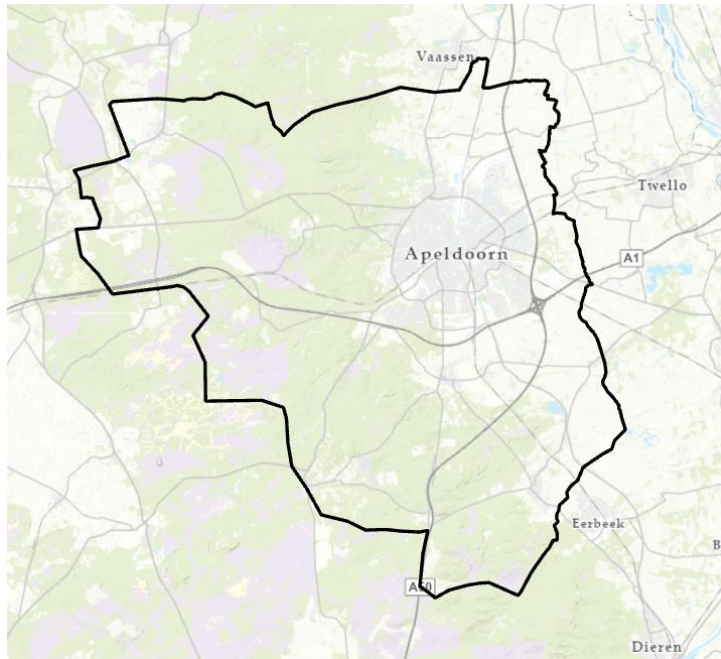


Exploring practice-driven mobility poverty mapping in two cities in Gelderland.



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*Master's Thesis for the Spatial Planning Programme
Specialization Urban and Regional Mobility
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Preface

Dear reader,

Finally, I can proudly present the Master's Thesis 'Exploring practice-driven mobility poverty mapping in two cities in Gelderland', which lies before you. This thesis concerns an explorative study into mapping mobility poverty mapping with the aid of practice. "Practice" in this case concerns conducted interviews with, amongst others, municipalities, provinces, public transport companies and neighbourhood managers. The Master's Thesis is the final requirement for completing the 'Urban and Regional Mobility Master's Specialisation of Spatial Planning' at the Radboud University (Nijmegen School of Management). The thesis was written roughly between September 2021 and March 2022. Writing this thesis was a challenging but valuable experience to finalize my time as a spatial planning student. I would like to thank those who aided (directly or indirectly) with the completion of my thesis.

First, many thanks to my thesis supervisor Sander Lenferink who guided me through the development of this thesis. Your sharp feedback engaged me in reflecting on the theoretical parts of my work and your insights helped a lot in the practical and process-related elements of this research.

Second, I would like to thank my internship supervisor Babet Hendriks and my wonderful colleagues at Mobycon for both aiding in the development of my thesis (especially the practical elements of this research) AND for letting me experience participating in projects in a non-academic setting. Thank you for the pleasant and inviting atmosphere during these projects. I am delighted that we will remain colleagues after the completion of my thesis!

Third, thank you to the interviewees that participated in this research as without your contribution this thesis could not have been developed. Also, thank you to those that did not participate in the interviews but guided me in some other way in the development of this thesis, like my fellow students.

And, finally, a big thank you to my family, my close friends and my korfbal squad who supported me from a distance during not only the development of this thesis but also during my years as a student.

I hope you will enjoy reading my thesis, and I am looking forward to answering further questions about my work.

Evert-Jan Hekman

Abstract

This research explores participatory mobility poverty mapping using a practical case study (Apeldoorn and Nijmegen). Mobility poverty occurs if people cannot reach desired activity locations due to a lack of transport options, problematic social-economic and spatial circumstances or a lack of competences to travel (Lucas et al., 2016; Jorritsma et al., 2018). Actors in spatial planning should constantly strive for the 'Just City' (Fainstein, 2009). Reducing mobility poverty fits with this 'Social Justice' approach. However, currently, it is relatively unclear how to map mobility poverty and which indicators should be included in mobility poverty maps. Furthermore, it is unclear how a mobility poverty map may be used in mobility policymaking and what approaches to reduce mobility poverty there are already. A participative mapping approach will be applied in this research to give more insights into these unclaritys.

The participative mapping approach is shaped by insights from various scales (province, municipality, neighbourhood organisation). More specifically, this research follows a 'grounded visualization' approach. Grounded visualization concerns mapping mobility poverty in an inductive, explorative and iterative fashion (Knigge & Cope, 2006). First, interviewees were asked what indicators of mobility poverty are important. Despite that for most interviewees mobility poverty was unknown, they were able to think of indicators, even beyond their own domain. Public health, accessibility of amenities and income were regarded as the most important indicators. Second, the indicators that were mentioned most and of which data on neighbourhood level was available were bundled in GIS into a mobility poverty map. Finally, the presented maps served as input for interviews with the same interviewees. This highlights the iterative aspect of grounded visualization (Knigge & Cope, 2006). Differences between Nijmegen and Apeldoorn were limited. Especially interviewees from the micro-level expressed doubt in the presented maps, as they were well aware of the (potential) mobility poverty situation within the neighbourhoods they work in. The grounded visualization approach showed that it is wise to consult stakeholders from multiple levels and domains when interpreting mobility poverty maps. The mobility poverty map is a valuable tool to start a multidisciplinary discussion between multiple domains and organisations. Integrating mobility poverty in policy with other social themes like durability or active mobility, for example in the context of the future Dutch Omgevingswet, can improve the uptake of mobility poverty in policy. A neighbourhood approach using surveys might make mobility poverty more tangible in the future.

Keywords

Mobility poverty, Social Justice, GIS mapping, participative mapping, grounded visualization, policy.

