Perceptions of accessibility;

interpersonal and spatial patterns of perceived accessibility in the Netherlands

Master thesis - Economic Geography

Faculty of Spatial Sciences

University of Groningen

Name: Marije Kooistra

Student number: S2927330

Supervisor: prof. dr. ir. T. Tillema

university of groningen

faculty of spatial sciences

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Summary

The concept of accessibility has been gaining traction in transport literature, but the adoption in transport planning has been relatively slow. This is partially due to the complexity of the concept and the lack of conceptual clarity system (Handy, 2020; Pereira et al., 2017). Quantitative methods often fail to capture the complexity of accessibility (particularly regarding the individual differences and subjective elements), and theoretical approaches lack empirical evidence and make comparing between groups and regions complex.

While the adoption of accessibility-based approaches has been slow, they are promising due to the relationship between accessibility and social exclusion (Preston & Rajé, 2007; SEU, 2002). Accessibility is about how easy it is to reach the goods, services and activities people need or want with the help of the transport system (Geurs et al., 2016; Handy, 2020; Pereira et al., 2017; van Wee, 2016). As such, it is more encompassing than traditional mobility-focused approaches. It includes the spatial dispersion of destinations, how easily those destinations can be reached, and the types of goods, services and activities present at those destinations.

This study uses perceived accessibility as a comprehensive yet easy-to-measure metric for accessibility. By using perceived accessibility, the different components of accessibility are measured through the individual's perception. Additionally, the subjective perceptions and preferences that govern accessibility are considered. This is relevant because individuals have diverse transport needs and preferences, which are essential to the level of accessibility they experience.

Studying patterns and predictors of perceived accessibility can help identify groups and areas that are at risk of experiencing accessibility-related problems. It is essential to consider that accessibility can differ in space and between individuals. As such, the goal of the research is to answer the following research question:

" What drives interpersonal and spatial differences in perceived accessibility across different levels of urbanity in the Netherlands? "

After the introduction, the second and third chapters explore the concept of accessibility and the possible predictors of accessibility, resulting in a conceptual framework that serves as a foundation for the analysis. The fourth chapter introduces the Perceived Accessibility Scale (PAC) used to measure perceived accessibility and operationalises the predictors of perceived accessibility and the spatial dimension (Lättman et al., 2016). The fifth chapter discusses the result of two regression models. A linear regression model that includes all the predictors is used to analyse the predictors of accessibility (on the individual level) across levels of urbanity. A second logistic regression model is used to estimate the risk of low accessibility at the municipal level.

In short, the most important findings are that there are significant differences in perceived accessibility across different levels of urbanity, with perceived accessibility being lower in more rural areas. However, these differences are not explained by the variation in spatial accessibility alone. While spatial accessibility is a significant predictor of perceived accessibility, individual and subjective predictors are also important. The determinants of accessibility are generally comparable across levels of accessibility, with some exceptions. Within levels of urbanity, differences in spatial accessibility only have a significant effect in the most rural areas. As such, differences in accessibility in urban areas result primarily from interpersonal differences and perceptions and preferences.

Furthermore, accessibility-related problems are not only a rural issue. The share of the population experiencing low perceived accessibility is almost identical across levels of urbanity. The estimation of the risk of low perceived accessibility on the municipal level partially confirms this. There are urban areas where the risk of low perceived accessibility is high and rural areas where the risk is low.

This is the result of differences in the composition of the population. However, the results do show that the risk of low perceived accessibility is generally higher in peripheral areas.

1 Introduction

The idea that accessibility should be a goal in transport planning has been around for decades, but the adoption of accessibility-based measures has been slow (Handy, 2020). Accessibility is about how easy it is to reach the goods, services and activities people need or want with the help of the transport system (Geurs et al., 2016; Handy, 2020; Pereira et al., 2017; van Wee, 2016). As such, it is more encompassing than traditional mobility-focused approaches. It includes the spatial dispersion of destinations, how easily those destinations can be reached, and the types of goods, services and activities present at those destinations. This multidimensionality of the concept of accessibility poses a challenge for its adaptation in transport planning as measuring accessibility is complex. However, accessibility-based approaches also offer opportunities to further embed transport planning into broader social policy as accessibility is associated with social inclusion.

In recent years there has been increased interest in the adverse outcomes of poor accessibility. Insufficient levels of accessibility are associated with various negative outcomes and social disadvantages (Preston & Rajé, 2007; SEU, 2002). When people experience inadequate accessibility, it is difficult or impossible for them to access crucial goods, services, and activities. This can refer to an inability to access necessities such as food, activities such as social interaction and physical activity or opportunities such as employment and education. Consequently, insufficient accessibility can result in an inability to partake in society and essential parts of normal life. As such, accessibility is generally recognised as fundamental to social inclusion and possibly well-being (Lucas, 2012; Lucas et al., 2016; Pereira et al., 2017; Preston & Rajé, 2007; SEU, 2002).

The relationship between accessibility and social inclusion is one of the reasons why accessibility-based approaches may be more suitable for specific transport planning goals than mobility-focussed approaches. While there is an obvious connection between mobility and accessibility, it is possible to have high mobility yet experience poor accessibility. Similarly, low mobility does not always result in a lack of accessibility (Handy, 2020). Good accessibility, being able to reach the destinations they want and need, is ultimately what matters to people and allows them to partake in society. From a broad social perspective, ensuring sufficient accessibility is a more reasonable policy goal than aiming for good mobility. A focus on accessibility is also well-suited to policy-making as a typical goal of transport policy is to ensure individuals can reach the goods, services and activities they need (Verlinghieri & Schwanen, 2020).

1.1 The concept of accessibility

The term accessibility has various interpretations and sometimes is used interchangeably with mobility. Pereira et al. (2017) conceptualise accessibility as: "the ease with which persons can reach places and opportunities from a given location, and be understood as the outcome of the interplay of characteristics of individuals, the transport system, and land use". Pereira et al. (2017) explicitly refer to the interplay of characteristics of individuals, the transport system, and land use. In some other contexts, accessibility is used to refer to only the potential mobility provided by the transport system and the spatial dispersion of destinations. In those contexts, accessibility is treated as a spatial issue. The differences in how people want to and are able to interact with the transport system and the differences in the destinations they need and want to reach are not taken into account.

In this research context, the broader definition from Pereira et al. (2017) is most suitable due to the relationship between accessibility and social inclusion. Good accessibility allows people to access destinations they need to live a normal life and partake in society. While spatial accessibility is highly relevant, multiple factors determine whether people can access those destinations. A broad interpretation of accessibility is necessary because individuals differ in their ability to interact with the transport system and the destinations they want and need to reach (Curl et al., 2015). At a given location, two individuals may experience different levels of accessibility due to their personal characteristics and needs. Even though their level of spatial accessibility is equal, the ease with which they can reach the goods, services and activities they need and want can differ significantly. Geurs and van Wee (2004) specify four components of accessibility: 'land use', 'transport', 'individual needs, abilities, and opportunities' and 'temporal constraints and dynamics'. In this research, accessibility is understood to be the outcome of all of these components.

1.2 Research objectives

1.2.1 Research problem

The multi-faceted nature of the concept of accessibility is its strength but simultaneously poses a significant challenge. The complexity of measures of accessibility forms an obstacle to the adoption of accessibility-based approaches in research and transport planning (Handy, 2020). The most straightforward measures of accessibility fail to capture much of the complexity, whereas more advanced measures have high data requirements, involve complex calculations and are challenging to understand and interpret (Geurs & van Wee, 2004; Handy, 2020). Accessibility is often measured using 'objective' measures, such as the distance to a set of destinations. These measures do not capture accessibility as it is defined in the context of this research but rather measure spatial accessibility. More complex quantitative approaches to measuring accessibility, such as agent-based models in time geography, do take the individual and temporal components into account and thus are more in line with our definition of accessibility (Jonsson et al., 2014). However, they are typically not used to identify accessibility-related problems on a large scale for the reasons mentioned above. As a result, there is relatively little large-scale quantitative research about where and among whom accessibility-related problems are prevalent.

Much of the available research on accessibility on the level of individuals and accessibility-related problems comes from people-based approaches. These studies focus on how individuals engage with the transport system and often take a theoretical or qualitative approach (Karner et al., 2020; Pereira et al., 2017). Qualitative studies on accessibility often focus on specific groups, modes or geographical areas. The results help us identify groups that are at risk of experiencing low accessibility. However, they do not allow for comparison between groups or geographical areas and don't expose the relative effects of different factors that impact accessibility.

In recent years there has been increased interest in the adverse outcomes associated with low accessibility and how individuals engage with the transport system. This development marks a shift from accessibility as a spatial issue toward a more individual conceptualisation of accessibility (Pereira et al., 2017). However, there is a need for a comprehensive measure of accessibility that includes the different components of accessibility, yet is easy to calculate, compare and interpret. Such a measure is necessary to identify where and among whom accessibility-related problems are prevalent and which factors contribute to good accessibility. Generally, 'objective' quantitative measures fall short because they take limited account of interpersonal differences or are highly complex. On the other hand, people-based approaches lack empirical evidence or have a limited scope.

1.2.2 Research aim

The goal of this research is to analyse patterns and predictors of accessibility. Doing so will help identify which areas and groups are at risk of accessibility-related problems and provide a basis for policy responses. Accessibility is measured through the perception of individuals. By measuring how easy individuals find it to reach the goods, services and activities they need or want through their subjective perception, the different components of accessibility are included in an easy-to-interpret measure without the high data requirements and complex calculations. Additionally, a subjective measurement is suitable because accessibility is inherently mediated by perceptions and preferences. Which goods, services and activities are important, what distances are acceptable and what makes a destination easy to reach are all subjective. Perceived accessibility can help bridge the gap between qualitative and people-based approaches by acting as a quantifiable measure of accessibility take simultaneously includes different components of accessibility through the perception of the individual.

Three crucial dimensions should be taken into account when studying patterns of accessibility: the differences in spatial accessibility, the interpersonal differences in how people are able to and want to interact with the transport system and the differences in the composition of the population. In this research, all three dimensions are considered. By measuring perceived accessibility on the level of the individual and taking into account their individual characteristics, perceptions and preferences and the spatial accessibility at their residential location, the outcome will provide insights into what factors govern accessibility. Based on the results and information about population characteristics, it's possible to estimate which geographical areas have a relatively higher risk of low accessibility. As such, the results of this research provide insights into which characteristics are associated with low accessibility as well as in which areas low accessibility is prevalent.

The spatial context is explicitly considered by comparing the predictors of accessibility between different levels of urbanity. Spatial accessibility is generally higher in urban areas than in rural areas due to denser transport systems and higher concentrations of goods, services and activities. Furthermore, there are some differences in the characteristics of urban and rural transport systems. For example, public transport services often have low coverage in rural areas, while urban areas have more congestion and lack parking space. As such, the differences in spatial accessibility are both quantitative and qualitative.

As discussed, individual characteristics and perceptions and preferences impact how individuals are able to and want to interact with the transport system and what destinations they need and want to access. For example, a high-income individual who owns a car is likely to find it easier to reach many destinations than someone with a lower income who relies on public transport. Similarly, someone for whom the destinations they need to access are far away from their residential location is likely to experience lower accessibility compared to someone for whom those locations are closer. How individual characteristics impact accessibility may vary depending on the context. For example, being unable to drive a car may have a different effect on someone's accessibility if they live in a car-dependent rural area compared to an urban area with a high-quality public transport system. Due to the differences in the characteristics of the transport system, the predictors of perceived accessibility may differ in magnitude or directionality between levels of urbanity. As such, not only accessibility itself may vary between levels of urbanity but also its predictors.

It is important to note that individual characteristics are not randomly dispersed in space. Some individual characteristics are more concentrated in certain areas. For example, rural areas typically have an older population. If age has a negative effect on accessibility, then average accessibility may be lower in those places due to the composition of the population rather than only differences in spatial accessibility. As such, spatial patterns in accessibility do not only result from differences in spatial accessibility. Furthermore, people may choose to live in places that suit their accessibility needs and preferences. As such, residential location decisions may mitigate the spatial differences in accessibility (van Wee, 2009).

1.2.3 Research questions

This thesis aims to study patterns of perceived accessibility and its predictors in the Netherlands. In doing so, the following research question is answered:

" What drives interpersonal and spatial differences in perceived accessibility across different levels of urbanity in the Netherlands? "

In order to answer the main research question, the following sub-questions are answered:

1. What are the determinants of perceived accessibility?
2. Does urbanity matter in how perceptions of accessibility are formed?
3. Which groups and areas are at risk of experiencing low accessibility?

1.3 Research relevance

1.3.1 Societal relevance

A good understanding of spatial patterns and individual differences in accessibility can help identify groups and areas that are most at risk of experiencing accessibility-related problems. Determining where and among whom low accessibility is prevalent is essential for increasing transportation equity and addressing broader social inequalities. Besides its role in designing policies to reduce transport inequality and social exclusion, it could also contribute to making these policies more economically efficient and sustainable. A focus on mobility and the use of predominantly spatial measures of accessibility results in an inherently spatial and transport-centred perspective on accessibility. From this perspective, the obvious solution to address accessibility-related issues is increasing potential mobility by improving the transport system and incentivising additional movement. However, infrastructure investment is costly and encouraging additional movement (by motorised vehicles) is not desirable from a sustainability perspective(Karner et al., 2020; Verlinghieri & Schwanen, 2020). Understanding the predictors of accessibility could help design policies that help target particular groups or areas that lack accessibility, for example, by helping individuals utilise existing transport opportunities or incentivising additional movements only for those who need them.

Using a subjective measure of accessibility provides a different perspective than existing approaches because it recognises the subjective nature of the concept itself. The diverse transport needs and the preferences and perceptions of the individual are taken into account. Accessibility is about how easy it is for someone to access the destinations they need and want, which is subjective in itself. Furthermore, perception and preferences influence transport behaviour. Transport-related social exclusion ultimately results from insufficient transport behaviour (Nordbakke & Schwanen, 2015). Since that outcome is an important reason for studying accessibility, it is logical to include perceptions and preferences in the conceptualisation and operationalisation of accessibility.

Finally, perceptions of accessibility (for specific transport modes) have been shown to influence modal choice, suggesting that understanding perceptions of accessibility may play a role in encouraging the use of sustainable transport (van Exel and Rietveld, 2009; Scheepers *et al.*, 2016).

1.3.2 Scientific relevance

Studying perceived accessibility and its predictors on a national scale and considering different spatial contexts can add to the existing body of literature on perceived accessibility. Existing studies on perceived accessibility typically have a less comprehensive approach (Budd & Mumford, 2006; Curl et al., 2011, 2015; Gebel et al., 2011; Lättman et al., 2016, 2018; Lotfi & Koohsari, 2009; Ma & Cao, 2019; Maddison et al., 2010). They predominantly consider the urban context, often focus on perceived accessibility for a specific transport mode or location and do not aim to identify general accessibility-related problems (Friman et al., 2020; Lättman et al., 2018; Ryan et al., 2015). While most existing studies on perceived accessibility have a relatively limited scope, they provide results that pose questions as to what factors drive accessibility in general.

Most studies find that perceived accessibility differs from what is measured by spatial measures of accessibility (Budd & Mumford, 2006; Curl et al., 2011, 2015; Gebel et al., 2011; Lättman et al., 2016, 2018; Lotfi & Koohsari, 2009; Ma & Cao, 2019; Maddison et al., 2010). These findings indicate that interpersonal differences and preferences are essential determinants of accessibility. Existing research also suggests that spatial patterns of perceived accessibility are not directly linked to spatial accessibility. A study in Malmö, Sweden, found that, across urban residential areas, the variation in spatial accessibility was far greater compared to the variation in perceived accessibility. Levels of perceived accessibility showed minimal variation in space and were comparable across areas (Lättman et al., 2018). One qualitative study found that, among older individuals in Israel, perceived accessibility is higher in rural settlements compared to mid-sized urban centres (Vitman-Schorr et al., 2019). This indicates a discrepancy between spatial and perceived accessibility, as spatial accessibility is commonly understood to be better in urban areas. Both results suggest that spatial accessibility may be relatively unimportant for accessibility and that most of the inequality in accessibility results from interpersonal differences.

Most studies on perceived accessibility focus on the urban context, so studying perceived accessibility on a national scale can provide insights as to whether the lack of spatial variation in perceived accessibility extends beyond the urban context. It is possible that the lack of spatial variation in perceived accessibility found in urban areas results from the actual differences in spatial accessibility being relatively small or that spatial accessibility in urban areas is generally high enough not to limit accessibility. On a national level or within rural areas, where there are more considerable differences in spatial accessibility, and there are areas that have poor spatial accessibility, there may be a stronger correlation between spatial accessibility and perceived accessibility.

1.4 Thesis structure

The second and third chapters provide the theoretical and conceptual foundation for analysing perceived accessibility. The second chapter covers the concept of accessibility. It elaborates on the definition of accessibility and its components. Subsequently, spatial accessibility, individual differences in accessibility and the relevance of subjective perceptions and preferences are discussed. The third chapter discusses the use of perceived accessibility as a measure of accessibility. It also introduces the different types of predictors of accessibility, resulting in the conceptual framework.

The fourth chapter introduces the data and methods. By using survey data to construct the Perceived Accessibility Scale (PAC) score, perceived accessibility can be measured relatively easily. The chapter also discusses the operationalisation of the predictors of accessibility and the spatial dimension. Finally, it introduces two regression techniques that will be used to analyse patterns and predictors of accessibility. The results are discussed in the fifth chapter. The final chapter provides a conclusion and discusses the societal and scientific relevance, shortcomings and suggestions for future research.

2 Theoretical background

Providing an adequate level of accessibility and combating (problematic) transport inequality is a common policy goal and is often one of the main reasons for studying accessibility. However, accessibility is a complex concept with multiple interpretations. In this chapter, the concept of accessibility will be discussed and dissected. It is vital to understand how accessibility is defined and how it differs from other transport-related concepts. The distinctions are important to consider as they are essential to determine which conceptualisation and operationalisation of accessibility are most suitable for particular research or policy objective. The first paragraph elaborates on the definition of accessibility and the four components discussed in the introduction. Subsequently, spatial accessibility is discussed. Spatial measures of accessibility are often used but have shortcomings that make them unsuitable for analysing accessibility as defined in this study. The chapter then elaborates on individual differences in accessibility and the relevance of subjective perceptions and preferences.

2.1 The concept of accessibility

2.1.1 Defining accessibility

Pereira et al. (2017) conceptualise accessibility as: "the ease with which persons can reach places and opportunities from a given location, and be understood as the outcome of the interplay of characteristics of individuals, the transport system, and land use". This is a broad interpretation that explicitly refers to the interplay of characteristics of individuals, the transport system, and land use. In many other contexts, accessibility refers to only the transport system (usually in combination with land use) but not individual differences. Understanding the distinction between these definitions is crucial as there are fundamental differences in meaning between the two. Which definition is used relates to everything from how accessibility is measured to what constitutes transport inequality. In order to understand what different definitions of accessibility refer to and how they relate to each other, it is necessary to consider the different components that constitute accessibility. Geurs and van Wee (2004) specify four components of accessibility.

- land-use (how activity locations are spread out through space)
- transport (relating to the time, cost, and effort associated with reaching destinations)
- individual needs, abilities, and opportunities (how individuals are able and want to interact with the transport system)
- temporal constraints and dynamics (referring to, for example, time-budgeting and time of activities)

It should be noted that the term accessibility is also used to refer to non-transport-related concepts. It sometimes refers to the accessibility of goods, services or activities themselves rather than their location. This type of accessibility is beyond the scope of this research.

2.1.2 Components of accessibility

2.1.2.1 Land-use component

The transport and land-use components reflect the time, costs, and effects associated with reaching goods, services, and activities that are spread out through space. The land-use component relates to where the goods, services, and activities are located. It determines the distance someone needs to cover from their location to a particular activity location. In urban areas, there is typically a greater variety and denser spread of goods, services, and activities than in rural areas. As such, rural residents have to cover larger distances to access the same types of activity locations.

2.1.2.2 Transport components

The transport component relates to the time, cost and effort associated with reaching activity locations. It is determined by the quality and density of transport infrastructure. Generally, urban areas have more dense and diverse transport infrastructure. Urban transport systems offer more opportunities to reach activity locations, theoretically making it easier to travel from one place to another. However, while urban and rural transport systems are different, urban infrastructure is not always necessarily better in all aspects. For example, travelling a certain distance by car may be far more time-consuming and costly in a city with congested roads and a lack of parking space compared to a more rural area.

2.1.2.3 Individual component

The individual component of accessibility refers to how individuals are able and want to interact with the transport system. As discussed in the previous chapter, not all individuals are able to interact with the transport system in the same way. Individuals may differ in their ability to engage with transport opportunities, for example, due to physical and financial limitations or lack of information. Furthermore, individuals have different transport needs and preferences.

2.1.2.4 Temporal component

The temporal component refers to temporal constraints and dynamics, which can apply to the three previous components. With regard to the land-use component, it can refer to which goods, services and activities can be reached at which times. For example, shops in urban areas typically have longer opening hours. With regard to the transport components, it can refer to the operating hours of public transport services or delays caused by traffic jams. With regard to the individual component, it can refer to things like time-budgeting or avoiding travelling at night.

2.1.3 Interactions between components

The land-use and transport components are strongly connected because they both impact how easy it is to reach goods, services and activities using the transport system. To some extent, a higher quality transport system can compensate for longer distances and vice versa. Together the land-use and transport components constitute spatial accessibility. We call this type of accessibility spatial accessibility because it is inherently spatial and does not differ between individuals at the same location.

When the individual component of accessibility is included, accessibility is no longer a purely spatial phenomenon, and inequalities in accessibility can exist at the same location. This type of accessibility is in line with the definition by Pereira et al. (2017).

2.2 Spatial accessibility

2.2.1 Spatial and objective measures of accessibility

Land use and transport constitute spatial accessibility. Spatial accessibility forms an essential foundation for accessibility but is often conflated with broader accessibility. Measures that are referred to as measures of accessibility are often simply measures of spatial accessibility. These measures are also frequently referred to as 'objective' measures of accessibility. However, the term objective may be somewhat misleading. Objective, in this case, does not imply a true reflection of reality but rather a measure that is not influenced by perceptions, opinions, and preferences.

As a substitute for true objective accessibility, indicators have been designed to serve as a proxy, such as travel time, cost, and distance to a set of destinations (Curl et al., 2011; Geurs & van Wee, 2004). A simple example of such a measure is the road distance to the nearest hospital, which Statistics

Netherlands (CBS) publishes yearly aggregated on the level of neighbourhoods. While these measures are considered objective in the sense that they do not measure perceptions, opinions and preferences, they are still influenced by the perceptions, opinions and preferences as the parameters are set by researchers.

Such measures are frequently used in transport research and policy-making and have many advantages. Simple measures of spatial accessibility are easy to interpret and compare between regions or over time. Collecting data is relatively easy, and outcomes can be aggregated for geographical areas. While these spatial measures are convenient, they are not suitable for measuring accessibility as defined in this research.

2.2.2 Spatial measures often take limited account of the individual component of accessibility

In the previous paragraph, four components of accessibility were discussed. Spatial measures of accessibility usually focus on the land-use and transport components of accessibility. As a result, they present accessibility as a purely spatial issue and neglect individual differences (Karner et al., 2020; Pereira et al., 2017). While focusing on spatial accessibility is not a problem, it does not reflect the definition of accessibility used in this research. Using these spatial measures to study inequalities in transport means we are studying inequality of transport resources or potential mobility rather than inequality of accessibility (Pereira et al., 2017). More complex measures of accessibility that include the individual component and combine different metrics do exist. For example, agent-based models in time geography consider individual time and budget constraints in modelling accessibility (Jonsson et al., 2014). However, such measures are used less frequently as they are more challenging to interpret and have high data and computational requirements.

2.2.3 Spatial measures overlook the complexity of accessibility

Accessibility is incredibly complex, even when the individual component is not considered. There are multiple ways to travel between two locations, depending on transport mode and route. Besides obvious metrics such as distance, cost and time, other factors that impact how accessible a specific route is, such as road safety. Furthermore, not all activity locations of the same type are equal. For example, supermarkets may carry different products, have different opening hours and charge different prices (van Wee, 2016). These complexities are not reflected in a measure that uses the distance to the nearest supermarket. It is impossible to include all these considerations into one measure. Besides, these factors interact with each other and can depend on external circumstances such as gas prices or the weather. Even the most complex measures cannot take all these factors into account.

2.2.4 Accessibility is subjective

As discussed, objective measures of accessibility refer to measures that are not influenced by perceptions, opinions, and preferences. However, while the actual measurement is objective, the selection of metrics and parameters is influenced by perceptions, opinions and preferences. Which destinations and modes are considered relevant and what distance, time or cost is acceptable are all based on subjective perceptions, opinions and preferences. When constructing spatial measures of accessibility, researchers must decide which modes and destinations to include and which metrics to use for the effort associated with reaching locations (McCahill et al., 2020). While this can be based on empirical evidence, some bias is inevitably introduced through the inclusion or exclusion of specific metrics, modes and destinations. Furthermore, in reality, what is more, or less accessible can differ between individuals.

This is especially problematic when some parameters are structurally excluded because they are difficult to measure or fall outside the norm. Easy to measure metrics, such as distance, and widely used modes, such as cars, can become the standard for measuring accessibility. The accessibility that individuals derive from utilising other forms of transport is not valued by these measures. Most commonly walking, car-use and public transport are taken into account. Less common modes, such as cycling, skateboarding and e-scooters, are typically not included. For some individuals, these alternative modes of transport may allow them to reach goods, services and activities they would not have otherwise (Kostrzewska & Macikowski, 2017). As such, accessibility may be underestimated, and potential sources of accessibility are overlooked.

