kilometres. Interestingly, a large body of individuals with a low number of amenities still perceive high levels of accessibility. In contrast, some individuals with many amenities experience lower accessibility levels.

In an effort to overcome the latter challenge, recent studies have focussed on perceived accessibility. This subjective evaluation of one's level of accessibility refers to the 'perceived potential to participate in spatially dispersed opportunities' (Pot et al., 2021, p.2). By accounting for the levels of accessibility experienced by individuals, rather than assuming that those living nearby experience similar accessibility levels, an understanding of the situations in which people experience (in)adequate access can be obtained.

1.2. Research focus

The body of research on perceived accessibility has steadily grown in recent years. However, it still suffers from a critical shortcoming: changes in an individual's perceived accessibility and the consequences of these changes for travel, activity participation, and well-being are limitedly explored.

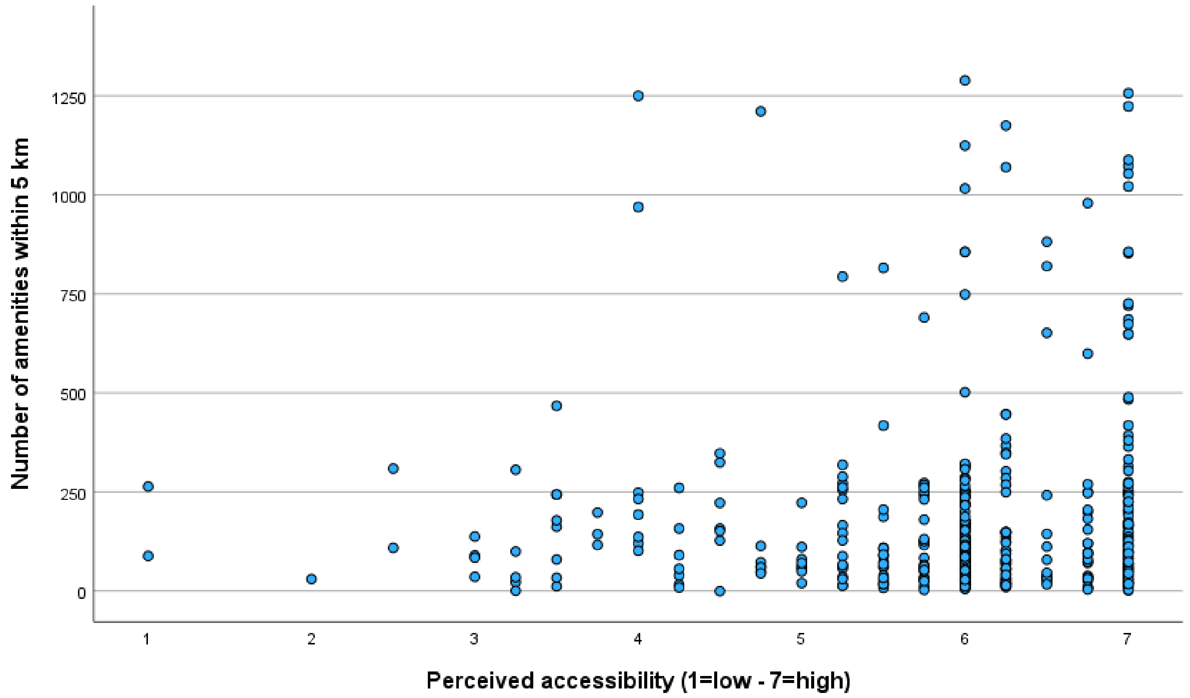

Fig. 1.1 – Spatial-perceived accessibility levels based on disaggregate data (from a survey on perceived accessibility in 2020 with 543 respondents; see Chapter 3)

Most existing research on perceived accessibility focuses on identifying factors that explain individual differences. In general, research has suggested that sociodemographic characteristics play a significant role in shaping such differences. Although studies remain inconclusive on the specific effects, factors such as gender, age, migration background, level of education, income, and household composition have all been linked to variations in perceived accessibility (e.g. Pot et al., 2023; Moleman and Kroesen, 2025b). Additionally, characteristics of the built environment and (travel) attitudes and/or experiences also contribute, while the built environment tends to have a less prominent role (Pot et al., 2023).

Luz and Portugal (2021) underscored that much of the research on (perceived) accessibility is based on between-person correlations rather than within-person causal changes. However, factors like socio-demographics, built environment characteristics, and attitudes may also change an individual's perceived level of accessibility over time. For example, changes in the physical environment or sociodemographic characteristics (such as income or car ownership) could alter how someone perceives the ease of reaching destinations. Existing studies that examine changes in perceived accessibility instead tend to focus on the effects of policy interventions. For instance, both Andersson et al. (2023) and Liu et al. (2023) evaluated changes in modal shifts and perceived accessibility attributed to implementing fare-free public transport scheme interventions. To my knowledge, non-interventional changes have not yet been assessed. Identifying those factors that cause changes in perceived accessibility is critical to designing policies that effectively target perceived accessibility.

In turn, changes in perceived accessibility could strongly influence whether people perceive activities to be within reach and encounter barriers to accessing work, education, and other life-enhancing opportunities. However, perceived accessibility is often treated as an endpoint, with most research overlooking how changes in perceived accessibility affect travel behaviour, activity participation, and ultimately well-being and social exclusion.

While some studies have indicated that perceived accessibility affects activity participation, travel behaviour, and satisfaction with these activities (e.g. Scheepers et al., 2016; Sukwadi et al., 2022; Pot et al., 2024), direct and indirect links from perceived accessibility towards well-being have been minimally explored. A few studies suggest positive correlations between perceived accessibility and life satisfaction, both directly (e.g. Lättman et al., 2019) and indirectly through activity participation (e.g. Mehdizadeh et al., 2025). Still, a comprehensive theory explaining the pathways through which perceived accessibility affects subjective well-being remains undeveloped.

Moreover, it is unclear whether a causal link between perceived accessibility and life satisfaction exists, as most studies only report correlations. The direction of this relationship is also uncertain. While it is generally assumed that perceptions of accessibility influence life satisfaction, it is possible that individuals who are satisfied with life tend to view their accessibility more positively. In other words, a person's cognitive evaluation of accessibility may be shaped by their overall outlook on life.

Overall, this lack of research on the outcomes of perceived accessibility complicates our understanding of how perceptions of accessibility and changes in those perceptions affect travel, activity participation, and well-being. Gaining such understanding is crucial to preventing inadequate access and social exclusion.

1.3. Research objective and questions

In light of the research focus formulated in the previous section, the overarching research objective of this thesis is:

'To offer a deeper understanding of determinants and outcomes of perceived accessibility, by accounting for changes in perceived accessibility over time.'

Four research questions have been formulated to fulfil this aim, which I intend to answer in subsequent order.

1. *What are the determinants and outcomes of perceived accessibility identified by earlier studies, and how can these relationships be conceptualised?*

To answer this research question, (review) articles on perceived accessibility will be retrieved from Scopus and Web of Science, followed by screening and reviewing suitable articles in Covidence. This process will identify the determinants and outcomes of perceived accessibility. Subsequently, a conceptual model of these factors and their relationship with perceived accessibility will be proposed. This model will serve as a reference for research questions 2 to 4.

2. *Which factors cause changes in perceived accessibility? Are these effects perceived differently across social groups?*

Panel data regression models will be specified and estimated to answer this research question. Both fixed and random effects panel data regressions will be conducted to separate within-person and between-person effects. Whereas the random effects regression allows the verification of which determinants explain variations in perceived accessibility between individuals using panel data, the fixed effects regression enables the identification of those determinants which cause changes in people's perceived ease of reaching destinations. A key objective of this part of the thesis is to examine whether changes in the built environment and, consequently, spatial accessibility indicators result in changes in perceived accessibility. Other determinants, identified by answering research question 1, will also be assessed. Additionally, whether changes in these determinants are perceived differently by various groups will be examined. For example, older adults may experience car ownership differently than younger adults. The Netherlands Mobility Panel, which includes data on perceived accessibility, sociodemographic characteristics, travel behaviour patterns, and travel attitudes in 2020 and 2023, will be used (for more information, see Hoogendoorn-Lanser et al., 2015). This dataset will be complemented by open-source spatial accessibility indicators at the neighbourhood level, provided by Statistics Netherlands.

3. *What is the impact of perceived accessibility on travel, activity participation, and well-being?*

After evaluating the impact of changes in determinants of perceived accessibility on individuals' experienced level of accessibility, this thesis aims to test a theory on the outcomes of perceived accessibility using structural equation modelling. This theory is based on the key outcomes identified in the literature and aims to assess mediating pathways from perceived accessibility to well-being. Factors included in this analysis are, among others, daily travel behaviour, satisfaction with travel, activity participation, residential satisfaction, and life satisfaction. Structural equation modelling allows for the estimation of both direct and indirect effects and possible mediating effects that confound the relationships between perceived accessibility and its outcomes. For this analysis, a 2020 questionnaire focused specifically on perceived accessibility and its outcomes will be used, with the results analysed using AMOS 29 (a software package dedicated to structural equation modelling).

4. *Does perceived accessibility affect life satisfaction or vice versa (for different social groups)?*

Studies that examine the relationship between perceived accessibility and life satisfaction focus on a unidirectional effect, estimating the impact of perceived accessibility on life satisfaction. This thesis aims to explore a potential bidirectional relationship between perceived accessibility and life satisfaction. In addition to exploring a general link, a subgroup analysis will be carried out to explore whether this link differs across social groups empirically. To this end, a random-intercept cross-lagged panel model will be estimated in Mplus 8.5 using three waves of the Netherlands Mobility Panel (2020, 2023, and 2024).

1.4. Societal and scientific relevance

Ultimately, this thesis presents a framework of transitions in perceived accessibility and the factors that drive such changes. This framework will aid policymakers and practitioners in designing policies that can help transition individuals to higher levels of perceived accessibility, reducing exposure to transport-related social exclusion. The framework may also provide theoretical foundations for studying perceived accessibility in longitudinal contexts.

1.5. Thesis outline

The remainder of this thesis is organised as follows: Chapter 2 presents and discusses the literature review on perceived accessibility, focusing on its determinants and outcomes. Afterwards, Chapter 3 outlines the methodological approach used to conduct the empirical analyses to answer research questions 2 to 4. Chapters 4 and 5 present the results of these analyses. More specifically, Chapter 4 details the regression results used to identify factors driving changes in perceived accessibility. Chapter 5 presents the findings of the structural equation models used to identify various mediating pathways from perceived accessibility to life satisfaction and test the bidirectional link between these constructs. Finally, Chapter 6 concludes the thesis by summarising the key findings, discussing them in the context of earlier research, proposing a framework for transitions in perceived accessibility, and outlining implications for policy and science and future research directions.

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2

Literature review and conceptual model

2.1. Introduction

In this section, the findings of the literature review will be presented and discussed. Earlier review articles on perceived accessibility (e.g. Jamei et al., 2022; Ma & Cui, 2024; Negm et al., 2025) have limitedly covered (a) changes in perceived accessibility and (b) outcomes of perceived accessibility. In light of this thesis's aim, this review intends to explore which factors may contribute to changes in perceived accessibility and to identify the outcomes related to perceived accessibility.

First, Section 2.2 will provide an overview of the definitions of and perspectives on perceived accessibility. Afterwards, Section 2.3 outlines possible determinants of changes in perceived accessibility, whereas Section 2.4 will present and discuss outcomes of perceived accessibility, particularly in relation to daily travel. Section 2.5 will address studies applying a longitudinal perspective on perceived accessibility, summarizing what we can learn from existing studies and identifying areas that require further exploration. Finally, this chapter offers a preliminary conceptual framework in Section 2.6, used as a reference in the analyses that will follow.

2.2. Perspectives on and components of perceived accessibility

Perceived accessibility is defined and operationalised in various ways. Some common definitions include 'how an individual experiences its own level of accessibility' (Curl, 2018, p. 1148), 'the perceived potential to participate in spatially dispersed opportunities' (Pot et al., 2021, p.2), 'an individual's perception on how easy it is to reach opportunities based on their own experiences' (Ryan et al., 2016, p. 406), and 'how easy it is to live a satisfactory life using the transport system' (Lättman et al., 2016, p. 258). As emphasized by Friman et al. (2020a), perceived accessibility is driven by 'objective/environmental conditions of travel (such as service quality in terms of travel time, punctuality, information, and comfort) and the individual experiences and evaluations of these conditions' (Friman et al., 2020a, p. 2). Departing from the definition of accessibility by Geurs and Van Wee (2004) and the definition of perceived accessibility by Pot et al. (2021), in this thesis perceived accessibility is defined as 'the perceived ease to which land-use and transport systems enable individuals to access destinations and/or activities'.

Following from this definition, and drawing upon the framework proposed by Pot et al. (2021), perceived accessibility can be conceptualised through four dimensions. These include the land use, transport, temporal, and individual dimension, which allows to identify different types of determinants. The land use component refers to how individuals perceive land use systems, which includes the demand and supply of activities at a given destination. Resulting from this confrontation between demand and supply, the transport component reflects the perceived disutility of covering the distance between origin and destination. In contrast, the temporal component entails the perceived temporal availability of opportunities. Besides, this temporal dimension can also reflect the time available to participate in or travel to certain activities. Finally, the individual component of accessibility includes socio-demographic characteristics, capabilities, attitudes, and preferences which result in individuals' needs, abilities, and desires. (Pot et al., 2021)

It is important to emphasise that perceived accessibility, unlike spatially-inferred levels of accessibility, is established by individuals' subjective evaluation of the land-use, transport, and temporal components of accessibility. In other words, a person's needs, abilities, and desires shape how the 'conditions of travel' (such as travel time and comfort) are perceived. This subjectivity allows to study heterogeneity in accessibility levels among individuals that live in the same geographical area, as individuals may experience these conditions differently.

In addition to these dimensions, characteristics of the physical environment also play a key role. Through self-selection, individuals choose residential locations that match their preferences. These built environment characteristics then provide the necessary information for evaluating the 'conditions of travel' represented by the land-use, transport, and temporal components of perceived accessibility.

2.3. Determinants of perceived accessibility

This section provides a review of the determinants of perceived accessibility, utilising the four dimensions of perceived accessibility discussed in section 2.2. Fig. 2.1 conceptualises the determinants per dimension and their role in shaping perceived accessibility.

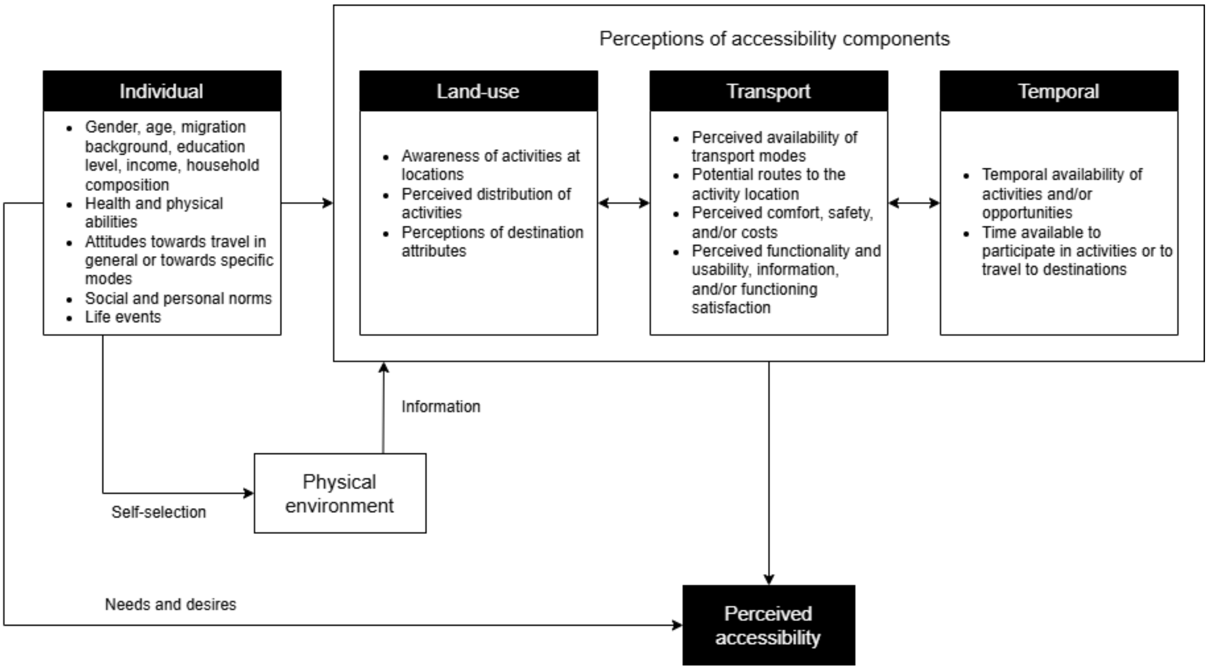

Fig. 2.1 – Determinants of perceived accessibility (adapted from: Pot et al., 2021)

2.3.1. Land-use dimension

Individuals may develop perceptions about factors within the land-use system, often based on their knowledge of the availability and locations of opportunities (Pot et al., 2021). These perceptions can include the (lack of) awareness of activities at certain locations (Chen et al., 2022), perceptions of the distribution of activities (Van der Vlugt et al., 2019), and/or the perceived characteristics of specific activity locations (Pot et al., 2021).

2.3.2. Transport dimension

Regarding the transport dimension, Pot et al. (2021) highlights two directions for potential determinants. The first avenue relates to the inadequate awareness of transport option (Pot et al., 2021). Perceptions are based on the perceived availability of transport modes and/or on the potential routes to an activity location selected by the individual (Pot et al., 2021). Chen et al. (2022) provides empirical evidence for such determinants of perceived accessibility, emphasising the role of perceived availability of dockless bike-sharing in influencing the perceived overall level of accessibility.

The second avenue involves travel resistance, which is evaluated through components of generalized transport costs (Pot et al., 2021). Examples are -but not limited to- the perceived comfort, costs, and/or safety (e.g. Friman et al., 2020b; Pot et al., 2020; Sukwadi et al., 2022). Sukwadi et al. (2022) studied the effect of service quality components on perceived accessibility for mass rapid transit in Jakarta, finding that reliability, safety, information, comfort, and costs significantly affected individuals' perceptions of accessibility. In line with this, Friman et al. (2020b) highlighted the significant impact of perceived safety, comfort, and costs of public transport on the level of accessibility experienced by individuals. Improving the perceived quality of services, thus reducing travel resistance, is likely to result in higher perceived accessibility.

2.3.3. *Temporal dimension*

Perceptions on the temporal availability of opportunities, or the time available to participate in or travel to certain activities, may also translate into perceived accessibility (Pot et al., 2021). Jamei et al. (2022) highlight that schedule limitations -such as those arising from work and household responsibilities- are common restrictions that reduce the time available to reach destinations or participate in activities (Jamei et al., 2022). However, as underlined by Jamei et al. (2022), empirical evidence for these temporal determinants of perceived accessibility remains limited.

2.3.4. *Individual dimension*

The individual dimension has been the primary focus in research on the determinants of perceived accessibility. Various factors affect individuals' needs, desires, and abilities, which, in turn, influence how the other dimensions are perceived. These factors include socio-demographic characteristics, capabilities, attitudes, preferences, and context.

Research has identified significant variations in perceived accessibility based on social determinants such as gender, age, education level, and income. Regarding gender, empirical evidence is mixed. While some studies report insignificant differences (e.g., Vitman-Schorr et al., 2019; Van der Vlugt et al., 2019), others (e.g., Moleman and Kroesen, 2025a; 2025b) reveal that men tend to perceive higher levels of accessibility compared to women. In contrast, Lättman et al. (2018) and Pot et al. (2023) found that men reported lower levels of perceived accessibility. Notably, studies that included travel modes in their analyses tended to find no significant gender differences in perceived accessibility (Jamei et al., 2022).

A similar pattern holds for age. While most studies find significant differences across age groups, it remains unclear whether older adults perceive lower levels of accessibility. For example, Van der Vlugt et al. (2019) found that perceived accessibility decreased with age in the United Kingdom but not in Germany. This discrepancy may relate to the fact that older adults report higher levels of perceived accessibility when urban services are accessible via public transport (Lättman et al., 2019). However, most studies suggest that perceived inaccessibility is more commonly experienced by older individuals (Ryan et al., 2016; Curl et al., 2018; Pot et al., 2023; Moleman and Kroesen, 2025a; 2025b).

In addition to gender and age, other socio-demographic characteristics such as education level, occupation, migration background, income, and household composition are frequently assessed. For example, Friman et al. (2020a) and Pot et al. (2023) found a negative relationship between education level (measured in years) and perceived accessibility. individuals with higher levels of education tended to perceive lower levels of accessibility, possibly because they have more complex demands that are harder to satisfy. In contrast, some studies (e.g., Vitman-Schorr et al., 2019; Van der Vlugt et al., 2019; Olsson et al., 2021) found no significant variation in perceived accessibility based on education level.

Similarly, research often concludes that higher-income individuals perceive lower levels of accessibility due to higher expectations. For instance, Van der Vlugt et al. (2019) found that lower-income individuals experienced a higher level of accessibility than their higher-income counterparts. However, some studies, such as those by Pot et al. (2023) and Lättman et al. (2018), found no significant differences between income groups.

Regarding migration background, Moleman and Kroesen (2025b) found that individuals with a Western background reported higher levels of accessibility in the Netherlands compared to those with a non-Western background. However, empirical evidence on the impact of migration background on perceived accessibility is still limited.

On a similar note, both Pot et al. (2023) and Moleman and Kroesen (2025b) emphasised the important role of employment status, with both studies finding significant effects of employment on perceived accessibility. Unemployed individuals systematically experienced a lower level of accessibility.

In contrast, no significant differences in perceived accessibility were found based on household composition by Pot et al. (2023) and Olsson et al. (2021). Similarly, Vitman-Schorr et al. (2019) studied the impact of marital status (whether or not an individual lived with a partner) and found that marital status did not lead to significant differences in perceived accessibility.