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1: Introduction

1.1: Problem statement

Ideally, people can reach any destination they like. However, people experiencing mobility poverty have trouble in reaching desired destinations. This can impact their quality of life. Recently, mobility poverty gets more attention. Recent research identifies mobility poverty as a research term and identifies who are at risk of mobility poverty. Limited research is already done on where mobility poverty occurs. This spatial question is crucial as this can inform stakeholders that are due to their position able to reduce mobility poverty where they should devote attention to. This research will add to knowledge regarding this spatial question by presenting a mobility map developed with aid of practice. This link with practice is currently limitedly investigated. Insights from practice are valuable to mobility poverty mapping as they can improve the quality of maps by comparing mobility maps to their own experiences. Furthermore, practice-driven mobility poverty research can also increase knowledge about what is required to put mobility poverty more firmly on the agendas of stakeholders able to reduce mobility poverty. This research will investigate this.

People who are at risk of mobility poverty typically have low incomes, have no jobs, are older (especially women), are from an ethnic minority, are rural inhabitants, have bad physical or mental health conditions or do not own a motorized vehicle (Jorritsma et al., 2018). Due to poor access to destinations (an expression of mobility poverty), these groups are at risk of being excluded from social activities (social exclusion). This should be avoided. Therefore, mobility poverty should be a key concept in spatial planning. However, it is not always the main topic of spatial planning. The ultimate goal of the transport network is to move all individuals (Martens, 2015), but this fundamental aspect has often been overlooked. Past transport planning often aimed at enhancing the ease to get around via for example highway expansions. These expansions often attracted new travellers, sparking the call for new highway expansions (Handy, 2005). Traces of this approach can still be found in expensive, environmentally unfriendly and social exclusive highway projects today. A highway expansion does improve the accessibility of some destinations but is not durable and people without a car do not directly benefit from this expansion. Mobility poverty can only be reduced if all people can travel to desired destinations, not just those who can afford a car.

Why is mobility poverty not yet solved? Mobility poverty is a ‘wicked problem’. Wicked problems are complex, hard to define, hard to measure and often connected to other wicked problems (Rittel & Webber, 1973). Wicked problems are often relatively invisible, difficult to understand and expensive to solve. Being a wicked problem is a reason why mobility poverty is not often the main planning objective. Another reason is that mobility poverty is a relatively new research concept (Lucas, 2012), and therefore not often the main planning objective of new projects.

Despite this, there are some notable approaches to mobility poverty. For example in Ugchelen, one of the cases in this research, a local bus service (the ‘buurtbus’) is run by volunteers to make sure people can still make use of this service despite that the service was previously not available. This can make sure that people can better reach locations. Another example is in the Kanaalzone in Nijmegen where e-hubs with shared e-bikes can improve the accessibility of destinations to those that have to travel far and do not own a car.

Typically, these approaches are developed without a thorough investigation into where mobility poverty actually occurs. A thorough local or regional investigation on where mobility poverty occurs is not yet often researched. However, such a thorough regional investigation could benefit local policymakers and other relevant stakeholders in making mobility poverty tangible and subsequently in making policy in mobility poverty. Investigating the problem of mobility poverty before dealing with mobility poverty is therefore central to this research. Therefore, this research will develop a mobility poverty map for two cases (Apeldoorn and Nijmegen) based on practice (bottom-up). By involving practice, this research can investigate whether theoretical ideas about mobility poverty match insights from practice and whether different aspects of mobility poverty are important in different cases.

Several authors have already attempted to map mobility poverty, for example, Kampert et al. (2019) and Martens and Bastiaansen (2019). Typically, these maps show for different locations how high the mobility poverty risk is. This risk factor is based on a combination of different indicators that contribute to mobility poverty. Relevant indicators are selected based on theoretical conceptual definitions of mobility poverty. Examples of these indicators are for example household income (Kampert et al., 2019, Jorritsma et al., 2018), distance to public transport (Kampert et al., 2019) and owning a motorized vehicle (e.g. Martens & Bastiaansen, 2019) (attachment A). This way of mapping is top-down, as the indicators are selected and mapped by a research team that operates at a distance from the real mobility poverty situation. Instead of top-down mapping, this research proposes a bottom-up approach that investigates how current theoretical-based mobility poverty maps can benefit from practice, something that is currently not often investigated.

This research will use grounded visualization as the core perspective. This concept links well to bottom-up mobility poverty mapping. 'Visualization' links directly with mapping. 'Grounded' refers to the research strategy "Grounded Theory", in which theories are constructed using data (Charmaz, 2014). Grounded visualization is a combination of these aspects. Grounded visualization is a concept about mapping based on multiple perspectives (Knigge & Cope, 2006). These multiple perspectives echo a bottom-up approach. They enhance the quality of both mobility poverty maps and mobility poverty mapping.

There are two reasons why a bottom-up approach like grounded visualization is a better approach to map mobility poverty than a top-down approach. First, as mobility poverty is a relatively new research concept (Lucas, 2012), there are different definitions of mobility poverty and different ways in how it can be operationalized. Mobility poverty is a social construct. A social construct is a product of our (=society) own making (Moses & Knutsen, 2012), and so is mobility poverty. Therefore, different ideas and definitions about mobility poverty exist. The consequence of this is that the concept and its important aspects are still evolving. A top-down mapping approach using only the insights of a single research team leads to one-sided conclusions regarding mobility poverty mapping. Therefore, using multiple actors in mobility poverty mapping is favoured. Secondly, maps are just like the term mobility poverty also value-laden by nature (Sidiq, 2021). According to Harley (2002, p35), a map is "*a social construction of the world expressed through the medium of cartography*". A map is thus a social construct in itself, and always conveys an interpretation of the developer of what the 'real' phenomenon is and how this can be best operationalized. According to Charmaz (2014),

this researcher's involvement is always present in the context of Grounded Theory and thus also in grounded visualization and mapping. It may well be that these authors select relevant indicators of mobility poverty out of practical or personal reasons. Kampert et al. (2019) for example acknowledge which indicators are not taken into the analysis. The question remains whether these indicators are not crucial for making a representative mobility poverty map. Due to the value-ladenness that is inherent to mobility poverty and mobility poverty maps, this research takes a participatory mapping approach. Chapter 3 will dive into to what extent participatory mapping is interwoven in this research.