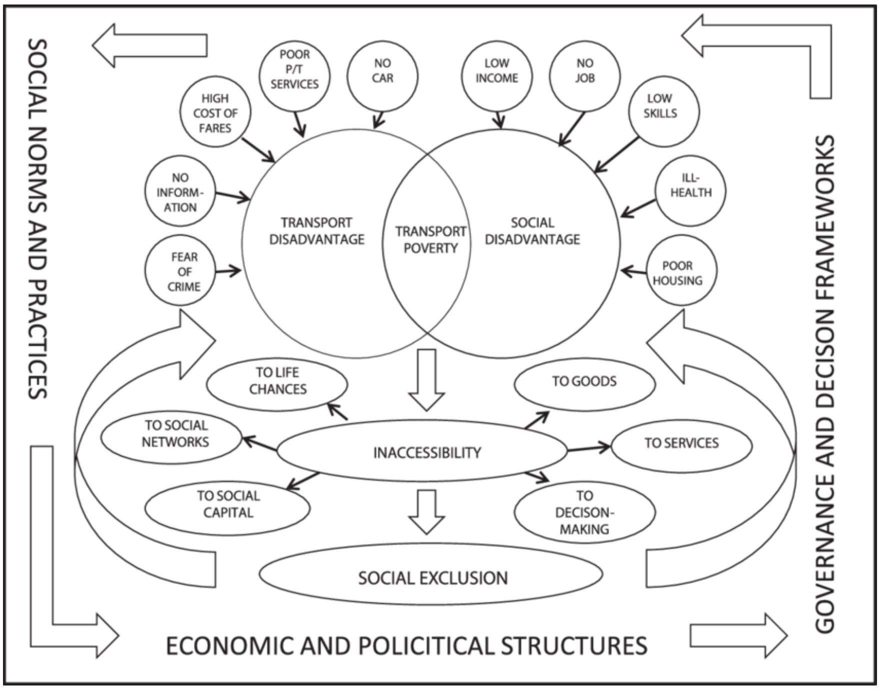
2.3 Interpersonal differences in accessibility

2.3.1 Accessibility on the individual level

While spatial accessibility is the same for everyone at a given location, accessibility is not. Personal characteristics determine how individuals can act upon spatial accessibility. Factors that restrict an individual's accessibility can range from obvious physical or financial limitations on mobility to more subtle differences in transport-related skills and abilities (Curl et al., 2015). Personal restrictions on mobility may lead to insufficient accessibility, meaning that individuals cannot access crucial goods, services, and activities such as food, employment, education, and social interaction. Depending on the severity of the personal restrictions, this can occur regardless of the level of spatial accessibility. For those who face no significant restriction on their mobility, poor spatial accessibility may not be problematic. For example, high-income individuals may be able to compensate for poor spatial accessibility (Currie et al., 2010).

The link between accessibility and social exclusion is often conceptualised on the individual level. Lucas (2012) conceptualises social exclusion as occurring where transport disadvantage and social disadvantage meet. Social exclusion refers to deprivation broader than poverty and is characterised by an inability to participate in social, cultural, economic and political life and a lack of resources, rights, goods and services (Lucas, 2012; Schwanen et al., 2015). Social exclusion is relative to others and is tied to well-being. Lucas' (2012) conceptual model of transport disadvantage shows that transport poverty, a problematic lack of accessibility, occurs only where social exclusion and transport disadvantage overlap. She conceptualises social disadvantages as consisting of factors such as low income, unemployment, low skills, health problems, and poor housing. Transport disadvantage is conceptualised as having no car, poor quality or expensive public transport, lack of information, and safety issues.

Both transport and social disadvantage can occur separately and do not always lead to social exclusion. However, transport poverty and social exclusion occur when transport disadvantage and social disadvantage interact. In this situation, individuals lack access to goods, services and activities that are crucial for their daily lives and to life-enhancing opportunities such as employment, education and health care (Lucas, 2012).



2.1 Conceptual framework of transport poverty (Lucas, 2012)

2.3.2 People-based approaches in theory and research

In transport literature, some scholars advocate for people-based approaches to transport and accessibility (Pereira et al., 2017). These approaches are typically more rooted in theoretical and philosophical perspectives and place interpersonal differences and individual constraints on transport behaviour at the foreground. While these approaches incorporate the interpersonal heterogeneity in accessibility that is often missing in quantitative research, they tend to be highly theoretical. Existing empirical studies using people-centred approaches often have a limited scope and rely on qualitative research (Karner et al., 2020; Pereira et al., 2017). As a result, they fail to provide a comprehensive understanding of accessibility and lack empirical evidence. Due to these weaknesses, people-centred approaches struggle to identify which groups and regions experience or are at risk of accessibility-related problems and are used less frequently in policy-making.

In 2018 the *Netherlands Institute for Transport Policy Analysis* (KiM) published a report on transport poverty (mobiliteitsarmoede) in the Netherlands. This report covers various studies that research the risk or prevalence of transport poverty among different social groups or in different geographical areas. However, the authors ultimately conclude that no definite answer can be given as to whether transport poverty is an issue in the Netherlands and, if so, to what extent. They attribute this to the lack of comprehensive research, making it difficult to compare results across groups and compare the effects of different factors that are associated with transport poverty.

2.3.3 Interactions between individual and spatial accessibility

Studies about accessibility on the individual level are primarily concerned with urban areas, although not always explicitly (Pereira et al., 2017). This is unfortunate as the differences in spatial accessibility likely also impact the interpersonal differences in accessibility. Furthermore, households' residential location decisions are related to their accessibility needs. The location of an individual is more complex than just a factor that determines the level of spatial accessibility they experience. Individuals are not immobile and can make decisions about their residential location. One study in the Netherlands found that accessibility plays a significant, yet relatively small, role in residential location decisions (Zondag & Pieters, 2005). Households may trade accessibility for other qualities in their location decisions, such as lower house prices or more space. In the most basic economic model of residential location choices, residential choices are a trade-off between land prices and commuting costs (Alonso, 1960). Households can either choose cheaper land and higher commuting costs or lower commuting costs and more expensive land. In Alonso's model, this results in the situation that households that cannot afford high commuting costs (in terms of money or time) will live closer to employment centres on more expensive land.

2.4 The role of perceptions and preferences in accessibility

2.4.1 Perceptions and realised behaviour

There is a relationship between subjective perceptions about the transport system and transport behaviour. Transport-related social exclusion is ultimately the result of realised behaviour when individuals do not engage in the movements needed to reach crucial goods, services, and activities. This behaviour can, of course, result from lacking spatial accessibility, but there are other possible factors as well. Adequate spatial accessibility alone is insufficient to ensure individuals access the goods, services, and activities they need.

Furthermore, mitigating the differences in accessibility that result from individual characteristics does not guarantee an effect on realised transport behaviour. A skewed or negative perception of the transport system may impact behaviour. Limited knowledge or familiarity with or negative perceptions of (parts of) the transport system may prevent individuals from acting upon transport opportunities (Ma & Cao, 2019; van Wee, 2016).

2.4.2 Transport needs

People differ in their preferences for locations. While these preferences are subjective, they are not irrelevant. Not all individuals require the same goods, services, and activities. For example, for an individual who does not work and does not have any need and desire to work, reaching employment or employment opportunities is not essential. Thus, the lack of access to the types of destinations does not necessarily impact their level of accessibility. For others, however, the same destinations are crucial for their level of accessibility. Similarly, individuals may desire to engage in social or cultural activities to various extents. Ignoring this and assuming that there is a certain universal acceptable level of accessibility may lead to over or under provision of transport.

2.4.3 Transport preferences

Another important reason for including preferences is that it can help shift the focus away from the car as the dominant mode of transport. The car is still often seen as the leading mode of transport, which offers the highest level of accessibility and which individuals will choose if they are able to. In many models of accessibility, car ownership is included in the transport component of accessibility. However, individuals may prefer different modes or choose different modes out of moral principle. Excluding this preference, as relevant, would result in the conclusion that individuals who choose to forgo motorised transport would not be considered to experience transport poverty even if there are very few existing transport opportunities they can utilise. Other relevant preferences include cultural or religious reasons. A report on transport poverty in the Netherlands notes that some groups (such as some women from a non-western background) are not allowed to travel by bicycle (KiM, 2018).

3 Theoretical framework

The third chapter introduces the theoretical framework. The first paragraph discusses why perceived accessibility is used to measure accessibility. The following paragraph examines the findings of existing research. Prior studies have shown that there is a mismatch between perceived accessibility and spatial accessibility. The spatial variation in perceived accessibility is much lower compared to the variation in spatial accessibility. The fourth and fifth paragraphs discuss how perceptions of accessibility are formed and how the predictors of perceived accessibility relate to each other. This results in the conceptual framework that will form the basis for the analysis in later chapters.

3.1 Perceived accessibility

3.1.1 What is perceived accessibility

Recently there has been an increased interest in measures of perceived accessibility, which capture individual and subjective aspects of accessibility (Curl et al., 2015; Lättman et al., 2016; Scheepers et al., 2016; van der Vlugt et al., 2019). Lättman et al. (2016) define perceived accessibility as "how easy it is to live a satisfactory life with the help of the transport system". This definition highlights that perceived accessibility is not only about the potential mobility that the transport system offers but also about how individuals want and are able to interact with the transport system and whether the transport system allows them to travel to the destinations that are important to them rather than a predetermined set of destinations.

3.1.2 Benefits of studying perceived accessibility

There are multiple reasons why studying perceived accessibility can aid our understanding of accessibility and transport inequality in general.

- Includes the subjective component of accessibility
- Measures accessibility through the perspective of the individual
- Comprehensive perspective with a simple measure

3.1.2.1 Includes the subjective component of accessibility

Conceptually, the most important reason for studying perceived accessibility is that it includes subjective elements of accessibility. Paragraph 2.4 explains this in more detail.

3.1.2.2 Measures accessibility through the perception of the individual

As discussed in the second chapter, quantitative measures of accessibility often fail to capture the individual component of accessibility. Furthermore, they can only partially capture differences in spatial accessibility due to the complexity of transport and land-use dynamics. Many factors that impact accessibility remain unobserved. Individual accessibility is often approached from a theoretical perspective or studied on a small scale with a limited scope. Quantitative measures are sometimes used, but these have high data requirements, and some individual characteristics such as transport-related skills are difficult to observe. By measuring perceived accessibility, the factors that remain unobserved in traditional studies are observed through the individual's perception.

3.1.2.3 Comprehensive perspective with a simple measure

Perceived accessibility can be presented as a single metric that can be used in quantitative analysis. This provides an advantage compared to other approaches for studying accessibility, which often has a limited scope making it challenging to compare between groups or regions.

3.1.3 Shortcoming of perceived accessibility

While using perceived accessibility as a measure to study accessibility has many benefits, some issues need to be addressed. Cognitive dissonance may influence perceptions. There may be a difference between an individual's ideal travel behaviour and the travel behaviour in which they are able to partake. According to Festinger's cognitive dissonance theory, individuals respond to such a gap between their beliefs and behaviour by either changing their behaviour or changing their beliefs (de Vos & Singleton, 2020). In the case of accessibility, this would entail either relocating to somewhere where the transport system is more suited to their ideal travel behaviour or changing their idea of ideal travel behaviour. As discussed, residential location choices are complex, and relocation is expensive. Most individuals are not able to relocate to reduce the discomfort they experience as a result of cognitive dissonance regarding their transport behaviour. The alternative is to alter their beliefs. In areas where spatial accessibility is high, and there are different modes available, individuals do not need to alter their beliefs to reduce dissonance as they are able to choose the behaviour that best suits their beliefs (de Vos & Singleton, 2020). However, in areas with low spatial accessibility where there are fewer modes available, individuals may be more inclined to alter their beliefs about their preferred travel behaviour. For example, inhabitants of a region where most destinations can only be reached by car may shift their preference towards travel by car and away from public transport or active travel modes. As a result, they may not perceive their accessibility to be lower compared to an area with better public transport services as they do not wish to use public transport regardless of whether it is available. In some cases, individuals with accessibility may not perceive their accessibility as low. Since this altering of beliefs primarily occurs in areas where spatial accessibility is lower, the process may contribute to a lack of spatial variation in perceived accessibility.

While this is a valid critique of the use of subjective measures of accessibility, it is not a good reason to avoid them. It is a good argument as to why subjective measures should be used in conjunction with other measures. Just as objective spatial measures fail to capture some aspects of transport inequality, subjective measures fail to capture some cases of poor accessibility. Ideally, both spatial accessibility and perceived accessibility should be above an acceptable level.

3.2 Existing research on perceived accessibility

3.2.1 The gap between perceived and spatial accessibility

While not much is known about perceived accessibility outside of urban areas, existing studies suggest that spatial patterns of perceived accessibility are not directly linked to spatial patterns of accessibility. Generally, the spatial variation of perceived accessibility does not seem to match the level of spatial variation. A study in Malmö, Sweden, found that, across urban residential areas, the variation in spatial accessibility was far greater compared to the variation in perceived accessibility. Levels of perceived accessibility showed minimal variation in space and were comparable across areas (Lättman et al., 2018). One qualitative study found that, among older individuals in Israel, perceived accessibility is actually higher in rural settlements compared to mid-sized urban centres (Vitman-Schorr et al., 2019). This indicates a discrepancy between spatial and perceived accessibility, as spatial accessibility is commonly understood to be better in urban areas.

Curl et al. (2015) provide an overview of three possible causes for this gap between perceived and ‘objective’ spatial accessibility, which can be summarised as measurement error, individual characteristics, and limited information. As previously discussed, what we call objective measures are proxies designed to reflect true accessibility as closely as possible given the information constraints. The gap between objective and perceived accessibility does not result from individuals' experiences not accurately reflecting reality but rather from measurement error. An individual's perceived accessibility may also deviate from objective measures due to personal characteristics. For an individual that deviates from the average individual, constraints, such as limited mobility, may impact the level of accessibility they experience. In this case, their perceived accessibility may differ from objective accessibility but accurately reflect reality for the individual. Lastly, differences in perceived accessibility may result from a lack of knowledge about available options or distorted perceptions due to familiarity with particular transport modes.

The explanations provided by curl et al. (2015) consider the discrepancy between perceived and spatial accessibility on the level of the individual. However, on a spatial level, self-selection may also explain the difference (van Wee, 2009). If people choose to locate somewhere that meets their accessibility needs, spatial variation in perceived accessibility would likely be lower than spatial variation in accessibility.

3.2.2 Implications of the mismatch between spatial and perceived accessibility

A lack of spatial variation in perceived accessibility suggests that the land-use and transport components of accessibility are not the sole determinants for the level of accessibility individuals experience. It means that in areas considered to have low accessibility by spatial measures, individuals are, on average, not less able to live a satisfactory lifestyle using the transport system. If the lack of spatial variation of perceived accessibility extends beyond the urban context, it has implications for transport policies and could provide a new element to discussions about transport equality. It should be noted that a lack of spatial variation in average perceived accessibility does not mean there are no spatial differences in the prevalence of low perceived accessibility.

While perceived accessibility has not been used extensively in transport planning as of yet, it has the potential to be used for identifying groups or areas for which the existing transport system does not provide adequate opportunities. Including measures of perceived accessibility in policy-making could contribute to increased quality of life by providing a stronger focus on the needs of citizens (Lotfi & Koohsari, 2009). It could also help to prevent over-or underinvestment in certain areas by identifying where transport needs are not being met and where the existing transport system is functioning well. Additionally, it could be used to test whether policies intended to increase accessibility have the desired outcome. Recent transport justice literature often points out that often infrastructure developments do not benefit the least-well of groups (Pereira et al., 2017). One of the reasons for this is that infrastructure project assessments often rely heavily on cost-benefit analysis. Project assessments have recently started, including broader interpretations of costs and benefits. Including improvements in perceived accessibility rather than only objective spatial accessibility could contribute to this.

3.3 Determinants of perceived accessibility

There are different types of factors that can determine the level of perceived accessibility that individual experiences. While there is some overlap and possible interaction between the types, they can be categorised into five types:

- Spatial accessibility
- Sociodemographic factors
- Transport related resources
- Skills and abilities
- Perception and preferences

3.3.1 Spatial accessibility

The first type, spatial accessibility, represents the transport and land-use components of accessibility. The available transport opportunities consist of only land-use and transport components of accessibility, such as the location of goods, services and activities, infrastructure, and public transport services. At a location, transport opportunities are equal for everyone as they consist merely of the set of opportunities the transport system offers to reach specific destinations. The set of existing transport opportunities consists of all possible means of transport to the locations of goods, services, and activities.

3.3.2 Sociodemographic factors

There are three types of factors that can differ between individuals and determine how an individual is able to make use of the transport system. Various sociodemographic factors such as age, income, and gender impact accessibility. The effect can be direct or act through transport-related resources or skills and abilities. For example, low-income individuals may have less access to transport-related resources, or some transport-related abilities may decline with age.

3.3.3 Transport related resources

Transport-related resources refer to resources that are needed to utilise the transport system. These factors are not part of the transport system itself but are resources needed to utilise it. For example, to utilise a highway, a motorised vehicle is needed. Owning a car does not provide potential mobility; it only allows the individual to act on that potential mobility. This interpretation differs from models such as Kaufman's theory of motility, where the transport system and the resources needed to use it are both included as contextual constraints on the range of possible mobilities (Kaufmann et al., 2004). In this research, these are deliberately separated to be able to make the distinction between individual and spatial predictors of accessibility.

3.3.4 Skills and abilities

Skills and abilities also determine which transport opportunities are acceptable for an individual. There are different types of abilities that determine whether individuals are able to utilise specific transport opportunities. The most obvious is physical ability. Different forms of transport require different physical abilities. Limited physical capabilities or disabilities can exclude an individual from utilising transport opportunities. However, other skills or abilities can also determine how individuals can utilise transport opportunities. Kaufman et al. (2004) call these acquired and organisational skills. This category includes skills and knowledge such as obtaining a driver's licence, being able to plan public transport trips, reading directions, and time management.

3.3.5 Perceptions and preferences

The final type of predictor comprises the subjective components of accessibility and is a combination of perception and preferences. Preferences and perceptions are often excluded from models of accessibility. However, as discussed in the previous chapter, there are strong arguments to include subjective components in accessibility research. Paragraph 2.4 provides a more in-depth discussion of the types of perceptions and preferences that are relevant.

3.4 Interaction between the predictors

The five types of predictors sometimes overlap and interact, and their effects on perceived accessibility depend on each other. Spatial accessibility forms the basis of perceived accessibility as it reflects the potential mobility that the transport system provides. The other predictors either restrict how individuals engage with that potential mobility or how they interpret, perceive and value it. Within sociodemographic factors, transport-related resources, and skills and abilities, there is much overlap and possible interaction and correlation. Sociodemographic factors that are assumed to impact accessibility may actually (partially) do so through their impact on transport-related resources and skills, and abilities. For example, lower-income individuals likely have less access to transport-related resources. Similarly, someone's level of education or age may be correlated with their transport-related skills and abilities.

Perceptions and preferences determine how individuals perceive spatial accessibility and how well it matches their constraints, needs and preferences. These perceptions and preferences can depend on individual characteristics such as sociodemographic factors, transport-related resources, skills and abilities, as well as on experiences. Furthermore, the spatial context, spatial accessibility and the built environment may also impact how people perceive and judge accessibility.

3.4.1 Spatial dimension

In the context of this research, it is assumed that the predictors of accessibility differ between levels of urbanity. There are differences in the transport system and land use between different levels of urbanity. There are also differences in the characteristics of the population and the perceptions and preferences of those living in urban and rural areas. These can either result from composition effects, self-selection or be the result of the environment itself. While analysing these effects is not the goal of this research in itself, it is essential to consider their existence. Furthermore, the analysis may provide results that suggest whether those effects are present.

Individuals may choose to locate in areas that suit their accessibility needs. As such, areas with different levels of accessibility attract people with different transport needs and preferences. These self-selection effects may have a positive effect on accessibility. As outlined in paragraph 3.2, the context itself may also impact perceptions and preferences. People subconsciously alter their preferences if no alternatives are available that are better suited to their needs.

The environment may also influence how journeys are perceived. (Curl et al., 2015) found that objective journey times are shorter than subjective journey times in urban areas. However, the pattern is reversed, and the differences are larger in rural areas. Another study found that perceptions of public transport journey times depend on trip characteristics and socio-economic factors (Meng et al., 2018). A study in Ghent found that participants who live in less walkable neighbourhoods overestimate walking times (Dewulf et al., 2012). Additionally, people perceive transport modes they are unfamiliar with more negatively (Ma & Dill, 2015; Meng et al., 2018). Modes that are not available may thus be viewed as less convenient.

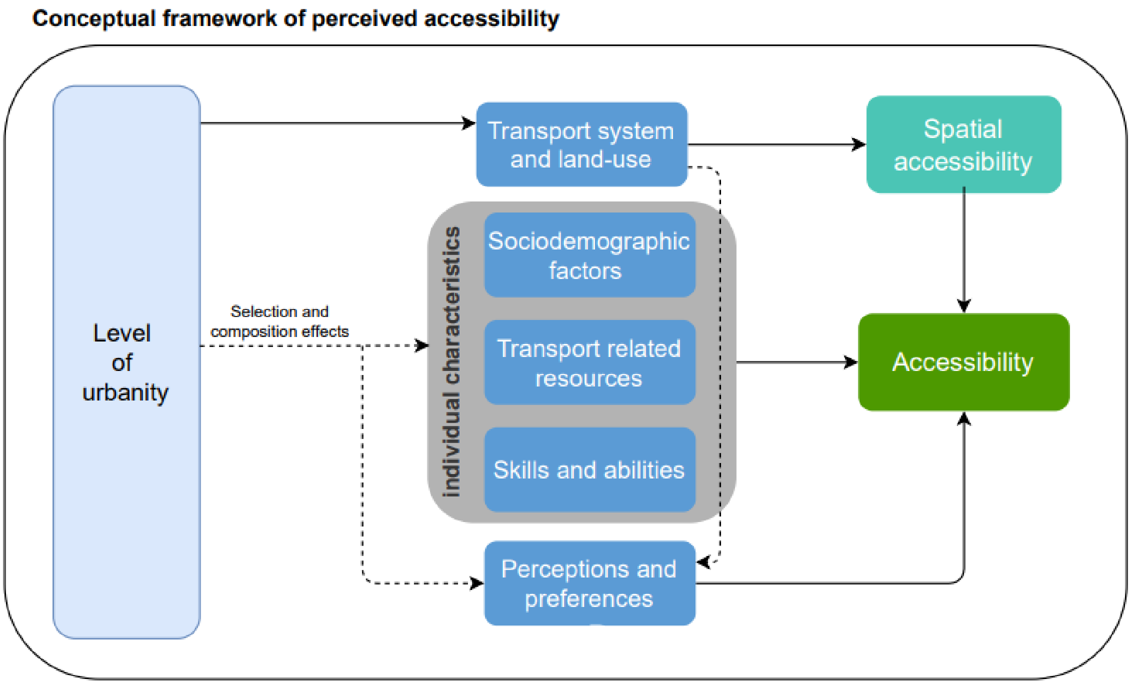
Besides differences in the predictors themselves, their effects on perceived accessibility are expected to differ between urban and rural areas. The factors that deviate from the norm for that particular level of urbanity likely have the greatest negative effect on perceived accessibility. For example, in regions with high car ownership, not owning a car and disliking cars as a transport mode are expected to have greater negative effects on perceived accessibility compared to regions with lower car ownership.

3.5 Conceptual framework

3.5.1 What constitutes accessibility

Perceived accessibility refers to how individuals perceive the transport system to help them live a satisfactory life. This means that it is based on the individual's perception, their personal preferences and transport needs, their characteristics and the transport system itself. The land-use and transport components determine the level of spatial accessibility at the residential location of the individual.

Spatial accessibility is the foundation of accessibility. The other factors determine to what extent an individual can use spatial accessibility to access the destinations they need and want. Individual characteristics act as limitations on how an individual can utilise the transport system. The individual judges how well this suits their transport needs and preferences to form their perception of accessibility. These perceptions and preferences differ between individuals but can also be correlated with the level of spatial accessibility. Individuals may (subconsciously) alter their preferences based on the characteristics of the transport system or land use at their location. Similarly, those characteristics can impact how spatial accessibility is perceived.



3.1: Conceptual framework

3.5.2 Outcomes of perceived accessibility

When people perceive their level of accessibility as low, they feel that the transport system does not offer them adequate opportunities to live a satisfactory life. This means they have mobility needs that are not met under the current circumstances. Low accessibility may thus result in individuals not accessing crucial goods, services and activities. This situation can result from a lack of spatial accessibility but also from individual constraints or a mismatch between the available transport opportunities and the individuals' transport needs and preferences. Regardless of the reason someone experiences low accessibility, if it prevents them from engaging in transport behaviour, they may be at risk of social exclusion. However, while the outcome is the same, the appropriate policy response depends on the cause. Improving spatial accessibility will not necessarily have the desired effect if the individual characteristics or subjective elements are why someone is experiencing transport-related social exclusion. Similarly, mitigating interpersonal differences may be futile if spatial accessibility is lacking. As such, it is essential to understand the determinants of accessibility as well as the actual level of accessibility some experiences.

4 Data and Methods

The previous chapter introduced the conceptual framework for studying perceived accessibility. In this chapter, this conceptual framework will be operationalised. A method is developed by which the predictors of perceived accessibility in the Netherlands will be studied. This chapter will discuss how perceived accessibility in the Netherlands can be measured based on survey data collected by the *Netherlands Institute for Transport Policy Analysis* (KiM). Subsequently, the different types of predictors will be discussed and operationalised. After this, a regression model is constructed to analyse which factors are associated with low perceived accessibility or transport poverty.

4.1 Measuring Perceived accessibility

4.1.1 data

The analysis of perceived accessibility is based on cross-sectional data (n= 3,789) from the Netherlands. The dataset was collected by *Mobiliteitspanel Nederland* (MPN). The spatial location of respondents is determined based on their postal code. 411 respondents were omitted from the sample for the reason that they did not enter a (valid and complete) postal code. A two-sample *t*-test showed no significant differences in perceived accessibility score (n=3381, t= 1.6849, p = 0.0921 > 0.05, df= 3379) between those who entered their postal code and those that did not enter their postal code. The age range of respondents is between 12 and 95, with an average of 54.6. 1,760 of the respondents are female (52.1%), 1569 are male (46.5%), and 48 did not give an answer (1.4%).

4.1.2 Perceived Accessibility Scale

Perceived accessibility can be measured using the *Perceived Accessibility Scale* (PAC), designed by Lättman et al. (2016) and further developed in Lättman et al. (2018). The PAC measures overall perceived accessibility based on the assessment of four quantifiable statements on a 7-point Likert scale. These four statements are based on key elements of (perceived) accessibilities that were derived from previous theories and research on accessibility. The PAC was initially developed to use for specific transportation modes but can also be used to capture general accessibility across transportation modes (Lättman et al., 2016, 2018). *Table 4.1* provides an overview of the four statements used in the PAC, the components of perceived accessibility they measure, and their use in the Dutch language survey. There is a slight difference in how the questions are structured in Lättman et al. (2016; 2018) compared to the survey used for this thesis. Most notably, in the Dutch survey, the statements are preceded by an introductory question “considering your current travel opportunities, to what extent do you agree or disagree with the following statements?”[1].

The PAC for an individual is calculated as the mean score on the four elements (*Table 4.1).* Omitting any of the statements does not negatively impact Cronbach’s Alpha. This indicates a high level of consistency between the four elements and thus suggests they can indeed be used to measure one concept. This is consistent with the findings presented by Lättman et al. (2016).

[1] Rekening houdend met uw huidige reismogelijkheden, in hoeverre bent u het met de volgende stellingen eens of oneens?”