Disabilities or physical incapabilities also strongly affect perceived accessibility. Studies (e.g., Márquez et al., 2019; Tanimoto and Hanibuchi, 2021; Pot et al., 2023) have shown that individuals with disabilities are more likely to perceive lower levels of accessibility. Furthermore, access to stable internet connections can significantly influence perceived accessibility, with individuals who have reliable internet access reporting higher levels of accessibility (Pot et al., 2023).

Attitudes towards travel, particular modes of transport, and residential locations also seem to impact perceived inaccessibility. For example, Olsson et al. (2021) emphasised that the connection to as well as familiarity with the living area, and perceived level of safety within the living area all impacted the perceived level of accessibility. Adding to this, Van der Vlugt et al. (2019) concludes that people's attitude towards public transport may significantly determine their perceived accessibility, whereas people's attitude towards car and bike will most likely not lead to variations in their accessibility. In line with Olsson et al. (2021) and Van der Vlugt et al. (2019), Pot et al. (2023) underlines that both land-use and transport system attitudes shape perceived (in)accessibility extensively.

While life events have generally been overlooked in studies on perceived accessibility, they represent a "window of opportunity" to adjust habitual travel patterns, likely leading to changes in perceived accessibility. Lanzendorf (2003) proposed a theoretical framework (see Fig. 2.2) that connects life events—such as changes in household composition or career—and shifts in individuals' mobility needs, desires, and abilities. Such changes can affect individuals' residential locations, employment, car ownership, and daily travel patterns, thereby influencing perceived accessibility.

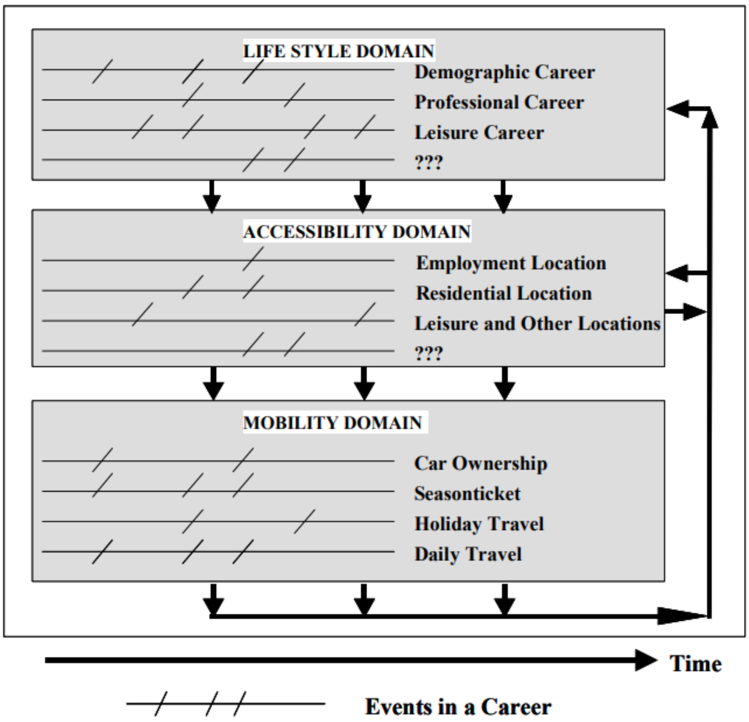

Fig. 2.2 – Mobility biography framework (source: Lanzendorf, 2003)

Lastly, the impact of contextual factors in shaping how individuals perceive the dimensions of perceived accessibility and, consequently, how these factors are reflected in their level of accessibility should not be underestimated. Moleman and Kroesen (2025a) underscore the wide range of contextual factors that may play a role in shaping perceived accessibility. One of them relates to the concept of adaptive preferences, which refers to individuals positively revisiting their perceptions in response to the lower capabilities that they experience. Whereas some studies have suggested a potential effect of adaptive preferences (e.g. Pot et al., 2023; Moleman and Kroesen, 2025b; Ryan and Pereira, 2021), empirical evidence has not yet been provided. In contrast, studies have empirically assessed the role of social and personal norms. For example, Chen et al. (2022) provided empirical evidence showing how social and personal norms shape individuals' perceptions of accessibility, specifically in the context of dockless bike-sharing. Similarly, Al-Rashid et al. (2021) pointed out that perceived social and personal norms regarding public transport use can reinforce mobility inequalities, particularly for individuals experiencing lower levels of accessibility.

2.4. Outcomes of perceived accessibility

Most studies on perceived accessibility evaluate general levels of perceived accessibility or reveal differences in these levels by identifying determinants of and barriers to perceived accessibility. While perceived accessibility is often regarded as an endpoint in academic research, individuals’ experienced level of accessibility has some key outcomes as well. The outcomes of perceived accessibility discussed in this section relate to travel behaviour, travel satisfaction, activity participation, and life satisfaction.

2.4.1. *Travel behaviour*

The majority of studies on the outcomes of perceived accessibility explore associations with travel behaviour. Perceived accessibility appears to be related to trip characteristics, with studies primarily highlighting its effect on trip duration and travel distance. For instance, Zhang and Hu (2024) found that travel distances by bike were positively correlated with overall perceived accessibility.

Still, much of the research on the link between perceived accessibility and travel behaviour focuses on how perceived accessibility relates to mode choices. Although research remains inconclusive on the specific effects of perceived accessibility on mode choice, different measurement scales for both perceived accessibility and travel mode choice have been used as well.

Scheepers et al. (2016) measured perceived accessibility by car, bicycle, and foot, and found that individuals were less likely to walk or bike when the accessibility they experienced by car was high. In contrast, individuals who perceived high accessibility through walking or biking were more likely to choose these modes. Tailored to public transport, both Sheng and Zhang (2022) and Watthanaklang et al. (2024) concluded that perceived access to destinations using public transport increased both the intention to use and actual use of public transport. Lukina et al. (2023) revealed a positive link between perceived accessibility and the frequency of public transport use. However, Friman et al. (2020b) and Olsson et al. (2021) found that public transport use was negatively correlated with perceived accessibility. For walking, Liu et al. (2022) and Van der Vlugt et al. (2022) both concluded that individuals with a higher level of perceived walking accessibility were more likely to walk.

2.4.2. *Travel satisfaction*

Although studies have revealed a link between perceived accessibility and travel behaviour, some studies have shown that travel satisfaction can be affected by individuals' perceived accessibility as well. With higher levels of perceived accessibility, people tend to be more satisfied with their daily travel (see Lättman et al., 2019; Sukwadi et al., 2022). In addition to this direct effect of perceived accessibility on travel satisfaction, it is likely that individuals' perceived accessibility also indirectly affects satisfaction with travel through travel choices and trip satisfaction. The perceived ease of reaching a destination may affect the way people travel and, as a consequence, how satisfied people are with their travel. In this case, perceived accessibility does not directly influence travel satisfaction, but rather indirectly through travel choices and trip satisfaction.

2.4.3. *Activity participation*

Besides links with travel behaviour and satisfaction, research has shown that perceived accessibility affects the number of out-of-home activities as well. For instance, Pot et al. (2024) revealed a weak, non-linear relationship between perceived accessibility and activity participation. With low number of out-of-home activities, the majority of individuals still reported high perceived access (Pot et al., 2024). In contrast, a large share of individuals carrying out most activities did experience lower accessibility levels (Pot et al., 2024).

2.4.4. Residential satisfaction

With regard to residential satisfaction, only a limited number of studies have been conducted. Olfindo (2021) found that the perceived accessibility of bus stops relates to residential satisfaction as well as the intention to move. Using 5200 residents living near bus stops Yangon City (Myanmar), a structural equation model was developed to test the effects both subjective and objective measures of bus stop accessibility on residential satisfaction, which highlighted that subjective rather than objective accessibility measures determine satisfaction with the residential location. Whereas Olfindo (2021) focused on residential satisfaction, Hu and Ettema (2023) studies the link between perceived accessibility and residential dissonance, that is a dissonance between the preferred and actual residence with regard to travel preferences, which was found to be significant. Interestingly, respondents categorized as dissonant based on their objectively determined level of accessibility did not perceive themselves as dissonant based on their perceived accessibility. Lastly, Hamersma et al. (2014) and Hamersma et al. (2015) studied the role of perceived accessibility on respectively residential satisfaction and moving intentions among individuals living close to highways. Using ordinal regression analysis, Hamersma et al. (2014) revealed that perceived accessibility of the residential location did significantly increase individuals' residential satisfaction. In contrast, structural equation modelling revealed that lower levels of accessibility were not associated with perceived highway nuisance and the intention to move (Hamersma et al., 2015).

2.4.5. Satisfaction with life

Ultimately, travel should provide the means to reach destinations, enabling individuals to participate in out-of-home activities, and -in doing so- allowing to enhance people's quality of life. Since satisfaction with travel and activities is known to have a clear impact on life satisfaction (e.g. Lättman et al., 2019, De Vos and Witlox, 2017), perceived accessibility will likely have an important effect on well-being as well. Studies on this relationship consistently found that perceived accessibility positively correlates with life satisfaction (e.g. Lättman et al., 2019; Friman and Olsson, 2023; Lim et al., 2020; Mehdizadeh et al., 2025). Lättman et al. (2019) also found a significant mediating effect of travel satisfaction on the relationship between perceived accessibility and life satisfaction, whereas Mehdizadeh et al. (2025) found a mediating pathway through activity participation.

While previous studies have been concerned with the effect of perceived accessibility on life satisfaction, satisfaction with life may also affect individuals' experienced level of accessibility. Those individuals satisfied with life may develop more positive emotions, which in turn may affect the cognitive evaluation of individuals' accessibility.

2.5. Perceived accessibility over time

Overall, perceived accessibility is only limitedly studied in a longitudinal setting. To the best of my knowledge, only Andersson et al. (2023) and Liu et al. (2023) evaluated mode choice and perceived accessibility before and after the implementation of fare-free public transport schemes. Whereas Andersson et al. (2023) found that perceived accessibility and public transport mode use increased after the implementation of a public transport fare free intervention, Liu et al. (2023) concluded that individuals' perceived accessibility did increase after implementing fare-free schemes. However, Liu et al. (2023) explicitly studied these changes in the context of tourism, whereas Andersson et al. (2023) focussed on daily travel.

2.6. Conceptualising perceived accessibility

This section offers a conceptual model of the determinants and outcomes of perceived accessibility, given the background on perceived accessibility provided in Sections 2.1 to 2.5. This model partly draws upon the framework proposed by Pot et al. (2021), which recognises the four dimensions of perceived accessibility and details how these dimensions are reflected in people's experienced level of accessibility. Yet, how these experienced levels of accessibility influence people's daily travel, activity participation, residential satisfaction, and quality of life is not yet detailed in Pot's framework. Hence, the conceptualisation offered in this chapter adds to the current body of literature by highlighting both the determinants and outcomes of perceived accessibility as well as the adaptive nature of perceived accessibility. In doing so, researchers and policymakers working on longitudinal analyses of perceived accessibility are aided in their research design.

The conceptual framework shown in Fig. 2.3 consists of three main components, namely the dimensions, determinants, and outcomes of perceived accessibility. These components will be discussed in respective order.

The model starts with an initial level of accessibility as experienced by an individual. This level is shaped by the four dimensions of perceived accessibility, namely the land-use, transport, temporal, and individual component. Whereas the land-use component reflects the perceived magnitude of opportunities in the land-use system, the transport system describes the set of travel modes, routes, etc. considered and perceived to be available for an individual (Geurs and Van Wee, 2004; Pot et al., 2021). In contrast, the temporal component of perceived accessibility relates to the estimated time needed to access a destination and/or temporal availability of activities at a given destination (Pot et al., 2021). Lastly, the individual component reflects the needs, desires, and abilities of individuals (Geurs and Van Wee, 2004; Pot et al., 2021). This component essentially influences how an individual perceives the other components of accessibility, by affecting the information that is gathered and processed by the individual itself. While not all links between all components of perceived accessibility are visualised, these interactions are present. For instance, the needs, desires and abilities of an individual will also reflect the process of gathering and processing information on the land-use system. The same holds for links between travel behaviour and activity participation.

The sources of interaction between the four components of perceived accessibility stem from characteristics of the built environment (and thus the objective accessibility levels inferred from spatial data), sociodemographic characteristics (e.g. age, migration background, level of education, income, household composition), and (travel) attitudes and experiences.

The first step in changing perceived accessibility has to do with changes in its determinants. A change in the distance to the nearest supermarket, household composition, or attitude towards driving will in turn reshape an individual's experienced level of accessibility. This process of revisiting one's perceived accessibility relates to the fact that these changes in the built environment, sociodemographic factors, or attitudes will most likely impact one or more dimensions of perceived accessibility. For instance, a changing built environment will be expressed in the disutility to cover distances from origin to destination (transport component) as well as in the magnitude of opportunities experienced by an individual (land-use component). This may, however, differ for specific social groups (e.g. in terms of age, gender, etc.).

After changes in the built environment, sociodemographic characteristics, and/or attitudes are translated in a new perceived level of accessibility, this change in perceived accessibility will potentially impact one's daily travel routine, satisfaction therewith, the number of activities carried out by an individual, satisfaction with the residential location, or ultimately even an individual's satisfaction with life.

Lastly, the direction of causality between perceived accessibility and life satisfaction remains unclear. While previous studies on this relationship assumed that perceived accessibility impacts satisfaction with life, it could well be that those individuals more satisfied with life develop a more positive stand towards their experienced level of accessibility as well.

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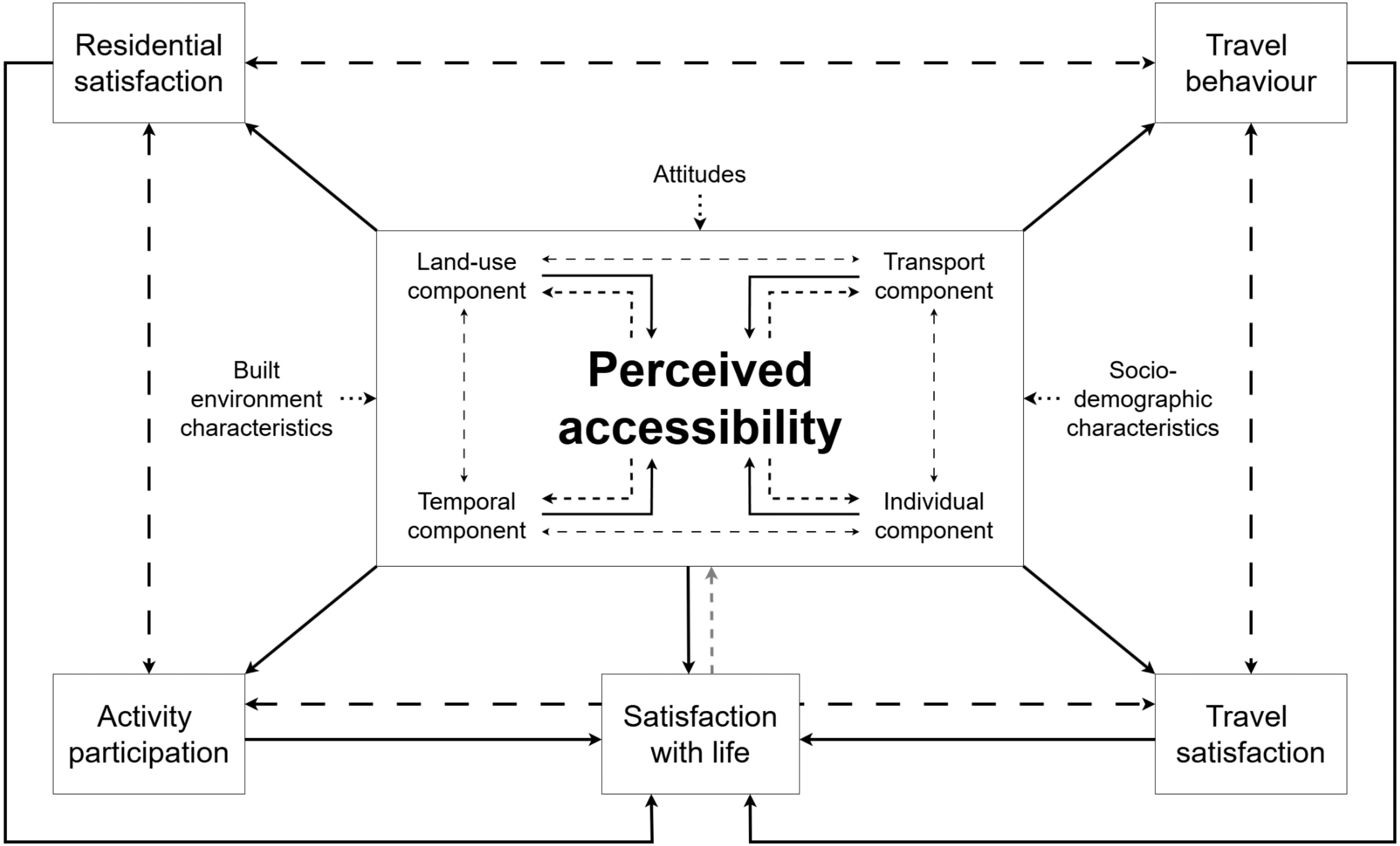

Fig. 3.3 – Conceptual framework of determinants and outcomes of perceived accessibility

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3

Methodology

3.1. A twofold approach

A twofold empirical approach is applied to understand changes in perceived accessibility and the determinants and outcomes associated with these changes. First, factors causing changes in perceived accessibility are assessed and identified using panel data regression models. Second, direct and indirect pathways from perceived accessibility to life satisfaction are examined using structural equation modelling. The literature review and conceptual model (see Chapter 2) support this twofold approach's design. The twofold approach will be detailed in subsequent order in the following subsections.

3.2. Unfolding the rationale behind changing perceived accessibility

3.2.1. Questionnaires and sampling strategy

This first analysis uses various data sources. Data on perceived accessibility is retrieved from two questionnaires distributed among respondents of the Netherlands Mobility Panel (MPN) in December 2020 and July 2023. These questionnaires posed questions on, among other things, perceived accessibility.

The data on perceived accessibility was enriched by respondents' data obtained from regular waves of the MPN. The MPN is an annual household panel that started in 2013. For these regular waves, household members complete a 3-day travel diary and fill in a questionnaire on household and personal related characteristics, such as socio-demographic characteristics, mobility tool ownership, and travel attitudes. More information on the MPN is provided by Hoogendoorn-Lanser et al. (2015).

Data from Statistics Netherlands (CBS) is used to study spatially inferred accessibility levels. CBS provides accessibility measures for several types of amenities at the neighbourhood level. Among others, accessibility of hospitals, primary and secondary schools, supermarkets, and train stations are included.

The data is linked as follows. First, a panel dataset was obtained by filtering out respondents who did not participate in both questionnaires and/or were younger than 18. This threshold has been used since only a few respondents are younger than 18, and is applied to 2020 and 2023. Second, respondents who took less than 6 minutes for the 2020 questionnaire and less than 3 minutes for the 2023 questionnaire on perceived accessibility were removed from the analysis. These thresholds for time duration are determined using boxplots. Third, spatially inferred accessibility measures were linked to participants' responses on their experienced level of accessibility using respondents' reported 6-digit postal codes. For the 2020 questionnaire, which was distributed in December 2020, spatial accessibility indicators calculated on January 1st, 2021, were linked. For the 2023 questionnaire, indicators calculated on January 1st 2023 were linked. For an accurate representation of changes in spatially inferred accessibility levels, those areas with a changed boundary for which accessibility levels were removed from the dataset. Fourth, additional personal and household data of respondents was included. For this dataset, missing values were imputed using an earlier year. In the end, a total sample of 543 individuals is obtained.

The residential areas of participants included in the analysis are highlighted in Fig 3.1 (dark areas), in combination with their residential classification. The residential classification of municipalities provided by Statistics Netherlands (CBS) is used to classify individuals as urban-, intermediate-, or rural-living. Urban municipalities are defined as those which have more than 2000 surrounding addresses per square km, whereas rural municipalities have less than 500 surrounding addresses. Municipalities that fall within are classified as intermediate. More information on the sample distribution of respondents' residential areas is detailed in Section 3.2.4.

3.2.2. Perceived accessibility

Earlier studies applied various approaches to measure individuals' perceived accessibility. Fig. 3.2 details the number of studies applying each approach, whereas Fig. 3.3 shows the ratio of studies using the Perceived Accessibility Scale (PAC) proposed by Lättman et al. (2016; 2018) versus those applying their self-made measurement scale. For this, literature retrieved from the Scopus database using the keyword 'perceived accessibility' has been reviewed. Only open-access, quantitative journal articles were considered. No Boolean operators and snowballing techniques were used or applied. The last date search was February 25th, 2025. In total, 52 articles were included in the analysis after screening the complete set of 186 articles. Interestingly, most studies in the analysis use the PAC-scale proposed by Lättman et al. (2018) to measure the overall level of perceived accessibility (18 studies apply the overall-based approach, of which 90% apply the PAC-2018 scale).