1.2: Research goals and research questions

Two main research goals are central to this research. First, this research aims to explore how insights from practice can improve understanding about operationalizing mobility poverty into mobility poverty maps. To do this, this research will use interviews before (to discuss relevant indicators) and after presenting a local mobility poverty map (to reflect whether the map matches reality). Secondly, this research will explore how and in what ways the developed mobility poverty maps can contribute to mobility poverty policy. Interviews are the main data source for this second research goal.

The interviewees in this research are (amongst others) municipal staff members, staff members from a public transport company and neighbourhood managers in Apeldoorn and Nijmegen, two cities in the province of Gelderland. These interviewees come from various scales in the mobility and social domain. The first round of interviews will highlight which indicators of mobility poverty are required for a local mobility poverty map. It is chosen to use various scales as this represents the whole society, not only (top-down) planning departments but also more bottom-up parties. Using the indicators claimed most important by them, a mobility poverty map for Apeldoorn and Nijmegen will be developed. A feedback interview with the same interviewees will highlight if this mobility poverty map confirms the views of the interviewees about the mobility poverty situation in their region. This reflection is crucial, as it will highlight if indicators are still missing in the analysis and if the conceptualized indicators of mobility poverty are operationalized and represented well in the map. The result is a mobility poverty map that tries to do justice to local specific circumstances (via the participatory approach). The mobility poverty map also elaborates on current (mostly theory-driven) mobility poverty mapping.

The abovementioned approach sheds light on whether a mobility poverty map based on practice within a local case is different from current mobility poverty maps based on theory. Using two cases can illustrate whether in different cases different aspects in mobility poverty maps are being regarded as important. This research will also shed light on how mobility poverty is currently dealt with and how mobility poverty maps or further research into mobility poverty can be used to improve how mobility poverty is dealt with currently.

The following main research question is central:

How do insights from practice improve mobility poverty maps and their uptake in policy?

The following sub questions will lead to an answer to the main research question:

- 1) What is mobility poverty and what are indicators of mobility poverty?
- 2) What indicators are most relevant in a mobility poverty map according to interviewees active in the public domain in Apeldoorn and Nijmegen?
- 3) What is the extent of mobility poverty in these two cities in Gelderland?
- 4) How do the same interviewees value the presented mobility poverty map?

The first sub question will highlight mobility poverty itself and will break mobility poverty down into indicators. The second sub question will use interviewees to investigate which of these indicators are most important in mapping mobility poverty. These indicators will be used for mapping mobility poverty in GIS in the third sub question. The final sub question will highlight whether the presented mobility poverty map matches the opinions of the interviewees. This will serve as an iterative reflection and will highlight whether operationalization went well and whether indicators are missing in the map. Furthermore, this sub question will highlight what already is being done to reduce mobility poverty and whether mobility poverty maps can put mobility poverty more firmly on the policy agenda or that a different way of analysis is required to realise this.

1.3: Relevance

The societal relevance of this research can be found in that this research aims to give, by taking a bottom-up approach, more insight into mobility poverty mapping and ways in which mobility poverty policy can benefit from mobility poverty maps. Mobility poverty maps are in themselves tools to guide the societal discussion about dealing with mobility poverty and thus improving mobility poverty mapping expresses a great deal of the societal relevance of this research. Generally, maps are used to explore, collect and display data (Mckinnon & McCallum Breen, 2020). As Talen (1998) stresses in the discussion of equity maps (maps that visualize equity), a similar type of map as mobility poverty maps: *“the production of equity maps serves to promote, through visualization, a sociological understanding of the relationship between distribution and need”* (Talen, 1998, p 36). Put differently, visualization can greatly help in monitoring current planning policy and formulating new planning policy (Ghose & Huxhold, 2002), for example on the topic of mobility poverty. More specifically, the mapping programme GIS is great for analysing and visualizing spatial data, and through visualization can highlight trends and patterns that may not be evident otherwise (Ghose & Huxhold, 2002). The resulting mobility poverty maps show where mobility poverty risk is high. Furthermore, the maps can show why this risk is high in some locations as the maps in this research also show results on individual indicators of mobility poverty. For example, the maps can show which neighbourhoods have low incomes. Low incomes impact the transport options of people, which is reflected in the mobility poverty map.

Mapping these individual indicators (as underlying causes of mobility poverty) and mobility poverty, in general, is useful to local policymakers as they then get a clearer picture of where mobility poverty occurs. This policy uptake focus is key in this research and goes beyond the mobility poverty maps themselves. In November 2018, the Dutch national communication body of the physical environment (the OFL) concluded that public authorities should make mobility poverty policy more explicit (OFL, 2018). However, they also noticed that this requires

both a more clear picture about where and the extent to which mobility poverty occurs and analysis about current approaches (“best practices”) of dealing with mobility poverty (OFL, 2018). This research focuses on both where and to what extent mobility poverty occurs and on current approaches and is therefore also relevant in the broader context of dealing with mobility poverty.

The scientific relevance of this research lies primarily in exploring mobility poverty mapping not top-down as in most current research into mobility poverty, but bottom-up. Top-down mapping of social phenomena fails to show the complexity of local circumstances as it is one-sided (Sidiq, 2021). This research will rather investigate mobility poverty mapping using multiple perspectives. The quality of mobility poverty maps will improve as practice is used to nuance top-down developed mobility poverty maps. Using multiple perspectives in improving knowledge of mobility poverty (Lucas, 2012) and mobility poverty maps (Sidiq, 2021) means that participatory mapping will be a key term. Finally, using practice in this research also sheds light on how mobility poverty maps and other research methods to investigate mobility poverty can be used to stimulate the uptake of mobility poverty in policy. This is valuable, as there is currently limited information about where and to what extent mobility poverty occurs and about potential approaches to reduce mobility poverty (OFL, 2018).

2: Theory

In this chapter, a literature review, the theoretical framework and the conceptual model will be presented.

2.1: Literature review

This section will describe how mobility poverty is defined and what research into mobility poverty has already been done. It will give more clarity on what this research will add to mobility poverty research and mobility poverty policy. First, the 'Social Justice' approach will be described as a departure point to illustrate the policy context of this research. This will highlight why mobility poverty should be avoided. Subsequently, mobility poverty, current academic literature about mobility poverty research and mobility poverty indicators will be discussed.