Table 4.1: Perceived Accessibility Scale (PAC)

Elements PAC developed by Lättman et al. (2018) (I don't agree = 1, I completely agree = 7)	*Survey statements* *(helemaal mee oneens = 1, helemaal mee eens = 7)*	*English translation survey statementd* *(Completely disagree = 1, completely agree = 7)*	*Key elements of perceived accessibility, as identified by Lättman et al. (2016)*	*Component of accessibility measured, as identified by Lättman et al. (2016)*
Considering how I travel today it is easy to do my daily activities	Ik kan mijn gewenste dagelijkse activiteiten makkelijk uitvoeren	I am able to do my daily activities with ease	Ease of reaching activities	Individual component: captures differences such as needs and abilities
Considering how I travel today I am able to live my life as I want to	Ik kan mijn leven leiden zoals ik dat wil	I am able to live my life the way I want	Perceived possibilities of travel and the potential of opportunities to travel	Transport component: defines the ease of physical movement
Considering how I travel to day I am able to do all activities I prefer	Ik kan alle activiteiten uitvoeren die ik wil	I am able to do all the activities I want	Perceived opportunities to access activities of interest. Process indicator of accessibility.	Land-use component; determines geographical issues
Access to my preferred activities is satisfying considering how I travel today	De bereikbaarheid van mijn gewenste activiteiten is goed.	Access to my preferred activities is good.	Outcome indicator of accessibility; captures satisfaction, not just possibilities	Temporal component: includes the availability of different destinations at different times

4.1.3 Levels of urbanity

Perceived accessibility and its predictors will be compared across levels of urbanity in order to understand the spatial dynamics of perceived accessibility. The level of urbanity is based on the density of addresses within a radius of 1 km. The level of urbanity for the residential location of respondents is based on the average level of urbanity in their four-digit postal code. *Table 4.2* shows the levels of urbanity and the corresponding address density. The categorisation is based on the levels of urbanity defined by *Statistics Netherlands* (CBS). However, the two highest levels of urbanity were combined to meet data requirements. The map *(figure 4.1)* shows the spatial patterns of urbanity in the Netherlands on the municipal level. The rural areas are primarily located near the north, east and south of the country, while the more urban areas are concentrated in the west. This map illustrates one of the shortcomings of using administrative units to study accessibility. In some places, strongly urban areas and not urban areas are immediately next to each other. In these cases, neighbours could be considered to live in vastly different levels of urbanity or have different spatial accessibility. This research circumvents this as much as possible by assigning urbanity based on the smallest unit for which the data is available: the 4-digit postal code.

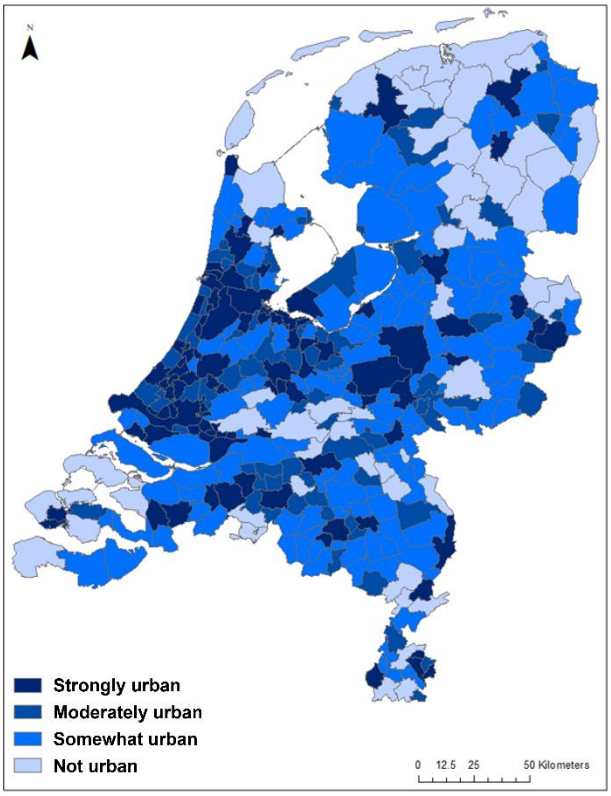


Figure 4.1: Levels of urbanity in the Netherlands

Table 4.2 Levels of urbanity and address density

Level of urbanity	*Number of addresses*	*N*	*Population 2020* (CBS, 2022a)
Strongly urban	1500 or more	244	8535720
Moderately urban	1000 – 1500	168	2971100
Somewhat urban	500 - 100	606	2956380
Not urban	500 or less	814	2944390

4.2 Measuring spatial accessibility

The basis of perceived accessibility is spatial accessibility. It results from a combination of transport and land use and is specific to a location. Three spatial characteristics are included in the model to measure spatial accessibility. These are the spatial accessibility of opportunities, the diversity of opportunities and the population development of the region.

4.2.1 Spatial accessibility of opportunities

Spatial accessibility can be defined as the opportunities for reaching spatially dispersed goods, services and activities. Place-based measures are most commonly used to measure this. These place-based measures can be operationalized as

$$A_i = \sum_j O_i f\left(d_{ij}\right) \qquad (4.1)$$

The level of accessibility (A) at the origin location i is the sum of all opportunities (O) available at destinations j weighted by a function of the distance (d_{ij}) between i and j. For the purpose of this research, jobs are used as a proxy for opportunities. The locations of opportunities are obtained from the Dutch establishment register LISA, which contains information about the locations of firms. The location, sector and number of jobs are recorded for each firm. These job locations are opportunities.

The function of travel distance discounts the weights of opportunities based on the travel time between i and j. Kwan suggests five impedance functions based on theoretical models (Kwan, 1998). The negative exponential function is most commonly applied in accessibility analysis (Higgins, 2019).

$$f\left(d_{ij}\right) = e^{-\beta\, d_{ij}} \qquad (4.2)$$

$-\beta$ is the distance decay parameter that determines the rate at which the weight of opportunities is discounted as distance increases. Here the distance decay parameter is set to 0.5. This translates to a threshold of approximately 5km, beyond which the weight given to opportunities is so low that it can be considered negligible. The distance (d_{ij}) is calculated as the road distance between the two locations rather than the Euclidian distance.

4.2.2 Diversity of opportunities

Besides the proximity of opportunities, the diversity of opportunities is calculated as an Entropy index:

$$EID_i = -\sum_s \frac{P_s ln(P_s)}{ln(S)} \quad (4.3)$$

Where EID_i is the diversity of opportunities at the origin location i.
P_s is the proportion of the opportunities, as reflected by A_i, within a given sector (s = 1, 2, … , S). The resulting entropy index is a number between 0 and 1, where 1 reflects a perfectly equal distribution of opportunities across sectors. As such, a number closer to 1 translates to a greater diversity of opportunities. A greater diversity of opportunities is associated with better spatial accessibility as it reflects a greater variety in the types of goods, services and activities an individual can access. As a stand-alone metric, diversity of opportunities offers minimal insights into spatial accessibility. However, in combination with the overall accessibility of opportunities, it is a good proxy for overall spatial accessibility. Diversity matters less in an area where the overall concentration of opportunities is high. However, in an area where opportunities are sparse, lower diversity of opportunities means it is more likely that particular goods, services or activities are not accessible at all.

4.2.3 Declining regions

The last spatial characteristic in the model is a dummy that indicates whether the individual resides in a declining region. Declining regions are regions that experience an ongoing decrease in population. Nine Dutch regions consisting of one or multiple municipalities are labelled as declining regions (krimpgebied) by the *Ministry of the Interior and Kingdom Relations* (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2019). The disappearance of services is a significant concern for these declining areas. As such, residents of these regions have likely experienced a decline in objective accessibility over the past few years. Respondents who live in a municipality that is part of a declining region are classified as living in a declining region.

4.3 Individual predictors of perceived accessibility

Based on the conceptual model discussed in chapter 2, there are five categories of predictors of perceived accessibility.

- Spatial accessibility
- Sociodemographic characteristics
- Transport-related resources
- Skills and abilities
- Perceptions and preferences

The operationalisation of spatial accessibility was discussed in the previous paragraph. In this paragraph, the remaining types of predictors are discussed briefly. The conceptual relevance of these predictors is discussed in chapter 2. The focus here will be on how these predictors can be operationalised so that they can be included in the model.

4.3.1.1 Sociodemographic characteristics and transport-related resources

As discussed in chapter two, some sociodemographic characteristics may impact the level of accessibility that an individual experiences. Respondents were asked about relevant personal characteristics such as age, employment, household income and other household characteristics. These are included in the model. Respondents were asked questions about the transport-related resources they have access to, such as the number of cars, (e)bikes, and motorbikes in the household. A high number of vehicles in the household does not necessarily mean an individual has access to these vehicles. As such, it is essential to include the number of people in the household in the model.

Furthermore, respondents were also asked whether they always had access to a car and whether they could arrange rides from friends and family. Having a good internet connection is also included as a transport-related resource. There are two reasons for this. Firstly, online services can reduce the need to physically go to specific locations and thus increase access to some goods, services or activities. Secondly, a good internet connection allows individuals to get better information about the transport system.

4.3.1.2 Skills and abilities

Transport-related skills and abilities impact an individual's level of accessibility as it affects how they can utilise transport opportunities. Disabilities are included in the model as physical abilities may determine to what extent some are able to utilise different transport opportunities. Having a driver's license is also included as a skill. In order to assess public transport-related skills, respondents were asked whether they found the public transport cards easy to understand, whether they found planning public transport trips easy and whether they felt the provision of public transport information was good. The answers to these questions were entered into principal component analysis, retaining one factor that indicates the level of public transport-related skills the individual has. *Table 4.3* shows that those from more urban areas have better public transport skills than those from more rural areas.

4.3.1.3 Perceptions and preferences

The subjective component of perceived accessibility comes from perceptions and preferences. Respondents were asked whether they considered different modes as comfortable, relaxing, or enjoyable and whether they considered the mode to give status. The sum of these four attitudes measures the general an individual has about a mode of transport. This is indicative of an individual's preference. Respondents were also asked whether they consider those modes time-saving, flexible, and safe. The answers provide information as to the perception individuals have of different modes. The sum of attitudes to these three statements measures how convenient an individual perceives those modes. Both measures were entered into a factor analysis. In both cases, the factor analysis resulted in the retention of three factors.

For general mode perception, the three factors are ‘pro active modes’, ‘pro public transport’, and ‘pro motorised transport’. *Table 4.3* shows that those living in more urban areas have a stronger preference for public transport. Active and motorised modes are judged more positively in rural areas, with the differences being largest for motorised transport. It is not surprising that public and motorised transport modes are viewed more positively in urban and rural areas respectively because those modes provide more accessibility in those specific types of transport systems. However, it is somewhat surprising that active modes are viewed more positively in rural areas. Active modes are generally used for covering shorter distances, whereas distances to goods, services and activities are often greater in rural areas.

Principal component analysis was also applied to perceived mode convenience (Appendix B; *Table 4.2*). For the perception of the convenience of modes, the factors are ‘public transport convenient ‘active and private motorised convenient, and ‘alternative modes convenient. For active and motorised transport and for public transport, the patterns are the same as for general mode preference. For alternative modes, the differences between levels of urbanity are not significant.

As discussed in the first chapter, individuals may have differences as to which goods, services and activities they want to reach. Respondents were asked whether they wanted to live near several types of locations. Principal component analysis resulted in two components: ‘want services close’ and ‘want activity locations close’. Individuals who want to live near services prefer living near services such as shops, public transport stations and healthcare. Wanting to have activity locations close means that an individual wants to live near locations where they engage in their daily activities, such as their job or school locations and the places where they engage in social contact and exercise. Table 4.3 shows that inhabitants of rural areas have a stronger preference for living near activity locations, whereas urban residents have a stronger preference for living near services.

4.4 Descriptive Statistics

Table 4.3 compares perceived accessibility and the independent variables across the levels of urbanity. It shows significant differences in perceived accessibility across regions, suggesting that there is more spatial variation in perceived accessibility than suggested by earlier studies. It also shows significant differences in population characteristics between the areas. Among all the five categories of predictors specified in the model, there are significant differences for most characteristics. There are differences in socio-demographic characteristics, transport-related resources, skills and abilities and preferences and perceptions. The patterns align with what is expected based on our general understanding of the differences between urban and rural areas. It should be noted that the overall characteristics of the sample should not be interpreted as representative for the Dutch population. Inhabitants of strongly urban and moderately urban areas are severely underrepresented in the sample (CBS, 2022a). *Table 4.2* shows the population per level of urbanity.

Table 4.3: descriptive statistics

Variables	Overall	Strongly urban	Moderately urban	Hardly urban	Not urban	Group differences
N	1832	244	168	606	814	
PAC	5.93	6.04	5.92	5.98	5.86	$F_{[2.61]} = 4.66$***
Spatial characteristics						
lnACC	6.35	8.15	7.06	6.29	5.21	$F_{[2.61]} = 3406.72$ ***
ENT	0.85	0.87	0.85	0.85	0.84	$F_{[2.61]} = 72.11$***
Declining region	23%	3%	23%	35%	31%	$\chi^2_{[3]} = 277.58$***
Socio-demographic characteristics						
age	54.56	49.01	53.79	56.49	56.45	$F_{[2.61]} = 34.87$***
Female	53%	54%	55%	51%	53%	$\chi^2_{[3]} = 2.01$
low education	28%	23%	29%	29%	28%	$\chi^2_{[3]} = 7.74$*
Employed	48%	45%	51%	49%	48%	$\chi^2_{[3]} = 4.23$
low income	21%	25%	19%	21%	19%	$\chi^2_{[3]} = 10.25$**
Household size	2.29	1.99	2.24	2.36	2.40	$F_{[2.61]} = 19.78$***
Length of residence	18.44	15.83	17.03	18.73	19.93	$F_{[2.61]} = 13.97$***
Accessibility related resources						
Number of cars	1.35	1.00	1.21	1.33	1.54	$F_{[2.61]} = 89.51$***
Number of (e)bikes	2.13	1.87	2.01	2.16	2.21	$F_{[2.61]} = 10.16$***
Number of motorbikes	0.12	0.06	0.13	0.10	0.16	$F_{[2.61]} = 10.89$***
car availability	80%	73%	80%	80%	85%	$\chi^2_{[3]} = 39.07$***
lift by car	25%	32%	29%	24%	22%	$\chi^2_{[3]} = 22.51$***
Pt card	26%	39%	25%	25%	20%	$\chi^2_{[3]} = 81.75$***
Poor internet connection	12%	5%	6%	11%	15%	$\chi^2_{[3]} = 58.79$***

friends family	33%	36%	33%	32%	31%	$\chi^2_{[3]}$ = 4.34
Skills and abilities						
disability	17%	18%	19%	20%	18%	$\chi^2_{[3]}$ = 1.49
Public transport skills	0.00	0.84	0.20	-0.13	-0.26	$F_{[2.61]}$ = 76.95***
No drivers licence	10%	17%	14%	9%	7%	$\chi^2_{[3]}$ = 61.05***
Perceptions and preferences						
active and private motorised convenient	0.00	-0.16	0.00	-0.07	0.04	$F_{[2.61]}$ = 2.89**
public transport convenient	0.00	0.18	-0.04	-0.02	-0.12	$F_{[2.61]}$ = 8.36***
alternative modes convenient	0	-0.03	-0.05	-0.02	0	$F_{[2.61]}$ = 0.23
Pro active modes	0.00	-0.16	-0.05	0.06	0.01	$F_{[2.61]}$ = 5.14***
Pro public transport	0.00	0.05	0.02	0.01	-0.08	$F_{[2.61]}$ = 2.34*
Pro motorised modes	0.00	-0.35	-0.03	-0.04	0.12	$F_{[2.61]}$ = 21.86***
Want activity locations close	0.00	-0.43	-0.14	-0.08	0.25	$F_{[2.61]}$ = 44.66***
Want essential services close	0.00	0.14	0.17	0.29	-0.34	$F_{[2.61]}$ = 22.75***

4.5 Regression models

4.5.1 Linear regression model

A linear regression model with estimated using the previously identified variables that capture the differences in the five types of predictors of perceived accessibility. For the linear regression model, there is assumed to be a linear relationship between y and variables $x_1, x_2, \dots\ x_K$ for observation i. The parameters of the linear regression are estimated using the ordinary least squares method (OLS).

$$y_i = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_K x_{iK} + \varepsilon_i \qquad (4.4)$$

In this study, the dependent variable is perceived accessibility as measured by the Perceived Accessibility Scale (PAC). Perceived accessibility (PAC) for an individual i is:

$$PAC_i = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_K x_{iK} + \varepsilon_i \qquad (4.5)$$

OLS is used to determine the coefficient of the independent variables. In order to estimate the predictors of perceived accessibility in the whole of the Netherlands, an overall model is estimated. The types of predictors are entered per category in the order they appear in the conceptual framework to analyse whether they add explanatory power to the model. Subsequently, separate models are generated for each level of urbanity in order to analyse whether there are differences in the predictors of perceived accessibility between different levels of urbanity.

4.5.2 Logistic regression model

The linear regression model will be used to determine the relative importance of different predictors of perceived accessibility and to investigate spatial patterns in perceived accessibility. A second model, using logistic regression, will be estimated in order to investigate low perceived accessibility in particular. There is no obvious PAC score at which we should consider an individual to have low perceived accessibility. However, a score of 4.5 or lower will be considered as experiencing low perceived accessibility. Different cut-off points will be used to check whether the results are robust. Overall, approximately 11% of the respondents have a PAC score of 4.5 or lower, ranging from 10% in the most urban areas to 12% in the most rural areas.

$$log(\frac{p_1}{1-p_1} = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_K x_{iK} + \varepsilon_i \quad (4.6)$$

A PAC score of 4.5 or below is considered as 'low' perceived accessibility, resulting in the following specification where $p_{(PAC <= 4.5)}$ is the probability of a PAC score equal to or below 4.5.

$$log(\frac{p_{(PAC <= 4.5)}}{1-p_{(PAC <= 4.5)}} = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_K x_{iK} + \varepsilon_i \quad (4.7)$$

This model will include a subset of the variables included in the linear regression. Only variables for which data is available on the municipal or provincial level are included. This is done in order to be able to apply the outcomes of the regression model to the national context to predict where there is a higher risk of people experiencing low perceived accessibility.

The analysis will result in a risk score for having a PAC score of 4.5 or lower on the municipal level. This approach bears similarities to a 2019 study by *Statistics Netherlands* (CBS) and the *Netherlands Environmental Assessment Agency* (PBL) that estimates the risk of transport poverty (vervoersarmoede) at the neighbourhood level (CBS & PBL, 2019). However, the key difference is that the factors used to determine the risk of low accessibility are based on the determinants of low perceived accessibility as derived from the logistic regression model rather than on a set of determinants of transport poverty derived from theory.

4.5.2.1 Variables

Table 4.4 provides an overview of the data that can be used to apply the results of the regression model at the municipal level. Municipalities are assigned a score for their risk of low perceived accessibility based on their spatial characteristics and population characteristics. If a municipality ranks in the top 25% for a given variable, it receives a score that is equal to the coefficient (or the log odds). If it ranks in the bottom 25%, it is assigned a score that is the inverse of the log odds. The scores are subsequently summed for each municipality. Municipalities that rank high on the variables associated with higher odds of low perceived accessibility will be assigned a higher score. In doing so, we can investigate spatial patterns of accessibility while taking into account the interpersonal differences that impact perceived accessibility.

Table 4.4: Logistic regression variables

Variable	*Data available at the regional level (municipal or provincial)*	*Source*
lnACC	Number of jobs within 10 km	CBS (2017)
ENT	Entropy index based on jobs per industry in the municipality	CBS (2020)
Declining region	Declining region	Ministry of the Interior and Kingdom Relations (2019)
age	Average age	CBS (2020)
Female	Female/male ratio	CBS (2020)
Low education	% low education	CBS (2020)
Employed	% employed	CBS (2020)
Low income	% low income	CBS (2019)
Number of cars	Cars per 1000 inhabitants	CBS (2020)
Lacking Internet access	% of daily internet users (Provincial level)	Eurostat (2021)
Disability	% of people with physical disabilities	CBS (2020)
Drivers licence	% of people with driver's licence (provincial level)	CBS(2020)
Moderately urban	Level of urbanity	CBS (2021)
Hardly urban	Level of urbanity	CBS (2021)
Not urban	Level of urbanity	CBS (2021)

5 Results

Chapter five discusses the results of the analysis as outlined in the previous chapter. The results can be found in *table 5.1*. The model fit and robustness are discussed in appendix A. First, the differences in perceived and spatial accessibility will be compared across the regions and compared to the expectation based on existing studies on perceived accessibility. Subsequently, the results of both regression models will be discussed.

5.1 Spatial patterns of perceived accessibility

There are significant differences in perceived accessibility between the four levels of urbanity. This suggests spatial differences in perceived accessibility exist on the national scale. Earlier studies found these differences to be absent or insignificant within urban areas. As shown in *table 4.3*, perceived accessibility is highest in most urban areas and lowest in most rural areas. Surprisingly perceived accessibility is lower in moderately urban areas compared to hardly urban areas. While the differences are significant, they are small compared to the differences in spatial accessibility, supporting the theory that perceived accessibility has lower spatial variation than spatial accessibility.

The results show that low perceived accessibility is not only a rural problem. There are people who experience low perceived accessibility across all levels of urbanity. The percentage of people that experience low perceived accessibility is somewhat higher in rural areas, but the difference is relatively small compared to urban areas. Overall, 11% of respondents have a perceived accessibility score of 4.5 or lower. The share of respondents with PAC scores of 4.5 or below varies from 10 % in the most urban areas to 12% in the most rural areas. The difference is small and not significant. As such, low perceived accessibility is not only a rural problem. In the most urban areas, where spatial accessibility is highest, a sizeable group of people experience low perceived accessibility. This reinforces the idea that accessibility goes beyond what is measured by spatial measures of accessibility and that individuals can experience different levels of accessibility at the same location.

There is also a sizable group of people who do not experience any accessibility problems whatsoever. Regardless of their urbanity level, around a quarter of respondents have the highest possible PAC score. Overall, 25% of respondents have a PAC score of 7 (the highest possible score), indicating that the transport system poses no limitations to living a satisfactory life for them whatsoever. This percentage is highest among respondents in the somewhat urban regions (29%), followed by those in the most rural and urban regions (26%). While the differences are significant, there is no clear pattern with regard to urbanity.

5.2 Regression results

Table 5.1 displays the results of the regression models per category of predictors. The results show that all types of predictors specified in the conceptual model impact perceptions of accessibility. For the overall model, five iterations were generated. With each step, an additional category of predictors was added, starting with only spatial characteristics. The explanatory value of the model increased with every step, as shown in appendix A. Furthermore, in every category, at least some of the independent variables were found to have a significant effect on perceived accessibility in the overall model.

Table 5.1 Results of the linear regression model

	Overall	Strongly Urban	Moderately Urban	Somewhat Urban	Not Urban
Spatial characteristics					
lnACC	0.130***	0.0458	0.0437	-0.0122	0.164***
	(0.0256)	(0.0924)	(0.156)	(0.0905)	(0.0525)
ENT	-0.355	1.773	-4.288	0.397	-0.540
	(0.616)	(2.419)	(3.218)	(1.135)	(0.746)
krimpregio	-0.0892	-0.0550	0.120	0.0130	-0.168**
	(0.0557)	(0.190)	(0.192)	(0.0877)	(0.0814)
Socio-demographic characteristics					
age	0.00795***	0.000859	-0.00863	0.00884**	0.00945***
	(0.00216)	(0.00446)	(0.00746)	(0.00363)	(0.00345)
female	0.107**	0.117	-0.285	0.193**	0.0871
	(0.0522)	(0.130)	(0.222)	(0.0802)	(0.0814)
Education: low	0.170**	0.0709	0.577**	0.281**	0.0652
	(0.0688)	(0.185)	(0.247)	(0.121)	(0.105)
employed	0.168***	0.199	0.179	0.285***	0.0899
	(0.0592)	(0.149)	(0.224)	(0.0928)	(0.0938)
Income: low	0.0449	0.452***	0.000666	-0.0636	-0.0417
	(0.0757)	(0.163)	(0.302)	(0.130)	(0.129)
Household size	0.0135	0.0582	-0.131	0.0584	-0.0238
	(0.0262)	(0.0629)	(0.0956)	(0.0485)	(0.0388)
Length of residence	0.00394*	0.0137**	0.00582	0.00253	0.00454
	(0.00235)	(0.00641)	(0.0103)	(0.00417)	(0.00340)
Accessibility related resources					
Number of cars	0.0961***	0.0493	0.241	0.0130	0.139***
	(0.0370)	(0.107)	(0.176)	(0.0634)	(0.0532)
Number of (e)bikes	-0.00976	0.00806	0.175**	-0.0317	-0.0234
	(0.0223)	(0.0612)	(0.0831)	(0.0392)	(0.0331)
Number of motorbikes	-0.0219	-0.0310	-0.121	-0.146	0.0400
	(0.0559)	(0.301)	(0.179)	(0.100)	(0.0736)
Car availability	0.185**	-0.0477	-0.0715	0.101	0.459***
	(0.0743)	(0.160)	(0.223)	(0.118)	(0.142)
Lift by car	0.186***	0.0835	0.0244	0.235**	0.221**
	(0.0571)	(0.117)	(0.243)	(0.100)	(0.0943)
Public transport card	-0.0451	-0.281**	0.0880	-0.0658	-0.0279
	(0.0615)	(0.126)	(0.268)	(0.0972)	(0.101)
Poor internet connection	-0.416***	0.0848	0.0714	-0.507***	-0.432***
	(0.0952)	(0.220)	(0.309)	(0.162)	(0.137)
Friends and family	0.0489	0.152	-0.0555	-0.0206	0.0278
	(0.0506)	(0.110)	(0.201)	(0.0825)	(0.0824)
Skills and abilities					
Disabilities	-0.552***	-0.323	-0.326	-0.517***	-0.636***
	(0.0935)	(0.247)	(0.358)	(0.149)	(0.151)
Public transport skills	0.0920***	0.127**	0.129*	0.112***	0.0871***
	(0.0193)	(0.0624)	(0.0754)	(0.0311)	(0.0276)
No driver’s licence	0.245	0.341	0.0848	-0.350	0.647*
	(0.185)	(0.226)	(0.602)	(0.356)	(0.379)
Female x No driver's licence	-0.721***	-0.259	-0.989	-0.591	-0.834**
	(0.213)	(0.247)	(0.646)	(0.432)	(0.404)
Low-income x No driver's licence	-0.118	-0.618**	-0.399	0.312	-0.383
	(0.251)	(0.301)	(0.752)	(0.459)	(0.431)
Perceptions and preferences					
alternative modes convenient	-0.0197	0.0504	0.0289	-0.0740	0.00955
	(0.0263)	(0.0538)	(0.0729)	(0.0475)	(0.0423)
active and private motorised convenient	-0.00392	-0.0118	0.0874	-0.0650	0.00741
	(0.0236)	(0.0574)	(0.0747)	(0.0405)	(0.0366)
public transport convenient	0.00215	0.131**	0.0720	0.0179	-0.0569*
	(0.0221)	(0.0567)	(0.0791)	(0.0381)	(0.0345)
Pro active modes	0.0687***	0.0194	0.00839	0.0661*	0.111***
	(0.0238)	(0.0561)	(0.0820)	(0.0377)	(0.0397)

Pro public transport	-0.00732	0.0487	-0.0303	-0.00157	-0.0377
	(0.0233)	(0.0478)	(0.0754)	(0.0366)	(0.0384)
Pro motorised modes	0.0389	-0.0135	-0.159*	0.136**	0.0226
	(0.0269)	(0.0521)	(0.0881)	(0.0550)	(0.0374)
Want activity locations close	0.0931***	0.0317	-0.00979	0.0406	0.135***
	(0.0252)	(0.0630)	(0.117)	(0.0407)	(0.0392)
Want essential services close	-0.0571***	-0.00547	-0.00716	-0.0373	-0.104***
	(0.0160)	(0.0479)	(0.0587)	(0.0291)	(0.0230)
Constant	4.593***	3.453*	9.106***	4.912***	4.368***
	(0.542)	(1.938)	(2.886)	(0.981)	(0.700)
Observations	1,826	244	168	604	810
R-squared	0.203	0.192	0.309	0.241	0.286

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2.1 Spatial characteristics

There is a relationship between some spatial characteristics and perceived accessibility. Higher spatial accessibility is associated with higher perceived accessibility, but, with the exception of the most rural areas, there was no significant effect within areas with the same level of urbanity. The regression results in *table 5.1* show that spatial accessibility (ACC) has a significant positive effect on perceived accessibility in the overall model. However, within regions with the same level of urbanity, spatial accessibility only has a significant positive effect on perceived accessibility in the most rural regions. For the other regions, the effects are not significant. This shows that additional variation in spatial accessibility is not relevant in most regions. These results are in line with earlier studies that found little variation in perceived accessibility in urban areas regardless of differences in spatial accessibility. These findings suggest that this holds true for moderately and somewhat urban areas. In most regions, differences in perceived accessibility are related to interpersonal differences, whereas, in the most rural areas, differences in spatial accessibility are also relevant. A possible explanation for this is that in most regions, the spatial level of accessibility is sufficiently high everywhere, so accessibility-related problems result primarily from interpersonal differences in how individuals utilise the transport system. However, in most rural areas, spatial accessibility is sufficiently low that it has a negative impact regardless of individual characteristics. Additionally, in the most rural regions, the variation in spatial accessibility is greater compared to other regions (Appendix B; *Figure 8.1*).