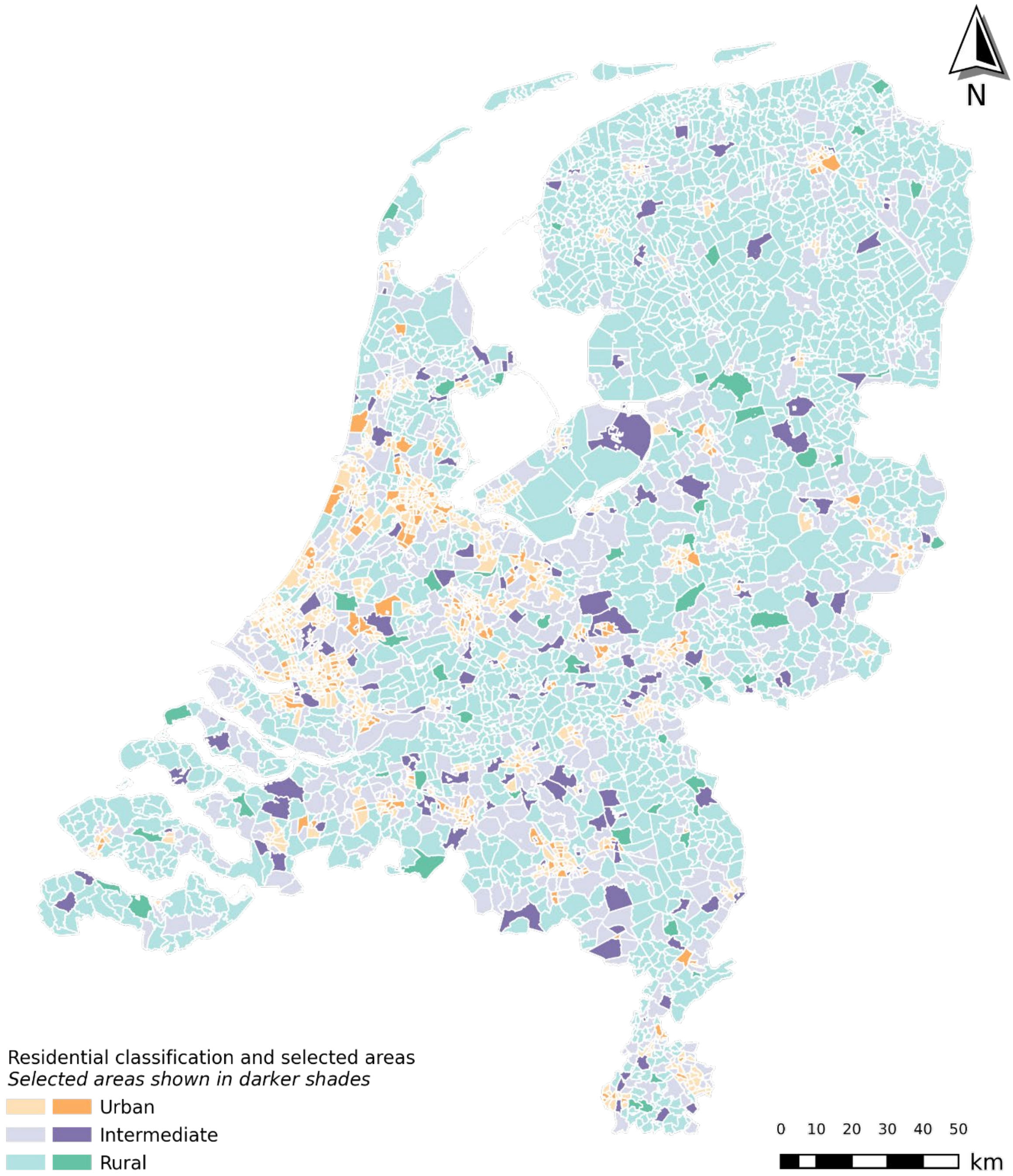

Fig. 3.1 – Residential classification of municipalities and selected areas (dark version of each colour)

Fuelled by the intention to measure the overall level of accessibility experienced by individuals, the Perceived Accessibility Scale (PAC) introduced by Lättman et al. (2018) is applied to our study. In contrast to the original PAC-scale proposed by Lättman et al. (2016), this scale does not differentiate between modes but rather measures the general level of accessibility as perceived by an individual. More specifically, this scale asks respondents to indicate the extent to which they agreed to four statements, which are formulated as "*Considering how I travel today, it's easy to do (daily) activities*", "*Considering how I travel today, I'm able to live my life as I want to*", "*Considering how I travel today, I'm able to do all the activities I prefer to do*", and "C*onsidering how I travel today, access to my preferred activities is satisfying*" (Lättman et al., 2018). For the questionnaire distributed in 2020, respondents were asked to rate the statements on a seven-point Likert scale, whereas a five-point Likert scale has been used to measure respondents their perceived accessibility in 2023. A shortcoming of this measurement scale is that the components of (perceived) accessibility, as detailed in Chapter 2, are not reflected sufficiently. This scale is mainly based on the transport component of perceived accessibility, and primarily neglects other (land-use, temporal, digital) components. This limitation is further addressed in Chapter 6.

For both years, a principal factor analysis was conducted to retrieve a single factor, for which the descriptive statistics, factor loadings and Cronbach's alpha are reported in Table 3.1. The scale measured in 2020 explains 75% of the variance (Eigenvalue $\lambda = 3.00$) with a high overall scale reliability (Cronbach's $\alpha = 0.89$) and no improvement after item deletion. The scale measured in 2023 explains 83% of the variance (Eigenvalue $\lambda = 3.33$). The Cronbach's alpha ($\alpha = 0.93$) also indicates a high overall reliability of the scale, with no improvements after item deletion as well. Lastly, the KMO (Kaiser-Meyer-Olkin) test indicates factor adequacy ($KMO_{2020} = 0.80$ and $KMO_{2023} = 0.85$). Scree plots of the decline in Eigenvalue for different number of factors are included in Appendix A.

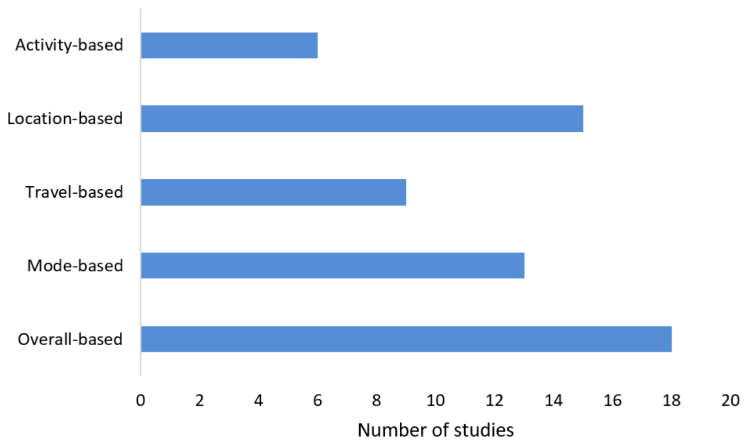

Fig. 3.2 – Application of approaches to study perceived accessibility

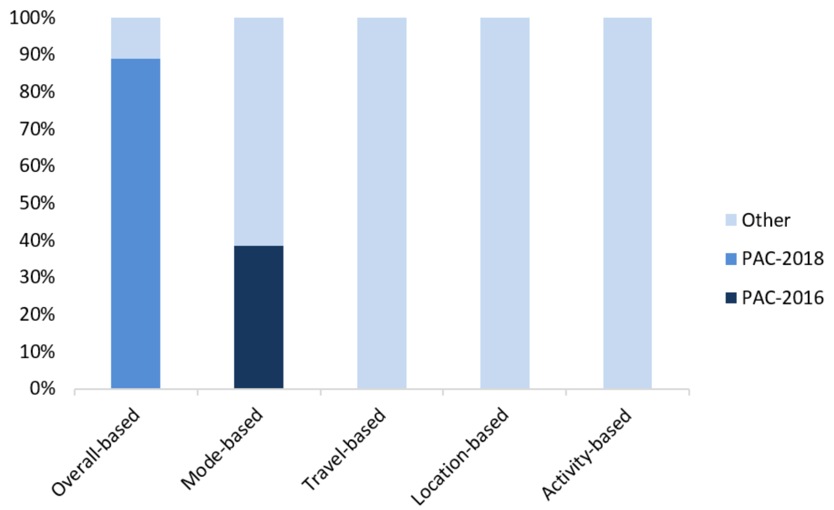

Fig. 3.3 – Percentage of studies applying the PAC-scale compared to self-developed scales

Table 3.1 – Descriptive statistics, factor loadings and change in Cronbach's alpha for items included in the PAC-index ($N = 543$, $\alpha_{2020} = 0.89$, $\alpha_{2023} = 0.93$)

Year	***"Considering how I travel today …"***	Mean	Std. Dev.	Factor loading	α if item deleted
2020	It is easy to do my daily activities	6.26 / 7	0.95	0.76	0.87
	I am able to live my life as I want to	6.03 / 7	1.14	0.89	0.84
	I am able to do all activities I prefer	5.84 / 7	1.35	0.87	0.84
	Access to my preferred activities is satisfying	6.09 / 7	1.01	0.75	0.88
2023	It is easy to do my daily activities	4.14 / 5	0.76	0.88	0.91
	I am able to live my life as I want to	4.00 / 5	0.88	0.92	0.90
	I am able to do all activities I prefer	3.95 / 5	0.91	0.92	0.90
	Access to my preferred activities is satisfying	4.05 / 5	0.80	0.82	0.93

Note. Principal axis factoring is applied to obtain PAC-factors for 2020 and 2023. $KMO_{2020} = 0.80$; Eigenvalue $\lambda_{2020} = 3.00$; $KMO_{2023} = 0.85$; Eigenvalue $\lambda_{2023} = 3.33$.

To assess changes in perceived accessibility between 2020 and 2023, factorial invariance between the two constructs is assumed. By doing so, these constructs are presumed to measure the same thing: the overall level of perceived accessibility by an individual. Nonetheless, configural, metric, and scalar invariance tests are conducted to assess whether factorial invariance indeed holds. The results of these tests are included in Appendix B, accepting weak factorial and partial strong factorial invariance for the factors with standardised items.

3.2.3. Spatial accessibility

Various spatial accessibility indicators are used to measure the level of accessibility per geographical area. A selection of measures has been made in light of potential multicollinearity and the primary, vital purpose of accessibility in terms of facilitating the opportunity to reach work, health, education, and daily groceries (Ministry of Infrastructure and Water Management, 2023). Most measures included in the analysis focus on the road distance to the nearest facilities. More specifically, measures used are the road distance to the hospital, secondary school, grocery store, train station, and highway. The number of GP offices, primary schools, and grocery stores within 5 kilometres has been included as a spatial accessibility indicator as well. In doing so, the effect of changes in the nearest opportunity versus the total number of opportunities on perceived (in)accessibility can be assessed. As highlighted in Table 3.2, the selected accessibility indicators are correlated with each other, whilst the variance inflation factor remains low (< 5). In addition to the correlations, descriptive statistics are provided for the selected indicators in Table 3.3. Whereas the distances to the nearest activity locations are relatively low, mean values are equal or lower in 2023 compared to 2020, indicating a negative trend in spatial accessibility levels. The mean number of amenities within 5 km has also declined over time. Additionally, the number of amenities within 5 km is strongly skewed, with approximately 25% of the respondents having less than 50 activity locations within 5 km (Fig. 3.4).

Table 3.2 – Two-tailed Pearson correlations between spatial accessibility indicators with Variance Inflation Factor (VIF) on diagonal

Indicator	AM	HO	SS	GS	TS	HI
Amenities within 5 km (AM)	1.65					
Distance to hospital (HO)	**- 0.44**	3.04				
Distance to secondary school (SS)	**- 0.32**	**0.39**	2.86			
Distance to grocery store (GS)	**- 0.26**	**0.28**	**0.31**	2.21		
Distance to train station (TS)	**- 0.27**	**0.37**	**0.43**	0.06	2.23	
Distance to highway (HI)	**0.18**	**- 0.11**	- 0.03	0.05	- 0.00	3.12

Note. Significant correlations with 99% confidence interval presented in bold.

Table 3.3 – Descriptive statistics of spatial accessibility indicators

Year	Indicator	Min	Max	Mean	Std. Dev.
2020	Total number of grocery stores, primary schools, and GP offices within 5 km	0.0	1288.8	167.4	219.7
	Distance to nearest hospital (km)	0.3	34.0	6.6	5.2
	Distance to nearest secondary school (km)	0.2	17.9	2.2	2.2
	Distance to nearest grocery store (km)	0.0	8.4	0.7	0.7
	Distance to nearest train station (km)	0.4	48.8	4.7	5.8
	Distance to nearest highway (km)	0.2	5.9	1.7	0.9
2023	Total number of grocery stores, primary schools, and GP offices within 5 km	1.0	1263.0	151.9	202.7
	Distance to nearest hospital (km)	0.6	34.1	6.8	5.3
	Distance to nearest secondary school (km)	0.3	17.8	2.3	2.2
	Distance to nearest grocery store (km)	0.0	5.6	0.7	0.7
	Distance to nearest train station (km)	0.5	48.9	5.0	5.9
	Distance to nearest highway (km)	0.2	7.5	1.8	1.0

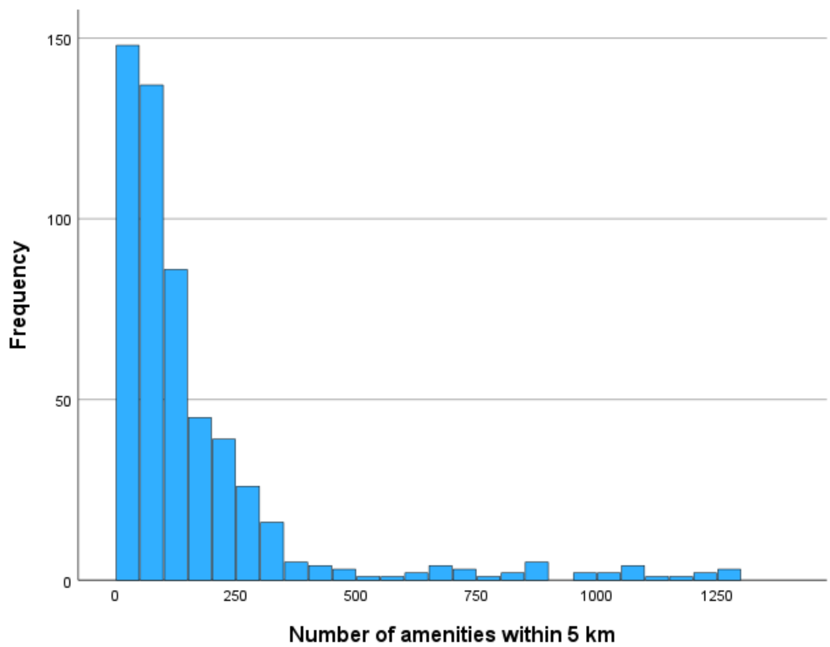

Fig. 3.4 – Distribution of spatial accessibility in wave 1 (N = 543)

3.2.4. Background variables

3.2.4.1. Socio-demographic characteristics and mobility tools

In line with the literature review (Chapter 2), several socio-demographic, mobility tools, and geographical variables are used to reflect the heterogeneity in individuals' needs, desires, and abilities. Socio-demographic variables such as gender, age, migration background, education level, employment status, net personal income, household composition, and difficulties with cycling are included. Mobility tools are measured using dummy variables, indicating whether an individual owns a driver's license, a public transport card, a bicycle, or an e-bike. Household car ownership is included in the analysis using a dummy as well. Lastly, the level of urbanity reflects differences in geographical areas.

Table 4.3 displays the descriptive statistics of the background variables in 2020. To assess the representativeness of this sample, an approximated population distribution from 2020 has also been provided. Here, the population is defined as all Dutch residents of 18 years and older. In general, the sample distributions match the population distributions, while age, migration background, level of education, bike ownership, and driver's license are notable exceptions. With regard to age, more younger adults seem to be included in the sample. The sample seems to overrepresent individuals without a migration background (outside the EU), lower-educated people, people without a bike, and individuals with a driver's license.

3.2.4.2. Attitudes

Attitudes relating to travel modes and residential location have been included in the analysis as well. For mode attitudes, respondents were asked to indicate their attitude towards car use, train use, bike use, and walking on a 5-point Likert scale ranging from 1 (strongly disagree to 5 (strongly agree) using a set of seven statements. These statements were formulated as:

- "I find travelling by [mode] comfortable",
- "I find travelling by [mode] relaxing",
- "Travelling by [mode] saves me time",
- "Travelling by [mode] is safe",
- "I find travelling by [mode] flexible",
- "Travelling by [mode] is pleasant", and
- "Travelling by [mode] gives me prestige".

Principal axis factoring was conducted to retrieve a single factor for each year, for which the factor loadings and Cronbach's alpha (after item deletion) are reported in Table 3.5. Those items with a factor loading lower than 0.5 are removed for each scale. In general, all factors show a high construct reliability. In addition to these mode-related attitudes, respondents were also asked to indicate to what extent their neighbourhood is 'easily accessible by car', 'easily accessible by bicycle, and 'easily accessible on foot' on a scale from 1 (strongly disagree) to 5 (strongly agree). A single factor is retained for this attitude towards the accessibility of the residential location through principal axis factoring. The Cronbach's alpha for both years equalled 0.82, indicating scale reliability.

Table 3.4 – Descriptive statistics of background variables (N = 543) in 2020 (wave 1)

Variables	Categories	Sample (%)	Population (%)
Socio-demographic variables			
Gender	Male	45.3	49.4
	Female	54.7	50.6
Age	18 – 34 years	18.0	29.8
	35 – 44 years	18.0	14.1
	45 – 54 years	16.0	16.8
	55 – 64 years	20.4	16.1
	65 years and older	27.4	23.2
Non-European migration background	No	96.9	82.4
	Yes	3.1	17.6
Education level	Low	21.2	30.6
	Medium	44.4	37.4
	High	34.4	32.0
Employment states	Employed	74.4	70.5
	Unemployed	25.6	29.5
Net personal income	Less than EUR 1000	15.7	19.6
	EUR 1001 to EUR 2000	28.0	28.8
	EUR 2001 to EUR 3000	37.4	26.6
	More than EUR 3000	19.0	25.0
Household size	1 person	47.0	38.5
	2 persons	32.2	32.6
	3 persons or more	20.8	28.9
Difficulties with cycling	Not at all or almost not	84.4	82.0[3]
	Somewhat	11.2	15.0[3]
	Very much	4.4	3.0[3]
Mobility tool variables			
Driver's license	No	13.6	23.0
	Yes	86.4	77.0
Public transport card	No	23.0	28.0
	Yes	83.1	72.0
Car ownership	No	16.9	15.2
	Yes	73.8	84.8
Bicycle ownership	No	35.2	23.0[4]
	Yes	64.8	77.0[4]
E-bike ownership	No	67.4	72.0
	Yes	32.6	28.0
Geographical variables			
Level of urbanity (surrounding address density per km^2)	Rural (less than 500)	22.7	33.9
	Intermediate (500 – 2000)	18.1	17.1
	Urban (more than 2000)	59.2	49.0

Data sources: Statistics Netherlands (CBS) and Dutch National Travel Survey (ODiN)
[3] Based on self-perceived health measured in 2024; [4] Based on bike use

3.2.4.3. Life events

Lastly, life events have been included to assess the effect these events on perceived accessibility as well. These life events are related to the household biography, employment biography, and digital biography, such as a new job, changes in working hours/days, or more online meetings.

Table 3.5 – An overview of attitude constructs

Construct	Items	Factor loading		α if item deleted	
		T1	T2	T1	T2
Attitude towards car use	I find travelling by car comfortable	0.81	0.91	0.87	0.85
$\alpha_{2020} = 0.89$, $\alpha_{2023} = 0.88$	I find travelling by car relaxing	0.75	0.76	0.88	0.86
	Traveling by car saves me time	0.73	0.71	0.88	0.87
	Travelling by car is safe	0.76	0.71	0.87	0.87
	I find travelling by car flexible	0.72	0.68	0.88	0.87
	Travelling by car is pleasant	0.83	0.84	0.86	0.85
Attitude towards train use	I find travelling by train comfortable	0.86	0.85	0.84	0.82
$\alpha_{2020} = 0.88$, $\alpha_{2023} = 0.86$	I find travelling by train relaxing	0.84	0.86	0.84	0.82
	Traveling by train saves me time	0.64	0.58	0.88	0.87
	I find travelling by train flexible	0.71	0.63	0.86	0.85
	Travelling by train is pleasant	0.80	0.84	0.85	0.82
Attitude towards bike use	I find cycling comfortable	0.82	0.84	0.85	0.83
$\alpha_{2020} = 0.88$, $\alpha_{2023} = 0.87$	I find cycling relaxing	0.87	0.89	0.85	0.83
	Cycling saves me time	0.57	0.54	0.89	0.88
	Cycling is safe	0.59	0.57	0.89	0.87
	I find cycling flexible	0.77	0.67	0.86	0.85
	Cycling is pleasant	0.91	0.87	0.84	0.83
Attitude towards walking	I find walking comfortable	0.85	0.82	0.83	0.83
$\alpha_{2020} = 0.87$, $\alpha_{2023} = 0.87$	I find walking relaxing	0.88	0.88	0.82	0.82
	Walking is safe	0.56	0.55	0.88	0.88
	I find walking flexible	0.60	0.61	0.88	0.87
	Walking is pleasant	0.92	0.91	0.81	0.81

A full overview of the life events included in this analysis as well as the corresponding frequency has been provided in Table 3.6. Having a new job, working from home more often, and meeting online more often are the life events that occurred the most (respectively 21.4%. 22.0%, and 24.1%).

Table 3.6 – Frequency of life events

Life event	Frequency	%
I have a new job	118	21.4
I have started to work more	51	9.3
My working hours/workdays have changed	86	15.6
My permanent work address has changed	65	11.8
I have started another educational programme or am attending a different school	34	6.2
I am now living together with my partner	17	3.1
I have moved out or am living in rented rooms	54	9.8
Someone in my household has moved out or is living in rented rooms	17	3.1
I work from home more often	121	22.0
I work elsewhere more often	40	7.3
I meet online more often	133	24.1

3.2.5. Modelling strategy

The modelling approach for this analysis aimed at identifying those factors causing changes in perceived accessibility is fivefold. First, a preliminary analysis is conducted to identify various clusters of individuals who differentiate based on their level of perceived accessibility. This allows us to understand the changes in perceived accessibility for each cluster without estimating the factors that facilitate these changes. Second, a random effects panel data regression analysis is carried out to examine the overall (both between- and within-person) effect of socio-demographic factors, built environment characteristics, attitudes, and life events on perceived accessibility. This allows us to identify those factors that explain the heterogeneity in these perceived accessibility patterns presented by the latent class analysis. Third, a fixed effects panel data model is estimated to further disentangle the within- from between-person effects. With two waves of data, this regression model allows to estimate first differences in perceived accessibility and, thus, to identify those factors contributing to changes in perceived accessibility at the within-person level. With the additional aim to assess the role of built environment characteristics in changing perceived accessibility, a fourth approach is to carry out a subgroup analysis. In doing so, those amenities and changes therein, most important to specific population subgroups, are assessed. Lastly, fuelled by a similar aim, quantile (fixed effects) regressions are conducted to evaluate whether the effect of changes in the physical environment is homogenous across the distribution of perceived accessibility. Below, a more detailed description of each element of this modelling approach is provided.