2.1.1: Departure: social justice

Before defining and mapping mobility poverty, it is first important to establish why it is relevant to research mobility poverty in the first place. The 'Social Justice' philosophy will serve as an answer to this question. In this philosophy, the 'Just City' is key. People active in spatial planning should constantly strive for this 'Just City', according to Fainstein (2009, p11). Moreover, these people are in key positions to do this (Bucknell, 2019). In line with the 'Just City', a good transport network has as the ultimate goal to move all individuals (Martens, 2015). Unfortunately, many spatial projects can only be accessed by some travellers. New highways are an example of this (Handy, 2005). The regional or national benefits that these infrastructural projects have are often offset by externalities that should be avoided. Externalities are for example traffic accidents, local air pollution, space uptake noise pollution and the enhanced greenhouse effect (Parry et al., 2007). Taking these externalities and 'Social Justice' into account means that everyone should be able to reach desired activity locations (Martens, 2015) while posing as little pressure as possible on the (living) environment (Lucas et al., 2016). This balance is also central in the durable development framework of Raworth (2012). According to Raworth, there is a safe and fair space for humanity, bordered by a social foundation (the minimum) and an environmental ceiling (the maximum). Although Raworth focuses primarily on the environment and ecology, her line of reasoning can be tailored to mobility as well (figure 1).

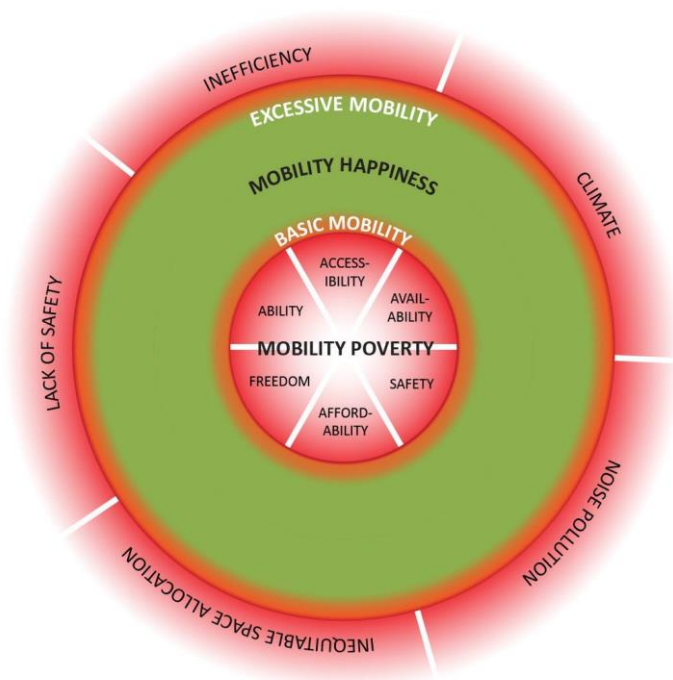


Figure 1: The mobility donut (Mobycon, n.d.).

Taking figure 1 into account, the departure point of this research is that planners and public authorities should strive to avoid reaching the environmental ceiling while simultaneously avoiding reaching the social foundation. Dealing with mobility poverty, the focus of this research, can avoid being below this social foundation, preferably without involving externalities. However, mobility poverty policy is currently limited. Policymakers always need to make choices about which themes they focus on and how they do this. Dealing with mobility poverty is only one of these themes. To put mobility poverty more prominent on the policy agenda, as it is a societally pressing topic, a more clear picture of where and to what extent mobility poverty occurs is needed (OFL, 2018). This research will contribute to this. But first, it is important to investigate what is already known regarding mobility poverty.

2.1.2: Mobility poverty research

Most known regarding mobility poverty is the theoretical base of mobility poverty, which is logical considering the ‘young age’ of this concept. This theoretical base will be discussed in chapter 2.1.3. Less investigated is mapping mobility poverty (Martens & Bastiaansen, 2019). Due to this young age, the definition and way of operationalization of mobility poverty are evolving. Consequently, there are differences between studies of mobility poverty maps. First of all, studies differ in types and numbers of used indicators of mobility poverty. For example, Jeekel and Martens (2017) only consider two indicators whereas the CBS (Kampert et al., 2019) uses more indicators. The question of what indicators should best be applied is central in this research as well. Secondly, studies differ in scale. This can vary from a local (Kampert et al., 2019) to a regional level (Martens & Bastiaansen, 2019). This research will investigate two local cases. This will be discussed further in chapter 3.1. The position of this research is thus now stated, but there is one final aspect that sets this research apart from most current research into mobility poverty. Most mobility poverty maps are developed in a top-down fashion, where one research team investigates what is important in mapping mobility poverty. This research however takes a bottom-up, participatory research approach.

2.1.3: Definition of mobility poverty

But what is mobility poverty precisely? The ‘young age’ of mobility poverty as a research concept leads to different overlapping definitions of mobility poverty (Lucas et al., 2016). In current research, there are related terms to mobility poverty like accessibility poverty and transport poverty. Let us first take a look at those.

“Accessibility poverty occurs if a person has a lack of access to key opportunities, such as employment, education, health care, or social support networks.” (Jeekel & Martens, 2017, p53).