The diversity of opportunities (ENT), another measure of spatial accessibility, did not have a significant effect. Besides spatial accessibility, living in a declining region also has a significant negative effect only in the most rural regions. In other areas, there was no significant difference in perceived accessibility for those who live in declining regions if all other variables are held constant. This does not necessarily mean that those in declining regions experience the same level of accessibility as those who do not. It could be that there are differences but that those differences are explained by different determinants correlated with living in a declining region.

5.2.2 Sociodemographic characteristics

Overall, sociodemographic characteristics impact perceived accessibility. The results show a relationship between perceived accessibility and age, gender, income, education and employment status. However, not all coefficients are significant in all the models.

Surprisingly age is found to have a positive relationship with perceived accessibility. Age has a significant positive effect on perceived accessibility in the overall model. It should be noted that the effect is relatively small. Holding all other factors constant, a 20-year age difference is associated with a 0.17 difference in perceived accessibility score. Generally, an inverted u-shaped relationship is expected between age and accessibility, where accessibility increases and eventually declines. However, different operationalisations of age, including using categories based on theory, did not result in a better model fit. The same positive effect of age on perceived accessibility was found in the somewhat urban and not urban regions. This is notable because elderly individuals are typically assumed to experience lower accessibility. An explanation for these findings may be that common causes of low accessibility among older adults, such as disabilities or lacking transport-related skills, are included in the model separately. Furthermore, older people may live in less accessible places. The population's average age is typically higher in more rural places (CBS/PBL, 2019).

Another explanation for the positive relationship between age and perceived accessibility in rural areas is that older individuals may, on average, have accessibility needs that align with what is available in rural areas compared to younger individuals. Younger people prefer a greater variety of goods, services and activities and typically have fewer transport-related resources available. As such, when people in rural areas age, their perceived accessibility may increase because their transport needs decline.

Low education was also found to have a significant positive effect in the overall model and in some regions. Similarly, low income was found to have a positive effect on perceived accessibility in the most urban areas and being employed has a negative effect in moderately urban areas. These findings contradict previous findings and theoretical understanding of their relationship to accessibility. A possible explanation is that those with low income or education may have lower transport needs, similar to older people. It is important to note that this does not mean these individuals do not experience social exclusion but simply that accessibility is not the limiting factor in obtaining certain goods and services and partaking in activities. Counterintuitively, their perceived accessibility may decrease with an increase in education or income because it may increase the number of goods, services and activities they want to access. The increased need for accessibility may then become a limiting factor.

5.2.3 Accessibility related resources

Accessibility-related resources, such as access to cars and public transport, impact perceived accessibility. Unsurprisingly, the number of cars in the household as well as always having access to a car have a positive effect on perceived accessibility in rural areas. The effects are not significant in more urban areas. The explanation is that those living in rural areas generally depend more on motorised transport.

Having a good internet connection was also included in the model as the ability to access online services reduces the need to travel to reach certain goods, services and activities. A poor internet connection has a significant negative effect on perceived accessibility in the overall model and the two least urban types of regions. The effect is large; those with poor internet access score around half a point lower on the perceived accessibility scale.

5.2.4 Skills and abilities

Skills and abilities were found to impact perceived accessibility. Both physical abilities and skills such as public transport-related skills and having a driver’s license impact how people perceive their level of accessibility. The effect of having a driver’s licence on perceived accessibility seems dependent on other socio-demographic characterises. For men, there is no clear relationship, but for women, particularly low-income women, there is a strong negative effect on perceived accessibility associated with not having a driver’s licence. *Table 7.6* in appendix A shows that, in the overall model, without the interaction effects included, not having a driver’s license has a significant negative effect. Disabilities that prevent an individual from using one or multiple transport modes also negatively affect perceived accessibility. The effect is largest in the most rural areas, indicating that having a disability impacts perceived accessibility more for those in rural areas.

Table 7.6 in Appendix A shows an overview of the interaction effects between income, gender and having a driver's licence. The table shows similar patterns across levels of urbanity. For those with a driver's license, income does not clearly affect perceived accessibility. For those who do not have a driver's licence, there are larger differences in perceived accessibility between gender and income groups. In this group, males who do not have low income perceived their accessibility as higher than those with a driver's license across the levels of urbanity. Women without a driver's licence have lower perceived accessibility compared to men who share the same characteristics regardless of income, but the negative effect is greatest for women who fall into the low-income group. It should be noted that not all coefficients are significant, and thus, the results may be unreliable. However, since the same pattern occurs across different levels of accessibility is unlikely that these findings are merely the result of chance.

Public transport skills have a positive effect on perceived accessibility across regions, although the effect is larger in the more urban regions. Since public transport offers more potential mobility in urban areas compared to rural areas, this effect is expected. However, the results show that even in the most rural areas, better public transport-related skills can positively impact how individuals perceive their level of accessibility.

5.2.5 Perceptions and preferences

While some subjective factors are associated with perceived accessibility, mode perception and preference generally do not seem to be very strong predictors of perceived accessibility, particularly in urban areas. In rural areas, preferences have a more noticeable effect on perceived accessibility. The results show that having preferences and perceptions that align with the characteristics of the transport system at your residential location, has a positive effect on perceived accessibility.

In strongly urban areas, the only significant predictor in the perceptions and preferences category is finding public transport convenient. This means that having a positive perception of public transport has a positive effect on perceived accessibility in urban areas. Interestingly, the effect is reversed in the most rural areas, where finding public transport convenient has a (small) negative effect on perceived accessibility. An explanation is that rural areas tend to have poorer public transport infrastructure. For those who perceive public transport as convenient but live in rural areas, their preferred transport behaviour does not match the available transport opportunities.

In rural areas, location preferences are also significant predictors of perceived accessibility. A preference for living near services such as shops, supermarkets and public transport has a negative effect in rural areas. A preference for living near activity locations such as near work and locations to engage in exercise and social contact has a positive effect on perceived accessibility. This shows that preferences that are in line with what the spatial context offers have a positive impact on perceived accessibility. Living near services such as shops, supermarkets, and public transport is more associated with urban areas, while living near activity locations is, for some people, also possible in rural areas.

5.3 Risk of low perceived accessibility

The linear regression results show that spatial accessibility, individual characteristics and subjective perceptions and preferences all impact perceptions of accessibility. While this is undoubtedly relevant from a theoretical perspective, the practical implications for identifying accessibility-related problems are limited without further (qualitative) research. However, it is possible to provide insight into where accessibility-related problems may be more prominent. Logistic regression is used to determine which factors are with low perceived accessibility. A smaller set of variables is used to produce results that are more applicable to everyday practice. The subjective factors, and some of the personal characteristics, that impact perceived accessibility are difficult to measure. There is no data available about the perceptions and preferences of the population in regards to transport.

5.3.1 Results

The results of the logistic regression model are shown in *table 5.2*. The coefficients show the effect on the log odds of having a PAC score below 4.5. Unsurprisingly, both measures of spatial accessibility have a negative effect on the log odds of experiencing low perceived accessibility. The log odds are positive for living in a declining region, meaning that the odds of having a PAC score of 4.5 or below are greater (above 1) for inhabitants of declining regions. The model fit and robustness are discussed in Appendix A. The results align with the findings based on the linear regression model discussed in the previous paragraph.

Table 5.2: Logistic regression results

VARIABLES	PAC 4.5 and below
lnACC	-0.243**
	(0.0965)
ENT	-0.756
	(1.374)
krimpregio	0.319**
	(0.141)
age	-0.0144***
	(0.00382)
Gender: female	-0.0691
	(0.128)
Education: low	-0.147
	(0.144)
Employment: low	-0.415***
	(0.146)
Income: Low	-0.00228
	(0.153)
Number of cars	-0.447***
	(0.101)
Good internet connection	1.208***
	(0.153)
Disabilities	1.212***
	(0.136)
	(0.326)
Moderately urban	0.347
	(0.268)
Somewhat urban	0.0231
	(0.189)
Not urban	-
Constant	0.821
	(1.248)
Observations	3,214
Pseudo R2	0.1165

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.3.2 Spatial patterns of perceived accessibility

The map shown in figure 5.1 displays the results. It shows that the risk of low perceived accessibility is generally higher in peripheral and rural municipalities. However, some municipalities that are neither rural nor peripheral have a high risk of low perceived accessibility. Comparing this map to a map of social-economic status (Appendix B; *figure 8.7*) shows a similar spatial pattern. The findings reinforce the notion that to identify accessibility-related problems, not only spatial accessibility should be considered but also the interpersonal differences that affect how individuals utilise the transport system.

Unfortunately, the results are not directly comparable to the 2019 study by CBS and PBL, which employs a similar approach but with a theoretical foundation. Whereas the results provided here are on the municipal level and cover the whole of the Netherlands, the CBS and PBL study provides results at the neighbourhood level but has limited coverage.

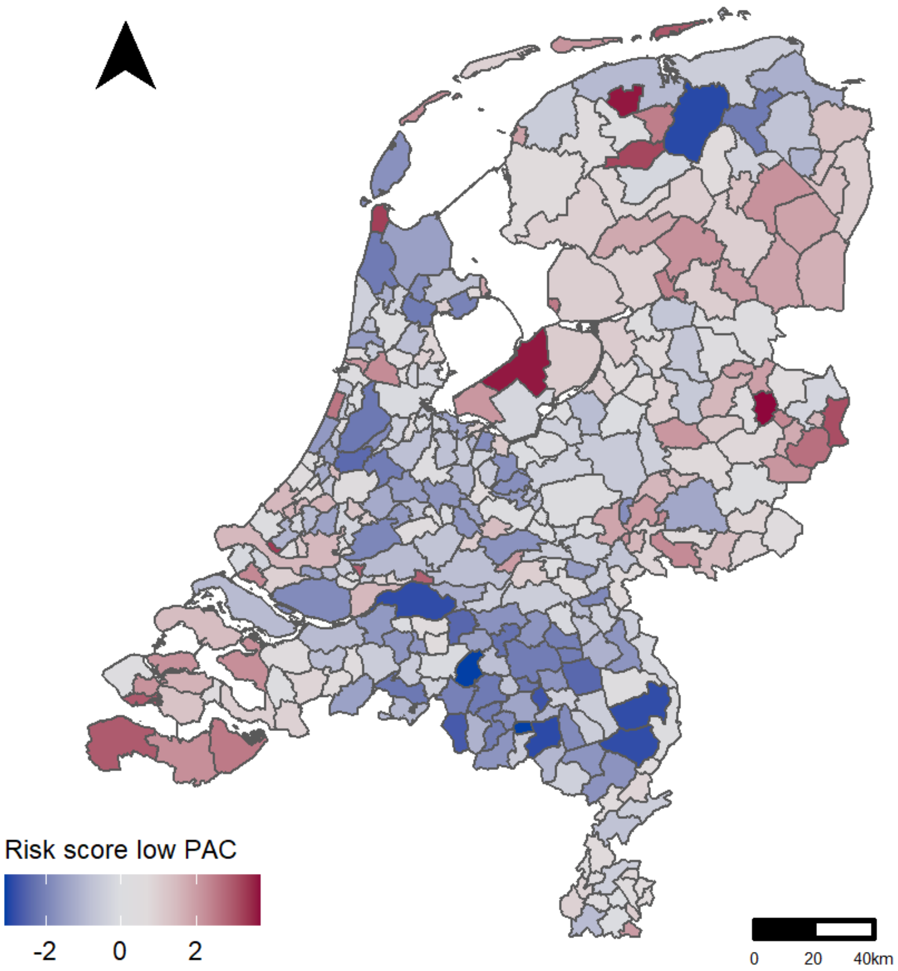


Figure 5.1: Risk of low perceived accessibility based on spatial and population characteristics

6 Conclusion and discussion

6.1 Main research findings

This thesis aimed to answer the question: " What drives interpersonal and spatial differences in perceived accessibility across different levels of urbanity in the Netherlands? ". In short, the answer to that question is that there are significant differences in perceived accessibility across different levels of urbanity, with perceived accessibility being lower in more rural areas. However, these differences are not explained by the variation in spatial accessibility alone. While spatial accessibility is a significant predictor of perceived accessibility, individual and subjective predictors are also important. The determinants of accessibility are generally comparable across levels of accessibility, with some exceptions. Within levels of urbanity, differences in spatial accessibility only have a significant effect in the most rural areas.

Accessibility can be conceptualised as consisting of four components: the land-use component, the transport component, the individual component, and the temporal component. Considering all these components is essential when studying accessibility from a social inclusion perspective. The first two components, land-use and transport, are most often included in research and policy-making and measure spatial accessibility. The level of spatial accessibility is generally higher in urban areas and lower in rural areas, where the transport system is typically less dense and goods, services and activities are more spread-out. However, regardless of spatial accessibility, individuals can experience different levels of accessibility as a result of their individual characteristics and perceptions and preferences.

By measuring perceived accessibility, the different components of accessibility are measured through the individual's perception, and the perceptions and preferences of individuals are taken into account. Not all individuals have the same transport needs and preferences. Ignoring this subjective dimension can lead to an over- or underestimation of accessibility-related problems.

The results show significant differences in perceived accessibility across different levels of urbanity. Previous studies found that within urban areas, perceived accessibility is homogenous across residential areas even when there are significant differences in spatial accessibility. These findings do not hold true when the analysis is extended beyond the urban context since perceived accessibility is significantly lower in more rural areas. The linear regression model showed that on the national scale, there is a significant positive relationship between spatial accessibility and perceived accessibility, meaning that those living in areas with higher spatial accessibility have higher perceived accessibility.

However, the results do suggest that there is indeed a mismatch between spatial and perceived accessibility. First, the variation in spatial accessibility is far greater than the variation in perceived accessibility. Furthermore, when perceived accessibility is modelled for each level of urbanity separately, the relationship between spatial accessibility and perceived accessibility is only significant in the most rural areas. These results suggest that perceived accessibility is only negatively affected when spatial accessibility is below a certain level. When a certain level of spatial accessibility is reached, further differences do not seem to matter.

Besides spatial accessibility, the way different predictors impact perceived accessibility is quite similar between levels of urbanity. Generally, the mechanism of how perceptions of accessibility are formed is comparable across levels of urbanity. However, perceptions of accessibility in rural areas are more easily explained than those in urban areas. Furthermore, some differences align with the differences in transport systems between urban and rural regions. In rural areas finding public transport convenient has a negative effect on perceived accessibility, whereas in urban areas, it has a positive effect. Additionally, determinants related to car use generally have a greater positive effect on perceived accessibility in rural areas.

Another interesting finding is that relatively few socio-demographic characteristics were found to have a significant effect on perceived accessibility. Transport-related resources and skills appear to be more important.

In the logistic regression model, which includes fewer determinants relating to resources and skills, more demographic characteristics were found to have a significant effect. The demographic characteristics likely determine, to an extent, which resources and skills people have access to. So while the actual effect on accessibility results from differences in transport-related resources and skills, if that information is unavailable, demographic characteristics can be used to determine groups that are more at risk of low accessibility.

6.2 Research implications

6.2.1 Societal relevance and policy implications

The results of the analysis show that there are spatial differences in perceived accessibility, with perceived accessibility being lower in more rural areas. Socio-demographic characteristics, accessibility-related resources and skills and abilities were also found to impact perceptions of accessibility. This is true on the national scale but also within different levels of accessibility. For most predictors, the direction of the relationship was the same across levels of urbanity. In most instances, the differences were that the relationship was not significant for some levels of urbanity, and the effect was larger for some levels of urbanity. The mechanism of how perceptions of accessibility are formed is comparable across levels of urbanity. A notable exception is the perception of the convenience of public transport. Viewing public transport as a convenient mode of transport is associated with higher perceived accessibility in urban areas and lower perceived accessibility in rural areas.

The results suggest that efforts to improve transport equality by improving spatial accessibility should be directed towards more rural areas and focus on reducing the larger differences in spatial accessibility between levels of urbanity. Within strongly urban, moderately urban and hardly urban areas, differences in spatial accessibility do not impact perceived accessibility. Based on these findings, there is likely some minimal level of spatial accessibility beyond which additional differences in spatial accessibility do not impact perceived accessibility. Further research is needed to identify whether such a cut-off point exists. If perceived accessibility is not positively affected by increased spatial accessibility beyond a certain point, this has important implications for transport policy. If spatial accessibility is above that level, transport policy should focus on other predictors of perceived accessibility by either mitigating interpersonal differences that impact the ability to utilize the transport system or altering the transport system to match the preferences of residents better. The same is true for mitigating differences in perceived accessibility in areas where spatial accessibility was not found to be a significant predictor.

Another important implication is that low accessibility does not typically result from one issue. Problems occur when individuals have a combination of spatial factors, individual characteristics and perceptions and preferences associated with lower accessibility. This supports theoretical frameworks from transport literature.

6.2.2 Scientific contribution

The most important finding is that perceived accessibility does have spatial variation on the national level and that the pattern, while less pronounced, does match patterns of spatial accessibility. Perceived accessibility is lower in rural areas compared to urban areas, matching differences in spatial accessibility. These results have already been discussed extensively in the previous paragraphs, so no further elaboration will be provided here.

Another notable result is that the percentage of people that experience low perceived accessibility is nearly the same for each level of urbanity. This shows that low perceived accessibility is not a rural problem and that accessibility-related problems can occur anywhere. Similarly, about a quarter of the population in each level of urbanity experience no accessibility-related problems whatsoever. This supports the idea that accessibility should not be seen as a purely spatial issue, as many inequalities in accessibility occur between people and not in space. However, the spatial dimension should not be ignored either. The fact that the share of the population that experiences low perceived accessibility is consistent across levels of urbanity suggests that there may be a group of people that experience low perceived accessibility regardless of their level of spatial accessibility.

Further analysis is needed to identify whether this is true and, if so, whether this group has identifiable shared characteristics. Cluster analysis may identify groups with shared socio-demographic, transport-related resources, skills and abilities and perceptions and preferences. If groups have different perceptions of accessibility, this may help identify people at risk of experiencing low perceived accessibility. Such findings could also be used to determine whether these people are more likely to experience social exclusion or engage in less mobility. This could substantiate the relationship between perceived accessibility and social exclusion and transport behaviour which is currently primarily founded in theory.

6.3 Research shortcomings

One of the shortcomings of this study is that an arbitrary PAC score was chosen as the threshold for low accessibility. Unfortunately, based on the results from this research and the available data, it is impossible to conclude at what level low accessibility is problematic. As stated in the introduction, poor accessibility is associated with social exclusion. However, social exclusion occurs when accessibility is low enough to prevent someone from participating in everyday activities and normal parts of life. A PAC score of 4.5 or lower was chosen as a threshold, and robustness checks confirmed that the coefficients were comparable for lower and higher thresholds. However, we cannot confirm at what level of accessibility there is a risk of social exclusion. It may be that this only occurs at exceptionally low levels of accessibility or can occur even at levels of accessibility slightly below the highest possible score. Low accessibility, as conceptualised in this research, is relative. Those defined as having low accessibility have low accessibility relative to others. Whether their level of accessibility is insufficient is uncertain.

This last point is also linked to some of the main critiques of using measures of perceived accessibility. The relationship to transport behaviour is not set in stone, and cognitive dissonance may influence perceptions. As such, spatial and subjective measures of accessibility should be used in conjunction. Just as spatial measures fail to capture some of the variation in accessibility, subjective measures fail to capture some cases of poor accessibility. Ideally, both spatial accessibility and perceived accessibility should be above an acceptable level.

6.4 Future research

6.4.1 Practical and societal

While the results provide valuable information as to what the determinants of accessibility are and how they differ geographically, improvements could be made to make the results more applicable in practice. Doing so would increase the societal impact of this study by improving its usefulness for policy-making. Combining the approach taken in this research with the approach of the 2019 study by CBS and PBL could be a promising path for future research. Analysing the determinants of perceived accessibility, as is done here, provides an empirical argument as to whether, and to what extent, various factors impact an individual's accessibility. However, the practical application for estimating how many people are at risk of low accessibility remains limited because the estimation is based on spatially aggregated data. Municipalities are assigned a higher risk score if they rank high on a spatial or population characteristic associated with low perceived accessibility. We do not know how these factors are distributed across the population. However, as outlined in the first chapter and can also be concluded from the results, low accessibility is typically the result of a combination of factors that limit accessibility. Using microdata would enable more precise estimates of the number of individuals or households that are likely to experience accessibility-related problems. Creating risk profiles based on the determinants of perceived accessibility rather than based on theory would strengthen the methodology as well as indirectly include the perceptions and preferences that govern accessibility. While perceptions and preferences cannot be directly observed with microdata, they are likely associated (to an extent) with specific individual characteristics. Thus, by basing risk profiles on the determinants of perceived accessibility for which microdata is available, they can be indirectly taken into account. This combined approach would have a solid empirical foundation and lead to a more accurate estimation of where accessibility-related problems may occur. It could also be performed on the neighbourhood level, leading to more geographically specific results than this research.

This information could be valuable as the problems require vastly different solutions. Identifying what is causing accessibility-related problems can lead to more efficient, cost-effective solutions that lead to the highest increase in utility that residents derive from the transport system.

6.4.2 scientific

From a scientific perspective, the results lead to a hypothesis that requires further research and leads to a question as to when low perceived accessibility is problematic.

The results show that differences in spatial accessibility matter on the national level but not within most levels of urbanity. Only in the most rural areas do additional differences in spatial accessibility have a significant effect on perceived accessibility. This suggests that there might be a threshold level of spatial accessibility above which further increases do not lead to higher accessibility. Further research is needed to assess whether this is indeed the case and, if so, where the threshold lies. Identifying a threshold would be helpful because it would mean that in areas where spatial accessibility is above the threshold, differences in accessibility are governed mostly by interpersonal differences and perceptions and preferences. Improving spatial accessibility will not help address accessibility-related problems if that is the case.

One of the shortcomings of this study is that an arbitrary PAC score was chosen as the threshold for low accessibility. Unfortunately, based on the results from this research and the available data, it is impossible to conclude when low accessibility is problematic. As stated in the introduction, poor accessibility is associated with social exclusion. However, social exclusion can occur when accessibility is low enough to prevent someone from taking part in everyday activities and normal parts of life. Too little is known about at which level of accessibility this occurs. While transport behaviour is complex and generally difficult to study, some efforts could be made to understand the relationship better. A survey that includes the questions needed to calculate the PAC score but also includes questions as to how often people do not engage in certain activities solely because of accessibility-related factors. For example, asking how frequently someone did not engage in a list of activities, they would otherwise have engaged in because of the time, difficulty and cost associated with transport. Furthermore, respondents could be asked to which extent accessibility influenced their choices regarding employment, residential location and education. While such an approach may still overlook some of the complexities of transport behaviour, it could provide more insight into the relationship between perceived accessibility and behaviour associated with social exclusion.