For this first analysis, a longitudinal latent class model has been estimated in Latent Gold 6.0, in which perceived accessibility indicators for 2020 and 2023 have been included. Latent class models with 1 through 10 classes were estimated to retrieve the optimal number of classes. Table 3.7 presents the corresponding model fit. Following the conventional rule of choosing the model with the lowest BIC (Bayesian Information Criterion), the 8-class model is deemed the most optimal. Given the difficulties that arise when interpreting many classes, I followed the more informal role of a minimum size of 5% for each class. Based on this rule, the 6-class latent class model was considered to be the most optimal.

Table 3.7 – Model fit of longitudinal latent class models

Clusters	Npar	BIC(LL)	Size smallest class
1	40	10459	-
2	49	9093	27,8%
3	58	8516	17,5%
4	67	8117	15,1%
5	76	7676	12,1%
6	85	7590	5,6%
7	94	7539	4,5%
8	103	7475	2,9%
9	112	7479	1,5%
10	121	7504	1,1%

To identify those factors that determine the heterogeneity in these perceived accessibility patterns identified by the longitudinal latent class model, a random effects panel data regression model is estimated. This model allows to account for unobserved entity-specific differences, capturing the time-invariant unobserved heterogeneity across individuals by adding an additional component to the error term (see formula 1). Since these unobserved entity-specific effects are assumed to be uncorrelated with the predictors, the random effects model allows to estimate both within-person and between-person effects. In doing so, predictors of differences in perceived accessibility levels can be identified.

$$Y_{it} = \beta_0 + \beta \cdot X_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

Where,

Y_{it}	is the perceived accessibility of individual i at time t;
β_0	is the intercept;
β	is the set of coefficients for the regressors;
X_{it}	is the set of regressors for individual i at time t;
α_i	is the individual-specific error component;
ε_{it}	is the time-varying error component.

Next, to reveal which factors determine transitions in perceived accessibility, a fixed effects panel data regression model is estimated. Since only two waves are used in this study, the fixed effects model collapses in a first-difference regression model, allowing one to examine (determinants of) changes in perceived accessibility between the two time periods. For this, a time-invariant intercept is estimated for each individual (see formula 2). In doing so, the model controls for individual-specific factors that remain constant over time. In other words, the fixed effects model allows identifying factors that affect within-individual variations over time (which, in this case, relates to perceived accessibility).

$$Y_{it} = \beta_i + \beta \cdot X_{it} + \varepsilon_{it} \quad (2)$$

Where,

Y_{it}	is the perceived accessibility of individual i at time t;
β_i	is the individual-specific fixed effect (time-invariant);
β	is the set of coefficients for the regressors;
X_{it}	is the set of regressors for individual i at time t;
ε_{it}	is the error term.

The fixed effects panel data model is specifically suited to control for time-invariant factors, which may confound the relationship between the set of regressors X and the dependent variable. Since this component is estimated for each entity, the fixed effects panel data model allows the estimate of within-person variations in Y, which can be attributed to changes in X. A specific drawback that comes with this, however, is that the fixed effect only controls for time-invariant factors and is unable to account for time-variant factors not included in the analysis but which may confound the relationship between Y and X. Hence, the fixed effects model only partially addresses omitted variable bias. Still, a wide range of regressors (relating to characteristics of the built environment, socio-demographics, attitudes, and life events) have been selected to control for changes therein.

A subgroup analysis is conducted to understand which factors contribute the most to changing perceived accessibility for specific subgroups of the population. More specifically, the effect of changes in spatial accessibility on changes in perceived accessibility is estimated for rural-living individuals, females, older adults, low-income individuals, single-person households, individuals without a car, people experiencing difficulties with cycling and train users. These groups are chosen in light of earlier research on heterogeneity in perceived accessibility among subgroups (e.g. Pot et al., 2023). In doing so, the effects found in this study can be compared with those found in previous studies.

In addition to estimating these panel data regression models, (fixed effects) quantile regressions are estimated to examine whether the effects found in the fixed effects regression model are homogeneous across different quantiles (in this case, perceived accessibility groups). In its original format, the fixed effects estimates will only provide the mean value for the whole sample. However, there might be heterogeneity in this mean effect across different distributional groups of perceived accessibility (e.g. those with a low versus high perceived accessibility).

The fixed and random effects models are estimated in Python 3.10.9 using Linearmodels (version 6.1), whereas the quantile regressions are estimated using Statsmodels (version 0.14.4).

3.3. Revealing pathways towards life satisfaction

The approach used to examine various pathways from perceived accessibility to life satisfaction consists of two parts. First, both direct and indirect pathways are assessed in a cross-sectional research design. Here, mediating effects through travel behaviour, travel satisfaction, activity participation, activity satisfaction, and residential satisfaction are analysed. Second, the bidirectional link between perceived accessibility and life satisfaction is examined. Using a random-intercept cross-lagged panel model, the direction and strength of this link can be assessed more thoroughly. A detailed description of each part is provided below.

3.3.1. Testing a theory on outcomes of perceived accessibility

For the purpose of (1) testing the impacts of perceived accessibility on its outcomes and (2) revealing mediating pathways from perceived accessibility to life satisfaction, a structural equation model will be developed. Such a model is commonly used to test complex causal structures, including both direct and indirect effects (see Golob, 2003).

Data from the 2020 questionnaire distributed among respondents of the Netherlands Mobility Panel will be used to estimate the structural equation model. In total, 1252 valid responses were collected. The majority of respondents are employed (69.4%) and possess a secondary education degree (43.1%), while 30.6% have a higher education degree. Women are better represented than men (respectively 52.6% and 47.4%), whereas the average age equals 46.7

years. Most respondents live in urban Dutch areas (52.8%), whereas only 27.3% are classified as rural living.

Table 3.7 provides a more detailed overview of participants' background information and population distributions. The sample generally represents the population (18+ Dutch residents), with a notable exception regarding income. Individuals with a net personal income between EUR 2000 and 3000 are overrepresented, whereas individuals with an income of more than EUR 3000 are slightly underrepresented. Chapter 6 reflects in more detail upon the representativeness of this sample.

Table 3.7 – Participants (*N* = 1252)

Variable	Categories	Sample	Population
Gender	Male	47.4 %	49.4 %
	Female	52.6 %	50.6 %
Age	Mean	46.7 years	42.4 years
Non-European migration background	No	96.9 %	82.4 %
		3.1 %	17.6 %
Level of education	Low	26.3 %	30.6 %
	Medium	43.1 %	37.4 %
	High	30.6 %	32.0 %
Employment	Unemployed	30.6 %	29.5 %
	Employed	69.4 %	70.5 %
Net personal income	Less than EUR 1000	18.6 %	19.6 %
	EUR 1001 to EUR 2000	29.2 %	28.8 %
	EUR 2001 to EUR 3000	36.1 %	26.6 %
	More than EUR 3000	16.1 %	25.0 %
Household size	1 person	40.1 %	38.5 %
	2 persons	34.8 %	32.6 %
	3 persons or more	25.1 %	28.9 %
Level of urbanity	Rural	27.3 %	33.9 %
	Intermediate	19.9 %	17.1 %
	Urban	52.8 %	49.0 %

Data source for population distribution: Statistics Netherlands (CBS)

Various measures have been included based on the outcomes identified by reviewing earlier studies (see Chapter 2). The descriptive statistics of these measures are provided in Table 3.8. Perceived accessibility is measured using a single statement formulated as 'Access to preferred activities is satisfying'. Respondents were asked to rate this statement on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Fig 3.5 presents the distribution of perceived accessibility, which is strongly skewed, with most respondents indicating a high level of perceived accessibility. As for travel mode choice, the frequency of use of car, train, bicycle, and walking was measured on a seven-point Likert scale ranging from (1) never, (2) less than 1 day per year, (3) 1 to 5 days per year, (4) 6 to 11 days per year, (5) 1 to 3 days per month, (6) 1 to 3 days per week, (7) 4 days or more per week. With respect to activity participation, the frequency of work-, medical care-, sport-, and grocery shopping-related activities was measured on a seven-point Likert scale ranging from (1) never, (2) less than 1 day per 3 months, (3) 1 to 2 days per 3 months, (4) 1 to 3 days per month, (5) 1 to 3 days per week, and (6) 4 days or more per week. For satisfaction with daily travel, activity participation, and residential location, single statements have been used as well, namely: 'All things considered, I am satisfied with how I can move around', 'It is easy to do daily activities', and 'I am satisfied with my current residential location' respectively. Respondents were asked to indicate to what extent they agreed with these statements on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Finally, life satisfaction was measured using the Satisfaction with Life Scale (SWLS) (Diener et al., 1985). The five statements are formulated as follows: 'In most ways, my life is almost ideal', 'The conditions of my life are excellent', 'I am satisfied with life', 'So far I have achieved the most important things in my life', and 'If I could start my life all over again, I wouldn't change almost anything'. For these statements, a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) was also applied.

Table 3.8 – Descriptive statistics ($N = 1252$)

Construct	**Variables**	**Mean**	**SD**
Perceived accessibility	Access to preferred activities is satisfying	6.07	0.97
Travel mode use	Driving frequency	5.22	2.21
	PT frequency	2.62	1.62
	Cycling frequency	4.41	2.37
	Walking frequency	6.12	1.49
Activity participation	Work-related activities	4.19	2.07
	Medical care-related activities	2.85	0.95
	Sport-related activities	3.56	1.74
	Grocery shopping-related activities	2.98	0.94
Travel satisfaction	All things considered, I am satisfied with how I can move around	6.31	0.82
Activity satisfaction	It is easy to do daily activities	6.24	0.95
Residential satisfaction	I am satisfied with my current residential location	6.05	1.08
Life satisfaction	In most ways my life is almost ideal	5.24	1.26
	The conditions of my life are excellent	5.54	1.13
	I am satisfied with life	5.63	1.14
	So far I have achieved the most important things in my life	5.23	1.28
	If I could start my life all over again, I wouldn't change almost anything	4.69	1.54

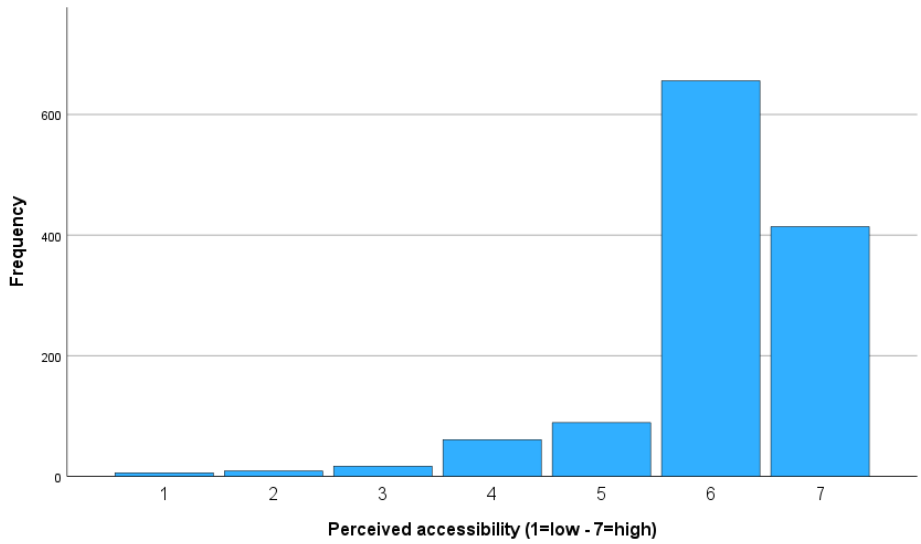

Fig. 3.5 – Distribution of perceived accessibility

Moreover, the following socio-demographic variables have been included in the model to account for possible confounding effects: age (0 = younger than 25 years, 1 = between 25 and 34 years, 2 = between 35 and 44 years, 3 = between 45 and 54 years, 4 = between 55 and 64 years, 5 = 65 years or older), gender (0 = female; 1 = male), non-EU migration background (0 = no; 1 = yes), educational attainment (0 = low (secondary school degree or less); 1 = medium; 2 = high (college or university degree)), employment status (0 = not working; 1 = working), personal net income (0 = less than EUR 1000; 1 = EUR 1001 to EUR 2000; 2 = EUR 2001 to EUR 3000; 3 = more than EUR 3000), household size (number of members in the household), car ownership (0 = no; 1 = yes), bike ownership (0 = no; 1 = yes), car driver's license (0 = no; 1 = yes), and level of urbanity (0 = extremely urban (more than 2500 surrounding addresses per square km2); 1 = very urban (2000 – 2500); 2 = moderately urban (1500 – 2000); 3 = slightly urban (500 – 1000); 4 = not urban (less than 500)). These variables have been included based on the outcomes of the first empirical analysis, which identified determinants of perceived accessibility, as well as based on earlier studies concerned with revealing mediating pathways towards life satisfaction (not necessarily using perceived accessibility) (e.g. De Vos, 2019; Mehdizadeh et al., 2025).

Due to the use of cross-sectional data, a single direction of causality is assumed. The structural equation model and corresponding direction of causality are conceptualised in Fig. 3.6. Perceived accessibility is specified as an exogenous variable and is thought to influence activity participation and travel behaviour. Out-of-home activities and travel mode use are operationalised so that they may mediate the effect of perceived accessibility on respective activity and travel satisfaction. In turn, activity and travel satisfaction may mediate the impact of perceived accessibility, activity participation, and travel behaviour on residential and life satisfaction. Besides activity and travel satisfaction, residential satisfaction is assumed to influence satisfaction with life. Error terms between behavioural outcomes (activity participation and travel behaviour) and short-term satisfaction-related outcomes (activity and travel satisfaction) are allowed to correlate. Since satisfaction with life is measured using five statements of the SWLS scale, a measurement and a structural model will be specified. The measurement model includes a latent variable for satisfaction with life. In contrast, the structural model consists of this latent variable and the other (observed) variables, allowing us to estimate the effect of perceived accessibility on its outcomes.

After estimating the whole model as depicted in Fig. 3.6, all insignificant direct effects ($p < 0.05$) are deleted using backward elimination. All correlations between error terms (significant and insignificant) are retained. The model is estimated using IBM AMOS 29 and yields a good model fit, as shown in Table 3.9.

Table 3.9 – Goodness-of-fit statistics

Fit indicator	Value
Chi-square	714.26
Degrees of freedom	249
P-value	< 0.001
CFI	0.964
RMSEA	0.039

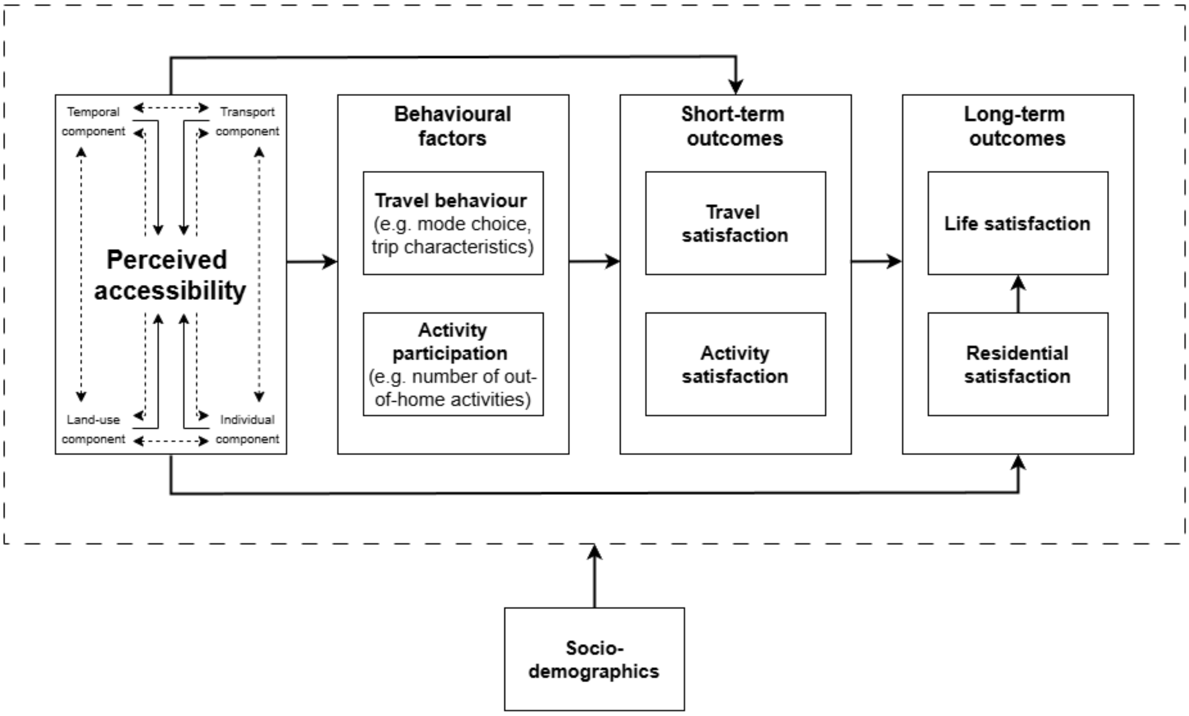

Fig 3.6 – A structural equation model of perceived accessibility and its outcomes

3.3.2. Testing a bidirectional link with life satisfaction

Multiple studies found significant associations between perceived accessibility on the one hand and travel or life satisfaction on the other hand (see Lättman et al., 2019; Sukwadi et al., 2022; Friman and Olsson, 2023; Lim et al., 2020). Despite this, the directionality of causality between these two constructs has not yet been empirically assessed. Instead, most studies assume that perceived accessibility directly or indirectly (through travel satisfaction) impacts individuals' life satisfaction. However, this effect might be the other way around as well.

This notion originates in the Broaden and Build theory, which articulates that *'positive emotions … broaden peoples' momentary thought-action repertoires and build their enduring personal resources'* (Fredrickson, 2004, p.1369). As depicted in Fig. 3.7, these positive emotions may ultimately enhance health, fulfilment, and life satisfaction. Afterwards, this enhanced well-being produces even more positive emotions, resulting in an upward spiral of greater satisfaction. In the context of daily travel, satisfaction with trips and activities may broaden the cognitive evaluation of one's experienced level of accessibility, resulting in increased satisfaction with life. This increased life satisfaction may result in even more positive emotions and, in turn, greater perceived accessibility.

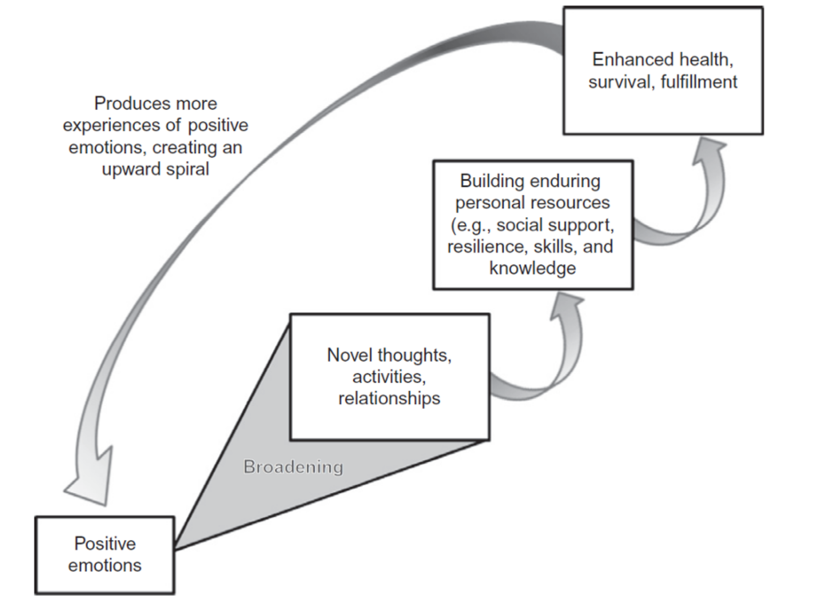

Fig. 3.7 – Broaden-and-build theory (source: Yarwood, 2022)

This last analysis aims to examine these possible carry-over effects between perceived accessibility and life satisfaction in more detail. For this, a longitudinal approach will be carried out to assess the strength and directionality of these effects. More specifically, a Random-Intercept Cross-Lagged Panel Model (RI-CLPM) (Hamaker et al., 2015) will be estimated, as this is a standard method to test causal reciprocal effects between two or more constructs using panel data. In doing so, this panel analysis allows to identify whether those individuals experiencing lower levels of accessibility are more prone to translate these lower levels into dissatisfaction with life and determine effects in the opposite direction (dissatisfaction with life resulting in individuals evaluating their accessibility levels as lower). Additionally, a subgroup analysis will be carried out to identify whether the relationship between perceived accessibility and life satisfaction differs across different social groups. Some (vulnerable) groups may experience more divergent emotions and/or perceptions than others, reducing their ability to broaden their momentary thought-action repertoires, which will be examined using the subgroup analysis.

3.3.2.1. Data and measures

A self-administered questionnaire was distributed among the Netherlands Mobility Panel respondents in 2020, 2023, and 2024. These surveys posed questions on, among other thing, the experienced level of accessibility, for which the Perceived Accessibility Scale (PAC) introduced by Lättman et al. (2018) was used.

The items were measured on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) in 2020 and 2024. In contrast, the statements were measured using a 5-point Likert scale in 2023. Fig. 3.8 presents the distributions of these statements for the first wave. Notably, the distributions of all four statements are highly skewed, with most respondents (strongly) agreeing with all statements. In other words, most respondents experience high levels of accessibility. Still, a small share of the sample perceive lower levels of accessibility to at least some degree.