People experiencing accessibility poverty thus have difficulties reaching destinations. The goal of this research is to reduce that by investigating where that occurs in the first place. But where this occurs depends on whether people are able to travel freely in the first place: mobility. So to find out where a lack of access occurs needs the question of where limited possibilities to go from A to B occurs. For this research, this means that mobility poverty is the key topic of interest although it is related to accessibility poverty. But what causes mobility poverty? Jorritsma et al. (2018) illustrate this based on Lucas (2012) in their definition of *mobility poverty*:

“Not or hardly able to reach activity locations (in terms of effort) as a consequence of a lack of transport options (objective and perceived), combined with social-economic and spatial circumstances of individuals and their competences. Consequently, individuals are hindered in their participation in society, due to which their quality of life is impacted negatively”. (Jorritsma et al., 2018, p3)

The definition shows that multiple aspects relate to mobility poverty. To investigate mobility poverty, one must not only focus on a lack of transport options as is the case in transport poverty (Jeekel & Martens, 2017) but on the full picture of transport options, competences (skills to travel), social-economic and spatial circumstances (Jorritsma et al., 2018). Another cause of mobility poverty, not mentioned in the definition of mobility poverty of Jorritsma et al. (2018), are emotional circumstances (feelings). A good working definition of mobility poverty considers all these causes so that it becomes clear what factors are related to mobility poverty. Furthermore, as illustrated by Jorritsma et al. (2018), mobility poverty can impact participation in society. This relates is typically coined by *social exclusion*:

“The lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas. It affects both the quality of life of individuals and the equity and cohesion of society as a whole.” (Levitas et al., 2007, p9).

Social exclusion is more than mobility alone. Consider for example age or ethnic related discrimination. Mobility poverty can negatively influence social exclusion (Lucas, 2012). This aspect is also important in a definition of mobility poverty. This, and the components of mobility poverty of Jorritsma et al. (2018) are included in the following working definition of *mobility poverty*:

Not or hardly able to reach activity locations due to a lack of transport options and competences or negative social-economic, spatial or emotional circumstances. Consequently, individuals are at risk of social exclusion and a decreased life quality.

First, note that this definition is a working definition. This means that this definition holds for this research, but might be updated in the future. Not all aspects related to mobility poverty are for example in this definition. Consider for example externalities of mobility as local air pollution, traffic accidents and space uptake (Parry et al., 2007). Externalities can be an emotional reason to not travel with a certain mode of transport so it is somewhere hidden in the definition. As this research explores mobility poverty from the bottom-up, insights from practice might highlight the importance of currently hidden elements not included in this definition. This can imply that later on the definition of mobility poverty needs to be redeveloped. This is of course not yet known, and therefore the above working definition is sufficient for this research. Also, note the word “risk”: when discussing concepts like transport poverty, mobility poverty and social exclusion, the relations between these concepts are not deterministic. Also, the word ‘hardly’ is vague. Consider this as ‘*not at reasonable time, ease and cost*’ that Lucas et al. (2016) mentioned in their definition of mobility poverty. For example, someone that has to travel one hour by bike can reach his activity, but this is hardly reasonable. This is thus also a valuable addition to the working definition of mobility poverty.

2.1.4: Indicators of mobility poverty

Mobility poverty is operationalized using various indicators. According to Innes (1990, p5), indicators highlight certain aspects at the expense of others. It allows observers to see the world through a particular lens. Some of the indicators of mobility poverty are already researched and even mapped (for example Kampert et al., 2019). A list of those has been documented in attachment A. It is theorized that these indicators affect mobility poverty, but to what extent is unclear. However, it is possible to at least consider the aspects of mobility poverty in a broader sense. Therefore, to give some indication of indicators that can be found in the results, table 1 is a less detailed interpretation of attachment A and presents categories and potential indicators of mobility poverty. The categories were also present in the definition of mobility poverty in chapter 2.1.3. The first category is transport options. Without sufficient transport options, locations cannot be reached. The second category is spatial circumstances. Franke et al. (2017) explain that “*the built environment affects people’s access to opportunities for social and physical activities*” (Franke et al., 2017, p68). A buffer analysis based on walking distance will highlight how neighbourhoods score on access to services such as education or groceries. The third category is social-economic circumstances. Examples as migration background and household income influence people’s travel behaviour. A fourth category is competences. Having skills in for example cycling and ICT influences people’s travel behaviour. The final category is emotional circumstances. Jorritsma et al. (2018) did not mention this category, but it deals with subjective meanings that people have when they travel. For example, people might feel unsafe in cycling, despite it being a relatively cheap option and one that can reduce mobility poverty.

Category	Potential indicators
Transport options	Related to owning or being able to access vehicles
Spatial circumstances	Related to time, money or distance issues required to get somewhere
Social-economic circumstances	Related to income or household characteristics
Competences	Related to skills required to get somewhere or use some vehicle
Emotional circumstances	Related to subjective meanings in travel

Table 1: Potential indicators of mobility poverty

2.1.5: Research gap

The past section highlights that there is already a profound scientific base regarding the definition of mobility poverty. Also, the indicators of mobility poverty are already theorized, despite that the extent to which they influence mobility poverty is somewhat unclear. This definition of indicators and choosing which indicators are used to map mobility is often done in a top-down fashion.

However, this research will involve practice to find the most suitable indicators of mobility poverty. This will reduce the researcher's influence on mapping mobility poverty and will improve the quality of mobility poverty mapping and will lead to desired extra knowledge that is required to put mobility poverty more firmly on the policy agenda. The theoretical framework will also clarify the connection between the 'Social Justice' philosophy and mobility poverty mapping.

2.2: Theoretical framework

In this section, the most important theories that will be central in this research to improve mobility poverty mapping will be discussed. First, it will be investigated how 'Social Justice' and the 'Just City' (section 2.1.1) and more specifically the midfare approach relate to mobility poverty mapping. This section will serve as a basis to define who exactly should be helped and thus what the mobility poverty map in this research should show. Secondly, this section will investigate what the use is of mapping mobility poverty in mobility poverty research. By highlighting the downsides of top-down mapping, it will devote special attention to how bottom-up mapping can improve mobility poverty mapping. Finally, this section will elaborate on grounded visualization and participatory mapping as the bottom-up foundations of this research.

2.2.1: The midfare approach

After the agreement of what mobility poverty is and that it needs to be dealt with, the question remains how this can be done. In this research, a mobility poverty map is developed as a tool to provide further insight into mobility poverty. The insights from this map can be used as a basis for policy approaches. However, before a mobility poverty map can be developed there remains still a question of who should be helped by policy and thus also what the mobility poverty map should show to policymakers. The midfare approach (Martens & Golub, 2012) is a way of considering who should receive aid.