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8 Appendices

Appendix A

A1 - Linear regression model iterations

Table 8.1 overall model, first iteration

VARIABLES	(1) PAC
Spatial characteristics	
lnACC	0.0642***
	(0.0168)
ENT	0.570
	(0.527)
krimpregio	-0.138***
	(0.0482)
Constant	5.080***
	(0.432)
Observations	3,448
R-squared	0.012

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8.2 overall model, second iteration

VARIABLES	(1) PAC
Spatial characteristics	
lnACC	0.0814***
	(0.0173)
ENT	0.421
	(0.529)
krimpregio	-0.128***
	(0.0487)
Socio-demographic characteristics	
age	0.00440***
	(0.00156)
female	-0.0510
	(0.0395)
Education: low	0.0552
	(0.0486)
employed	0.342***
	(0.0450)
Income: low	-0.262***
	(0.0571)
Household size	0.0153
	(0.0180)
Length of residence	0.00376**
	(0.00170)
Constant	4.650***
	(0.460)
Observations	3,233
R-squared	0.047

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8.3 overall model, third iteration

VARIABLES	(1) PAC
Spatial characteristics	
lnACC	0.0987***
	(0.0210)
ENT	0.141
	(0.552)
krimpregio	-0.0929*
	(0.0522)
Socio-demographic characteristics	
age	0.00248
	(0.00182)
female	-0.0329
	(0.0465)
Education: low	0.0859
	(0.0564)
employed	0.256***
	(0.0543)
Income: low	-0.0910
	(0.0630)
Household size	-0.0180
	(0.0235)
Length of residence	0.00236
	(0.00197)
Accessibility related resources	
Number of cars	0.0519
	(0.0361)
Number of (e)bikes	0.0595***
	(0.0195)
Number of motorbikes	-0.0332
	(0.0506)
Car availability	0.418***
	(0.0695)
Lift by car	0.232***
	(0.0477)
Public transport card	0.0253
	(0.0538)
Poor internet connection	-0.599***
	(0.0917)
Friends and family	0.0564
	(0.0456)
Constant	4.421***
	(0.482)
Observations	2,354
R-squared	0.120

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8.4 overall model, fourth iteration

VARIABLES	(1) PAC
Spatial characteristics	
lnACC	0.0943***
	(0.0216)
ENT	0.218
	(0.550)
krimpregio	-0.0948*

	(0.0523)
Socio-demographic characteristics	
age	0.00593***
	(0.00189)
female	0.0537
	(0.0489)
Education: low	0.146**
	(0.0604)
employed	0.155***
	(0.0553)
Income: low	0.0357
	(0.0663)
Household size	-0.00222
	(0.0237)
Length of residence	0.00229
	(0.00201)
Accessibility related resources	
Number of cars	0.0776**
	(0.0366)
Number of (e)bikes	0.0203
	(0.0198)
Number of motorbikes	-0.0193
	(0.0495)
Car availability	0.272***
	(0.0704)
Lift by car	0.207***
	(0.0495)
Public transport card	-0.0530
	(0.0561)
Poor internet connection	-0.433***
	(0.0919)
Friends and family	0.0796*
	(0.0463)
Skills and abilities	
Disabilities	-0.642***
	(0.0830)
Public transport skills	0.0710***
	(0.0170)
No drivers licence	0.153
	(0.172)
Female x No driver's licence	-0.665***
	(0.201)
Low-income x No driver's licence	0.00956
	(0.231)
Constant	4.441***
	(0.490)
Observations	2,210
R-squared	0.177

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8.5 overall model, fifth iteration

	(1)
VARIABLES	PAC
Spatial characteristics	
lnACC	0.130***
	(0.0237)
ENT	-0.355
	(0.590)

krimpregio	-0.0892
	(0.0550)
Socio-demographic characteristics	
age	0.00795***
	(0.00207)
female	0.107**
	(0.0519)
Education: low	0.170***
	(0.0657)
employed	0.168***
	(0.0580)
Income: low	0.0449
	(0.0750)
Household size	0.0135
	(0.0248)
Length of residence	0.00394*
	(0.00219)
Accessibility related resources	
Number of cars	0.0961**
	(0.0401)
Number of (e)bikes	-0.00976
	(0.0228)
Number of motorbikes	-0.0219
	(0.0540)
Car availability	0.185**
	(0.0734)
Lift by car	0.186***
	(0.0579)
Public transport card	-0.0451
	(0.0609)
Poor internet connection	-0.416***
	(0.0788)
Friends and family	0.0489
	(0.0524)
Skills and abilities	
Disabilities	-0.552***
	(0.0716)
Public transport skills	0.0920***
	(0.0179)
No drivers licence	0.245
	(0.171)
Female x No driver's licence	-0.721***
	(0.181)
Low-income x No driver's licence	-0.118
	(0.192)
Perceptions and preferences	
pc_conv_alternative_motorised	-0.0197
	(0.0233)
pc_conv_motor_act	-0.00392
	(0.0253)
pc_conv_pt	0.00215
	(0.0233)
pc_like_active	0.0687***
	(0.0248)
pc_like_pt	-0.00732
	(0.0217)
pc_like_motorised	0.0389
	(0.0260)
pc_activity_locations_close	0.0931***
	(0.0239)
pc_want_essential_services_close	-0.0571***
	(0.0141)
Constant	4.593***
	(0.532)

Observations	1,826
R-squared	0.203

Robust standard errors in parentheses

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

A2 - Linear regression model fit and robustness

The distribution of PAC is negatively skewed, possibly indicating that the functional form of the model is not compatible with linear regression. PAC is a measure comprised of Likert-scale data, meaning that the variable is not technically continuous. There is disagreement as to whether such data should be used in linear regression. Some think Likert-scale data should only be treated as ordinal data and any other approaches are unacceptable. However, studies have shown that this is overly restrictive and that parametric approaches are suitable as long as model assumptions are verified, especially when dealing with a composite measure consisting of multiple items (Harpe, 2015).

As such, we can use linear regression, but the negative skew can still be problematic. A log transformation of PAC did not lead to a more normal distribution or better model fit. However, in dealing with subjective and well-being-related data, it is not uncommon to use linear regression in such instances. Green (2021) proposes several alternatives to linear regression for strongly skewed data or data with many zero's. Such distributions are common when dealing with subjective or behaviour-related data. While the distribution of PAC does not have too many zero's, it has a similar problem. Rather than being strongly left-skewed with many zero's, it is strongly right-skewed and has many cases with a PAC score of 7 (the highest possible score). Reversing the data, so that a score of 7 becomes 0, and a score of 1 turns into 6, creates a distribution like those that Green (2021) deals with. The resulting distribution can be treated as a negative binomial distribution.

The results of a general linear model with a negative binomial distribution are in line with those of the linear regression model. The coefficients are very similar to those produced by the linear regression model both in significance and size, and directionality. Note that PAC was reversed in order to fit the negative binomial distribution meaning that the signs of the coefficients are also reversed. Since the results are similar, the linear regression model is preferred for ease of interpretation and model diagnostics.

The linear model still needs to conform to the model assumption and the OLS error term assumptions. The residuals are not normally distributed (Shapiro-Wilk W test, z: 10.94***). However, this is virtually inconsequential as we can consider normality a given for large samples based on the central limit theorem. The model residuals are also heteroscedastic (Breusch-Pagan $\chi^2_{[1]} = 263.61$***), potentially impacting the efficiency of the model. To circumvent this problem, heteroscedasticity-consistent standard error estimates are used. As a result of using robust standard errors, no adjusted R-squared values can be calculated.

The R-squared for the overall model is 0.204. While this is generally considered quite low, low R-squared values are common when dealing with subjective data. The R-squared is highest for moderately urban, somewhat urban and not urban regions. It is lowest for strongly urban regions, suggesting that it is most difficult to identify who is at risk of experiencing accessibility-related problems in urban areas.

Table 8.6 Results of linear regression model without interaction effects

VARIABLES	All	Strongly urban	Moderately urban	Somewhat urban	Not urban
Spatial characteristics					
lnACC	0.131***	0.0553	0.0565	0.00117	0.152***
	(0.0257)	(0.0913)	(0.149)	(0.0898)	(0.0529)
ENT	-0.418	1.604	-3.527	0.324	-0.707
	(0.620)	(2.465)	(3.141)	(1.125)	(0.761)
krimpregio	-0.0892	-0.0444	0.112	-0.00158	-0.170**
Socio-demographic characteristics	(0.0559)	(0.219)	(0.188)	(0.0872)	(0.0814)
age	0.00762***	0.000994	-0.00943	0.00857**	0.00878**
	(0.00218)	(0.00449)	(0.00730)	(0.00363)	(0.00347)

female	0.0515	0.0987	-0.357*	0.146*	0.0380
	(0.0515)	(0.115)	(0.209)	(0.0814)	(0.0805)
Education: low	0.176**	0.0273	0.588**	0.279**	0.0784
	(0.0692)	(0.180)	(0.247)	(0.121)	(0.104)
employed	0.168***	0.193	0.162	0.269***	0.0826
	(0.0594)	(0.153)	(0.223)	(0.0929)	(0.0944)
Income: low	0.0407	0.337**	-0.0440	-0.0133	-0.0869
	(0.0752)	(0.152)	(0.291)	(0.130)	(0.125)
Household size	0.0152	0.0541	-0.128	0.0653	-0.0213
	(0.0268)	(0.0618)	(0.0949)	(0.0514)	(0.0390)
Length of residence	0.00402*	0.0141**	0.00410	0.00279	0.00451
	(0.00237)	(0.00639)	(0.0104)	(0.00420)	(0.00341)
Accessibility related resources					
Number of cars	0.0991***	0.0642	0.253	0.0174	0.142***
	(0.0376)	(0.109)	(0.175)	(0.0638)	(0.0539)
Number of (e)bikes	-0.0133	0.00218	0.173**	-0.0349	-0.0314
	(0.0224)	(0.0631)	(0.0837)	(0.0394)	(0.0332)
Number of motorbikes	-0.0253	-0.0562	-0.138	-0.139	0.0262
	(0.0558)	(0.305)	(0.173)	(0.101)	(0.0729)
Car availability	0.194***	-0.0600	-0.0307	0.0982	0.488***
	(0.0747)	(0.162)	(0.220)	(0.118)	(0.142)
Lift by car	0.193***	0.0395	0.0464	0.250**	0.216**
	(0.0572)	(0.117)	(0.247)	(0.101)	(0.0961)
Public transport card	-0.0372	-0.266**	0.0825	-0.0663	-0.0186
	(0.0615)	(0.128)	(0.266)	(0.0967)	(0.100)
Poor internet connection	-0.425***	0.0389	0.0960	-0.469***	-0.473***
	(0.0951)	(0.216)	(0.318)	(0.164)	(0.135)
Friends and family	0.0455	0.153	-0.0477	-0.0232	0.0164
	(0.0508)	(0.109)	(0.202)	(0.0826)	(0.0823)
Skills and abilities					
Disabilities	-0.556***	-0.332	-0.362	-0.509***	-0.646***
	(0.0932)	(0.243)	(0.346)	(0.148)	(0.152)
Public transport skills	0.0936***	0.136**	0.126*	0.114***	0.0871***
	(0.0194)	(0.0639)	(0.0740)	(0.0311)	(0.0275)
No driver's license	-0.252**	0.0324	-0.789**	-0.617***	-0.0192
	(0.124)	(0.182)	(0.369)	(0.223)	(0.232)
Perceptions and preferences					
pc_conv_alternative_motorised	-0.0229	0.0439	0.0193	-0.0743	0.00656
	(0.0264)	(0.0526)	(0.0727)	(0.0475)	(0.0422)
pc_conv_motor_act	0.00189	-0.00939	0.0829	-0.0681*	0.0164
	(0.0236)	(0.0564)	(0.0734)	(0.0407)	(0.0368)
pc_conv_pt	0.00395	0.132**	0.0875	0.0197	-0.0587*
	(0.0221)	(0.0566)	(0.0810)	(0.0382)	(0.0343)
pc_like_active	0.0630***	0.00873	0.0127	0.0653*	0.101**
	(0.0238)	(0.0552)	(0.0829)	(0.0377)	(0.0399)
pc_like_pt	-0.00636	0.0420	-0.0463	-0.00815	-0.0210
	(0.0238)	(0.0471)	(0.0761)	(0.0383)	(0.0384)
pc_like_motorised	0.0327	-0.00779	-0.158*	0.137**	0.0128
	(0.0268)	(0.0509)	(0.0878)	(0.0552)	(0.0369)
pc_activity_locations_close	0.0955***	0.0360	-0.00645	0.0454	0.139***
	(0.0251)	(0.0629)	(0.116)	(0.0403)	(0.0388)
pc_want_essential_services_close	-0.0566***	-0.000268	-0.0193	-0.0338	-0.102***
	(0.0161)	(0.0479)	(0.0569)	(0.0294)	(0.0231)
Constant	4.678***	3.572*	8.439***	4.913***	4.644***
	(0.545)	(2.004)	(2.788)	(0.985)	(0.724)
Observations	1,826	244	168	604	810
R-squared	0.195	0.179	0.299	0.235	0.279

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8.7 Full results of linear regression model

	Overall	Strongly Urban	Moderately Urban	Somewhat Urban	Not Urban
Spatial characteristics					
lnACC	0.130***	0.0458	0.0437	-0.0122	0.164***
	(0.0256)	(0.0924)	(0.156)	(0.0905)	(0.0525)
ENT	-0.355	1.773	-4.288	0.397	-0.540
	(0.616)	(2.419)	(3.218)	(1.135)	(0.746)
krimpregio	-0.0892	-0.0550	0.120	0.0130	-0.168**
	(0.0557)	(0.190)	(0.192)	(0.0877)	(0.0814)
Socio-demographic characteristics					
age	0.00795***	0.000859	-0.00863	0.00884**	0.00945***
	(0.00216)	(0.00446)	(0.00746)	(0.00363)	(0.00345)
female	0.107**	0.117	-0.285	0.193**	0.0871
	(0.0522)	(0.130)	(0.222)	(0.0802)	(0.0814)
Education: low	0.170**	0.0709	0.577**	0.281**	0.0652
	(0.0688)	(0.185)	(0.247)	(0.121)	(0.105)
employed	0.168***	0.199	0.179	0.285***	0.0899
	(0.0592)	(0.149)	(0.224)	(0.0928)	(0.0938)
Income: low	0.0449	0.452***	0.000666	-0.0636	-0.0417
	(0.0757)	(0.163)	(0.302)	(0.130)	(0.129)
Household size	0.0135	0.0582	-0.131	0.0584	-0.0238
	(0.0262)	(0.0629)	(0.0956)	(0.0485)	(0.0388)
Length of residence	0.00394*	0.0137**	0.00582	0.00253	0.00454
	(0.00235)	(0.00641)	(0.0103)	(0.00417)	(0.00340)
Accessibility related resources					
Number of cars	0.0961***	0.0493	0.241	0.0130	0.139***
	(0.0370)	(0.107)	(0.176)	(0.0634)	(0.0532)
Number of (e)bikes	-0.00976	0.00806	0.175**	-0.0317	-0.0234
	(0.0223)	(0.0612)	(0.0831)	(0.0392)	(0.0331)
Number of motorbikes	-0.0219	-0.0310	-0.121	-0.146	0.0400
	(0.0559)	(0.301)	(0.179)	(0.100)	(0.0736)
Car availability	0.185**	-0.0477	-0.0715	0.101	0.459***
	(0.0743)	(0.160)	(0.223)	(0.118)	(0.142)
Lift by car	0.186***	0.0835	0.0244	0.235**	0.221**
	(0.0571)	(0.117)	(0.243)	(0.100)	(0.0943)
Public transport card	-0.0451	-0.281**	0.0880	-0.0658	-0.0279
	(0.0615)	(0.126)	(0.268)	(0.0972)	(0.101)
Poor internet connection	-0.416***	0.0848	0.0714	-0.507***	-0.432***
	(0.0952)	(0.220)	(0.309)	(0.162)	(0.137)
Friends and family	0.0489	0.152	-0.0555	-0.0206	0.0278
	(0.0506)	(0.110)	(0.201)	(0.0825)	(0.0824)
Skills and abilities					
Disabilities	-0.552***	-0.323	-0.326	-0.517***	-0.636***
	(0.0935)	(0.247)	(0.358)	(0.149)	(0.151)
Public transport skills	0.0920***	0.127**	0.129*	0.112***	0.0871***
	(0.0193)	(0.0624)	(0.0754)	(0.0311)	(0.0276)
No driver’s license	0.245	0.341	0.0848	-0.350	0.647*
	(0.185)	(0.226)	(0.602)	(0.356)	(0.379)
Female x No driver's licence	-0.721***	-0.259	-0.989	-0.591	-0.834**
	(0.213)	(0.247)	(0.646)	(0.432)	(0.404)
Low-income x No driver's licence	-0.118	-0.618**	-0.399	0.312	-0.383
	(0.251)	(0.301)	(0.752)	(0.459)	(0.431)
Perceptions and preferences					
pc_conv_alternative_motorised	-0.0197	0.0504	0.0289	-0.0740	0.00955
	(0.0263)	(0.0538)	(0.0729)	(0.0475)	(0.0423)
pc_conv_motor_act	-0.00392	-0.0118	0.0874	-0.0650	0.00741
	(0.0236)	(0.0574)	(0.0747)	(0.0405)	(0.0366)
pc_conv_pt	0.00215	0.131**	0.0720	0.0179	-0.0569*
	(0.0221)	(0.0567)	(0.0791)	(0.0381)	(0.0345)
pc_like_active	0.0687***	0.0194	0.00839	0.0661*	0.111***

	(0.0238)	(0.0561)	(0.0820)	(0.0377)	(0.0397)
pc_like_pt	-0.00732	0.0487	-0.0303	-0.00157	-0.0377
	(0.0233)	(0.0478)	(0.0754)	(0.0366)	(0.0384)
pc_like_motorised	0.0389	-0.0135	-0.159*	0.136**	0.0226
	(0.0269)	(0.0521)	(0.0881)	(0.0550)	(0.0374)
pc_activity_locations_close	0.0931***	0.0317	-0.00979	0.0406	0.135***
	(0.0252)	(0.0630)	(0.117)	(0.0407)	(0.0392)
pc_want_essential_services_close	-0.0571***	-0.00547	-0.00716	-0.0373	-0.104***
	(0.0160)	(0.0479)	(0.0587)	(0.0291)	(0.0230)
Constant	4.593***	3.453*	9.106***	4.912***	4.368***
	(0.542)	(1.938)	(2.886)	(0.981)	(0.700)
Observations	1,826	244	168	604	810
R-squared	0.203	0.192	0.309	0.241	0.286

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8.8 Interaction effects table

		driver license		**no driver license**	
		low income	not low income	low income	not low income
Overall	male	0.0531	0	0.1891	0.25
	female	0.1601	0.107	-0.4169	-0.356
Strongly urban	male	0.446	0	0.174	0.34
	female	0.559	0.113	0.039	0.205
Moderately urban	male	0.00482	0	-0.29908	0.0811
	female	-0.28318	-0.288	-1.57208	-1.1919
Somewhat urban	male	-0.0388	0	-0.0948	-0.355
	female	0.1472	0.186	-0.4758	-0.736
Not urban	male	-0.0415	0	0.2305	0.634
	female	0.0494	0.0909	-0.4916	-0.0881

A3 - Logistic regression model

The pseudo-R2 of the model is 0.1165. While this is generally regarded as low, this does not necessarily mean the model serves no purpose in identifying the risk of low perceived accessibility. The model classifies 90.1% of cases correctly. It should be noted that this is only slightly more than the correctly classified cases with an empty model specification. However, since the coefficients are significant and the Pseudo R2 shows that the model does indeed have explanatory power, the coefficients can be used to predict perceived accessibility.

Different cut-off values for low perceived accessibility were entered into the model, and the coefficients are generally robust. Furthermore, the coefficients show the same patterns as the more comprehensive linear regression model, which has a higher explanatory value. As such, we can assume the model can help us identify groups and areas that are at risk of experiencing low perceived accessibility.

Table 8.9 Results of Logistic regression model

VARIABLES	PAC_45_or_lower	PAC_5_or_lower	PAC_55_or_lower
lnACC	-0.243**	-0.258***	-0.190***
	(0.0965)	(0.0804)	(0.0683)
ENT	-0.756	-0.515	-1.999**
	(1.374)	(1.150)	(0.963)
krimpregio	0.319**	0.166	0.258**
	(0.141)	(0.118)	(0.100)
age	-0.0144***	-0.0134***	-0.0140***
	(0.00382)	(0.00320)	(0.00276)
Gender_female	-0.0691	0.0202	-0.0287
	(0.128)	(0.105)	(0.0890)
education_low	-0.147	-0.122	-0.240**
	(0.144)	(0.119)	(0.104)
Employment_low	-0.415***	-0.439***	-0.413***
	(0.146)	(0.120)	(0.101)
income_dummy	-0.00228	0.186	0.229**
	(0.153)	(0.127)	(0.112)
ncars	-0.447***	-0.285***	-0.194***
	(0.101)	(0.0814)	(0.0677)
internet_dummy	1.208***	1.047***	0.828***
	(0.153)	(0.137)	(0.127)
dummy_disability_all	1.212***	1.193***	1.075***
	(0.136)	(0.115)	(0.103)
Strongly urban	0.438	0.229	-0.0450
	(0.326)	(0.271)	(0.230)
Moderately urban	0.347	0.245	0.0881
	(0.268)	(0.222)	(0.188)
Somewhat urban	0.0231	0.0232	0.0102
	(0.189)	(0.153)	(0.128)
Not urban	-	-	-
Constant	0.821	1.101	2.600***
	(1.248)	(1.047)	(0.888)
Observations	3,214	3,214	3,214
Pseudo R2	0.1165	0.1059	0.0849

Sensitivity	8.16%	11.39%	17.55%
Specificity	99.58%	98.70%	96.55%
Correctly classified	90.17%	84.38%	76.66%

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix B – tables and figures

B1 - PAC Scores

Table 8.10: PAC score elements

item	*Mean*	*SD*	*Cronbach's alpha if item deleted*	*Sk*	*Kur*
I am able to do my daily activities with ease	6.109	1.152	0.885	-2.078	8.233
I am able to live my life the way I want	6.000	1.237	0.861	-1.922	7.097
I am able to do all the activities I want	5.780	1.433	0.856	-1.532	4.890
Access to my preferred activities is good.	5.808	1.312	0.887	-1.538	5.327

B2 - Variation in spatial accessibility

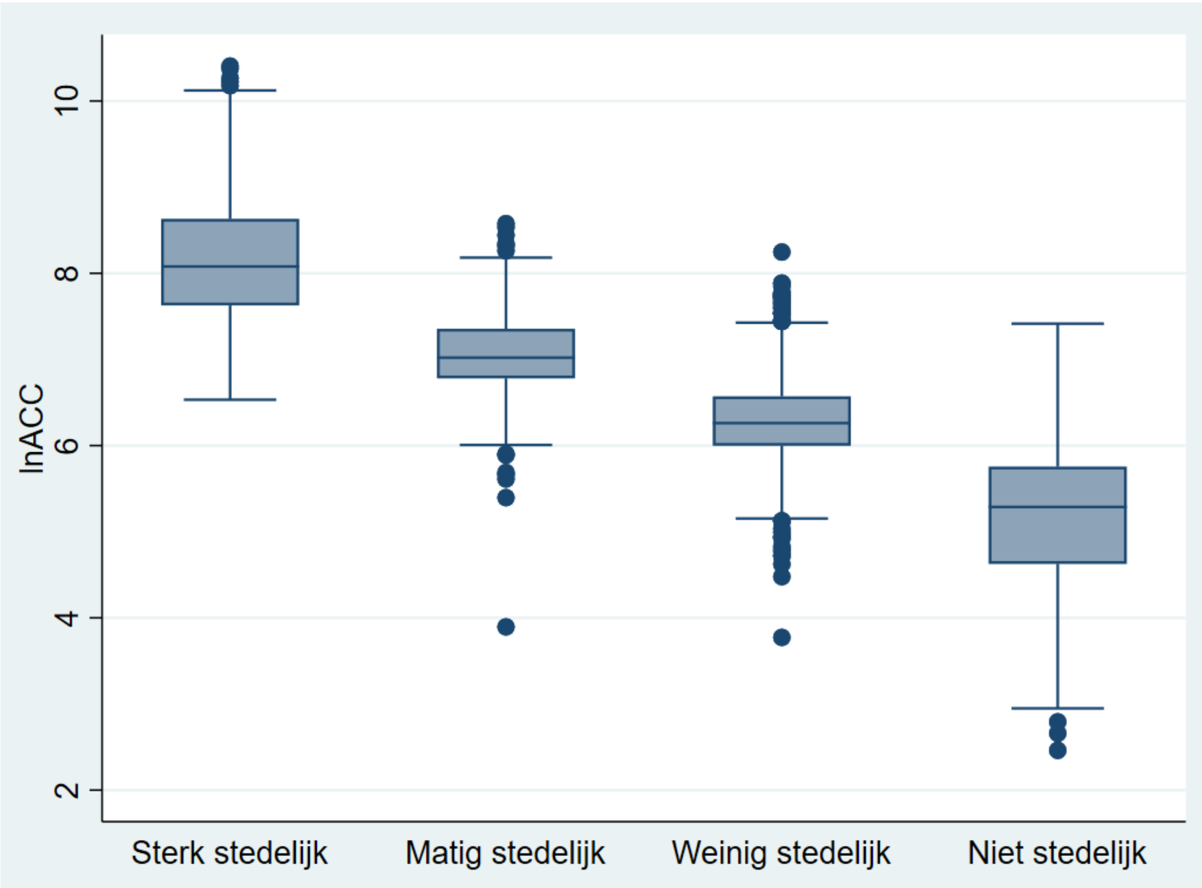

Figure 8.1: variance lnACC across levels of urbanity

B3 - PCA general mode perception

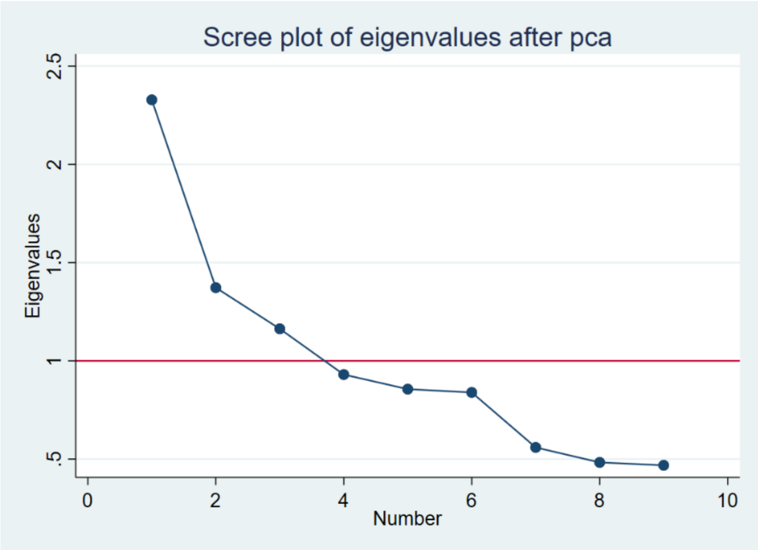

Figure 8.2: screeplot general mode perception

Table 8.11: PCA general mode perception

Variable	Pro active modes	Pro public transport	Pro private motorised transport	Unexplained
Walking	0.562			.396
Bike	0.621			.368
Ebike			0.518	.592
Scooter			0.448	.624
DRT		0.454		.591
Bus/tram/metro		0.655		.308
Train		0.568		.369
Car (passenger)			0.490	.487
Car (driver)			0.524	.400

Notes: Principal axis factoring with oblique rotation. KMO=0.652. Only factor loadings above 0.3 are reported.