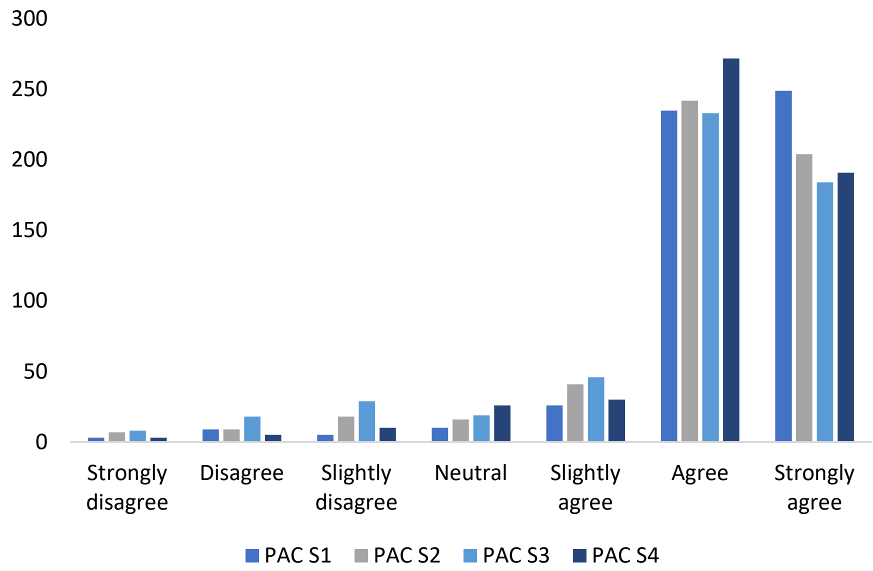

Fig. 3.8 – Distributions of Perceived Accessibility Scale (PAC) statements (wave 1)

Data from the regular waves of the Netherlands Mobility Panel are used to measure life satisfaction. Here, the Satisfaction with Life Scale (SWLS) (Diener et al., 1985) has been employed to measure respondents' life satisfaction, similarly to the measurement scale used for assessing mediating pathways (see Section 3.3.1). Fig. 3.9 presents the distributions of the SWLS items, highlighting a more nuanced response than respondents' perceived accessibility. Most respondents indicate that they (slightly) agreed with the four statements, with only a minor group of individuals strongly agreeing. While the distribution is slightly skewed, the skewness is less than that of PAC items.

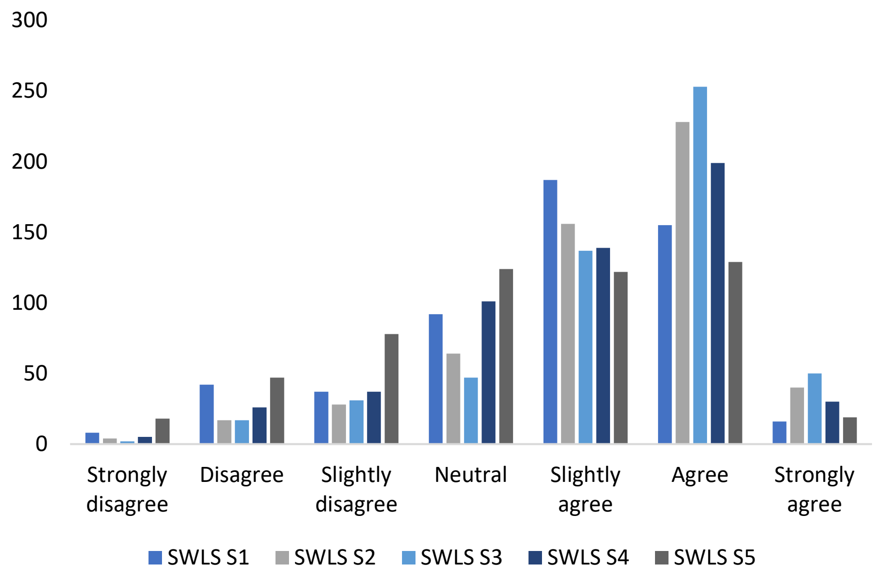

Fig. 3.9 – Distributions of Satisfaction with Life Scale (SWLS) for wave 1 (2020)

Table 3.10 presents the confirmatory factor analysis. The results show that, for both perceived accessibility and life satisfaction, the items converged on a single respective factor. All factor loadings are sufficiently high (all > 0.65), with the Cronbach's alpha indicating internal consistency (both > 0.8). The correlation between the factor scores equals 0.349 and is significant at the 1% level.

Table 3.10 – Confirmatory factor analyses with Varimax rotation (wave 1)

	Factor 1	Factor 2
Factor loadings		
it's easy to do (daily) activities	0.818	
I'm able to live my life as I want to	0.874	
I'm able to do all the activities I prefer to do	0.866	
access to my preferred activities is satisfying	0.748	
In most ways my life is almost ideal		0.832
The conditions of my life are excellent		0.768
I am satisfied with life		0.893
So far I have achieved the most important things in my life		0.719
If I could start my life all over again, I wouldn't change almost anything		0.666
Scale statistics		
Cronbach's alpha of scale	0.902	0.888
Scale variance	16.855	28.729
Correlation between both factor scores	0.349	

3.3.2.2. Participants

An overview of participants' socio-demographic characteristics and an approximated population distribution of these characteristics are presented in Table 3.11. Here, the population is defined as all Dutch residents aged 15 years or older. Collectively, the sample distribution matches the distribution of socio-demographic factors in the population, with notable exceptions for age, income, and household car ownership. With regard to age, the sample underrepresents individuals aged between 15 and 35 years and overrepresents older adults to a large degree. In addition, individuals with a net personal income of EUR 3000 or more are also overrepresented in the sample. Lastly, individuals with two or more cars in households are strongly underrepresented. The implication of the overrepresentation of certain groups is discussed in Chapter 6.

Table 3.11 – Respondents' background information in wave 3 ($N = 542$)

Variable	Categories	Sample	Population [a]
Gender	Male	52.4	50.5
	Female	44.8	49.5
	Missing	2.8	-
Age	15-25	2.6	17.6
	25-35	7.7	15.0
	35-45	17.7	14.0
	45-55	13.5	14.5
	55-65	17.7	15.6
	65+	38.0	23.4
	Missing	2.8	-
Migration background	No	89.3	83.8[b]
	Yes	7.6	16.2[b]
	Missing	3.1	-
Level of education	Low	61.6	64.4
	High (university or college degree)	32.8	35.6

	Missing	5.5	-
Employment	Unemployed	28.8	38.1
	Employed	62.4	61.9
	Missing	8.9	-
Net personal income	Less than EUR 1000	3.7	24.8
	EUR 1001 to EUR 2000	22.0	27.8
	EUR 2001 to EUR 3000	33.6	26.8
	EUR 3001 to EUR 4000	19.2	12.4
	More than EUR 4000	18.8	8.2
	Missing	2.8	-
Household size	1 person	43.9	39.9
	2 persons	36.0	32.3
	3 persons or more	17.3	27.8
	Missing	2.8	-
Level of urbanity	Not urban	7.6	6.9
	Slightly urban	15.1	20.9
	Moderately urban	16.2	16.1
	Very urban	31.0	29.7
	Extremely urban	27.1	26.4
	Missing	3.0	-
Household car ownership	0	17.5	16.3
	1	60.7	47.7
	2 or more	19.0	36.0
	Missing	2.8	-

[a] Data sources for population distribution: Statistics Netherlands (CBS) and Dutch National Travel Survey (ODiN)

[b] Value for whole population

3.3.2.3. Method and approach

To test the bidirectional relationships between perceived accessibility and life satisfaction, a random-intercept cross-lagged panel model (RI-CLPM) is used. In this section, the RI-CLPM is discussed in some more detail (for a full description, see Hamaker et al., 2015).

Fig. 3.10 presents a general structure of the RI-CLPM. In this model, x_t and y_t are the observed variables, for which each variable is linked to a latent variable (p_t for x_t and q_t for y_t). The factor loadings are constrained to 1. Temporal means μ_t and π_t are included for each wave as well. In doing so, the latent variables p_t and q_t capture individuals' temporal deviations from the sample mean. However, to account for the trait-like, time-invariant stability of the variables, random intercepts k and w are used. These intercepts effectively separate within-person from between-person differences over time. To capture trait-like, time-invariant influences on the outcomes, the paths between the random intercepts and observed variables are constraint to 1. In doing so, the random intercepts capture between-person differences, allowing the autoregressive α_t and δ_t and cross-lagged relations β_t and γ_t to solely capture within-person effects. The cross-lagged paths are of interest in this study, since these paths indicate to what extent perceived accessibility and life satisfaction impact each other over time. In addition, the correlation between random intercepts k and w indicates to what extent perceived accessibility and life satisfaction are correlated on the between-person level.

Since perceived accessibility and life satisfaction are both measured using multiple indicators, we rely upon an extension of the RI-CLPM as described by Mulder and Hamaker (2020). In this regard, a measurement model with a common factor for each construct at each occasion is included (rather than observed variables x_t and y_t as depicted in Fig. 3.10). The random intercepts for both perceived accessibility and life satisfaction are included at the measurement level. A schematic overview of such an extended RI-CLPM is presented in Fig. 3.11. Note that in the present study 3 rather than 5 waves of data are included.

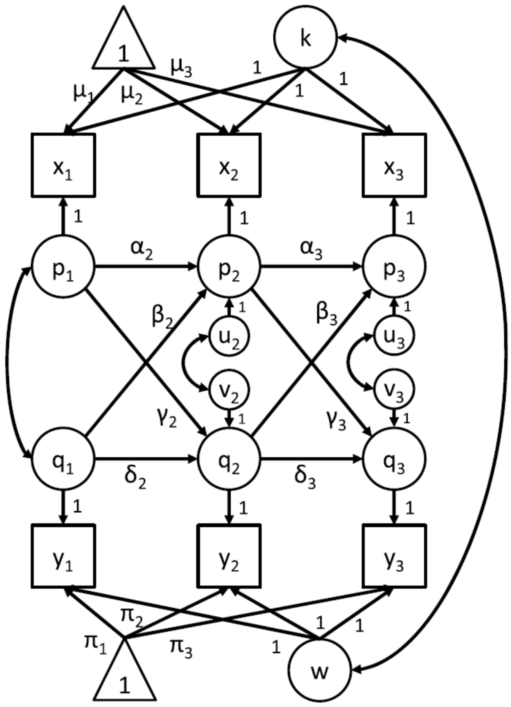

Fig. 3.10 – A 3-wave random-intercept cross-lagged panel model (Hamaker et al., 2015)

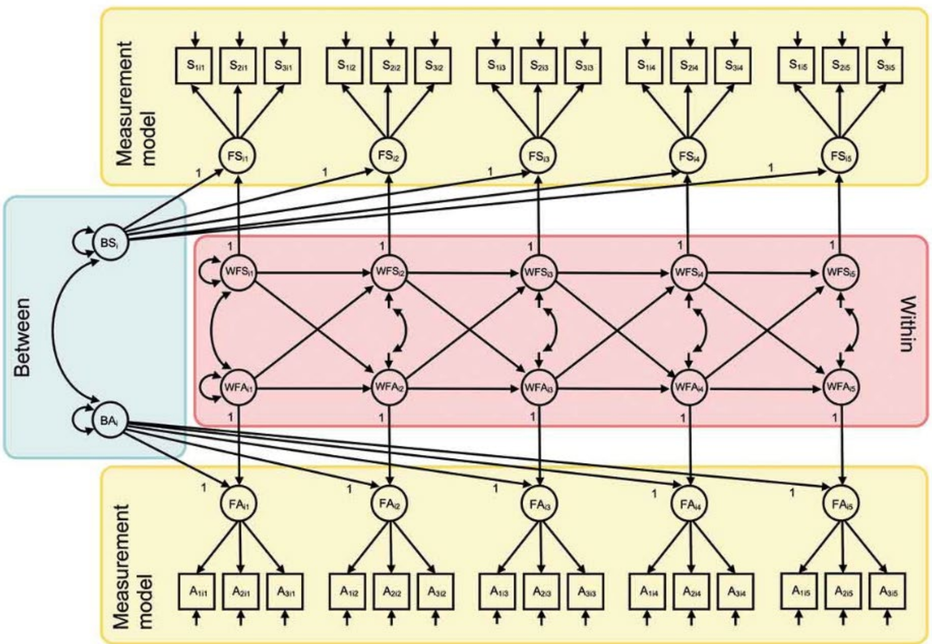

Fig. 3.11 – An extension of the RI-CLPM

Table 3.12 presents the goodness-of-fit statistics of various cross-lagged panel models. First, the conventional CLPM has been estimated as a baseline. RI-CLPM with configural, metric, and scalar factorial invariance have been estimated to assess whether longitudinal factorial invariance holds. The RI-CLPM with configural factor invariance (e.g. factor structure invariant over time) slightly improves model fit compared to the CLPM, indicating that the RI-CLPM captures between-person differences using the random intercepts. Both the model fit of the RI-CLPM with metric (e.g. factor loadings invariant over time) and scalar (e.g. factor loadings and intercepts invariant over time) factorial invariance indicates that strong factorial invariance holds for both the PAC and SWLS. The factorial constraints imposed on the model do not significantly harm the model fit since the Chi-square difference test is insignificant in both cases. Other goodness-of-fit statistics (CFI, RMSEA, SRMR) also differ slightly.

Additionally, an RI-CLPM with equality-constrained lagged parameters was estimated to assess whether the autoregressive and carry-over effects remain constant over time. Following the Chi-square difference test results, which do not reach statistical significance, it is assumed that the within-person (autoregressive and cross-lagged) effects are time-invariant.

As a final step, socio-demographic characteristics presented in Table 3.11 have been included as predictors of the random intercepts. In doing so, we control for possible confounding effects which may be present. All models have been estimated with the MLR (maximum likelihood with robust standard errors) estimator in Mplus 8.5. This estimator is less sensitive to non-normality and non-independence, leading to more robust parameter estimates and standard errors.

Table 3.12 – Goodness-of-fit statistics

	CLPM *Configural*	**RI-CLPM** *Configural*	**RI-CLPM** *Metric*	**RI-CLPM** *Scalar*	**RI-CLPM** *Scalar & parameter constraints*
Df	313	310	324	336	340
Chi-square	1171	1143	1148	1167	1168
Df difference	-	3	14	12	4
Chi-square difference	-	28 ($p < 0.001$)	5 ($p = 0.986$)	19 ($p = 0.089$)	1 ($p = 0.910$)
CFI	0.903	0.906	0.907	0.906	0.906
RMSEA	0.071	0.070	0.068	0.068	0.067
SRMR	0.058	0.053	0.054	0.054	0.055

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Appendix A

Fig. A1 and A2 highlight the optimal number of factors for perceived accessibility in 2020 and 2023, based on the Eigenvalue of each factor. For both scales, a single factor is adequate and used in the first empirical analysis.

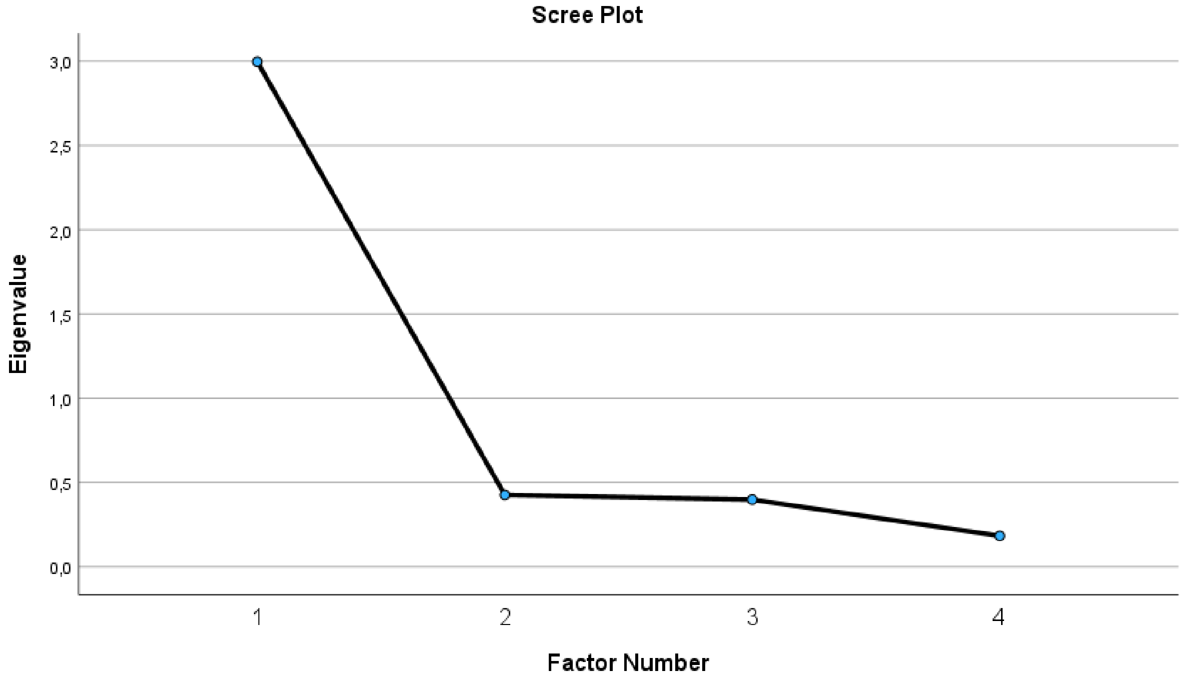

Fig. A1 – Scree plot indicating optimal number of factors for perceived accessibility in 2020

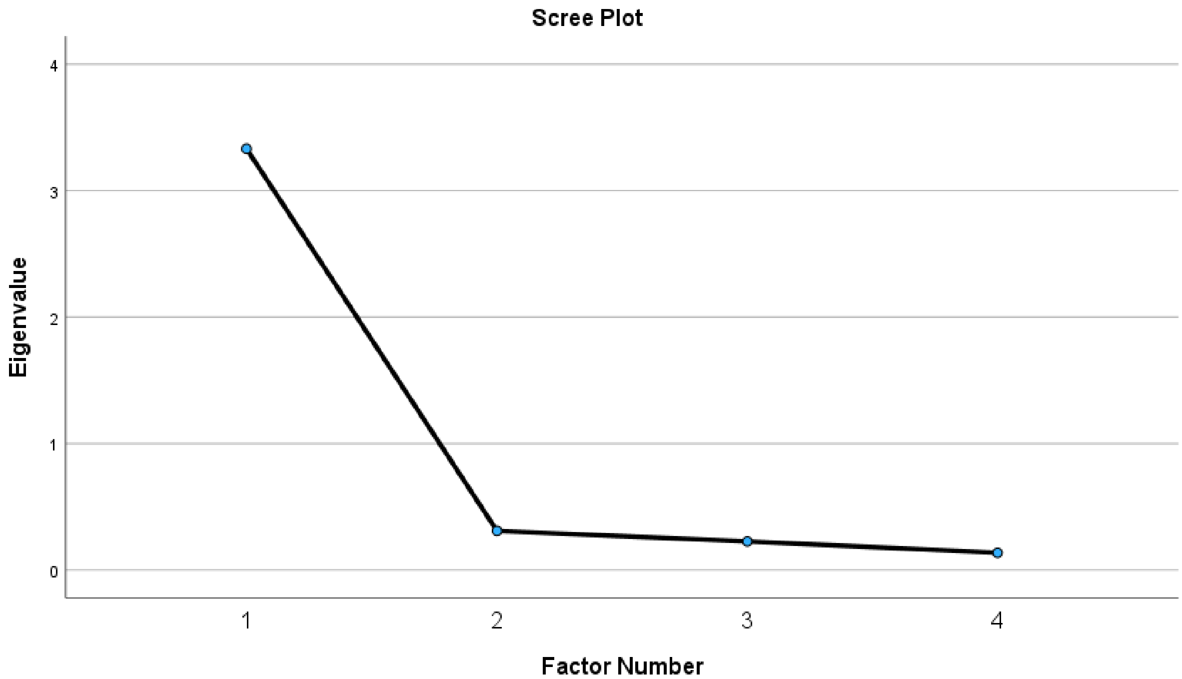

Fig. A2 – Scree plot indicating optimal number of factors for perceived accessibility in 2023

Appendix B

Table B1 shows results of the factorial invariance tests, highlighting the factorial variation between the original items but partial factorial invariation between standardised items (when partially relaxing intercept constraints).

Table B1 – Longitudinal factorial invariance results

Model	χ2 (df)	CFI	RMSEA (90% CI)	SRMR	Model comp.	Δχ2 (df)	ΔCFI	ΔRMSEA	ΔSRMR	Decision
Factor										
M1: Configural invariance	110.694 * (19)	.972	.094 (.078-.112)	.040	--	--	--	--	--	--
M2: Metric invariance	137.194 * (22)	.965	.098 (.083-.114)	.050	M1	26.501 * (3)	.007	.004	.010	Reject
M3: Scalar invariance	94.488 * (18)	.976	.091 (.074-.109)	.048	M2	38.706 * (4)	.011	.007	.002	Reject
Factor of standardised items										
M6: Configural invariance	110.694 * (19)	.972	.094 (.078-.112)	.040	--	--	--	--	--	--
M7: Weak factorial (metric) invariance	115.982 * (22)	.972	.089 (.073-.105)	.040	M6	5.289 (3)	.000	.005	.000	Accept
M8: Scalar (strong factorial) invariance	73.573 * (18)	.983	.075 (.058-.094)	.034	M7	42.409 * (4)	.011	.014	.006	Reject
M8a: Partial scalar invariance	114.612 * (20)	.971	.093 (.077-.110)	.037	M7	1.370 (2)	.001	.004	.003	Accept

Note. N = 543; Signif. codes: * $p \leq .05$

4

Unfolding the rationale behind changing perceived accessibility

This chapter presents the results of the first empirical analysis, which aims to provide a more thorough understanding of the determinants of (changes in) perceived accessibility. Following the modelling approach detailed in Chapter 3, the various parts of this analysis will be discussed in subsequent order.