The donut philosophy of Raworth (2012), and the mobility donut in particular (figure 1) greatly illustrate the Social Justice philosophy. However, the safe space for humanity in figure 1 differs per individual, as mobility poverty is subjective. People travel to get a certain value out of their

travels: utility. This value is different for every individual and depends on for example destinations, means and options to travel. Means and options are referred to as resources (Martens and Golub, 2012). Martens and Golub (2012) state that there are three ways to deal with this subjectivity whilst providing an equitable approach to dealing with mobility poverty. First of all, in the 'welfare approach', everyone is seen as equal and welfare should be shared equally. This means that extra attention is devoted to people with limited resources. However, critics of this approach claim that some people have expensive tastes regarding mobility and require more resources than others. The second approach, the 'resource approach', deals with this by stating that resources (transport modes, infrastructure) should be shared equally. However, critiques of this approach point out that those with limited resources remain in this position. Therefore, Martens and Golub (2012) propose the 'midfare approach' which Talen calls the 'compensatory equity approach' (1998). In this approach, resources and utility do not have to be shared equally as in the other approaches, but at least everyone should be able to reach crucial activity locations. The difference with the 'welfare approach' is that the 'midfare approach' concerns those who are in need and not everyone, including those that might not need help at all.

Echoing this midfare approach means that mobility poverty maps should highlight those in need. Maps have great societal benefits as they can help to monitor inequalities, target deprived areas, set priorities and reallocate resources (Martinez, 2009). This means that if the mobility poverty map successfully shows the locations where mobility poverty occurs most, policy can be targeted to this.

A specific theoretical map type that connects to this midfare approach are equity maps. Equity maps aim to promote equity (Talen, 1998). Mobility poverty mapping resembles equity mapping in two ways. First, both equity mapping and mobility poverty mapping concern a definition of equity. Both concepts concern a need-based approach in which those in need should receive the most help. This compensatory approach (Talen, 1998) connects to the midfare approach (Martens & Golub, 2012). Secondly, both maps depend on the definitions of the concept and the ways of operationalization or representation of the concept on the map (Talen, 1998). Especially this operationalization part is also important in this research. Mobility poverty was defined in section 2.1.3. Operationalization refers to how mobility poverty can be mapped. This concerns what and how many indicators (determinants) of mobility poverty are included in the analysis. Because of the resemblance of equity mapping with mobility mapping, these two ways indicate the focus points of the mobility poverty maps in this research.

2.2.2: Mapping mobility poverty

After defining mobility poverty and the midfare viewpoint that every person should be able to reach crucial activity locations (and not to improve mobility and accessibility of all people), this section investigates what mapping can mean for mobility poverty. The section will end with attention points of mobility poverty maps and how this research takes these into account.

1) The purpose of maps and GIS

To understand how mapping can benefit mobility poverty research, it is first important to understand what the purposes of maps are. In essence, a map is '*a social construction of the world expressed through the medium of cartography*' (Harley, 2002, p35). Maps are fixed

representations of real-world phenomena. Maps show how attributes vary over space and time (McKinnon & McCallum Breen, 2020) and mainly concern spatial data. According to McKinnon and McCallum Breen (2020), there are three main purposes of maps. Maps are used in collecting, exploring and displaying data. Knigge and Cope (2006) add further detail to these purposes by stating that maps help to understand, visualize and communicate geographic data (Knigge & Cope, 2006). Communication is the ultimate goal of the mobility poverty map in this research. Maps can present a baseline of information to relevant stakeholders, and can in that way assist and inspire the creation of new policy (Ghose & Huxhold, 2002). A map can also be used to investigate temporal patterns (van Elzakker, 2004). Spotting trends in where mobility poverty occurs or spotting how the most important indicators of mobility poverty change over time can be of value in modelling where mobility poverty might occur in the future. But as the primary goal of the mobility poverty map is to investigate where mobility poverty occurs, this research will not investigate temporal patterns.

GIS is mapping software that facilitates strategic planning through its data analysis and visualization capabilities (Ghose & Huxhold, 2002). GIS can be used to explore spatial relationships, can bring together disparate data sets and can produce new insights and reveal otherwise hidden relationships (McKinnon & McCallum Breen, 2020; Ghose & Huxhold, 2002). GIS can also visualize non-spatial qualitative data. The benefit of GIS is that it can integrate various layers of data and thus hands some power to the user (McKinnon & McCallum Breen, 2020). The user can vary the scale to highlight specific issues. This can involve various layers of data. In that way, GIS allows researchers to *'recursively explore data in order to identify themes and processes, raise new questions, and begin to build theories'* (Knigge & Cope, 2006). The mobility poverty map will also use these interactive benefits to explore mobility poverty with practice.

2) Attention points of mapping

In this section, the most important attention points of mapping will be discussed and how this research takes these into account. A first attention point of mapping concerns cartographic guidelines, for example regarding the level of detail. Maps should be detailed enough so the questions of the user are answered (Brodersen, 2001), but should not be confusing due to being too detailed (McKinnon & McCallum Breen, 2020). Maps should serve the end-user. GIS maps should therefore be easily understood and transparent (Martinez, 2009), as communication is the ultimate goal of the mobility poverty map. There are many more cartographic guidelines. For example, visual differences should be subtle to avoid exaggerating distinctions in data (McKinnon & McCallum Breen, 2020). The mobility poverty maps in this research will all get a similar colour style and legends will be made clear to avoid misinterpretations amongst the interviewees that interpret the maps.

A second attention point is that maps are not value-free (Sidiq, 2021). Map-makers construct their own ontology (what is the world), potentially different from the real world itself (Leszczynski, 2009). Maps are always situated in the conception of reality of its maker (van Elzakker, 2004). This is called the cartographer's influence (McCall, 2011; van Elzakker, 2004). A map can therefore not be seen as absolute truth. Sidiq (2021) explains this value-ladenness of maps by the hand of the case of land grabbing of forests by governmental organisations in Indonesia. Governmental organisations use top-down developed maps (remote sensing) to confirm that cutting down forests is legitimate. However, these top-down maps fail to

consider the value of these forests for local communities. Sidiq (2021) mentions an Indonesian term called 'spidologi', which means that maps are made without going into the field and based on a single outsider's perspective. A bottom-up or demand-driven (van Elzakker, 2004) response is counter-mapping. Counter-mapping is mapping from different perspectives. Although this is an extreme case of spatial and even political complexity surrounding maps, Sidiq (2021) clarifies that top-down developed maps are one-sided and fail to deal with the complexity of local circumstances. Therefore, this research suggests a bottom-up approach.