B5 - PCA mode convenience

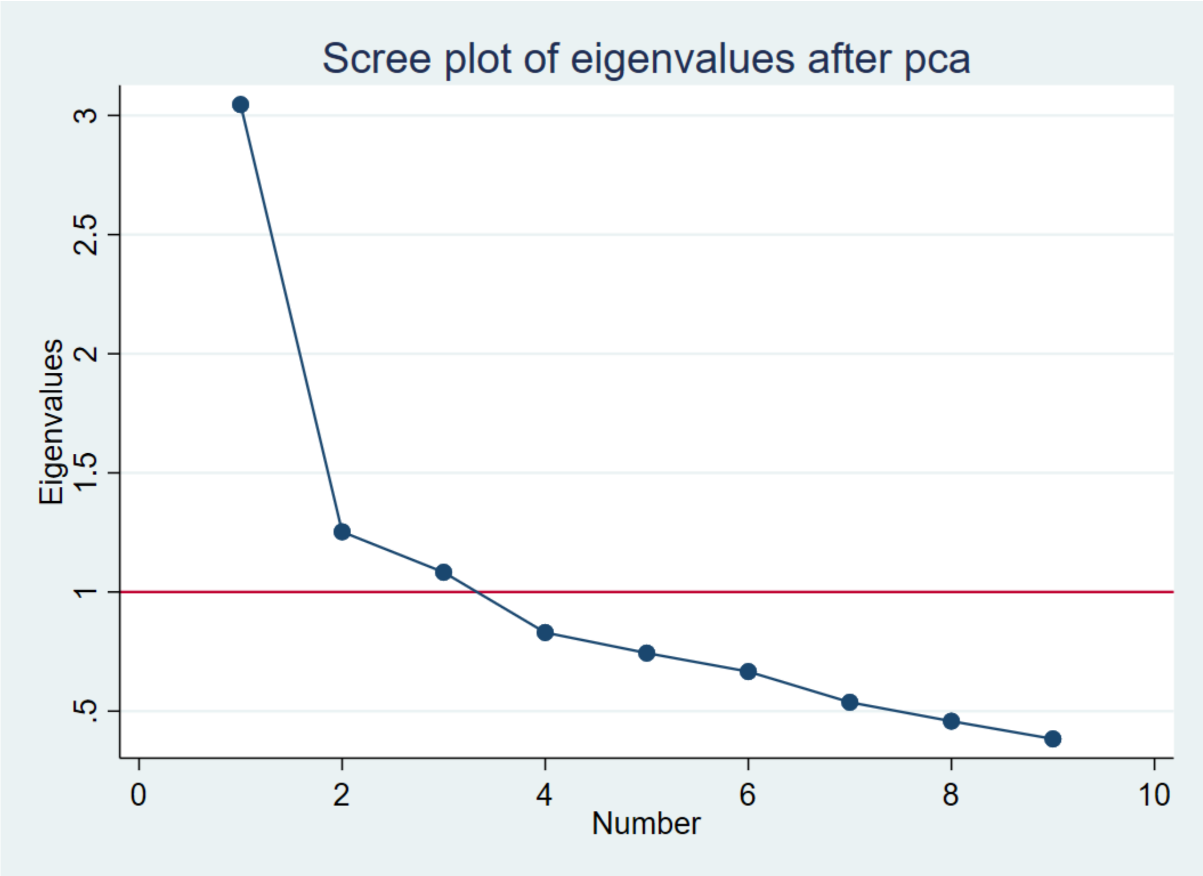

Figure 8.3 Screeplot perception of mode convenience

Table 8.12 PCA perception of mode convenience

Variable	Active and private motorised convenient	Public transport convenient	Alternative modes convenient	Unexplained
Walking	0.432			.420
Bike	0.419			.448
Ebike			0.451	.538
Scooter			0.656	.404
DRT			0.582	.425
Bus/tram/metro		0.649		.256
Train		0.625		.280
Car (passanger)	0.490			.469
Car (driver)	0.555			.380

Notes: Principal axis factoring with oblique rotation. KMO=0.767. Only factor loadings above 0.3 are reported.

B6 - PCA Public transport skills

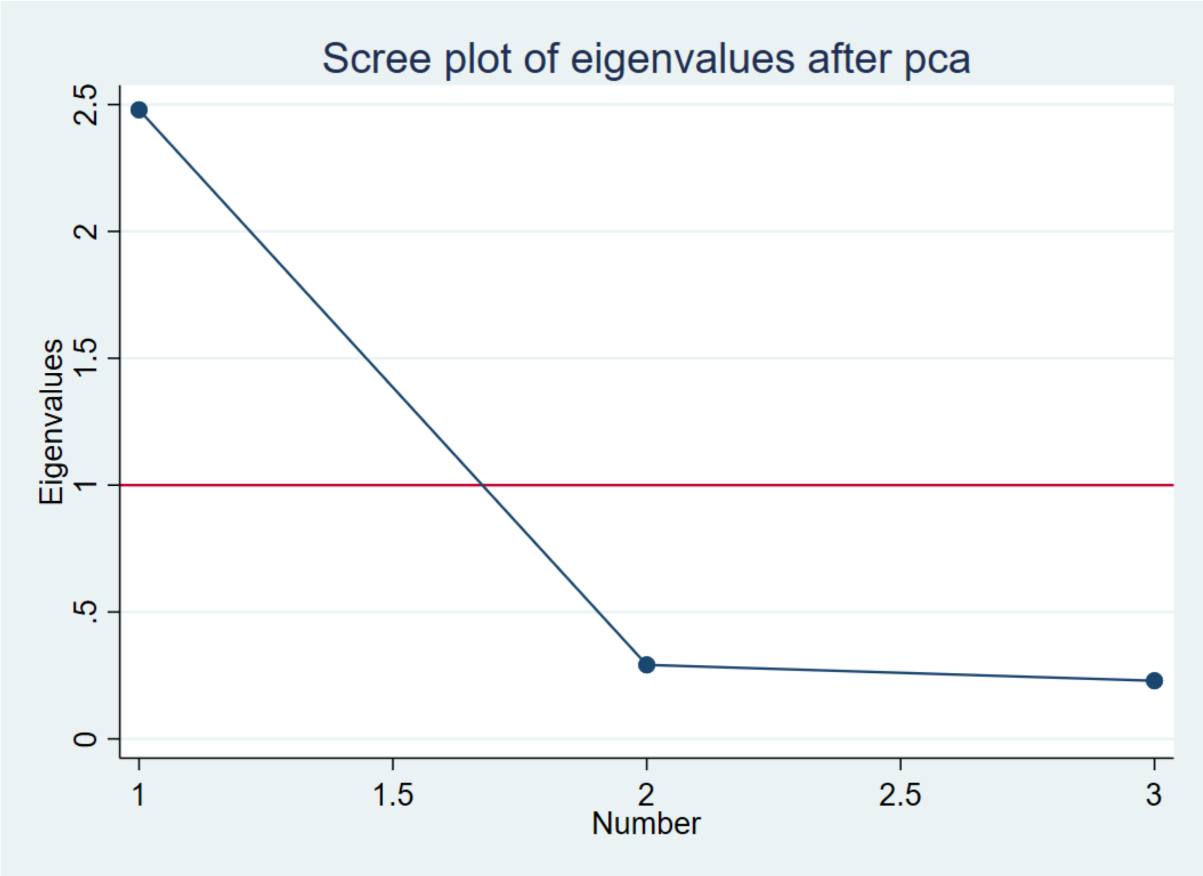

Figure 8.4 Screeplot PT skills

Table 8.13 PCA PT skills

Variable	PC skills	Unexplained
ptonlinep~sy	0.5851	.1512
ovchipeasy	0.5717	.1898
ptinfo	0.5752	.1798

Notes: Principal axis factoring with oblique rotation. KMO=0.747.

B7 - PCA location preferences

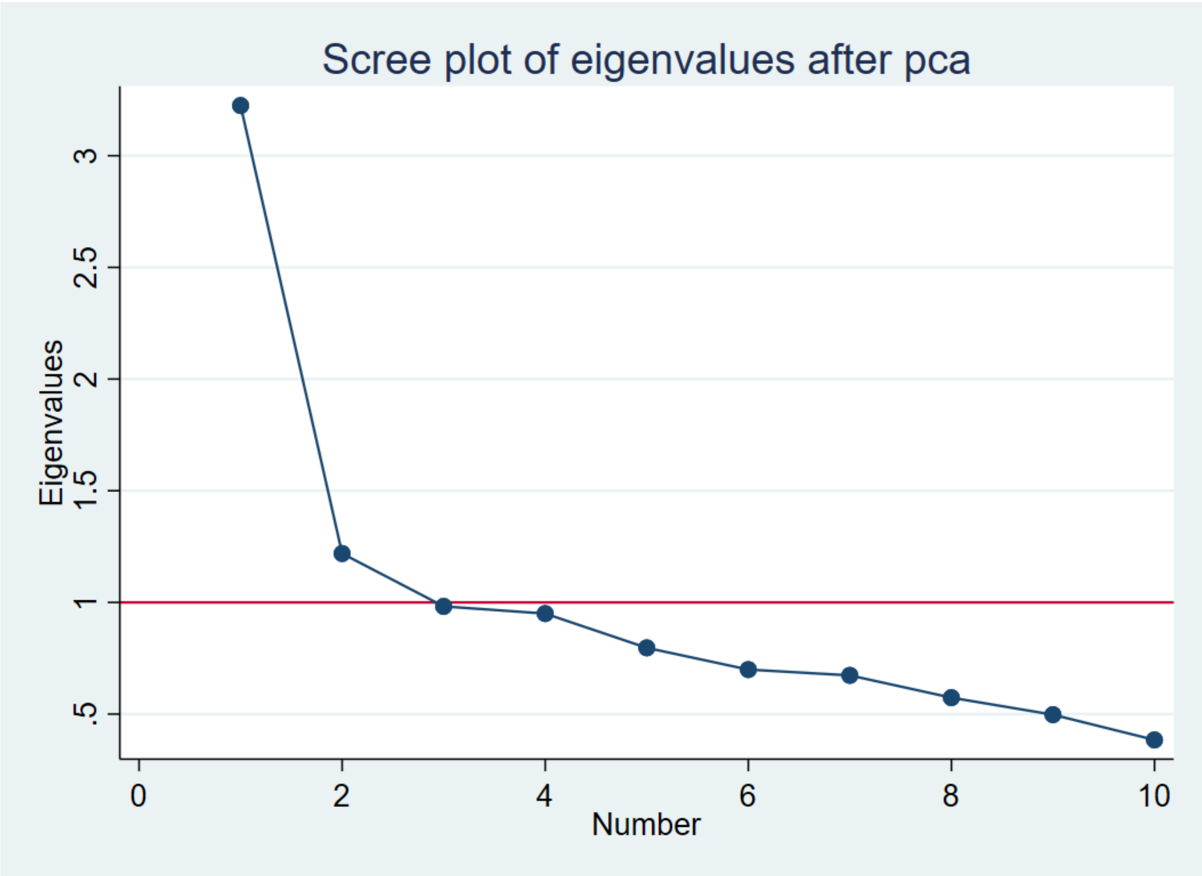

Figure 8.5 Screeplot location preferences

Table 8.14 PCA location preferences

Variable	Want services close	Want activity locations close	Unexplained
wantpt_wal~e	0.5157		.5178
wantmanysh~s	0.4988		.4402
wantfamily~e		0.4368	.6127
wantsporti~s		0.4776	.4741
wantcommun~e		0.3517	.7265
wantjobclose		0.3605	.7241
wantsuperm~e	0.4882		.4305
wanthealth~e	0.4194		.5062
wanteducat~s		0.5030	.496
wantcultur~s			.6265

Notes: Principal axis factoring with oblique rotation. KMO= 0.793. Only factor loadings above 0.3 are reported.

B8 - Social Economic Status

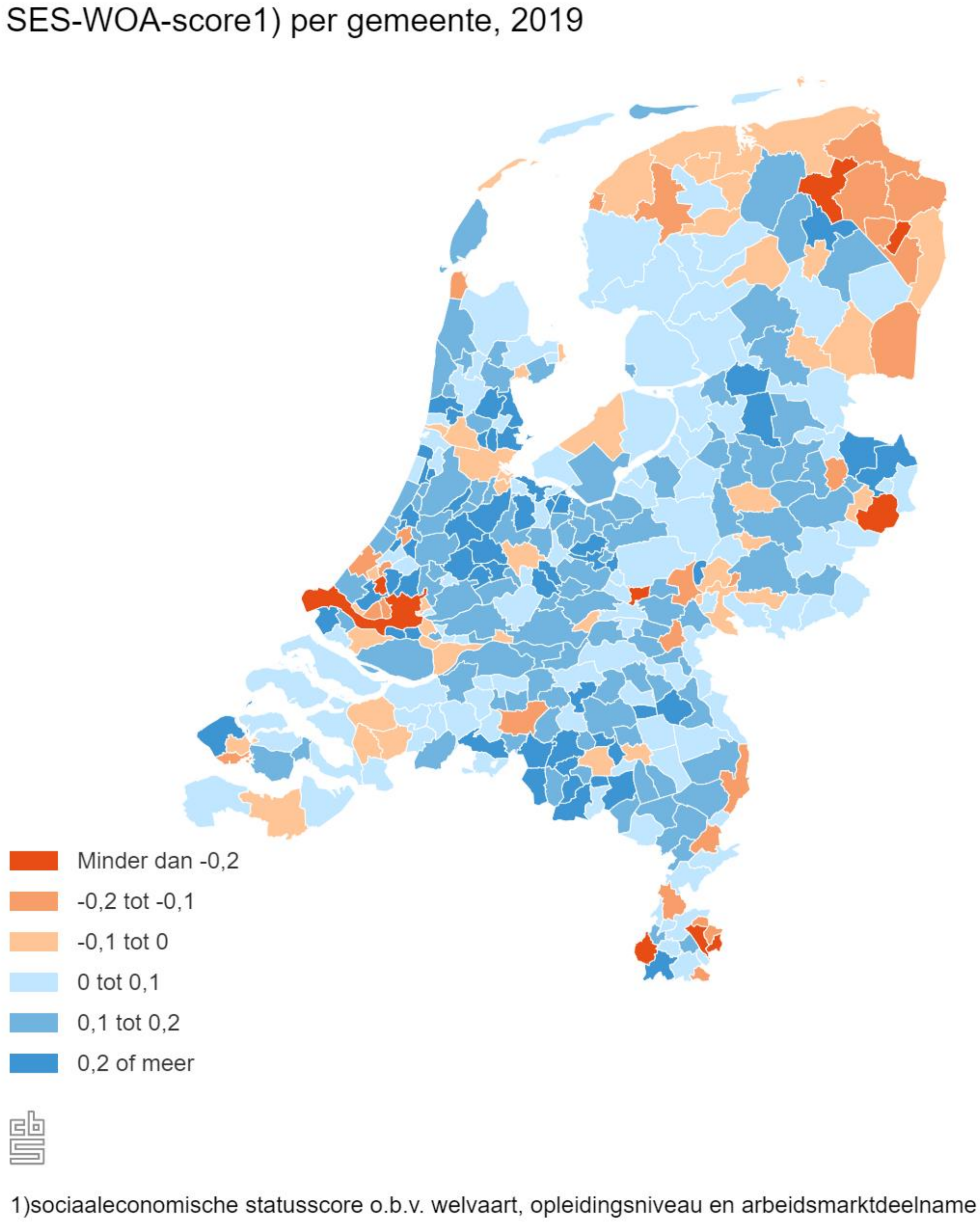

Figure 8.6 Map Social Economic Status (CBS, 2022b)

Appendix C – Codebook

Variable name	description
lnACC	The natural logarithm of the spatial accessibility of opportunities at the residential location of the individual. Paragraph 4.2 provides a more in-depth explanation.
ENT	An entropy index that measures the diversity of opportunities at the residential location of the individual. 1 indicates perfect diversity of opportunities. Paragraph 4.2 provides a more in-depth explanation.
Declining region	A dummy that indicates whether the municipality in which the individual resides is classified by the Ministry of the Interior and Kingdom Relations as a declining region. 0= not classified as declining region 1 = declining region
Gender_female	A dummy indicating that the individual is female. 0 = Male, Other/prefer not to say 1= Female
Education_low	A dummy indicating that the level of education of the respondent is low 0 = HAVO, pre-university, HBS, MBO-2, 3, or 4, Higher vocational education, University degree, other 1 = Primary school, LTS, huishoudschool
Employed	A dummy indicating that the respondent is employed 0 = (Partly) incapacitated, Volunteer, Retired, Homemaker, Student, Looking for a job/social welfare, Other, Prefer not to say 1 = Paid contract, Entrepreneur with staff, Solo self-employed
hhsize	The number of individuals (adults and children) in the household
Length of residence	A continuous variables indicating how many years the respondent has lived at their current address
ncars	The number of cars in the household
nbikes	The number of bikes (regular bikes and e-bikes) in the household
nmotorbikes	The number of motorbikes in the household
caravailability_dummy	I always have a car available for use 0 = Neutral, Disagree, Totally disagree 1 = Totally agree, Agree
Lift by car	I can always arrange a lift by car 0 = Neutral, Disagree, Totally disagree 1 = Totally agree, Agree
Public transport card	I have some PT subscription 0= No 1= Yes
Poor internet connection	I have a good internet connection 0 = Totally agree, Agree 1 = Neutral, Disagree, Totally disagree
Friends and family	
dummy_disability_all	A dummy indicating whether the respondent has a disability that prevents them from use one or multiple modes of transport.

	Disability to drive during the day Disability to drive during the night Disability to use PT Disability to use bike Disability to use e-bike Disability to walk 0 = respondent did not answer yes to experiencing any of these disabilities 1 = respondent answered indicated that they one or multiple of the listed disabilities
Pc_pt_scores	Factor resulting from principle component analysis on the following three statements. The 'OV-chipkaart' is easy to understand Planning a PT trip online is easy The provision of PT-information is good 1= Totally disagree 2= Disagree 3= Neutral 4= Agree 5= Totally agree
driverslicense	I have a driver's license 0 = No 1 = Yes
pc_like_active	Factor that indicates the respondent enjoys using active transport modes
pc_like_pt	Factor that indicates the respondent enjoys using public transport
pc_like_motorised	Factor that indicates the respondent enjoys using motorised transport
pc_conv_alternative_motorised	Factor that indicates the respondent considers alterative motorised modes (scooters, ebikes) convenient
pc_conv_motor_act	Factor that indicates the respondent considers motorised transport and active modes convenient
pc_conv_pt	Factor that indicates the respondent considers public transport convenient
pc_activity_locations_close	Factor that indicates the respondents wants to live near activity locations (exercise, friends and family, work)
pc_want_essential_services_close	Factor that indicates the respondents wants to live near essential services (shops, healthcare, public transport stations)

Appendix D - syntax

For the initial analysis of the data and the regression models the statistical software STATA was used. The syntax can be found in *appendix C1*. R was used for the analysis in chapter 5 which combines the outcomes of the logistic regression model with open data to identify municipalities where there is an above average risk of inhabitants experiencing low perceived accessibility. The packages 'dplyr', 'stringr', 'tidyr' and 'cbsodataR' were used for importing and cleaning the data. The 'sf' package was used for importing and analysing spatial data and the 'ggplot2' and 'RColorBrewer' were used for creating maps. The syntax can be found in *appendix C2*.