4.1. Revealing perceived accessibility profiles

The six perceived accessibility profiles are presented in Fig 4.1. The vertical axis shows the normalised perceived accessibility score, whereas the horizontal axis depicts the PAC statements for each year. Collectively, the latent trajectories reflect partial variations in the initial level of accessibility experienced by individuals (first four statements) and in the transitions to another level over time (changes are shown between statement 4 in 2020 and statement 1 in 2023). The largest class (40% of the sample) consists of individuals who experienced the highest level of accessibility in 2020 and who did not transition towards a higher or lower level over time. The fourth and fifth classes (respectively 12% and 11% of the sample) initially had a satisfactory level of accessibility, with a score of 80% out of 100%. However, they changed their perceived accessibility over time. Whereas the fourth class transitions towards the highest level possible, the group of individuals in the fifth class drastically downscale their perceived accessibility over time. A relatively large body of individuals perceive their level of accessibility as very good (around 31% of the sample), whilst half of these individuals (second class; 16% of the sample) did adjust their perceived accessibility to satisfactory. Lastly, only a small portion of the sample (sixth class; 6% of the sample) consistently experiences a low level of accessibility compared to the other classes.

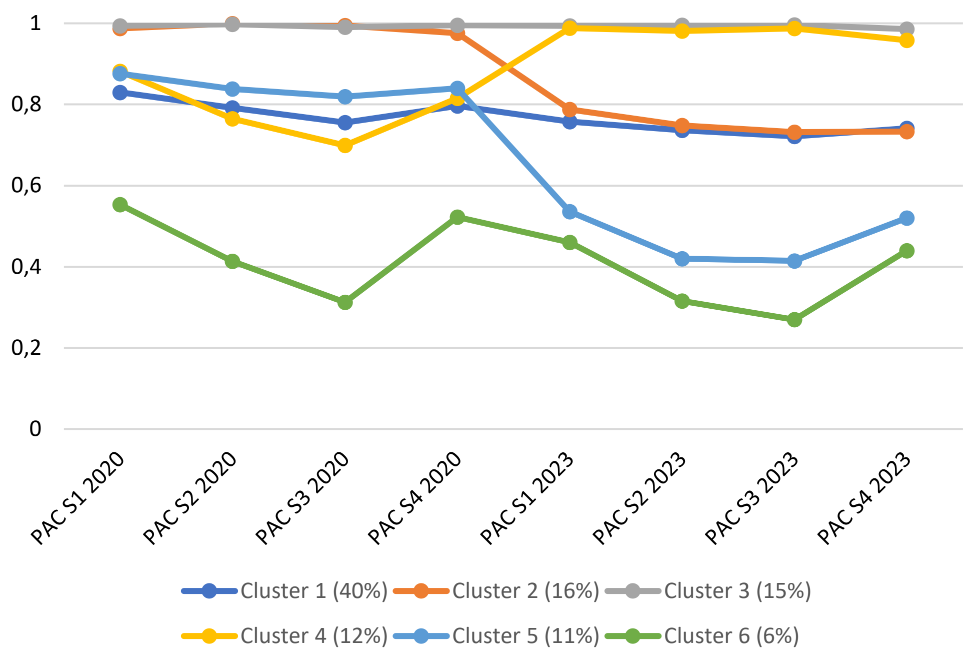

Fig 4.1 – Latent trajectories in perceived accessibility between 2020 and 2023 for six classes

4.2. Determinants of variations in perceived accessibility

Table 4.1 shows the results of the random effects regression analysis. This analysis aims to understand the determinants of the heterogeneity in perceived accessibility patterns highlighted by the longitudinal latent class model in section 4.1. The first model only includes spatial accessibility indicators, whereas the second and third models include (1) socio-demographics and (2) attitudes and life events.

In the first model, characteristics of the built environment in terms of spatial accessibility do not reach statistical significance. In other words, these spatial accessibility indicators do not differ significantly from zero and, thus, do not explain the differences in perceived accessibility. This is in line with the explained variance of perceived accessibility by these indicators, which is almost zero (0.3%).

Respondents' sociodemographic characteristics are accounted for in the second model, with a relatively significant increase in explained variance (12.5%). As of this, sociodemographic rather than built environment characteristics seem to determine the variations in perceived accessibility across individuals. More specifically, age, migration background, level of education, physical health, personal income, car ownership, and bike ownership significantly affect perceived accessibility. Here, migration background, physical health, and car ownership contribute the most, with the results indicating that individuals with a non-EU migration background have lower levels of perceived accessibility. Those individuals experiencing difficulties with cycling and without a car in the household also experience lower accessibility levels. Interestingly, most spatial accessibility indicators remain insignificant, except for the number of amenities within 5 kilometres. Here, a higher (lower) number of amenities in proximity will contribute to a higher (lower) perceived accessibility. Still, the corresponding coefficient highlights that variations in the number of amenities only limitedly contribute to variations in perceived accessibility.

Table 4.1 – Unstandardised coefficients of the random effects models with covariates predicting perceived accessibility (2020 – 2023)

	Estimate	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**
Intercept	- 0.098	0.320	- 0.453	0.027	- 0.335	0.095
Spatial indicators						
Amenities within 5 km	0.000	0.282	0.000	0.017	0.000	0.018
Distance to nearest hospital	- 0.000	0.976	0.000	0.966	- 0.003	0.636
Distance to nearest secondary school	0.006	0.735	- 0.002	0.894	- 0.002	0.920
Distance to nearest grocery store	0.030	0.538	0.016	0.796	0.038	0.388
Distance to nearest train station	- 0.004	0.545	- 0.002	0.782	- 0.000	0.984
Distance to nearest highway	0.030	0.390	0.037	0.254	0.030	0.335
Socio-demographic variables						
Female (ref.: male)			0.030	0.661	0.016	0.814
Age			0.060	0.016	0.041	0.103
Migration background (ref.: no)			- 0.402	0.027	- 0.377	0.031
Level of education			0.082	0.089	0.069	0.139
Employed (ref.: no)			- 0.028	0.705	- 0.046	0.520
Personal income			0.074	0.032	0.065	0.055
Household size			0.037	0.248	0.039	0.218
Difficulty with cycling			- 0.288	0.000	- 0.258	0.000
Driver's license (ref.: no)			0.022	0.827	0.022	0.824
Public transport card (ref.: no)			- 0.033	0.648	- 0.032	0.652
Car ownership (ref.: no)			0.311	0.002	0.259	0.009
Bicycle ownership (ref.: no)			0.150	0.022	0.094	0.153
E-bike ownership (ref.: no)			0.055	0.406	0.050	0.449
Attitudes						
Attitude towards accessibility of residential location					0.119	0.000
Attitude towards car					0.063	0.053
Attitude towards public transport					0.039	0.229
Attitude towards biking					0.004	0.907
Attitude towards walking					0.122	0.000
Life events						
A new job					- 0.108	0.317
Started to work more					0.021	0.876
Working hours/workdays have changed					- 0.066	0.574
Work address changed					0.105	0.445
Started an educational program					0.083	0.584
Living together with partner					0.105	0.637
Moved out					0.226	0.075
Someone in household moved out					0.250	0.232
I work from home more often					- 0.132	0.227
I work elsewhere more often					- 0.146	0.313
I meet online more often					0.235	0.022
Model fit						
R-squared	0.003		0.125		0.180	

In the last model, attitudes and life events are included as well. These model results highlight no changes in the effect of spatial accessibility indicators on perceived accessibility, with a significant effect only on the number of amenities. The sociodemographic factors that contributed the most to the second model remained significant, in addition to the effect of people's net income. In contrast, the other factors that explained perceived accessibility differences in the second model (age, level of education, bike ownership) became insignificant. Instead, the attitude towards the residential location, car use, and walking positively influence people's perceived ease of reaching destinations. Lastly, meeting online more often does affect perceived accessibility positively too.

Only a small portion of the variation in perceived accessibility is explained by characteristics of the built environment, sociodemographic factors, attitudes, and life events. The final model retained an explained variance of 18%, highlighting that almost 82% of the variation in perceived accessibility remained unexplained. The relative contribution of built environment characteristics to the 18% of explained variance is somewhat limited, highlighting that respondents' background information contributes the most.

4.3. Factors causing changes in perceived accessibility over time

The results of the fixed effects regression analyses are presented in Table 4.2, highlighting those factors that contribute to transitions in perceived accessibility at the within-person level. The model structure applied is similar to that used in the random effects model: starting with spatial accessibility indicators only, followed by adding sociodemographic variables, and finally including attitudes and life events.

The first model shows that changes in the spatially-determined level of accessibility do affect perceived accessibility. More specifically, an increase in the number of amenities seems to decrease individuals' experienced level of accessibility. This may follow from a slight overrepresentation of urban Dutch areas in the sample, which have many nearby amenities, resulting in low marginal benefits of an additional amenity. Using a similar train of thought, the type of amenities (primary school, doctor's offices, and grocery stores) can be seen as vital and will most likely be accessibility across all areas in the country. Moreover, increasing distances to the nearest secondary school, grocery store, and train station translate into lower perceived accessibility.

When controlling for respondents' sociodemographic characteristics, which may confound the relationship between the spatial accessibility indicators and perceived accessibility, the influence of changes in the number of amenities on perceived accessibility no longer reaches statistical significance. However, changes in the distance to the nearest secondary school, grocery store, and train station still (partly) explain changes in perceived accessibility. An increase in distance to these amenities, due to the loss of amenities, significantly reduces people's perceived ease of reaching destinations. Additionally, changes in mobility tool ownership do significantly affect changes in perceived accessibility. Both household car ownership and personal bike ownership contribute positively to people's transitions in perceived accessibility. In other words, individuals becoming in possession of a car or bike will have a positive impact on the experienced level of accessibility of those individuals. Conversely, individuals may develop lower perceived accessibility when they lose a car or bike.

Accounting for changes in attitudes and the occurrence of life events does not drastically change these model results. Changes in mobility tool ownership and distances to the nearest amenities still significantly change the perceived level of accessibility. Additionally, an increase (decrease) in the number of household members results in a higher (lower) perceived accessibility.

Table 4.2 – Unstandardised coefficients of the fixed effects models with covariates predicting changes in perceived accessibility (2020 – 2023)

	Estimate	P-value	Estimate	P-value	Estimate	P-value
Spatial indicators						
Amenities within 5 km	- 0.001	0.023	- 0.001	0.154	- 0.001	0.298
Distance to nearest hospital	0.023	0.345	0.028	0.261	0.032	0.217
Distance to nearest secondary school	- 0.130	0.023	- 0.127	0.024	- 0.126	0.034
Distance to nearest grocery store	- 0.149	0.040	- 0.161	0.022	- 0.149	0.059
Distance to nearest train station	- 0.037	0.068	- 0.043	0.048	- 0.046	0.077
Distance to nearest highway	0.132	0.185	0.152	0.128	0.154	0.123
Socio-demographic variables						
Age			0.155	0.176	0.105	0.373
Level of education			- 0.040	0.900	- 0.117	0.716
Employed (ref.: no)			- 0.188	0.164	- 0.218	0.121
Personal income			0.128	0.250	0.118	0.342
Household size			0.145	0.240	0.222	0.089
Difficulty with cycling			- 0.056	0.413	- 0.091	0.194
Driver's license (ref.: no)			0.414	0.149	0.390	0.162
Public transport card (ref.: no)			- 0.005	0.973	0.068	0.637
Car ownership (ref.: no)			0.384	0.038	0.329	0.080
Bicycle ownership (ref.: no)			0.248	0.025	0.273	0.016
E-bike ownership (ref.: no)			- 0.105	0.303	- 0.118	0.256
Attitudes						
Attitude towards accessibility of residential location					0.070	0.201
Attitude towards car					0.035	0.554
Attitude towards public transport					- 0.002	0.971
Attitude towards biking					- 0.087	0.181
Attitude towards walking					0.031	0.603
Life events						
A new job					- 0.180	0.148
Started to work more					0.152	0.449
Working hours/workdays have changed					0.113	0.469
Work address changed					0.089	0.611
Started an educational program					0.137	0.485
Living together with partner					0.214	0.294
Moved out					0.018	0.897
Someone in household moved out					0.252	0.150
I work from home more often					- 0.092	0.544
I work elsewhere more often					- 0.194	0.292
I meet online more often					0.210	0.123
Model fit						
R-squared	0.018		0.056		0.083	

Note. Robust standard errors are used to compute significance

While the fixed-effects regression model identified several factors contributing to changes in perceived accessibility, the explained variance of all three models is relatively low (at best 8.3%). In other words, other factors that do not relate to characteristics of the built environment, sociodemographics, attitudes, and life events explain perceived accessibility to a larger extent.

4.4. Effects for specific subgroups

Table 4.3 presents the results of the subgroup analyses used to assess whether the relative contribution of changes in the physical environment differed across social groups of the population. With regard to rural living and low-income individuals, only the distance to the nearest supermarket reaches statistical significance. For rural-living individuals, this result suggests that the loss of a supermarket nearby is experienced more detrimental in areas with fewer amenities. For individuals with a lower income, Pot et al. (2023) argue that preventing unnecessary daily travel costs may be an incentive, resulting in low-income individuals' preference for daily necessities nearby.

Not having a car, difficulties with cycling, and train use do not translate into a different appreciation of changes in the number of amenities nearby or distances to these amenities. Still, it may be the case that a combination of factors, such as not having a car and living in rural areas, ultimately will translate into a different appreciation of spatial accessibility. However, the subgroups of combinations of social factors are too small to estimate such effects. Nonetheless, this notion has been tested extensively by Moleman and Kroesen (2025) based on cross-sectional data.

Concerning the distance to the nearest train station, this has only reached significance for the subgroup with women. The impact of the number of amenities nearby and the distance to the nearest supermarket are also appreciated differently by women. While previous research has found that distances to educational facilities are relatively important to women (e.g. Pot et al., 2023), our results contradict this observation. Distance changes to secondary school do not necessarily develop into a different experienced level of accessibility. Instead, the distance to the nearest supermarket and train station negatively influences the perceived accessibility of women.

Table 4.3 – Unstandardised coefficients of the fixed effects model predicting changes in perceived accessibility for different groups (2020 – 2023)

	Full sample	Rural areas	Women	Age (65+)	Income (< €1000)	No car in household	Single-person household	Difficulties with cycling	Train users
Intercept	**0.341**	0.450	0.191	0.393	0.177	0.654	0.283	- 2.554	0.335
	(0.028)	(0.765)	(0.267)	(0.458)	(0.563)	(0.681)	(0.432)	(0.444)	(0.942)
Number of amenities	**- 0.001**	- 0.025	**- 0.001**	**- 0.003**	- 0.001	- 0.003	- 0.001	- 0.002	0.001
	(0.023)	(0.464)	**(0.020)**	**(0.022)**	(0.086)	(0.287)	(0.156)	(0.775)	(0.962)
Distance to hospital	0.023	0.266	0.032	- 0.025	0.035	- 0.005	**0.063**	0.244	0.075
	(0.345)	(0.069)	(0.216)	(0.603)	(0.076)	(0.956)	**(0.006)**	(0.626)	(0.772)
Distance to sec. school	**- 0.130**	- 0.068	- 0.108	0.060	- 0.092	- 0.515	**- 0.202**	0.981	- 0.291
	(0.023)	(0.527)	(0.093)	(0.417)	(0.470)	(0.502)	**(0.001)**	(0.541)	(0.868)
Distance to grocery store	**- 0.149**	**- 0.264**	**- 0.188**	- 0.880	**- 0.274**	- 1.167	**- 0.229**	- 1.198	0.073
	(0.040)	**(0.000)**	**(0.009)**	(0.104)	**(0.000)**	(0.298)	**(0.001)**	(0.339)	(0.989)
Distance to train station	- 0.037	- 0.348	**- 0.064**	- 0.012	- 0.057	0.012	- 0.033	- 0.135	- 0.407
	(0.068)	(0.075)	**(0.011)**	(0.774)	(0.415)	(0.967)	(0.587)	(0.757)	(0.638)
Distance to highway	0.132	0.634	0.184	0.396	0.105	0.559	0.056	- 0.111	0.374
	(0.185)	(0.213)	(0.181)	(0.302)	(0.565)	(0.519)	(0.691)	(0.942)	(0.615)
Model fit									
Observations	1086	257	594	448	451	178	510	189	81
Respondents	543	169	297	238	240	102	266	120	64
R-squared	0.018	0.079	0.025	0.023	0.020	0.035	0.031	0.037	0.031

Note. Unstandardised estimate (p-value in parenthesis) presented. Significant effects on 90% confidence interval highlighted in bold.

Only the number of amenities significantly affects perceived accessibility with regard to age. The coefficient's sign contradicts expectations, stressing that an increase (decrease) in the number of opportunities within 5 km will decrease (increase) one's perceived accessibility.

Finally, the distance to the nearest hospital, secondary school, and supermarket is more important for single-person households. An increase in the distance to the nearest hospital is found to have a positive impact on perceived accessibility, which suggests that this distance is of less importance for single-person households. The distance to the secondary school and grocery store is negatively valued, underlining that these single-person households are unable to fall back on a partner.

4.5. Testing for homogenous effects

Lastly, Fig. 4.2 presents the quantile regression results for all spatial accessibility indicators across the distribution of perceived accessibility from the 10th to 50th quantile. Here, the vertical axes present the coefficient estimate, whereas the horizontal axes depict the quantiles (in terms of perceived accessibility). In general, the effect of spatial accessibility indicators on perceived accessibility is relatively constant across the distribution of perceived accessibility. Notably, the effect of changes in spatial accessibility on perceived accessibility does not reach significance for the lowest quantiles since the confidence interval crosses the zero line in most cases. In other words, changes in the number of amenities or distances to the nearest amenity do not result in perceived accessibility transitions for individuals with the lowest levels.

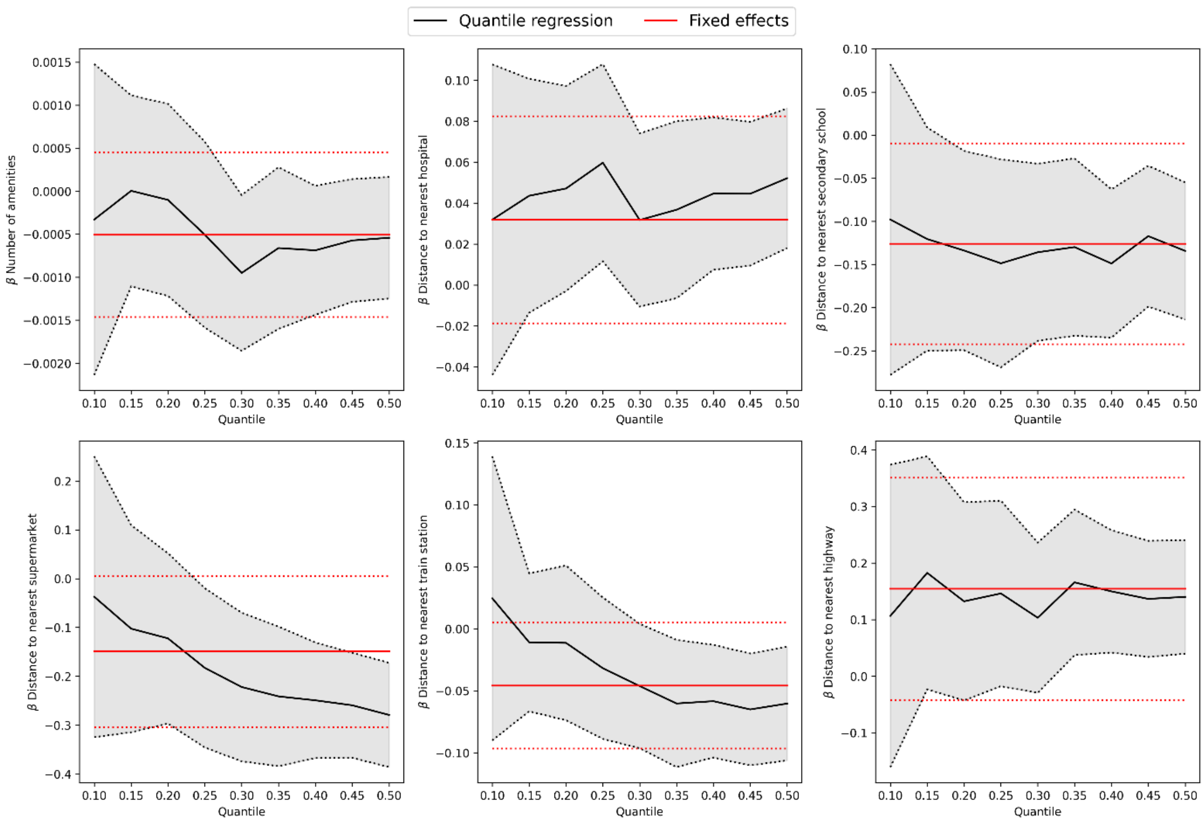

Fig 4.2 – Quantile regression results for spatial accessibility indicators

References

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Pot, F. J., Koster, S., & Tillema, T. (2023). Perceived accessibility in Dutch rural areas: Bridging the gap with accessibility based on spatial data. *Transport Policy*, *138*, 170-184. https://doi.org/10.1016/j.tranpol.2023.04.014

5

Revealing pathways towards life satisfaction

This section presents and discusses the results of the structural equation modelling approaches. More specifically, Section 5.1 discusses mediating pathways through travel and activity participation towards satisfaction with life, whereas Section 5.2 explores a potential causal reciprocal link between perceived accessibility and life satisfaction.

5.1. Testing a theory on outcomes of perceived accessibility

5.1.1. Links with travel, activity participation, and well-being

Table 5.1 and Fig. 5.1 show how perceived accessibility affects life satisfaction through several pathways. First, perceived accessibility significantly affects the behavioural constructs tested in this analysis. More specifically, significant positive links with walking (=0.06), sports (=0.06), and grocery shopping (=0.05) are retained. In other words, a higher (lower) perceived accessibility is associated with more (less) walking and activities related to sports and grocery shopping. In addition, perceived accessibility is negatively associated with health-related activities (=-0.09), indicating that individuals with higher perceived accessibility less often carry out such activities. Interestingly, no significant effects with car, bike, e-bike, and train use have been found. Hence, overall perceived accessibility does not significantly affect individuals' use of these modes. Consequently, the model findings highlight that perceived accessibility relates to activity participation more than travel mode use and decisions.