Knigge and Cope (2006) stress that feminist engagements with GIS show *"concerns for subjectivity, positionality, difference, reflexivity, context, socially constructed or situated knowledge, power, everyday life, meaning, discourse, and the relationships between researchers and subjects"* (Knigge & Cope, 2006, p2023). This subjectivity, power, situated knowledge and relationships between researchers and subjects that constitute the cartographer's influence, should be reduced as much as possible. The approach of participatory mapping (see next section) as a complementary method to a theory-based mobility poverty map is used in this research to limit this one-sidedness.

Still, even when using multiple perspectives, maps present partial knowledge and not the full picture (the real-world phenomenon). Map-makers have to make various cartographic choices including those regarding practical limitations (McKinnon & McCallum Breen, 2020). For example, data should be available and of sufficient quality (Martinez, 2009). If this is unavailable, then the map will be of insufficient quality as well. Another issue is that not all data is spatial and can therefore not be included in the map. For mobility poverty specifically, most indicators are quantitative and have a spatial dimension (like a neighbourhood's income level). However, some indicators are qualitative and have no spatial dimension and cannot be included in the map, like the service level of public transport. Ideally, all indicators of mobility poverty can in some way be incorporated in the map. If not, indicators that cannot be presented in the map can point to potential solutions to reducing mobility poverty risk.

Maps do not yield definitive answers (Talen, 1998). The main goal of the mobility poverty map is not to present absolute truth, but to inform about where the risk of mobility poverty is likely to be high. Mobility poverty and the way of operationalization is still evolving. Therefore, mobility poverty maps communicate partial knowledge. Also, the mobility poverty map in this research can only present a risk as the purpose of this research is not to go out in the field to measure mobility poverty but to develop a municipality-wide mobility poverty map. This is another aspect of uncertainty of the map. As long as the map at least communicates where attention to mobility poverty should be devoted to, this might help spatial planners and policy-makers to allocate resources to deal with mobility poverty more effectively.

A final attention point of maps is the scale factor (Martinez, 2009). As mobility poverty is a personal phenomenon, ideally mobility poverty should be visualized on a household level. However, this is not possible due to ethical and privacy-related reasons. Therefore, the scale of interest in this research is the aggregated neighbourhood level, where mobility poverty will be presented as a risk and not as an absolute.

2.2.3: Bottom-up mapping: participatory mapping and grounded visualization

Maps can be made in a top-down or a bottom-up fashion, as highlighted by Sidiq (2021). In this research, a mobility poverty map will be developed participatory (bottom-up). Participatory mapping raises awareness amongst those involved, integrates multiple sources of spatial knowledge and increases the local stakeholders' decision-making capacity (Akbar et al., 2021). A participatory approach uses local knowledge. Local knowledge is insiders' knowledge from a local community and assists GIS-based indicators studies in determining indicators (Ghose & Huxhold, 2002). Local knowledge concerns (amongst others) ideas, beliefs and feelings and addresses societal norms and locals' everyday reality (Berman, 2017). Local knowledge does not have to involve all members of the community but should involve the key members (experts) of this community. If these members are involved, local knowledge can help in understanding mobility poverty for a local case. Key members in this research will be discussed in chapter 3.3.

To effectively involve multiple perspectives in mapping mobility poverty, a grounded visualization approach is suggested. Grounded visualization combines grounded theory and visualization (Knigge & Cope, 2006). 'Grounded Theory' concerns the inductive construction of theories from data about the social world. It embraces partial knowledge and the need to investigate phenomena from multiple viewpoints (Knigge & Cope, 2006). It involves collecting, coding and categorizing qualitative data. Visualization concerns exploring, understanding and communicating spatial data. In grounded visualization, mixed methods contribute to the knowledge of a concept. In this research, for example, interviews form the basis of mapping mobility poverty in GIS. These maps are subsequently analysed using feedback interviews (chapter 3).

Grounded visualization has four key components (Knigge & Cope, 2006). First of all, grounded visualization is *exploratory*. This research is also explorative. Second, grounded visualization is *iterative*. It follows a nonlinear approach. This research in particular is also iterative. It uses data to construct a map, which again will serve as data for interviews. It may well be that the feedback interviews highlight that some indicators are not present in the development of the map. These findings can lead to further research. Similarly, it might also be that the interviewees highlight flaws in the mobility poverty maps or the mobility poverty mapping approach. This is also iterative. Third, grounded visualization concerns both the *particular and general*. This means that researchers should look at the concrete and abstract, at the small and large scale. In this research, concrete indicators of mobility poverty are combined into an abstract layer of risk of mobility poverty. This information will be aggregated on a neighbourhood scale, and consequently, a regional mobility poverty map is constructed. However, the particular indicators will also remain present in the research. Furthermore, this research makes use of interviewees active in different levels. For example, this research takes into account both views of macro stakeholders as the province and a transport company and views of micro stakeholders as a neighbourhood manager. This also reflects both the particular (a specific neighbourhood) and the general (the province). Finally, grounded visualization concerns *multiple interpretations*. This links to the participatory mapping approach in this research.

2.3: Conceptual model

The conceptual model in this research expands on the inequality indicator selection framework of Martinez (2009) (figure 2). In that framework, indicators are selected based on the problem perspective ('Social Justice'), the policy goal (proportional equality), literature on indicators and validation with practice (policymakers) (Martinez, 2009). This approach fits well with the approach of mapping mobility poverty in this research, but there are some differences.



Figure 2: Steps in the selection of inequality indicators (Martinez, 2009, p389).