D1 - STATA syntax

```
cd "C:\Users\marij\OneDrive\Thesis OV\data"

*****loading orginal file*****
use "DATA_orgineel2", clear

*****packages*****
ssc install estout, replace

*****generating PAC variable*****
gen PAC = 0
replace PAC = ((pac_easytodomydailyactivities + pac_livelifeasiwant + pac_doallactivitiesiwant + pac_accessibilityissatisfying)/4)

gen lnPAC = ln(PAC)

gen PAC_trans = ln(8-PAC)


* PAC below ....

gen PAC_55_or_lower = PAC
replace PAC_55_or_lower = 0 if PAC > 5.5
replace PAC_55_or_lower = 1 if PAC <= 5.5
replace PAC_55_or_lower = . if PAC == .

gen PAC_5_or_lower = PAC
replace PAC_5_or_lower = 0 if PAC > 5
replace PAC_5_or_lower = 1 if PAC <= 5
replace PAC_5_or_lower = . if PAC == .

gen PAC_45_or_lower = PAC
replace PAC_45_or_lower = 0 if PAC > 4.5
replace PAC_45_or_lower = 1 if PAC <= 4.5
replace PAC_45_or_lower = . if PAC == .

gen PAC_4_or_lower = PAC
replace PAC_4_or_lower = 0 if PAC > 4
replace PAC_4_or_lower = 1 if PAC <= 4
replace PAC_4_or_lower = . if PAC == .

*****Spatial information*****
gen pc4 = substr(homeadress_postalcode,1,4)
merge m:1 pc4 using DATA_indeling_KIM.dta
drop if _merge == 2

*adding BU/WK/GM codes
drop _merge
gen PC6 = upper(homeadress_postalcode)
merge m:m PC6 using DATA_CBS_gebiedsindelingen.dta
```

```
drop if _merge==2
list PC6 if _merge==1
drop _merge

*****gebiedstype*****
gen KIM_gebiedstype = 1 if gebiedstype == "landelijke krimp"
replace KIM_gebiedstype = 1 if gebiedstype == "landelijke krimp"
replace KIM_gebiedstype = 2 if gebiedstype == "landelijke groei"
replace KIM_gebiedstype = 3 if gebiedstype == "stedelijke groei"
replace KIM_gebiedstype = 4 if gebiedstype == "stedelijke krimp"
fre KIM_gebiedstype

label define KIM_gebiedstype_label 1"landelijke krimp" 2"landelijke groei" 3"stedelijke groei" 4"stedelijke krimp"
label values KIM_gebiedstype KIM_gebiedstype_label
sum PAC

gen krimp = KIM_gebiedstype
replace krimp = 0 if KIM_gebiedstype == 2
replace krimp = 0 if KIM_gebiedstype == 3
replace krimp = 1 if KIM_gebiedstype == 1
replace krimp = 1 if KIM_gebiedstype == 4

label define krimp_label 0"groei" 1"krimp"
label values krimp krimp_label

tab krimp, sum(PAC)

ttest PAC, by(krimp)


gen Postcode4 = pc4
merge m:1 Postcode4 using DATA_urban.dta
drop if _merge==2

label define stedelijk_label 1"Zeer sterk stedelijk" 2"Sterk stedelijk" 3"Matig stedelijk" 4"Weinig stedelijk" 5"Niet stedelijk"
label values Stedelijkheid stedelijk_label

gen urban_or_rural = KIM_gebiedstype
replace urban_or_rural = 1 if KIM_gebiedstype == 3 | KIM_gebiedstype == 4
replace urban_or_rural = 2 if KIM_gebiedstype == 1 | KIM_gebiedstype == 2

label define urban_or_rural_label 1"urban" 2"rural"
label values urban_or_rural urban_or_rural_label



gen dummy_stedelijk = KIM_gebiedstype
replace dummy_stedelijk = 0 if KIM_gebiedstype == 1
replace dummy_stedelijk = 0 if KIM_gebiedstype == 2
replace dummy_stedelijk = 1 if KIM_gebiedstype == 3
```

```
replace dummy_stedelijk = 1 if KIM_gebiedstype == 4
fre dummy_stedelijk

gen Sted4 = Stedelijkheid
replace Sted4 = 2 if Stedelijkheid == 1


gen str_stedelijkheid = string(Stedelijkheid)

*****calculating spatial accessibility*****
*ACC
gen spatial_acc = (cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)

tab KIM_gebiedstype, summarize(spatial_acc)

rename spatial_acc ACC



*ENT


* gen ENT
gen prop_sec_cultural = cultural_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_cultural

gen prop_sec_sport = sport_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_sport

gen prop_sec_hospitality = hospitality_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_hospitality

gen prop_sec_health = health_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_health

gen prop_sec_retail = retail_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_retail
```

```
gen prop_sec_supermarkt = supermarket_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_supermark

gen prop_sec_edu = edu_2018_exp0_5/(cultural_2018_exp0_5+sport_2018_exp0_5+hospitality_2018_exp0_5+health_2018_exp0_5+retail_2018_exp0_5+supermarket_2018_exp0_5+edu_2018_exp0_5)
sum prop_sec_edu


gen ent_prop_sec_cultural = (prop_sec_cultural * ln(prop_sec_cultural))/ln(7)
gen ent_prop_sec_sport = (prop_sec_sport * ln(prop_sec_sport))/ln(7)
gen ent_prop_sec_hospitality = (prop_sec_hospitality * ln(prop_sec_hospitality))/ln(7)
gen ent_prop_sec_health = (prop_sec_health * ln(prop_sec_health))/ln(7)
gen ent_prop_sec_retail = (prop_sec_retail * ln(prop_sec_retail))/ln(7)
gen ent_prop_sec_supermarkt = (prop_sec_supermarkt * ln(prop_sec_supermarkt))/ln(7)
gen ent_prop_sec_edu = (prop_sec_edu * ln(prop_sec_edu))/ln(7)

gen ENT = -(ent_prop_sec_cultural+ent_prop_sec_edu+ent_prop_sec_health+ent_prop_sec_hospitality+ent_prop_sec_retail+ent_prop_sec_sport+ent_prop_sec_supermarkt)

*****creating dummies*****

* dummy disability_bike and ebike
gen dummy_disability_bike = 0
replace dummy_disability_bike = 1 if disability_bike == 1
replace dummy_disability_bike = 1 if disability_ebike == 1

* dummy Disability walk
codebook disability_walk
gen dummy_disability_walk = 0
replace dummy_disability_walk = 1 if disability_walk == 1


*variables****************************
*car drive dummy

fre fcar_driver
codebook fcar_driver

gen car_driver_dummy = fcar_driver
replace car_driver_dummy = 1 if fcar_driver == 6
replace car_driver_dummy = 1 if fcar_driver == 7
replace car_driver_dummy = 0 if fcar_driver < 6

fre car_driver_dummy

*car passenger dummy

fre fcar_passenger
```

```
codebook fcar_passenger

gen car_passenger_dummy = fcar_passenger
replace car_passenger_dummy = 1 if fcar_passenger == 6
replace car_passenger_dummy = 1 if fcar_passenger == 7
replace car_passenger_dummy = 0 if fcar_passenger < 6

fre car_passenger_dummy

*bike dummy

fre fbike
codebook fbike

gen bike_dummy = fbike
replace bike_dummy = 1 if fbike == 6
replace bike_dummy = 1 if fbike == 7
replace bike_dummy = 0 if fbike < 6

fre bike_dummy

*ebike dummy

fre febike
codebook febike

gen ebike_dummy = febike
replace ebike_dummy = 1 if febike == 6
replace ebike_dummy = 1 if febike == 7
replace ebike_dummy = 0 if febike < 6

fre bike_dummy

*scooter dummy

fre fscooter
codebook fscooter

gen scooter_dummy = fscooter
replace scooter_dummy = 1 if fscooter == 6
replace scooter_dummy = 1 if fscooter == 7
replace scooter_dummy = 0 if fscooter < 6

fre scooter_dummy

*train dummy

fre ftrain
codebook ftrain

gen train_dummy = ftrain
replace train_dummy = 1 if ftrain == 6
```

```
replace train_dummy = 1 if ftrain == 7
replace train_dummy = 0 if ftrain < 6

fre train_dummy

*bus dummy

fre fbus
codebook fbus

gen bus_dummy = fbus
replace bus_dummy = 1 if fbus == 6
replace bus_dummy = 1 if fbus == 7
replace bus_dummy = 0 if fbus < 6

fre bus_dummy

*drt dummy

fre fdrt
codebook fdrt

gen drt_dummy = fdrt
replace drt_dummy = 1 if fdrt == 6
replace drt_dummy = 1 if fdrt == 7
replace drt_dummy = 0 if fdrt < 6

fre drt_dummy

*scootmobiel dummy

fre fscootmobiel
codebook fscootmobiel

gen scootmobiel_dummy = fscootmobiel
replace scootmobiel_dummy = 1 if fscootmobiel == 6
replace scootmobiel_dummy = 1 if fscootmobiel == 7
replace scootmobiel_dummy = 0 if fscootmobiel < 6

fre scootmobiel_dummy

*walking dummy

fre fwalking
codebook fwalking

gen walking_dummy = fwalking
replace walking_dummy = 1 if fwalking == 6
replace walking_dummy = 1 if fwalking == 7
replace walking_dummy = 0 if fwalking < 6

fre walking_dummy
```

```
*taxi dummy

fre ftaxi
codebook ftaxi

gen taxi_dummy = ftaxi
replace taxi_dummy = 1 if ftaxi == 6
replace taxi_dummy = 1 if ftaxi == 7
replace taxi_dummy = 0 if ftaxi < 6

fre taxi_dummy

*dummy work
fre fwork
codebook fwork

gen work_dummy = fwork
replace work_dummy = 1 if fwork == 5
replace work_dummy = 1 if fwork == 6
replace work_dummy = 0 if fwork < 5

fre work_dummy

*dummy edu
fre fedu
codebook fedu

gen edu_dummy = fedu
replace edu_dummy = 1 if fedu == 5
replace edu_dummy = 1 if fedu == 6
replace edu_dummy = 0 if fedu < 5

fre edu_dummy

*dummy grocery
fre fgrocery
codebook fgrocery

gen grocery_dummy = fgrocery
replace grocery_dummy = 1 if fgrocery == 5
replace grocery_dummy = 1 if fgrocery == 6
replace grocery_dummy = 0 if fgrocery < 5

fre grocery_dummy


*dummy health
fre fhealth
codebook fhealth

gen health_dummy = fhealth
```

```
replace health_dummy = 1 if fhealth == 5
replace health_dummy = 1 if fhealth == 6
replace health_dummy = 0 if fhealth < 5

fre health_dummy


*dummy shopping
fre fshopping
codebook fshopping

gen shopping_dummy = fshopping
replace shopping_dummy = 1 if fshopping == 5
replace shopping_dummy = 1 if fshopping == 6
replace shopping_dummy = 0 if fshopping < 5

fre shopping_dummy


*dummy largeshopping
fre flargeshopping
codebook flargeshopping

gen largeshopping_dummy = flargeshopping
replace largeshopping_dummy = 1 if flargeshopping == 5
replace largeshopping_dummy = 1 if flargeshopping == 6
replace largeshopping_dummy = 0 if flargeshopping < 5

fre largeshopping_dummy

*dummy goingout
gen goingout_dummy = fgoingout
replace goingout_dummy = 1 if fgoingout == 5
replace goingout_dummy = 1 if fgoingout == 6
replace goingout_dummy = 0 if fgoingout < 5

*dummy outdooractivity
gen outdooractivity_dummy = foutdooractivity
replace outdooractivity_dummy = 1 if foutdooractivity == 5
replace outdooractivity_dummy = 1 if foutdooractivity == 6
replace outdooractivity_dummy = 0 if foutdooractivity < 5

*dummy event
gen event_dummy = fevent
replace event_dummy = 1 if fevent == 5
replace event_dummy = 1 if fevent == 6
replace event_dummy = 0 if fevent < 5

*dummy friendsfamily
gen friendsfamily_dummy = ffriendsfamily
replace friendsfamily_dummy = 1 if ffriendsfamily == 5
replace friendsfamily_dummy = 1 if ffriendsfamily == 6
```

```
replace friendsfamily_dummy = 0 if ffriendsfamily < 5

*dummy ovchipeasy
gen ovchipeasy_dummy = ovchipeasy
replace ovchipeasy_dummy = 1 if ovchipeasy == 4
replace ovchipeasy_dummy = 1 if ovchipeasy == 5
replace ovchipeasy_dummy = 0 if ovchipeasy < 4

*dummy ptonlineplanningeasy
gen ptonlineplanningeasy_dummy = ptonlineplanningeasy
replace ptonlineplanningeasy_dummy = 1 if ptonlineplanningeasy == 4
replace ptonlineplanningeasy_dummy = 1 if ptonlineplanningeasy == 5
replace ptonlineplanningeasy_dummy = 0 if ptonlineplanningeasy < 4

*dummy ptinfo
gen ptinfo_dummy = ptinfo
replace ptinfo_dummy = 1 if ptinfo == 4
replace ptinfo_dummy = 1 if ptinfo == 5
replace ptinfo_dummy = 0 if ptinfo < 4

*dummy liftbycar
gen liftbycar_dummy = liftbycar
replace liftbycar_dummy = 1 if liftbycar == 4
replace liftbycar_dummy = 1 if liftbycar == 5
replace liftbycar_dummy = 0 if liftbycar < 4

*dummy carhabit
gen carhabit_dummy = carhabit
replace carhabit_dummy = 1 if carhabit == 4
replace carhabit_dummy = 1 if carhabit == 5
replace carhabit_dummy = 0 if carhabit < 4

*dummy caravailability
gen caravailability_dummy = caravailability
replace caravailability_dummy = 1 if caravailability == 4
replace caravailability_dummy = 1 if caravailability == 5
replace caravailability_dummy = 0 if caravailability < 4

*dummy internet
gen internet_dummy = internet
replace internet_dummy = 1 if internet == 4
replace internet_dummy = 1 if internet == 5
replace internet_dummy = 0 if internet < 4

*dummy moveintention
gen moveintention_dummy = moveintention
replace moveintention_dummy = 1 if moveintention == 5
replace moveintention_dummy = 1 if moveintention == 6
replace moveintention_dummy = 1 if moveintention == 7
replace moveintention_dummy = 0 if moveintention < 5

*dummy large distances
```

```
gen largedistances_dummy = largedistances
replace largedistances_dummy = 1 if internet == 4
replace largedistances_dummy = 1 if internet == 5
replace largedistances_dummy = 0 if internet < 4

*dummy importantfacilitiesgonerecently
gen facilitiesgonerecently_dummy = importantfacilitiesgonerecently
replace facilitiesgonerecently_dummy = 1 if internet == 4
replace facilitiesgonerecently_dummy = 1 if internet == 5
replace facilitiesgonerecently_dummy = 0 if internet < 4

*dummy enoughschools
gen enoughschools_dummy = enoughschools
replace enoughschools_dummy = 1 if internet == 4
replace enoughschools_dummy = 1 if internet == 5
replace enoughschools_dummy = 0 if internet < 4

*dummy leftbehind
gen leftbehind_dummy = leftbehind
replace leftbehind_dummy  = 1 if leftbehind == 4
replace leftbehind_dummy  = 1 if leftbehind == 5
replace leftbehind_dummy  = 0 if leftbehind < 4

*dummy moreworkfromhome
gen moreworkfromhome_dummy = moreworkfromhome
replace moreworkfromhome_dummy = 1 if internet == 4
replace moreworkfromhome_dummy = 1 if internet == 5
replace moreworkfromhome_dummy = 0 if internet < 4

*dummy buycarintention
gen buycarintention_dummy = buycarintention
replace buycarintention_dummy  = 1 if buycarintention == 4
replace buycarintention_dummy  = 1 if buycarintention == 5
replace buycarintention_dummy  = 0 if buycarintention < 4

*dummy onlineshopping
gen onlineshopping_dummy = onlineshopping
replace onlineshopping_dummy  = 1 if onlineshopping == 4
replace onlineshopping_dummy  = 1 if onlineshopping == 5
replace onlineshopping_dummy  = 0 if onlineshopping <=4

* dummy Disability to drive during the day
codebook disability_drive_day
gen dummy_drive_dis_day = 0
replace dummy_drive_dis_day = 1 if disability_drive_day == 1

* dummy Disability to drive during the night
codebook disability_drive_night
gen dummy_drive_dis_night = 0
replace dummy_drive_dis_night = 1 if disability_drive_night == 1

* dummy_disability drive
```

```
gen dummy_disability_drive = 0
replace dummy_disability_drive = 1 if disability_drive_day == 1 | disability_drive_night == 1

* dummy_disability pt
gen dummy_disability_pt = 0
replace dummy_disability_pt = 1 if disability_pt == 1

* dummy all disabilities
gen dummy_disability_all = 0
replace dummy_disability_all = 1 if dummy_disability_bike == 1
replace dummy_disability_all = 1 if dummy_disability_drive == 1
replace dummy_disability_all = 1 if dummy_disability_pt == 1
replace dummy_disability_all = 1 if dummy_disability_walk == 1

*****mode sentiments*****
gen sen_cardriver = carasdrivercomfotrable
replace sen_cardriver = (carasdrivercomfotrable + carasdriverrelaxing + carasdrivertimesaving + carasdriverflexible + carasdriversafe + carasdriverfun)/6

gen sen_caraspassenger = caraspassengercomfotrable
replace sen_caraspassenger = (caraspassengercomfotrable + caraspassengerrelaxing + caraspassengertimesaving + caraspassengerflexible + caraspassengersafe + caraspassengerfun)/6

gen sen_bike = bikecomfotrable
replace sen_bike = (bikecomfotrable + bikerelaxing + biketimesaving + bikeflexible + bikesafe + bikefun)/6

gen sen_ebike = ebikecomfotrable
replace sen_ebike = (ebikecomfotrable + ebikerelaxing + ebiketimesaving + ebikeflexible + ebikesafe + ebikefun)/6

gen sen_scooter = scootercomfotrable
replace sen_scooter = (scootercomfotrable + scooterrelaxing + scootertimesaving + scooterflexible + scootersafe + scooterfun)/6

gen sen_train = traincomfotrable
replace sen_train = (traincomfotrable + trainrelaxing + traintimesaving + trainflexible + trainsafe + trainfun)/6

gen sen_bustrammetro = bustrammetrocomfotrable
replace sen_bustrammetro = (bustrammetrocomfotrable + bustrammetrorelaxing + bustrammetrotimesaving + bustrammetroflexible + bustrammetrosafe + bustrammetrofun)/6

gen sen_drt = drtcomfotrable
replace sen_drt = (drtcomfotrable + drtrelaxing + drttimesaving + drtflexible + drtsafe + drtfun)/6

gen sen_walking = walkingcomfotrable
replace sen_walking = (walkingcomfotrable + walkingrelaxing + walkingtimesaving + walkingflexible + walkingsafe + walkingfun)/6

*mode sentiments enjoyment
gen like_cardriver = carasdrivercomfotrable
```

```
replace like_cardriver = (carasdrivercomfotrable + carasdriverrelaxing + carasdriverfun + carasdriverstatus)/4

gen like_caraspassenger = caraspassengercomfotrable
replace like_caraspassenger = (caraspassengercomfotrable + caraspassengerrelaxing + caraspassengerfun + caraspassengerstatus)/4

gen like_bike = bikecomfotrable
replace like_bike = (bikecomfotrable + bikerelaxing + bikefun+ bikestatus)/4

gen like_ebike = ebikecomfotrable
replace like_ebike = (ebikecomfotrable + ebikerelaxing + ebikefun + ebikestatus)/4

gen like_scooter = scootercomfotrable
replace like_scooter = (scootercomfotrable + scooterrelaxing + scooterfun + scooterfun + scooterstatus)/4

gen like_train = traincomfotrable
replace like_train = (traincomfotrable + trainrelaxing + trainfun + trainstatus)/4

gen like_bustrammetro = bustrammetrocomfotrable
replace like_bustrammetro = (bustrammetrocomfotrable + bustrammetrorelaxing + bustrammetrofun + bustrammetrostatus)/4

gen like_drt = drtcomfotrable
replace like_drt = (drtcomfotrable + drtrelaxing + drtfun + drtstatus)/4

gen like_walking = walkingcomfotrable
replace like_walking = (walkingcomfotrable + walkingrelaxing + walkingfun + walkingstatus)/4

*mode convieniance
gen conv_cardriver = carasdrivercomfotrable
replace conv_cardriver = (carasdrivertimesaving + carasdriverflexible + carasdriversafe)/3

gen conv_caraspassenger = caraspassengercomfotrable
replace conv_caraspassenger = (caraspassengertimesaving + caraspassengerflexible + caraspassengersafe )/3

gen conv_bike = bikecomfotrable
replace conv_bike = (biketimesaving + bikeflexible + bikesafe)/3

gen conv_ebike = ebikecomfotrable
replace conv_ebike = (ebiketimesaving + ebikeflexible + ebikesafe)/3

gen conv_scooter = scootercomfotrable
replace conv_scooter = (scootertimesaving + scooterflexible + scootersafe)/3

gen conv_train = traincomfotrable
replace conv_train = (traintimesaving + trainflexible + trainsafe)/6

gen conv_bustrammetro = bustrammetrocomfotrable
```

```
replace conv_bustrammetro = (bustrammetrotimesaving + bustrammetroflexible + bustrammetrosafe)/3

gen conv_drt = drtcomfotrable
replace conv_drt = (drttimesaving + drtflexible + drtsafe)/3

gen conv_walking = walkingcomfotrable
replace conv_walking = (walkingtimesaving + walkingflexible + walkingsafe)/3

*province
gen prov_naam = 0
replace prov_naam = 1 if PROV_naam == "Drenthe"
replace prov_naam = 2 if PROV_naam == "Flevoland"
replace prov_naam = 3 if PROV_naam == "Friesland"
replace prov_naam = 4 if PROV_naam == "Gelderland"
replace prov_naam = 5 if PROV_naam == "Groningen"
replace prov_naam = 6 if PROV_naam == "Limburg"
replace prov_naam = 7 if PROV_naam == "Noord-Brabant"
replace prov_naam = 8 if PROV_naam == "Noord-Holland"
replace prov_naam = 9 if PROV_naam == "Overijssel"
replace prov_naam = 10 if PROV_naam == "Utrecht"
replace prov_naam = 11 if PROV_naam == "Zeeland"
replace prov_naam = 12 if PROV_naam == "Zuid-Holland"

*****decling regions*****
gen krimpgemeente = 0
replace krimpgemeente = 1 if Gemeentenaam == "Appingedam"
replace krimpgemeente = 1 if Gemeentenaam == "Delfzijl"
replace krimpgemeente = 1 if Gemeentenaam == "Loppersum"
replace krimpgemeente = 1 if Gemeentenaam == "Oldambt"
replace krimpgemeente = 1 if Gemeentenaam == "Pekela"
replace krimpgemeente = 1 if Gemeentenaam =="Stadskanaal"
replace krimpgemeente = 1 if Gemeentenaam =="Veendam"
replace krimpgemeente = 1 if Gemeentenaam =="Westerwolde"
replace krimpgemeente = 1 if Gemeentenaam == " Het Hogeland"
replace krimpgemeente = 1 if Gemeentenaam == "Brunssum"
replace krimpgemeente = 1 if Gemeentenaam == "Heerlen"
replace krimpgemeente = 1 if Gemeentenaam =="Kerkrade"
replace krimpgemeente = 1 if Gemeentenaam =="Nuth"
replace krimpgemeente = 1 if Gemeentenaam =="Landgraaf"
replace krimpgemeente = 1 if Gemeentenaam =="Onderbanken"
replace krimpgemeente = 1 if Gemeentenaam =="Simpelveld"
replace krimpgemeente = 1 if Gemeentenaam =="Voerendaal"
replace krimpgemeente = 1 if Gemeentenaam == "Eijsden-Margraten"
replace krimpgemeente = 1 if Gemeentenaam == "Gulpen-Wittem"
replace krimpgemeente = 1 if Gemeentenaam == "Maastricht"
replace krimpgemeente = 1 if Gemeentenaam == "Meerssen"
replace krimpgemeente = 1 if Gemeentenaam == "Vaals"
replace krimpgemeente = 1 if Gemeentenaam =="Valkenburg aan de Geul"
replace krimpgemeente = 1 if Gemeentenaam =="Beek"
replace krimpgemeente = 1 if Gemeentenaam =="Beekdaelen"
replace krimpgemeente = 1 if Gemeentenaam =="Sittard-Geleen"
```

```
replace krimpgemeente = 1 if Gemeentenaam =="Stein"
replace krimpgemeente = 1 if Gemeentenaam =="Hulst"
replace krimpgemeente = 1 if Gemeentenaam == "Sluis"
replace krimpgemeente = 1 if Gemeentenaam == "Terneuzen"
replace krimpgemeente = 1 if Gemeentenaam == "Aalten"
replace krimpgemeente = 1 if Gemeentenaam == "Bronckhorst"
replace krimpgemeente = 1 if Gemeentenaam =="Berkelland"
replace krimpgemeente = 1 if Gemeentenaam =="Doetinchem"
replace krimpgemeente = 1 if Gemeentenaam =="Montferland"
replace krimpgemeente = 1 if Gemeentenaam =="Oost Gelre"
replace krimpgemeente = 1 if Gemeentenaam =="Oude IJsselstreek"
replace krimpgemeente = 1 if Gemeentenaam =="Winterswijk"
replace krimpgemeente = 1 if Gemeentenaam =="Noardeast-Fryslân"
replace krimpgemeente = 1 if Gemeentenaam =="Tytsjerksteradiel"
replace krimpgemeente = 1 if Gemeentenaam =="Achtkarspelen"
replace krimpgemeente = 1 if Gemeentenaam =="Dantumadiel"

replace krimpgemeente = 2 if Gemeentenaam == "Harlingen"
replace krimpgemeente = 2 if Gemeentenaam == "Waadhoeke"
replace krimpgemeente = 2 if Gemeentenaam == "Ameland"
replace krimpgemeente = 2 if Gemeentenaam == "Schiermonnikoog"
replace krimpgemeente = 2 if Gemeentenaam == "Terschelling"
replace krimpgemeente = 2 if Gemeentenaam =="Heerenveen"
replace krimpgemeente = 2 if Gemeentenaam =="Ooststellingwerf"
replace krimpgemeente = 2 if Gemeentenaam =="Opsterland"
replace krimpgemeente = 2 if Gemeentenaam == "Smallingerland"
replace krimpgemeente = 2 if Gemeentenaam == "Weststellingwerf"
replace krimpgemeente = 2 if Gemeentenaam == "Aa en Hunze"
replace krimpgemeente = 2 if Gemeentenaam =="Borger-Odoorn"
replace krimpgemeente = 2 if Gemeentenaam =="Coevorden"
replace krimpgemeente = 2 if Gemeentenaam =="Emmen"
replace krimpgemeente = 2 if Gemeentenaam =="Den Helder"
replace krimpgemeente = 2 if Gemeentenaam =="Hollands Kroon"
replace krimpgemeente = 2 if Gemeentenaam =="Schagen"
replace krimpgemeente = 2 if Gemeentenaam == "Texel"
replace krimpgemeente = 2 if Gemeentenaam == "Gulpen-Wittem"
replace krimpgemeente = 2 if Gemeentenaam == "Schouwen-Duiveland"
replace krimpgemeente = 2 if Gemeentenaam == "Middelburg"
replace krimpgemeente = 2 if Gemeentenaam == "Veere"
replace krimpgemeente = 2 if Gemeentenaam =="Vlissingen"
replace krimpgemeente = 2 if Gemeentenaam =="Binnenmaas"
replace krimpgemeente = 2 if Gemeentenaam =="Cromstrijen"
replace krimpgemeente = 2 if Gemeentenaam =="Korendijk"
replace krimpgemeente = 2 if Gemeentenaam =="Hoeksche Waard"
replace krimpgemeente = 2 if Gemeentenaam =="Strijen"
replace krimpgemeente = 2 if Gemeentenaam == "Krimpenerwaard"
replace krimpgemeente = 2 if Gemeentenaam == "Beesel"
replace krimpgemeente = 2 if Gemeentenaam == "Bergen"
replace krimpgemeente = 2 if Gemeentenaam == "Gennep"
replace krimpgemeente = 2 if Gemeentenaam == "Horst aan de Maas"
replace krimpgemeente = 2 if Gemeentenaam == "Mook en Middelaar"
replace krimpgemeente = 2 if Gemeentenaam == "Venlo"
```

```
replace krimpgemeente = 2 if Gemeentenaam =="Venray"
replace krimpgemeente = 2 if Gemeentenaam =="Echt-Susteren"
replace krimpgemeente = 2 if Gemeentenaam =="Leudal"
replace krimpgemeente = 2 if Gemeentenaam =="Maasgouw"
replace krimpgemeente = 2 if Gemeentenaam =="Nederweert"
replace krimpgemeente = 2 if Gemeentenaam =="Roerdalen"
replace krimpgemeente = 2 if Gemeentenaam == "Roermond"
replace krimpgemeente = 2 if Gemeentenaam == "Weert"

label define krimpgemeente_labell 0"other" 1"krimpregio" 2"anticipeerregio"
label values krimpgemeente krimpgemeente_labell
rename krimpgemeente krimpregio

tab krimpregio, sum(PAC)

gen krimpregio_dummy = krimpregio
replace krimpregio_dummy = 0 if krimpregio == 2

***** categoircal variables *****

*income
gen income_3 = income
replace income_3 = 1 if income == 1
replace income_3 = 1 if income == 2
replace income_3 = 2 if income == 3
replace income_3 = 2 if income == 4
replace income_3 = 3 if income == 5
replace income_3 = 3 if income == 6
replace income_3 = 3 if income == 7
replace income_3 = 4 if income == 8

label define income_3label 1"low" 2 "middle" 3 "high" 4 "no answer"
label values income_3 income_3label

*income dummy
gen income_dummy = income_3
replace income_dummy = 1 if income_3 == 1
replace income_dummy = 0 if income_3 == 2
replace income_dummy = 0 if income_3 == 3
replace income_dummy = 0 if income_3 == 4
label define income_dummy_lab 1"low" 0"not low"
label values income_dummy income_dummy_lab

*education
gen education_3 = education
replace education_3 = 1 if education == 1
replace education_3 = 1 if education == 2
replace education_3 = 2 if education == 3
replace education_3 = 3 if education == 4
replace education_3 = 3 if education == 5
replace education_3 = 4 if education == 6
```

```
label define education_3label 1"low" 2"middle" 3"high" 4"other"
label values education_3 education_3label

*education dummy
gen education_dummy = education_3
replace education_dummy = 1 if education_3 == 1
replace education_dummy = 0 if education_3 == 2
replace education_dummy = 0 if education_3 == 3
replace education_dummy = 0 if education_3 == 4
label define edu_dummy_label 1"low" 0"not low"
label values edu_dummy edu_dummy_label

*employment
gen employment_3 = workingsituation
replace employment_3 = 1 if workingsituation == 1
replace employment_3 = 2 if workingsituation == 2
replace employment_3 = 6 if workingsituation == 3
replace employment_3 = 6 if workingsituation == 4
replace employment_3 = 5 if workingsituation == 5
replace employment_3 = 6 if workingsituation == 6
replace employment_3 = 2 if workingsituation == 7
replace employment_3 = 3 if workingsituation == 8
replace employment_3 = 4 if workingsituation == 9
replace employment_3 = 6 if workingsituation == 10
replace employment_3 = 6 if workingsituation == 11

label define employment_3label 1"paid contract" 2"self-employed" 3"student" 4"social welfare/ seeking employment" 5"retired" 6"other"

label values employment_3 employment_3label

*employment 4 categories

gen employment_4 = workingsituation
replace employment_4 = 1 if workingsituation == 1
replace employment_4 = 1 if workingsituation == 2
replace employment_4 = 6 if workingsituation == 3
replace employment_4 = 6 if workingsituation == 4
replace employment_4 = 6 if workingsituation == 5
replace employment_4 = 6 if workingsituation == 6
replace employment_4 = 1 if workingsituation == 7
replace employment_4 = 3 if workingsituation == 8
replace employment_4 = 4 if workingsituation == 9
replace employment_4 = 6 if workingsituation == 10
replace employment_4 = 6 if workingsituation == 11

label define employment_4label 1"employed" 2"self-employed" 3"student" 4"social welfare/ seeking employment" 5"retired" 6"other"

label values employment_4 employment_4label
```

```
*employment dummy
gen employment_2 = workingsituation
replace employment_2 = 1 if workingsituation == 1
replace employment_2 = 1 if workingsituation == 2
replace employment_2 = 0 if workingsituation == 3
replace employment_2 = 0 if workingsituation == 4
replace employment_2 = 0 if workingsituation == 5
replace employment_2 = 0 if workingsituation == 6
replace employment_2 = 1 if workingsituation == 7
replace employment_2 = 0 if workingsituation == 8
replace employment_2 = 0 if workingsituation == 9
replace employment_2 = 0 if workingsituation == 10
replace employment_2 = 0 if workingsituation == 11

label define employment_2label 1"employed" 0"not employed"

label values employment_2 employment_2label

*age categories
gen age_cat = age
replace age_cat = 1 if age < 25
replace age_cat = 2 if age >= 25
replace age_cat = 3 if age >= 65

label define age_cat_label 1"under 25" 2"25-65" 3"65 and older"
label values age_cat age_cat_label

*household size*

replace hhsize_children = 0 if missing(hhsize_children)
gen hh_size = hhsize_adult + hhsize_children

***** tests *****

hist(ACC)
gen lnACC = ln(ACC)
hist age
hist PAC_trans
hist PAC
gen neg_PAC = 8 - PAC
hist neg_PAC
centile PAC if Stedelijkhe , centile (20 80)
_pctile PAC, p(25)
ret li
fre PAC

*****factor analysis******

*modes general
pca sen_walking sen_bike sen_ebike sen_scooter sen_drt sen_bustrammetro sen_train
sen_caraspassenger sen_cardriver if ! missing(PAC) & ! missing(ACC), mineigen(1) blanks(.3)
```

```
rotate, promax
rotate, promax blanks(.3)
rotate, clear

estat kmo

estat loadings
predict pc_pro_active_and_motorised pc2_pro_pt pc3_pro_moterised, score

estat kmo

*modes likeability
pca like_walking like_bike like_ebike like_scooter like_drt like_bustrammetro like_train like_caraspassenger like_cardriver, mineigen(1) blanks(.3)

rotate, promax blanks(.3)
estat kmo
estat loadings
predict pc_like_active pc_like_pt pc_like_motorised, score
esttab using pca.rtf, rtf replace

*modes convenience
pca conv_walking conv_bike conv_ebike conv_scooter conv_drt conv_bustrammetro conv_train conv_caraspassenger conv_cardriver, mineigen(1) blanks(.3)
rotate, promax blanks(.3)
estat kmo
estat loadings
predict pc_conv_motor_act pc_conv_pt pc_conv_alternative_motorised, score


*importance of facilities
sum wanthighway_location wantpt_walkingdistance wantmanyshops wantfamilyclose wantsportingfacilities wantcommunitycentre wantsupermarketclose wanthealthclose wanteducationalfacilities wantculturalfacilities

pca wanthighway_location wantpt_walkingdistance wantmanyshops wantfamilyclose wantsportingfacilities wantcommunitycentre wantjobclose wantsupermarketclose wanthealthclose wanteducationalfacilities wantculturalfacilities, mineigen(1.09) blanks(.3)
screeplot, yline(1)

rotate, promax
rotate, promax blanks(.3)
rotate, clear

estat loadings
predict pc_want_essential_services_close pc_activity_locations_close, score

estat kmo


*pt planning
```

```
factor ptonlineplanningeasy ovchipeasy ptinfo

pca ptonlineplanningeasy ovchipeasy ptinfo, mineigen(1) blanks(.3)

rotate, promax
rotate, promax blanks(.3)
rotate, clear

estat loadings
predict pc_pt_skills, score
estat kmo

*online services
pca onlineshopping internet onlinegrocery, mineigen(1) blanks(.3)

rotate, promax
rotate, promax blanks(.3)
rotate, clear

*disability
mca disability_bike disability_drive_day disability_drive_night disability_ebike disability_pt
disability_walk, plot
screeplot
mca dummy_disability_drive dummy_disability_pt dummy_disability_walk dummy_disability_bike,

screeplot

*other
pca activitychain onlineshopping onlinegrocery mobilefacilities, mineigen(1) blanks(.3)

rotate, promax
rotate, promax blanks(.3)
rotate, clear

pca covid_activitieseasy covid_lesslikept covid_impactonlife covid_onlinegroceries covid_lesspt
covid_impactontravel covid_moreworkfromhome, mineigen(1) blanks(.3)

rotate, promax
rotate, promax blanks(.3)
rotate, clear
estat kmo

*general life preferences
pca trynewthings spontaneous goodalone boredquickly varietyloving,mineigen(1) blanks(.3)

rotate, promax
rotate, promax blanks(.3)
rotate, clear


*****sample stats***********************
sum(lengthofresidence)
```

```
tab Stedelijkheid, sum(lengthofresidence)
oneway lengthofresidence Stedelijkheid

sum(hhsize)
tab Stedelijkheid, sum(hhsize)
oneway hhsize Stedelijkheid


tab Stedelijkheid gender, chi2

fre dummy_disability_drive
tab Stedelijkheid dummy_disability_drive, chi2
tab Stedelijkheid, sum(dummy_disability_drive)

fre krimpregio

tab Stedelijkheid krimpregio_dummy, chi2
tab Stedelijkheid, sum(krimpregio_dummy)

fre driverslicense
tab Stedelijkheid driverslicense, chi2
tab Stedelijkheid, sum(driverslicense)

fre ptcard
tab Stedelijkheid ptcard, chi2
tab Stedelijkheid, sum(ptcard)

fre ovchipeasy_dummy
tab Stedelijkheid ovchipeasy_dummy, chi2
tab Stedelijkheid, sum(ovchipeasy_dummy)


fre ptonlineplanningeasy_dummy
tab Stedelijkheid ptonlineplanningeasy_dummy, chi2
tab Stedelijkheid, sum(ptonlineplanningeasy_dummy)

oneway PAC Stedelijkheid
oneway lnACC Stedelijkheid
oneway ENT Stedelijkheid
tab krimpregio_dummy Stedelijkheid, chi2
oneway age Stedelijkheid
tab gender Stedelijkheid, chi2
tab education_dummy Stedelijkheid, chi2
tab employment_2 Stedelijkheid, chi2
tab income_dummy Stedelijkheid, chi2
oneway hhsize Stedelijkheid
oneway ncars Stedelijkheid
oneway nbikes Stedelijkheid
oneway nmotorbikes Stedelijkheid
tab ptcard Stedelijkheid, chi2
tab driverslicense Stedelijkheid, chi2
tab dummy_disability_bike Stedelijkheid, chi2
```

```
tab dummy_disability_drive Stedelijkheid, chi2
tab dummy_disability_pt Stedelijkheid, chi2
tab dummy_disability_walk Stedelijkheid, chi2
oneway pc_pt_skills Stedelijkheid
oneway pc3_pro_moterised Stedelijkheid
oneway pc_pro_active_and_motorised Stedelijkheid
oneway pc_activity_locations_close Stedelijkheid
oneway pc_want_essential_services_close Stedelijkheid


replace Stedelijkheid = 2 if Stedelijkheid == 1

oneway PAC Stedelijkheid
oneway lnACC Stedelijkheid
oneway ENT Stedelijkheid
tab krimpregio_dummy Stedelijkheid, chi2
oneway age Stedelijkheid
tab gender Stedelijkheid, chi2
tab education_dummy Stedelijkheid, chi2
tab employment_2 Stedelijkheid, chi2
tab income_dummy Stedelijkheid, chi2
oneway hhsize Stedelijkheid
oneway ncars Stedelijkheid
oneway nbikes Stedelijkheid
oneway nmotorbikes Stedelijkheid
tab ptcard Stedelijkheid, chi2
tab driverslicense Stedelijkheid, chi2
tab internet_dummy Stedelijkheid, chi2
tab liftbycar_dummy Stedelijkheid, chi2
tab caravailability_dummy Stedelijkheid, chi2
tab dummy_disability_all Stedelijkheid, chi2
oneway pc_pt_skills Stedelijkheid
oneway pc3_pro_moterised Stedelijkheid
oneway pc_pro_active_and_motorised Stedelijkheid
oneway pc_activity_locations_close Stedelijkheid
oneway pc_want_essential_services_close Stedelijkheid
oneway lengthofresidence Stedelijkheid
tab friendsfamily_dummy Stedelijkheid, chi2
fre employment_2
oneway pc_pt_skills Stedelijkheid
oneway pc_conv_motor_act Stedelijkheid
oneway pc_conv_pt Stedelijkheid
oneway pc_like_active Stedelijkheid
oneway pc_like_pt Stedelijkheid
oneway pc_like_motorised Stedelijkheid
oneway pc_activity_locations_close Stedelijkheid
oneway pc_want_essential_services_close Stedelijkheid
oneway pc_conv_motor_act Stedelijkheid
oneway pc_conv_alternative_motorised Stedelijkheid

sum pc_conv_alternative_motorised if Stedelijkheid == 5
```