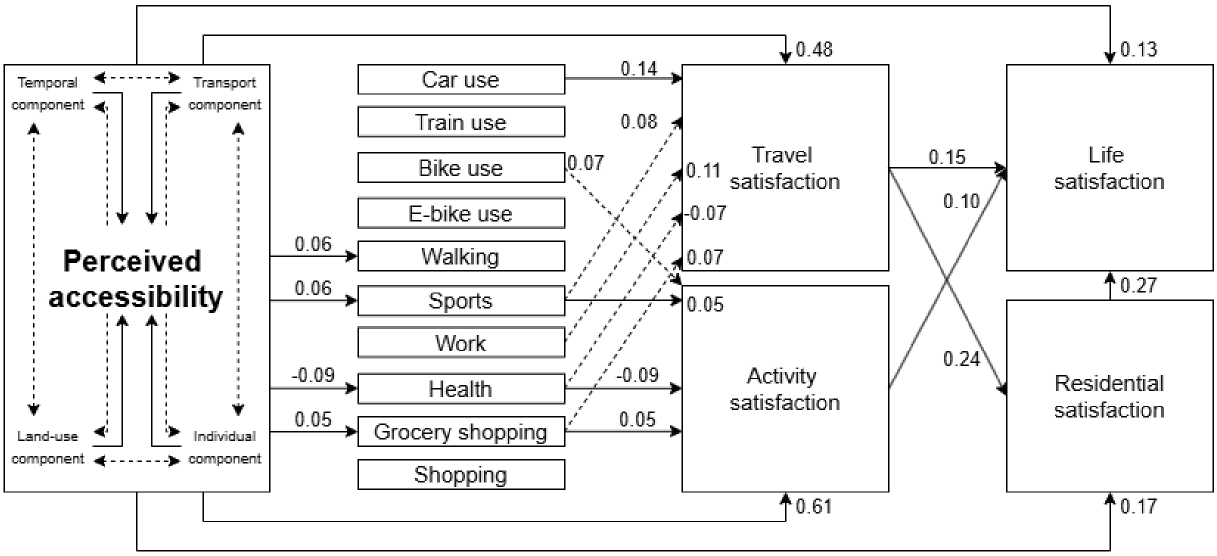

Fig. 5.1 – Path diagram with direct estimates (effects from socio-demographics have been suppressed to enhance readability but are shown in Table 5.1)

Second, perceived accessibility directly and indirectly affects travel, activity, and residential satisfaction. The direct effect on activity satisfaction is highest (β=0.61), whilst perceived accessibility significantly directly affects satisfaction with daily travel (β=0.48). The effect on residential satisfaction is much lower (β=0.17). Besides these direct links, the link between perceived accessibility and satisfaction with daily travel, activities, and origin location is partly mediated by travel behaviour and activity participation. With regard to travel mode use, driving is positively associated with travel satisfaction (β=0.14). More driving will most likely result in higher satisfaction towards individuals' daily travel. Interestingly, bike use seems to positively affect the overall satisfaction with activities at the destination (β=0.07), indicating that biking towards activities will result in more positive emotions associated with these activities. For activity participation, activities related to sports, health, and grocery shopping have significant effects on both travel and activity satisfaction. Here, engaging in sports and grocery shopping contribute positively to travel (β=0.08 and β=0.07) and activity (β=0.05 for both) satisfaction, whereas health-related activities such as visiting the doctor's office negatively influence travel (β=-0.07) and activity (β=-0.09) satisfaction.

Third, perceived accessibility affects satisfaction with life both directly and through behavioural decisions and the satisfaction therewith. A higher (lower) perceived accessibility is associated with higher (lower) life satisfaction (β=0.13). Additionally, both behavioural decisions (travel behaviour and activity participation) and the satisfaction with these decisions (daily travel, activities, residential location) mediate the link between perceived accessibility and life satisfaction since life satisfaction is directly affected by travel satisfaction (β=0.15), activity satisfaction (β=0.10) and residential satisfaction (β=0.27). Interestingly, satisfaction with the residential location directly influences life satisfaction, highlighted by the magnitude of the standardised estimate compared to those of activity and travel satisfaction.

The combined direct and indirect effect of these constructs should be assessed to draw conclusions about the total effect of constructs on satisfaction with life. Table 5.2 presents these total effects. First, perceived accessibility and short-term satisfaction-related outcomes significantly affect life satisfaction compared to activity participation and travel mode frequencies. Notably, the direct effect of perceived accessibility on satisfaction with life is relatively low (β=0.13) compared to the total effect through activity participation and satisfaction, travel behaviour and satisfaction, and residential satisfaction (β=0.35). In other words, the influence of perceived accessibility on life satisfaction is primarily mediated by other (behaviour- and satisfaction-related) constructs.

Table 5.2 – Standardised total effects on life satisfaction

	Estimate
Perceived accessibility	0.35
Sports	0.02
Health	- 0.03
Grocery shopping	0.02
Work	0.02
Cycling	0.01
Driving	0.03
Activity satisfaction	0.10
Travel satisfaction	0.22
Residential satisfaction	0.27

5.1.2. Additional links

Socio-demographics also have significant effects on perceived accessibility, travel, activity participation and well-being. Variations in perceived accessibility among individuals are partly explained by education attainment (β=0.08), employment status (β=0.08), car ownership (β=0.10), and level of urbanity (β=-0.07). Interestingly, individuals living in rural Dutch areas seem to have greater perceived accessibility compared to those living in urban areas of the Netherlands. In contrast to the model results of Chapter 4, migration background does not significantly affect differences in perceived accessibility. Life satisfaction seems to be higher for older adults, individuals with a higher personal net income, those with a driver's license, or large households.

Correlations between the error terms of behavioural constructs also provide interesting results. Working activities are positively correlated with driving and to a lesser extent with public transport, whereas grocery shopping is strongly correlated with walking. In line with the expectation, sport-related activities correlate with active travel modes (e.g. cycling and walking) to a great extent.

Table 5.1 – Standardised direct effects and correlations

	PA	Sports	Work	Health	Grocery shopping	Shopping	Car use	Train use	Bike use	E-bike use	Walking	TS	AS	RS	LS
Socio-demographics															
Age	-	-	-0.17	-	0.16	-	-0.04	-	-0.17	0.20	-	-	-	0.16	0.09
Gender	-	-0.05	-	-0.13	-0.17	-0.18	0.08	-0.07	-	-	-	-	-	-	-
Migration background	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Educational attainment	0.08	0.14	-	-	-	-	-	0.12	-	-	-	-	-	-	-
Employment status	0.08	-	0.69	-	0.06	-	0.09	0.10	-	-	-	-0.08	-	-	-
Personal net income	-	-	0.07	-	-	-	0.06	0.08	-	-	-	-	-	-	0.06
Household size	-	-	-	-	-0.21	-	-	-0.09	-	-	-	-	-	0.08	0.12
Bike ownership	-	0.15	0.04	-0.10	-	-	-	0.14	0.58	-0.28	0.08	-	-	-0.07	-
Car ownership	0.10	-	0.05	-	-	0.07	0.39	-0.28	-0.07	-	-	-	-	-	-
Driver's license	-	0.08	0.05	-	0.12	-	0.50	-	0.06	-	-	-	0.10	-0.07	0.09
Level of urbanity	-0.07	-	-	-	-0.09	-0.06	0.06	-0.13	-	0.06	-0.07	-	-	-	-
Perceived accessibility															
Perceived accessibility (PA)	-	0.06	-	-0.09	0.05	-	-	-	-	-	0.06	0.48	0.61	0.17	0.13
Activity participation															
Sports	-	-	-	-	-	-	-	-	-	-	-	0.08	0.05	-	-
Work	-	0.05	-	-	-	-	-	-	-	-	-	0.11	-	-	-
Health	-	0.03	-0.05	-	-	-	-	-	-	-	-	-0.07	-0.09	-	-
Grocery shopping	-	0.02	0.05	0.10	-	-	-	-	-	-	-	0.07	0.05	-	-
Shopping	-	0.16	0.05	0.27	0.28	-	-	-	-	-	-	-	-	-	-
Travel mode use															
Car use	-	-0.01	0.10	0.05	0.01	0.01	-	-	-	-	-	0.14	-	-	-
Train use	-	0.14	0.05	-0.05	0.13	0.13	-0.13	-	-	-	-	-	-	-	-
Bike use	-	0.16	0.02	-0.04	0.10	0.03	-0.12	0.12	-	-	0.15	-	0.07	-	-
E-bike use	-	0.09	-0.01	-0.01	0.03	0.07	-0.07	0.09	-0.21	-	-	-	-	-	-
Walking	-	0.16	0.02	-0.09	0.16	0.09	-0.02	0.22	0.09	-	-	-	-	-	-
Satisfaction															
Travel satisfaction (TS)	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24	0.15
Activity satisfaction (AS)	-	-	-	-	-	-	-	-	-	-	-	0.24	-	-	0.10
Residential satisfaction (RS)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27

5.2. Testing a bidirectional link with life satisfaction

As indicated in the previous section, the direct effect of perceived accessibility on life satisfaction is relatively low, highlighting significant mediating pathways through travel and activity participation. In this section, I present and discuss the cross-lagged panel model results, highlighting whether perceived accessibility influences life satisfaction or vice versa. First, the within-person effects and between-person correlation will be interpreted. Second, correlations between within-person constructs are discussed. Finally, a sub-group analysis is conducted to evaluate whether the relationship between perceived accessibility and life satisfaction differs across groups.

5.2.1. The link between perceived accessibility and life satisfaction

Table 5.3 presents the standardised estimates of the RI-CLPM with strong factorial invariance. At the between-person level, the correlation between the random intercepts for perceived accessibility and life satisfaction reveals that these constructs are strongly related (r=0.728, p=0.000). In other words, individuals who generally experience higher levels of accessibility also denote higher levels of life satisfaction.

At the within-person level, the stability coefficients indicate that perceived accessibility and life satisfaction are somewhat stable over time. The standardised autoregressive estimate for perceived accessibility equals β=0.190 (p=0.036), whereas the estimate for life satisfaction is β=0.381 (p=0.003). Since the estimate for perceived accessibility is relatively low compared to the estimate for life satisfaction, the findings indicate that individuals' experienced level of accessibility is subject to more change. In line with this, the within-person cross-lagged effect from life satisfaction to perceived accessibility is significant at the 10% level (β=0.174, p=0.076). In contrast, the cross-lagged effect from perceived accessibility to satisfaction with life does not reach statistical significance (β=0.107, p=0.207). In other words, an individual's experienced level of accessibility does not result in a higher satisfaction with life over time. Instead, satisfaction with life is carried over into a greater perceived accessibility.

Table 5.3 – Standardised estimates of RI-CLPM

	Estimate	p-value
Within-person effects		
Perceived accessibility (t-1) → perceived accessibility (t)	0.190	0.036
Life satisfaction (t-1) → life satisfaction (t)	0.381	0.003
Perceived accessibility (t-1) → life satisfaction (t)	0.107	0.207
Life satisfaction (t-1) → perceived accessibility (t)	0.174	0.076
Between-person correlation	0.728	0.000

Note. Mean standardised estimates across waves have been provided. While the unstandardised estimates are constrained over time, the standardised estimates may differ slightly due to time-variation in variances.

5.2.2. Correlations

Table 5.4 presents the correlations between within-person constructs. Overall, most within-construct associations of perceived accessibility and life satisfaction are positive, with a notable exception for the correlation between perceived accessibility and life satisfaction measured in 2020. Most autoregressive and cross-lagged effects between two consecutive waves are significant at the 5% level.

Table 5.4 – Correlations between within-person constructs

		1.	2.	3.	4.	5.	6.
1.	Perceived accessibility T1	1.00					
2.	Perceived accessibility T2	**0.17**	1.00				
3.	Perceived accessibility T3	0.05	**0.26**	1.00			
4.	Life satisfaction T1	- 0.04	0.16	0.09	1.00		
5.	Life satisfaction T2	0.08	**0.38**	**0.25**	**0.34**	1.00	
6.	Life satisfaction T3	0.05	**0.26**	0.11	0.16	**0.46**	1.00

Note. Significant correlations at 5% level underlined and presented in bold.

5.2.3. Heterogeneity in carry-over effects for social groups

Table 5.5 presents the estimated links between perceived accessibility and life satisfaction for different 'vulnerable' groups. The RI-CLPM without covariates has been estimated for individuals living in rural areas, females, older adults, low-income groups, individuals without a car, single-person households, and individuals with a physical disability. This subgroup analysis allows us to examine whether the relationship between perceived accessibility and life satisfaction differs across various social groups.

First, the between-person correlation for perceived accessibility and satisfaction with life remains significant for all subgroups considered in the analysis. While some variation in the magnitude of the correlation exists, this finding indicates that a high perceived level of accessibility is associated with satisfaction with life for various groups.

Mixed findings were obtained at the within-person level. Both rural-living individuals and females are prone to adjust the experienced level of accessibility based on their life satisfaction. In other words, satisfied individuals are more likely to develop a more positive attitude towards their perceived accessibility. In contrast, individuals dissatisfied with life will account for this dissatisfaction when evaluating their level of accessibility. For females specifically, the level of accessibility as experienced by females may develop into a different level of satisfaction with life over time. Nonetheless, this directional effect from perceived accessibility on life satisfaction is much lower than the other way around. For other groups, reciprocal within-person effects between perceived accessibility and life satisfaction do not reach statistical significance. In other words, these constructs do not influence each other over time for these subgroups.

Table 5.5 – Standardised estimates of RI-CLPM without covariates for different social groups

	Full sample	**Rural areas**	**Female**	**Elderly (65+)**	**Income (€1000 or less)**	**No car**	**Single-person household**	**Physical disability**
Within-person effects								
PA (t-1) -> PA (t)	**0.183**	-0.022	0.175	-0.081	0.097	0.149	**0.362**	0.361
	(0.027)	(0.907)	(0.105)	(0.661)	(0.690)	(0.412)	**(0.006)**	(0.280)
LS (t-1) -> LS (t)	**0.359**	0.358	**0.506**	-0.064	0.429	**0.467**	**0.512**	0.006
	(0.002)	(0.085)	**(0.012)**	(0.792)	(0.150)	**(0.007)**	**(0.001)**	(0.983)
PA (t-1) -> LS (t)	0.156	0.185	**0.284**	-0.275	0.166	0.010	0.086	-0.112
	(0.052)	(0.104)	**(0.025)**	(0.175)	(0.403)	(0.955)	(0.461)	(0.813)
LS (t-1) -> PA (t)	**0.220**	**0.465**	**0.432**	-0.067	0.184	0.181	0.123	0.126
	(0.012)	**(0.018)**	**(0.001)**	(0.623)	(0.451)	(0.396)	(0.372)	(0.517)
Between-person correlation	**0.704**	**0.653**	**0.529**	**0.705**	**0.745**	**0.804**	**0.869**	**0.670**
	(0.000)	**(0.000)**	**(0.003)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.002)**
Model fit								
No. of respondents	542	123	284	206	139	170	238	113
CFI	0.906	0.906	0.904	0.906	0.907	0.864	0.881	0.889
RMSEA	0.067	0.075	0.069	0.069	0.078	0.090	0.081	0.083
SRMR	0.055	0.068	0.066	0.082	0.069	0.075	0.066	0.080

Note. Mean standardised estimate (p-value in parenthesis) presented; PA = perceived accessibility; LS = life satisfaction; Estimates significant on 95% confidence interval underlined and bold, estimates significant on 90% confidence interval underlined

6

Concluding remarks

This thesis has been concerned with *'offering a deeper understanding of determinants and outcomes of perceived accessibility, by accounting for changes in perceived accessibility over time'*. To this end, a preliminary conceptual model has been drafted based on an overview of the literature (Chapter 2). A panel analysis was also conducted to identify factors related to such changes in perceived accessibility (Chapter 3). Afterwards, the effect of perceived accessibility on its outcomes (e.g. travel behaviour and satisfaction, activity participation and satisfaction therewith, residential satisfaction, and satisfaction with life) has been estimated to identify pathways towards life satisfaction (Chapter 4). Lastly, the bidirectional link between perceived accessibility and life satisfaction has been evaluated using cross-lagged panel modelling (Chapter 5). In the following subsections, the main findings derived from these studies will be discussed in relation to their subsequent research question and earlier studies. Based on this discussion, a conceptual framework of transitions in perceived accessibility is offered. Lastly, implications for policy and science and future research directions will be discussed in more detail.

6.1.Conclusions and discussion

6.1.1. What are determinants and outcomes of perceived accessibility identified by earlier studies, and how can these relationships be conceptualised?

The first research question aimed to provide an overview of the existing body of research on perceived accessibility. First, perspectives on and definitions of perceived accessibility have been explored. In its simplest form, perceived accessibility can be defined as 'how an individual experiences its own level of accessibility' (Curl, 2018, p. 1148). Pot et al. (2021) have provided theoretical foundations for perceived accessibility, conceptualising perceived accessibility through the use of four dimensions. These include land use, transport, temporal, and individual dimensions. Perceived accessibility can best be understood as individuals' needs, desires, and abilities (individual component), which provide the necessary information to cognitively evaluate land use, transport, and temporal systems.

Second, determinants of variations in perceived accessibility between individuals have been identified. In general, research has suggested that sociodemographic characteristics play a significant role in shaping such differences. Although studies remain inconclusive on the specific effects, factors such as gender, age, migration background, level of education, income, and household composition have all been linked to variations in perceived accessibility (e.g. Pot et al., 2023; Moleman and Kroesen, 2025b). Additionally, characteristics of the built environment and (travel) attitudes and/or experiences also contribute to such variations. In contrast, the built environment tends to have a less prominent role (Pot et al., 2023).

Third, outcomes of perceived accessibility have been identified as well. Research on the outcomes of perceived accessibility is relatively scarce, yet links have been explored with travel behaviour (e.g. Zhang and Hu, 2024; Scheepers et al., 2016), activity participation (e.g. Pot et al., 2024), travel satisfaction (e.g. Lättman et al., 2019; Sukwadi et al., 2022), residential satisfaction (e.g. Hu and Ettema, 2023; Hamersma et al., 2015), and life satisfaction e.g. Lättman et al., 2019; Friman and Olsson, 2023; Lim et al., 2020; Mehdizadeh et al., 2025). While perceived accessibility is often linked to (transport-related) social exclusion, studies that empirically evaluate this relationship are relatively scarce. This may be due to difficulties that arise when quantifying social exclusion.

Lastly, studies examining changes in perceived accessibility have been discussed. Existing studies that do so focus on the effects of policy interventions. For instance, both Andersson et al. (2023) and Liu et al. (2023) evaluated changes in modal shifts and perceived accessibility attributed to implementing fare-free public transport scheme interventions. Transitions in perceived accessibility attributed to non-interventional changes have not yet been assessed to the best of my knowledge.

6.1.2. Which factors cause changes in perceived accessibility? Are these effects perceived differently across social groups?

A fivefold approach has been employed to assess which factors result in changes in the perceived ease of reaching destinations. First, a preliminary analysis of changes in perceived accessibility has been conducted using a longitudinal latent class analysis. In doing so, different groups of individuals with different perceived accessibility profiles and the changes therein have been empirically quantified. In total, six different clusters of individuals have been revealed by the analysis. Only a small share of the sample (15%) experienced the highest level of accessibility in 2020 and remains to do so in 2023. Two other clusters of individuals (respectively 40% and 6% of the sample) did not revisit their perceived ease of reaching destinations. At the same time, they experience a lower level of accessibility to at least some extent (in both years). A single cluster (12% of the sample) did develop a more positive stand towards their level of accessibility in 2023 compared to 2020. In contrast, almost 27% of the sample developed a lower level of accessibility over time.

After providing an overview of trajectories in perceived accessibility, panel regression analyses have been conducted to identify those factors causing (changes in) perceived accessibility. More specifically, both random and fixed effects panel data regressions have been estimated. The results of the random effects regression analysis highlight that socio-demographics and attitudes seem to explain the trajectories (i.e. both initial variations and/or dynamic changes) in perceived accessibility to a large extent, which is in line with earlier research conducted in the Dutch context. In line with Moleman and Kroesen (2025a; 2025b), the present analysis showed that individuals with a Western background are more likely to experience a higher level of accessibility, whereas individuals experiencing difficulties with cycling could experience a lower perceived accessibility as well. This may also hold for individuals experiencing other disabilities (Pot et al., 2023). Additionally, in line with Pot et al. (2023) and Moleman and Kroesen (2025b), car ownership plays an important role in rural and urban areas. Whereas Pot et al. (2023) only studied rural Dutch areas, Moleman and Kroesen (2025b) explored the effect of car ownership in the Netherlands' urban and rural areas. Both found a relationship between car ownership and perceived accessibility, underscoring that owning a car could significantly increase the perceived ease of reaching destinations. The random effects regression analysis validates this conclusion. Lastly, attitudes towards individuals' residential location and driving and walking have been found, which align with the findings of Pot et al. (2023). Interestingly, links with other socio-demographics such as gender, age, educational attainment, and income have not been found in the present analysis, contradicting earlier empirical research. Both Moleman and Kroesen (2025a; 2025b) and Pot et al. (2023) found such links, highlighting, among others, that females, older adults and individuals with a lower income are more likely to experience a lower level of accessibility. Still, these earlier studies have applied cross-sectional rather than panel data, which does not support causal inference. Characteristics of the built environment seem to play a less prominent role in explaining variations in perceived accessibility, in line with Pot et al. (2023), indicating that individuals may have accepted their current situation. As a result, individuals living in areas with a lower spatial accessibility may not necessarily have a lower perceived accessibility.