sum PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize i.gender##i.employment_2 c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close i.onlineshopping_dummy if Stedelijkheid == 5

sum PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize i.gender##i.employment_2 c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close i.onlineshopping_dummy if Stedelijkheid == 4

sum PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize i.gender##i.employment_2 c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close i.onlineshopping_dummy if Stedelijkheid == 3

sum PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize i.gender##i.employment_2 c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close i.onlineshopping_dummy if Stedelijkheid == 2 | Stedelijkheid == 1

*****regression*****

*logit
logit PAC_5_or_lower c.ACC c.ENT c.age ib2.education_3 ib2.income_3 i.employment_3 ib0.krimpregio i.dummy_disability_bike i.dummy_disability_pt i.dummy_disability_walk i.driverslicense i.driverslicense##i.Stedelijkheid i.ptcard c.lengthofresidence i.gender i.driverslicense i.ptcard c.lengthofresidence ncars nbikes nmotorbikes nscooter nscootmobiel fcar_driver fcar_passenger fbike febike fscooter fdrt fscootmobiel fwalking ftaxi fedu fgrocery fhealth fshopping fgoingout foutdooractivity fevent ncarkm ovchipeasy_dummy ptonlineplanningeasy_dummy ptinfo_dummy liftbycar_dummy internet_dummy caravailability_dummy liftbycar_dummy carhabit_dummy i.moveintention_dummy ib5.Stedelijkheid i.PROV_code i.friendsfamily_dummy
estat gof, group(10)
estat classification

* glm
meglm lnPAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_3 i.employment_2 i.income_3 ncars nbikes nmotorbikes nscooter nscootmobiel || str_stedelijkheid:, covariance(unstructured)

regress PAC_trans c.ACC c.ENT c.age ib2.education_3 ib1.employment_2 ib2.income_3 ib0.krimpregio i.dummy_disability_bike i.dummy_disability_pt i.dummy_disability_walk i.dummy_disability_drive i.driverslicense i.ptcard i.gender ncars nbikes nmotorbikes nscooter nscootmobiel c.pc_pt_skills c.pc2_pro_pt c.pc3_pro_moterised i.liftbycar_dummy i.internet_dummy caravailability_dummy carhabit_dummy i.moveintention_dummy i.leftbehind_dummy c.pc_activity_locations_close c.pc_pro_active_and_motorised c.pc_want_essential_services_close if KIM_gebiedstype == 3 | KIM_gebiedstype == 4

sum PAC_5_or_lower c.ACC c.ENT c.age ib2.education_3 ib1.employment_2 ib2.income_3 ib0.krimpregio i.dummy_disability_bike i.dummy_disability_pt i.dummy_disability_walk i.dummy_disability_drive i.driverslicense i.ptcard i.gender ncars nbikes nmotorbikes nscooter nscootmobiel c.pc_pt_skills c.pc2_pro_pt c.pc3_pro_moterised c.pc_pro_active_and_motorised i.liftbycar_dummy i.internet_dummy caravailability_dummy carhabit_dummy i.leftbehind_dummy

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close, vce(robust)
outreg2 using results_all, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close if Stedelijkheid == 1| Stedelijkheid== 2, vce(robust)
outreg2 using results_strongly_urban, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close if Stedelijkheid == 3, vce(robust)

outreg2 using results_moderatly_urban, word replace
regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close if Stedelijkheid == 4, vce(robust)
outreg2 using results_somewhat_urban, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt

```
c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close if Stedelijkheid
== 5, vce(robust)
outreg2 using results_not_urban, word replace

logit PAC_55_or_lower c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy c. hhsize  c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy
i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all
c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense
c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt
c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close
i.onlineshopping_dummy i.Sted4
estat classification

logit PAC_55_or_lower c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy ncars ib1.internet_dummy i.dummy_disability_all ib1.driverslicense i.Sted4
estat classification
outreg2 using results_logistic525, word replace
estat classification


*adding variables per type
regress PAC c.lnACC c.ENT i1.krimpregio, vce(robust)
outreg2 using results_lin_step1, word replace


regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy c. hhsize  c.lengthofresidence, vce(robust)
outreg2 using results_lin_step2, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy c. hhsize  c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy
i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy , vce(robust)
outreg2 using results_lin_step3, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy c. hhsize  c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy
i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all
c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense ,
vce(robust)
outreg2 using results_lin_step4, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy
i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all
c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense
c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt
c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close
i.onlineshopping_dummy
outreg2 using results_lin_step5, word replace

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2
i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy
```

i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i.dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close, vce(robust)

regress PAC c.lnACC c.ENT i1.krimpregio c.age i.gender i.education_dummy i.employment_2 i.income_dummy c. hhsize c.lengthofresidence ncars nbikes nmotorbikes i.caravailability_dummy i.liftbycar_dummy i.ptcard ib1.internet_dummy i.friendsfamily_dummy i. dummy_disability_all c.pc_pt_skills ib1.driverslicense i.gender##ib1.driverslicense i.income_dummy##i.driverslicense c.pc_conv_alternative_motorised c.pc_conv_motor_act c.pc_conv_pt c.pc_like_active c.pc_like_pt c.pc_like_motorised c.pc_activity_locations_close c.pc_want_essential_services_close i.onlineshopping_dummy, vce(robust)

D2 - R syntax

```
#packages#
library(dplyr)
library(sf)
library(cbsodataR)
library(ggplot2)
library(stringr)
library(tidyr)
library(RColorBrewer)

#loading spatial data#
gem <- st_read("C:\\Users\\marij\\OneDrive\\Thesis
OV\\data\\map_gemeentes\\WijkBuurtkaart_2021_v1\\gemeente_2021_v1.shp")
str(gem)
gem <- gem %>%
  filter(H2O == "NEE") %>%
  select(-H2O, -BEV_DICHTH, -P_OVER_NW, -P_TURKIJE, -P_SURINAM, -P_ANT_ARU, -
P_MAROKKO, -P_N_W_AL, -P_WEST_AL, -P_VERWEDUW, -P_GESCHEID, -P_GEHUWD,
-P_ONGEHUWD, -P_EENP_HH, -P_HH_Z_K, -P_HH_M_K, -AANTAL_HH, -OPP_TOT, -
OPP_LAND, -OPP_WATER)

gem <- gem %>%
  mutate(man_per_vrouw = AANT_MAN/AANT_VROUW) %>%
  select(-AANT_MAN, -AANT_VROUW)

#employement data#
data <- cbs_get_data("84961NED")
metadata <- cbs_get_meta("84961NED")

data <- data %>%
  filter(Perioden == "2020JJ00", Persoonskenmerken == "T009002") %>%
  mutate(employed = WerkzameBeroepsbevolking_3/BeroepsEnNietBeroepsbevolking_1)
%>%
  mutate(Key = RegioS) %>%
  full_join(metadata[["RegioS"]], by = "Key") %>%
  mutate(Regio = Title) %>%
  select(RegioS, employed, BrutoArbeidsparticipatie_15)

gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "RegioS"))


#disabilities data#

data <- cbs_get_data("85012NED")
metadata <- cbs_get_meta("85012NED")
data <- data %>%
  filter(Leeftijd == "10000", Marges == "MW00000") %>%
  select(RegioS, EenOfMeerLichamelijkeBeperkingen_3)

gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "RegioS"))

#accessibility data#
```

```
data <- cbs_get_data("80305ned")
metadata <- cbs_get_meta("80305ned")

data <- data %>%
  select(RegioS, Binnen10Km_72, Perioden) %>%
  filter(Perioden == "2017JJ00") %>%
  select(-Perioden)

gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "RegioS"))


#income data#

data <- cbs_get_data("84868NED")
metadata <- cbs_get_meta("84868NED")

data <- data %>%
  filter(Perioden == "2019JJ00", InkomensgrensHuishouden == "1050290",
DuurInkomenspositie == "A028721", KenmerkenVanHuishoudens == "1050010") %>%
  mutate(laag_inkomen = PersonenRelatief_5) %>%
  select(RegioS, laag_inkomen)

gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "RegioS"))


#region data#

data <- cbs_get_data("84929NED")
metadata <- cbs_get_meta("84929NED")

data <- data %>%
  select(RegioS, Code_26, Naam_27)

str_trim(data$RegioS)
str_trim(gem$GM_CODE)

data <- data.frame(data)
str(data)
str(gem)

data <- data %>%
  mutate(RegioS = trimws(as.character(RegioS)))

gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "RegioS")) %>%
  mutate(provincie = Naam_27, prov_code = Code_26) %>%
  select(-Naam_27, -Code_26)

#car ownership data#
data <- cbs_get_data("70072ned")
metadata <- cbs_get_meta("70072ned")
data <- data %>%
```

```
  filter(Perioden == "2020JJ00") %>%
  select(RegioS, PersonenautoSParticulierenRelatief_199)

gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "RegioS"))

#internet usage data#
data <- read.csv("C:\\Users\\marij\\Downloads\\internet_use.csv")

data <- data %>%
  mutate(prov_code = Code_289, internet_use = ï..2021) %>%
  select(-Code_289, -ï..2021)
data <- data %>%
  mutate(prov_code = trimws(as.character(prov_code)))

gem <- gem %>%
  mutate(prov_code = trimws(as.character(prov_code)))

gem <- gem %>%
  left_join(data, by = c("prov_code"))

#education data#

data <- cbs_get_data("85051NED")
metadata <- cbs_get_meta("85051NED")

data <- data %>%
  left_join(metadata[["Opleidingsniveau"]], by = c("Opleidingsniveau" = "Key")) %>%
  filter(Marges == "MW00000")

data_hoog <- data %>%
  filter(Title == "Hoog") %>%
  mutate(bevolking_hoog = Bevolking15Tot75Jaar_2) %>%
  select(WijkenEnBuurten, bevolking_hoog)

data_middelbaar <- data %>%
  filter(Title == "Middelbaar ") %>%
  mutate(bevolking_middelbaar = Bevolking15Tot75Jaar_2) %>%
  select(WijkenEnBuurten, bevolking_middelbaar)

data_laag <- data %>%
  filter(Title == "Laag") %>%
  mutate(bevolking_laag = Bevolking15Tot75Jaar_2) %>%
  select(WijkenEnBuurten, bevolking_laag)

data <- data_hoog %>%
  left_join(data_laag, by = c("WijkenEnBuurten")) %>%
  left_join(data_middelbaar, by = c("WijkenEnBuurten")) %>%
  mutate(opleiding_totaal = bevolking_hoog + bevolking_laag + bevolking_middelbaar) %>%
  mutate(prop_laag = bevolking_laag/opleiding_totaal, prop_hoog =
bevolking_hoog/opleiding_totaal)


gem <- gem %>%
  left_join(data, by = c("GM_CODE" = "WijkenEnBuurten"))
```

```
#entrophy index#

data <- cbs_get_data("83582NED")
metadata <- cbs_get_meta("83582NED")

data <- data %>%
  left_join(metadata[["BedrijfstakkenBranchesSBI2008"]], by =
c("BedrijfstakkenBranchesSBI2008" = "Key")) %>%
  filter(Perioden == "2020JJ00")

totaal <- data %>%
  filter(BedrijfstakkenBranchesSBI2008 == "T001081") %>%
  select(RegioS, totaal = BanenVanWerknemersInDecember_1)

data <- data %>%
  left_join(totaal, by = c("RegioS"))

data <- data %>%
  filter(CategoryGroupID == 3) %>%
  mutate(proportion = BanenVanWerknemersInDecember_1/totaal) %>%
  filter((BedrijfstakkenBranchesSBI2008 != "T001081")) %>%
  na.omit() %>%
  group_by(RegioS) %>%
  mutate(count = n_distinct(BedrijfstakkenBranchesSBI2008)) %>%
  ungroup()

data <- data %>%
  filter(BanenVanWerknemersInDecember_1 != 0) %>%
  mutate(ln_prop = log(proportion)) %>%
  mutate(ln_count = log(count)) %>%
  mutate(prop_log_prop = proportion * ln_prop) %>%
  mutate(sector = prop_log_prop/ln_count)

index <- data %>%
  group_by(RegioS) %>%
  summarize(index = -(sum(sector)))

#declining regions #
gem <- gem %>%
  left_join(index, by = c("GM_CODE" = "RegioS"))

gem <- gem %>%
  mutate(krimpregio = case_when(GM_NAAM =="Appingedam" ~ 1, GM_NAAM =="Delfzijl" ~
1, GM_NAAM =="Loppersum" ~ 1, GM_NAAM =="Oldambt" ~ 1, GM_NAAM =="Pekela" ~ 1,
GM_NAAM =="Stadskanaal" ~ 1, GM_NAAM =="Veendam" ~ 1, GM_NAAM =="Westerwolde"
~ 1,  GM_NAAM =="Het Hogeland" ~ 1,  GM_NAAM =="Brunssum" ~ 1,  GM_NAAM
=="Heerlen" ~ 1,  GM_NAAM =="Kerkrade" ~ 1,  GM_NAAM =="Nuth" ~ 1,  GM_NAAM
=="Landgraaf" ~ 1,  GM_NAAM =="Onderbanken" ~ 1,  GM_NAAM =="Simpelveld" ~
1,  GM_NAAM =="Voerendaal" ~ 1,  GM_NAAM =="Eijsden-Margraten" ~ 1,  GM_NAAM
=="Gulpen-Wittem" ~ 1,  GM_NAAM =="Maastricht" ~ 1,  GM_NAAM =="Meerssen" ~
1,  GM_NAAM =="Vaals" ~ 1,  GM_NAAM =="Valkenburg aan de Geul" ~ 1,  GM_NAAM
=="Beek" ~ 1,  GM_NAAM =="Beekdaelen" ~ 1,  GM_NAAM =="Sittard-Geleen" ~
1,  GM_NAAM =="Stein" ~ 1,  GM_NAAM =="Hulst" ~ 1,  GM_NAAM =="Sluis" ~
1,  GM_NAAM =="Terneuzen" ~ 1,  GM_NAAM =="Aalten" ~ 1,  GM_NAAM =="Bronckhorst" ~
```

```
1,  GM_NAAM =="Berkelland" ~ 1,  GM_NAAM =="Doetinchem" ~ 1,  GM_NAAM
=="Montferland" ~ 1,  GM_NAAM =="Oost Gelre" ~ 1,  GM_NAAM =="Oude IJsselstreek" ~
1,  GM_NAAM =="Winterswijk" ~ 1,  GM_NAAM =="Noardeast-Fryslân" ~ 1,  GM_NAAM
=="Tytsjerksteradiel" ~ 1,  GM_NAAM =="Achtkarspelen" ~ 1,  GM_NAAM =="Dantumadiel" ~
1))
gem <- gem %>% replace_na(list(krimpregio = 0))

#risk factors limits#

employed_low25 <- quantile(gem$BrutoArbeidsparticipatie_15, 0.25, na.rm = TRUE)
employed_high25 <- quantile(gem$BrutoArbeidsparticipatie_15, 0.75, na.rm= TRUE)
cars_low25 <- quantile(gem$PersonenautoSParticulierenRelatief_199 , 0.25, na.rm = TRUE)
cars_high25 <- quantile(gem$PersonenautoSParticulierenRelatief_199 , 0.55, na.rm = TRUE)
ENT_low25 <- quantile(gem$index, 0.25, na.rm = TRUE)
ENT_high25 <- quantile(gem$index, 0.75, na.rm= TRUE)
ACC_low25 <- quantile(gem$Binnen10Km_72, 0.25, na.rm = TRUE)
ACC_high25 <- quantile(gem$Binnen10Km_72, 0.75, na.rm= TRUE)

men_low25 <- quantile(gem$man_per_vrouw, 0.25, na.rm = TRUE)
men_high25 <- quantile(gem$man_per_vrouw, 0.75, na.rm= TRUE)

laagopl_low25 <- quantile(gem$prop_laag, 0.25, na.rm = TRUE)
laagopl_high25 <- quantile(gem$prop_laag, 0.75, na.rm= TRUE)

laagink_low25 <- quantile(gem$laag_inkomen, 0.25, na.rm = TRUE)
laagink_high25 <- quantile(gem$laag_inkomen, 0.75, na.rm= TRUE)


dis_low25 <- quantile(gem$EenOfMeerLichamelijkeBeperkingen_3, 0.25, na.rm = TRUE)
dis_high25 <- quantile(gem$EenOfMeerLichamelijkeBeperkingen_3, 0.75, na.rm= TRUE)


internet_low25 <- quantile(gem$internet_use, 0.25, na.rm = TRUE)
internet_high25 <- quantile(gem$internet_use, 0.75, na.rm= TRUE)

#risk factors#
gem$employed_low <- case_when(gem$BrutoArbeidsparticipatie_15 <= employed_low25 ~ 1,
gem$BrutoArbeidsparticipatie_15 > employed_low25 ~ 0)
gem$employed_high <- case_when(gem$BrutoArbeidsparticipatie_15 > employed_high25 ~ -
1, gem$BrutoArbeidsparticipatie_15 <=  employed_high25 ~ 0)

gem$cars_low <- case_when(gem$PersonenautoSParticulierenRelatief_199 <= cars_low25 ~
1, gem$PersonenautoSParticulierenRelatief_199 > cars_low25 ~ 0)
gem$cars_high <- case_when(gem$PersonenautoSParticulierenRelatief_199 > cars_high25 ~
-1, gem$PersonenautoSParticulierenRelatief_199 <=  cars_high25 ~ 0)

gem$ENT_low <- case_when(gem$index <= ENT_low25 ~ 1, gem$index > ENT_low25 ~ 0)
gem$ENT_high <- case_when(gem$index > ENT_high25 ~ -1, gem$index <=  ENT_high25 ~
0)


gem$ACC_low <- case_when(gem$Binnen10Km_72 <= ACC_low25 ~ 1,
gem$Binnen10Km_72 > ACC_low25 ~ 0)
gem$ACC_high <- case_when(gem$Binnen10Km_72 > ACC_high25 ~ -1,
gem$Binnen10Km_72 <=  ACC_high25 ~ 0)
```

```
gem$Men_low <- case_when(gem$man_per_vrouw <= men_low25 ~ -1,
gem$man_per_vrouw > men_low25 ~ 0)
gem$Men_high <- case_when(gem$man_per_vrouw > men_high25 ~ 1,
gem$man_per_vrouw <=  men_high25 ~ 0)


gem$laagopl_low <- case_when(gem$prop_laag <= laagopl_low25 ~ 1, gem$prop_laag >
laagopl_low25 ~ 0)
gem$laagopl_high <- case_when(gem$prop_laag > laagopl_high25 ~ -1, gem$prop_laag <=
laagopl_high25 ~ 0)


gem$laagink_low <- case_when(gem$laag_inkomen <= laagink_low25 ~ -1,
gem$laag_inkomen > laagink_low25 ~ 0)
gem$laagink_high <- case_when(gem$laag_inkomen > laagink_high25 ~ 1,
gem$laag_inkomen <= laagink_high25 ~ 0)


gem$dis_low <- case_when(gem$EenOfMeerLichamelijkeBeperkingen_3 <= dis_low25 ~ -1,
gem$EenOfMeerLichamelijkeBeperkingen_3 > dis_low25 ~ 0)
gem$dis_high <- case_when(gem$EenOfMeerLichamelijkeBeperkingen_3 > dis_high25 ~ 1,
gem$EenOfMeerLichamelijkeBeperkingen_3 <= dis_high25 ~ 0)


gem$internet_low <- case_when(gem$internet_use <= internet_low25 ~ -1, gem$internet_use
> internet_low25 ~ 0)
gem$internet_high <- case_when(gem$internet_use > internet_high25 ~ 1, gem$internet_use
<= internet_high25 ~ 0)


#total risk#
gem[is.na(gem)] <- 0

gem$risk_PAC <- gem$employed_low + gem$employed_high + gem$cars_low +
gem$cars_high + gem$ENT_low + gem$ENT_high + gem$ACC_low + gem$ACC_high +
gem$Men_low + gem$Men_high + gem$laagopl_low + gem$laagopl_high + gem$laagink_low
+ gem$laagink_high + gem$dis_low + gem$dis_high + gem$internet_low + gem$internet_high

#creating map#
library(RColorBrewer)

ggplot(gem) +
  geom_sf(aes(fill = risk_PAC)) +
  scale_fill_gradientn(colours = colorspace::diverge_hcl(10))
```