The fixed effects regression analysis allows us to purely examine factors causing changes in perceived accessibility by disentangling within-person from between-person effects (and thus excluding factors that solely explain variations in perceived accessibility among individuals). In contrast to the random effects regression analysis, the fixed effects regression analysis results indicate that individuals living in geographical areas with changes in the physical environment do adept their experienced level of accessibility. More specifically, a change in distance to the nearest supermarket, train station, and secondary school explains perceived accessibility. These effects are relatively homogenous across distributional groups of perceived accessibility, highlighted by the quantile (fixed effects) regressions. Overall, individuals thus may have accepted their current situation, resulting in insignificant variations in perceived accessibility among individuals living in different geographical areas. However, when a change comes, those individuals will likely revisit their perceived accessibility. Still, other factors seem to contribute to changes in perceived accessibility to a larger extent. The fixed effects regression analysis highlights that individuals' perceived ease of reaching destinations will primarily be revisited when mobility tool ownership changes occur. Both changes in household car ownership and private bike ownership have significant and large effects on changes in perceived accessibility. In addition, changes in the household composition (e.g., the number of persons in the household) and the number of times they meet online result in a different level of accessibility.

Lastly, the results of the subgroup analysis underscore the importance of basic amenities close by. For different social groups, the relationship between changes in the distance to the nearest supermarket and changes in perceived accessibility was estimated to be stronger. In other words, a change in spatially inferred accessibility levels, specifically a change in the distance to the nearest supermarket, is perceived as more substantial for vulnerable groups. Among others, rural-living individuals, women, older adults, people with a low income, and single-person households are impacted to a larger extent compared to the whole sample.

6.1.3. What is the impact of perceived accessibility on travel, activity participation, and well-being?

This second empirical analysis tested a theory on the outcomes of perceived accessibility. The literature has identified links with travel behaviour, out-of-home activities, travel satisfaction, residential satisfaction, and satisfaction with life. Using a structural equation modelling approach, direct relationships on these constructs, as well as mediating pathways from perceived accessibility to life satisfaction, have been tested.

The model findings indicate that perceived accessibility is significantly associated with the constructs considered in the analysis. With respect to travel behaviour, the structural equation model underscores that overall perceived accessibility is positively linked with walking. This finding aligns with earlier studies on perceived accessibility and walking behaviour. In particular, Hou et al. (2020) also found that higher (lower) perceived accessibility resulted in a higher (lower) number of walking trips. Additionally, other studies found a positive relationship between perceived walking accessibility and walking behaviour (e.g. Liu et al., 2022; Van der Vlugt et al., 2022), collectively highlighting that walking behaviour is both related to overall perceived accessibility as well as perceived walking accessibility. Interestingly, links with car and public transport have not been found, contradicting earlier studies which concluded that overall perceived accessibility negatively correlates with car, public transport or (e-)bike use (e.g. Blandin et al., 2024; Friman et al., 2020; Andersson et al., 2023). However, these studies are also contradicted by other findings of studies focussing on mode-specific rather than overall accessibility, concluding that perceived accessibility by car, public transport or bike is positively related to car, public transport or bike use (e.g. Scheepers et al., 2016; Sheng and Zhang, 2022; Watthanaklang et al., 2024; Negm and El-Geneidy, 2025; Mehdizadeh and Kroesen, 2025).

For activity participation, the model findings indicate that perceived accessibility is related to out-of-home activities, while this relationship varies for different types of activities. A positive link has been found between overall perceived accessibility and grocery shopping and sports, whereas the link with health-related activities is estimated to be negative. These findings add to the current body of literature, which either focuses on mode-specific accessibility (Mehdizadeh et al., 2025) or on general activity participation levels (in the Dutch context: Pot et al., 2024). Mehdizadeh et al. (2025) concluded that perceived accessibility by car, bike, and public transport was negatively associated with grocery shopping. However, the present analysis shows that individuals' general ease of reaching destinations positively correlates with grocery shopping. Mehdizadeh et al. (2025) also found that perceived walking accessibility positively correlated with sports-related activities, which aligns with the present analysis in which a higher (lower) overall perceived accessibility seems to result in more (less) sports-related activities. Pot et al. (2024) concluded that individuals experiencing lower levels of accessibility still report high levels of activity participation. However, the structural equation modelling findings underscore that individuals experiencing perceived inaccessibility are likelier to report fewer out-of-home activities. While Pot et al. (2024) also studied general levels of perceived accessibility, a notable difference in research designs relates to the operationalisation of activity participation. Whereas this thesis has been concerned with testing various types of activities, Pot et al. (2024) assessed the general level of activity participation, which may have resulted in different outcomes.

While the findings highlighted significant links with travel behaviour and activity participation, the strongest correlations have been found between perceived accessibility and satisfaction-related outcomes (travel, activity, residential, and life satisfaction). In line with several other studies on these links (e.g. Lättman et al., 2019; Liu et al., 2019; Sukwadi et al., 2022; Friman and Olsson, 2023; Lim et al., 2020), the model results show that perceived accessibility is positively associated with daily travel, residential, and life satisfaction. The link with activity satisfaction is also estimated to be positive, which has not been assessed in previous studies to the best of my knowledge.

Notably, the direct effect of perceived accessibility on satisfaction with life is substantially lower than the indirect effect mediated by other constructs. In contrast to earlier studies, which did not disentangle direct and indirect pathways from perceived accessibility to life satisfaction, the present analysis highlights that this effect is primarily indirect through behavioural choices (e.g. travel mode choices and activity participation) and individuals' satisfaction with these choices (e.g. travel, activity, and residential satisfaction), rather than direct.

6.1.4. Does perceived accessibility affect life satisfaction or vice versa (for different social groups)?

To further assess the direct effect of perceived accessibility on life satisfaction, the causal reciprocal links between these two constructs have been tested using cross-lagged panel modelling. The strong positive association between perceived accessibility and life satisfaction across individuals is in accordance with the findings of Lättman et al. (2019), Liu et al. (2019), Friman and Olsson (2020), and Sukwadi et al. (2019), who also found that perceived accessibility is positively correlated with life satisfaction. This finding aligns with the earlier conclusion on the direct link between perceived accessibility and life satisfaction, as tested in the second empirical analysis.

Additionally, the panel analysis conducted in this study reveals that within-person carry-over effects exist between individuals' experienced level of accessibility and their satisfaction with life. More specifically, the findings highlight that, at the 90% confidence interval, a person who is satisfied with life is more likely to develop a more positive stand towards their experienced level of accessibility as well. In contrast, individuals with a higher perceived accessibility do not necessarily develop a greater satisfaction with life over time. Therefore, it is more likely that life satisfaction affects how individuals evaluate their level of accessibility rather than the other way around, as assumed by earlier studies. Additionally, the analysis showed that perceived accessibility and life satisfaction are relatively stable constructs, while life satisfaction seems more stable than perceived accessibility.

Adding to the existing body of literature, the findings indicate that the link between perceived accessibility and life satisfaction may differ for some social groups. While for most groups, insignificant reciprocal links have been found, indicating that carry-over effects between perceived accessibility and life satisfaction are non-existent for these individuals, rural-living individuals and females seem to develop a more positive (negative) stand towards their perceived level of accessibility over time when their satisfaction with life is high (low). A narrowed thought-action repertoire due to lower positive emotions and satisfaction with life may thus result in a narrow cognitive evaluation of one's perceived accessibility. As a result, this perceived ease of reaching destinations is negatively impacted.

6.2.Towards a framework of transitions in perceived accessibility

This section revisits the conceptual framework of Pot et al. (2021) to synthesise the empirical findings of this research in light of earlier studies. Fig. 6.1 presents the revised conceptual framework articulating the dynamic nature of individuals' perceived accessibility. While Pot et al. (2021) already highlighted the impact of perceived accessibility on behavioural decisions and, in turn, the feedback loop from these decisions to perceived accessibility based on experiences and learning experiences, the key novelty of the framework depicted in Fig. 6.1. lies in the validation of links with determinants and outcomes. Additionally, some constructs depicted in the original model have been further elaborated upon.

As illustrated in Fig. 6.1, the framework starts with the individual component of accessibility, which determines how an individual evaluates the other components of accessibility (e.g., transport, land use, and temporal components). The needs, desires, and abilities (path 1), as well as the characteristics of the physical environment (path 2), provide the necessary information for individuals to evaluate their accessibility cognitively. Through self-selection, the physical environment may change (path 3), after which individuals' cognitive evaluation of the land use, transport, and temporal aspects of accessibility also changes (path 2). Ultimately, this translates into the accessibility experienced by an individual (path 4).

From an individual's perceived ease of reaching destinations, travel and/or activity decisions may follow (path 5). While the second empirical analysis showed that this unidirectional effect of perceived accessibility on travel behaviour and activity participation was relatively small, significant links were retained. Still, other needs and abilities derived from the individual accessibility component also determine these travel and activity decisions (path 6).

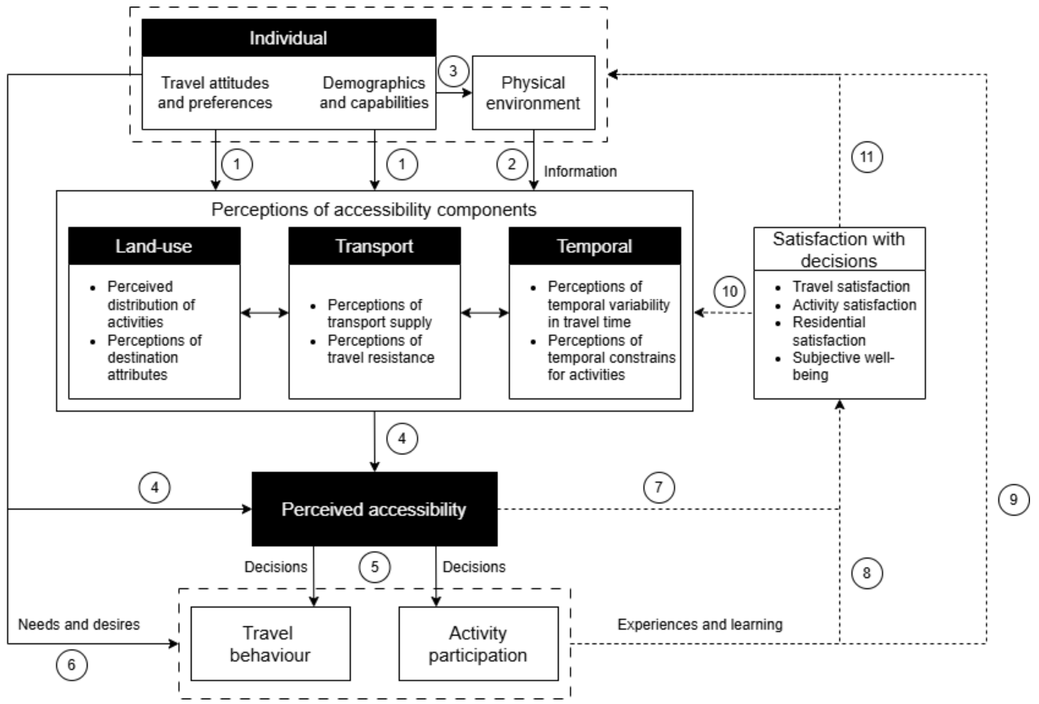

Fig. 6.1 – A conceptual framework of transitions in perceived accessibility (adapted from Pot et al., 2021)

Individuals will evaluate their decisions based on their experiences with travel and out-of-home activities (path 8). This not only results in levels of satisfaction with daily travel (or trips) or out-of-home activities but may also impact residential satisfaction and/or subjective well-being (through life satisfaction). A direct link from perceived accessibility to satisfaction-related outcomes has been included as well (path 7) since significant associations have been found in the second empirical analysis.

Decisions and decision-related satisfaction may influence perceived accessibility through three mechanisms. Firstly, travel behaviour and activity participation can reshape an individual's needs, desires, or abilities (path 9). Recent research has emphasised the bidirectional relationship between travel attitudes and behaviour (e.g. Kroesen et al., 2017). Secondly, satisfaction with decisions could influence the individual component of perceived accessibility (path 11). In the context of daily travel, De Vos and Witlox (2017) highlight how satisfaction with trips and daily travel can affect travel attitudes. Lastly, positive emotions experienced during travel or activities may broaden an individual's 'thought-action repertoire' (see Fredrickson, 2004). As a result, these emotions could influence how individuals perceive the components of perceived accessibility (path 10).

Lastly, the cyclical nature of the framework is highlighted through the indirect changes in socio-demographic and built environment characteristics, which cause transitions in perceived accessibility. Using panel regression analyses, the effects of changes in mobility tool ownership (household car ownership and private normal bike ownership) and changes in spatial accessibility indicators (e.g., distance to nearest amenities) on changes in perceived accessibility have been revealed.

6.3. Implications for policy and science

6.3.1. Lessons for policy

Various policy lessons can be derived from this thesis. For one, this research found that changes in the built environment translate into different levels of experienced accessibility, especially for vulnerable groups. The analysis explored how changes in spatial accessibility, socio-demographics, attitudes, and life events affected perceived accessibility, highlighting that individuals actively account for changes in spatially inferred accessibility levels. These effects are estimated to be more substantial for those living in rural Dutch areas, older adults, females, individuals with low income, and single-person households. With the loss of amenities and, inherently, increasing distances to activity locations in the Netherlands, an important policy lesson is to identify the neighbourhoods where vulnerable groups live, monitor the corresponding trends in spatial accessibility, and address the decline in amenities in these neighbourhoods using policy designs. An essential component in these designs should be the support of vulnerable groups identified in this thesis in areas most likely to experience lower spatial accessibility. Targeted interventions, such as improving transportation options, local services, or access to essential amenities, could mitigate the adverse effects experienced by vulnerable groups in terms of their perceived ease of reaching destinations.

A related policy lesson from this research concerns the role of mobility tool ownership in individuals' perceived accessibility. The analysis found that individuals who had to deal with changes in their mobility tool ownership, and in particular changes in household car ownership and private bike ownership, did change their perceived accessibility. Individuals who got in possession of a car or bike positively changed their perceived accessibility. In contrast, those who suffered losses in their mobility means did develop a more negative stand towards the ease of reaching destinations. With respect to the relative importance of these 'tools', the effect of changes in mobility tool ownership was estimated to be more considerable than changes in spatial accessibility levels. Therefore, losing access to the means that allow them to travel to places, regardless of whether these places have become further away, is a key factor in why individuals change their perceived accessibility. As a result, providing individuals with the means to travel might mitigate the loss of a private ownership tool and, in turn, maintain one's level of perceived accessibility. In this respect, investments in shared mobility or public transport services such as trains, buses, and demand-responsive transport could mitigate private losses.

These lessons provide possible starting points to maintain or improve perceived accessibility levels in the Netherlands, enabling individuals to travel and engage in various activities. Through empirical analysis, this thesis shows that individuals experiencing higher levels of accessibility are more likely to travel to destinations and participate in out-of-home activities. Conversely, those facing lower levels of accessibility are less likely to make travel and activity decisions. By maintaining or improving perceived accessibility, activities such as walking, grocery shopping, and engaging in sports can be facilitated. Health-related activities will be carried out to a lesser extent for those who denote higher levels of perceived accessibility. Additionally, the analysis revealed connections between travel, activity, and residential satisfaction. Thus, perceived accessibility is a key factor influencing how individuals travel, participate in activities, and their satisfaction with these decisions.

While a 'between-person' association has been identified between perceived accessibility and life satisfaction, this thesis also found that life satisfaction influences perceived accessibility at the 'within-person' level rather than the reverse. This suggests that while greater perceived accessibility may facilitate more travel and activity participation, it may not be sufficient to enhance life satisfaction directly. Therefore, improving life satisfaction should not solely rely on improving perceived accessibility. Instead, improvements in accessibility levels should most likely be part of a broader policy design that addresses (perceived) social inclusion and (subjective) well-being.

6.3.2. Lessons for science

Two main lessons can be identified for science. First and foremost, this research found a discrepancy between factors causing (between-person) variations in perceived among individuals and those causing (within-person) changes in perceived accessibility. The random effects regression aligns with previous research on perceived accessibility, which has primarily focussed on explaining differences in accessibility levels among individuals, revealing that various determinants such as socio-demographics (e.g. age, gender, income, educational attainment), mobility means, and travel attitudes and preferences explain these differences. In contrast, the fixed effects regression model showed that changes in mobility mean, as well as spatial accessibility, dictate whether within-person changes in perceived accessibility take place. Thus, there are different determinants of perceived accessibility, either reflecting factors causing differences between or within persons. Researchers in the field of transportation research, and particularly research on perceived accessibility, should actively consider and/or account for these differences in future research.

A second lesson relates to the measurement scale used to assess participants' perceived accessibility. This thesis used the Perceived Accessibility Scale (PAC scale) proposed by Lättman et al. (2018) to capture experienced levels of accessibility. As revealed by a small review of literature related to perceived accessibility, this scale is most often used to ask respondents to rate their overall level of accessibility experienced in daily travel (see Chapter 3; p. 36-37). Nonetheless, an important drawback of this scale in this thesis is that it was measured on a 7-point Likert scale in 2020 and 2024 but measured on a 5-point Likert scale in 2023. While factorial invariance holds, this lack of consistency in measurement may affect this thesis's findings. It can be seen as an important lesson for future studies employing a longitudinal design to study changes in perceived accessibility over time.

Another drawback of this scale is the potential for exaggerating what is being measured. The scale does not exclusively include statements about perceived accessibility; it also asks respondents to rate statements concerning their satisfaction with activities and, more broadly, their general satisfaction with life. This presents a limitation in accurately capturing perceived accessibility as a standalone construct, primarily for research focussing on the influence of perceived accessibility on broader concepts such as travel, activity participation, and well-being (as in this thesis). An important lesson for researchers is to be more cautious in their choice of measurement scale. While using an often applied scale is reasonable and defensible, in turn allowing researchers to compare findings with earlier studies, it is crucial to recognise that such a scale may not perfectly isolate the construct of interest.

6.4. Avenues for future research

This research could benefit from future research in various directions. First, fixed effects have been estimated at the individual rather than household level. While this approach allows for the estimation of 'within-person' effects for each participant, these effects may correlate at the household level. Household members could experience similar changes in built environment characteristics if the household members live together, meaning that developments in distances to the nearest amenities or the number of amenities would likely be the same for individuals within the same household. Therefore, an avenue for future research could be to assess household-level instead of individual-level fixed effects.

Second, it would be interesting to explore whether a deterioration and an improvement in spatially inferred accessibility levels have a similar effect on changes in perceived accessibility. In its current form, the panel data analysis did not account for such effects and assumed that a deterioration has the same impact on perceived accessibility as an improvement. However, it would be interesting to analyse whether an increase in the distance to the nearest amenities would be experienced differently than a decrease in this distance. For this, a piecewise regression framework could be used, allowing for the estimation of effects for different data segments.

Third, assessing other amenities could be another direction for future research. In this study, a specific set of amenities has been composed in light of multicollinearity and the primary purpose of accessibility to facilitate the opportunity to reach work, health, education, and daily groceries as recognised by the Ministry of Infrastructure and Water Management in their 'Mobiliteitsvisie 2050'. As of this, amenities such as recreational facilities have not been included in this analysis, while changes in the spatial accessibility of such activity locations could matter in (re)shaping individuals' perceived accessibility.

Fourth, measuring individuals' perceived and spatial accessibility simultaneously could yield interesting, new results. For this thesis, datasets were collected at different times, with a one-month gap in 2020 and a six-month gap in 2023. This may have resulted in a potential misalignment between when changes in spatial accessibility occurred and when they are reflected in perceived accessibility. Future work should explore the extent to which these discrepancies in data collection impacted the results. In doing so, we could gain a better understanding of the dynamic interplay between changes in spatial and perceived accessibility.

Fifth, research could look at changes in perceived accessibility, which can be attributed to moving. The effect of moving to a new residential location is only marginally assessed in the panel data regression models by including a dummy variable for moving. This group is commonly underrepresented since movers often withdraw from panel surveys such as the Netherlands Mobility Panel. Therefore, a more detailed analysis with a separate data collection procedure is needed to disentangle changes in the residential location that stem from the loss of amenities nearby and those that result from individuals moving to new residents.

Sixth, this thesis has only examined the reciprocal causal link between perceived accessibility and life satisfaction, yet other bidirectional effects between perceived accessibility and its outcomes may exist as well. Specifically, perceived accessibility may causally affect activity participation, travel behaviour, travel satisfaction, and residential satisfaction (Chapter 4), and vice versa. A positive or negative view of daily travel, out-of-home activities, and/or residential location may influence how individuals cognitively evaluate their level of accessibility. For this, a cross-lagged panel modelling approach and two or more waves of data would suffice.

Seventh, several mediating pathways from perceived accessibility to life satisfaction have been explored. This thesis relied upon travel and activity constructs linked to perceived accessibility in earlier studies. These are travel behaviour, activity participation, travel satisfaction, and residential satisfaction. Other potential outcomes of perceived accessibility, as well as their mediating role in the link between perceived accessibility and life satisfaction, have not been examined. In line with the methodological approach taken in this thesis, structural equation modelling would allow researchers to disentangle both direct and indirect effects of perceived accessibility through these potential mediators on life satisfaction.

Another avenue for future research relates to the role of adaptive preferences in perceived accessibility. As hypothesised by earlier studies (e.g., Ryan and Pereira, 2021; Pot et al., 2023; Moleman and Kroesen, 2025b), individuals experiencing lower levels of accessibility may accept their situation and, in turn, positively re-evaluate their perceived accessibility. Conversely, those individuals experiencing the highest levels of accessibility may develop higher expectations, leading to a negative reassessment of their perceived accessibility. In this respect, the longitudinal latent class model (Chapter 3) has shown that the trajectories for individuals with the lowest level of accessibility do not change extensively between 2020 and 2023 (Cluster 6; 6% of the sample). In contrast, some individuals with the highest level of accessibility in 2020 develop a somewhat lower level in 2023 (Cluster 2; 16% of the sample). In light of these results, it remains unclear whether adaptive preferences indeed shape individuals' perceived accessibility, for which future research is needed. Quantitative methods (e.g. latent transition modelling) and qualitative methods (e.g. focus group discussions, interviews) could shed more light on this potential role.

Lastly, this thesis is (one of) the first to identify factors causing changes in perceived accessibility. For this, I used data collected in the Netherlands. Little is known about changes in perceived accessibility and the factors causing such changes in different geographical and/or cultural contexts, which could provide novel insights on within-person transitions in perceived accessibility.

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