Figure 3 presents the conceptual model of this research. Similar to Martinez (2009), the problem perspective is 'Social Justice'. The policy goal is reducing mobility poverty. To do that, a literature review will be used to define mobility poverty and to break this topic into different categories. These categories are input for the interviews.

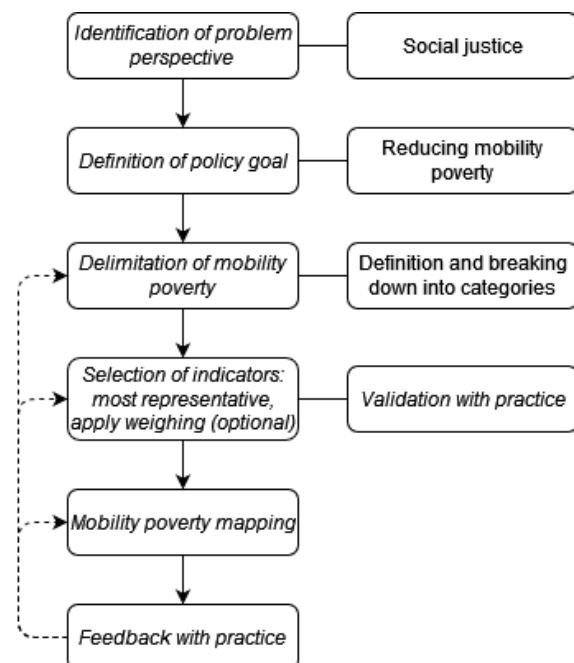


Figure 3: Conceptual model

Compared to figure 2, three aspects are added to the conceptual model (figure 3). First, validation with practice is not as in figure 2 the validation of a preselected set of indicators. Rather, the indicators are selected based on practice. This conforms to the explorative component of grounded visualization as explained in chapter 2.2.3. Second, this research does not end with the selection of indicators. Rather, these indicators are input for the mobility poverty map. Third, this research also does not end with this map. The map is theoretically a valuable communication tool of mobility poverty. However, it is not treated as an absolute in this research. Rather, feedback interviews will shine a light on the map and the mapping process. Interesting feedback questions are: Has representation of the indicators in the map gone well? Is the selection of the indicators and the optional weight applied done well, or do interviewees regard other indicators as important? And when different indicators should have been included in the map, does that mean that the working definition of mobility poverty should be adapted? This feedback links to all components of grounded visualization. The conceptual model (figure 3) shows the explorative nature of this research (validation with practice), the iterative nature (feedback loops), the particular and the general (generalizing insights from practice) and multiple interpretations (feedback and validation with practice).

3: Methodology

The next paragraphs will dive into the methodology of this research, as sketched in figure 3. First, the cases of this research will be discussed. After that, the research strategy and research methods will be presented. This will be followed by the way of data collection and analysis. The final section of this chapter will discuss reliability and validity.

3.1: The cases: Apeldoorn and Nijmegen

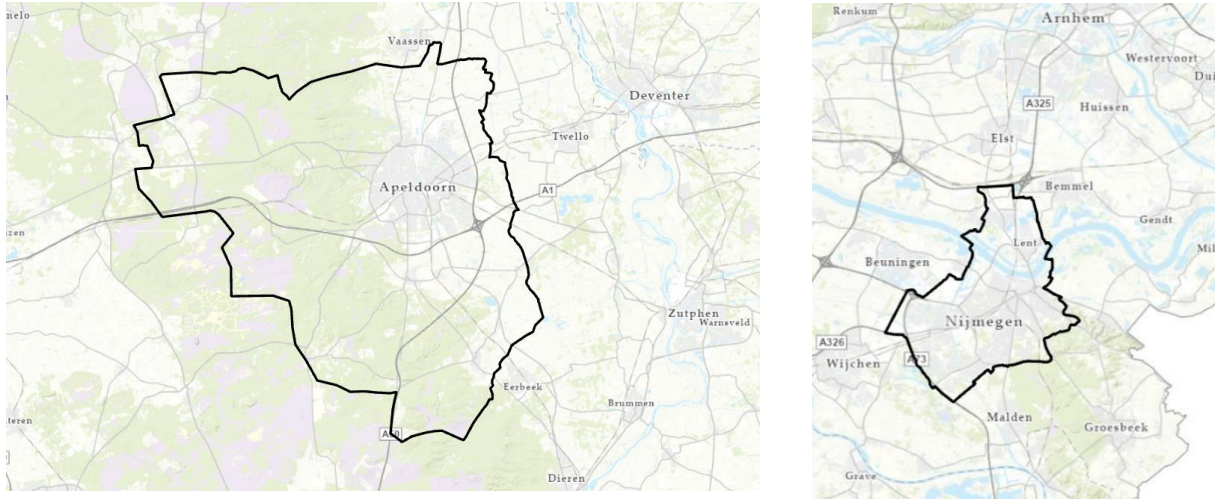
This research will investigate where in the municipalities of Apeldoorn and Nijmegen mobility poverty occurs. Apeldoorn and Nijmegen are two major cities in the province of Gelderland in The Netherlands. For this investigation, aggregated data on a neighbourhood level will be used. Mobility poverty will be presented on a local scale (the municipalities). Mobility poverty does not stop at municipal borders, so mapping mobility poverty for a daily urban system might be more logical. However, delineating what for these locations the daily urban system is goes beyond the available time for this research. Care is however taken that some important locations for indicators just outside the municipal borders are included in the map, like bus stops and work locations.

Apeldoorn and Nijmegen are the cases of this research. Both cases are regional cities within the same province (Gelderland) and have a similar population size (Allecijfers, 2021-2; Allecijfers, 2021-3) of about 170.000 inhabitants. This focus on cities is echoed by Martens and Bastiaansen (2019), who conclude that accessibility poverty, which links closely to mobility poverty (chapter 2.1.3), is expected to be the highest within urban areas. They state that whilst accessibility poverty in rural areas is likely more intense than in urban areas as distances to activities are larger and people are more dependent on car ownership, the extent of accessibility poverty is larger in urban areas as urban areas house a larger population of poor inhabitants (Martens & Bastiaansen, 2019). Therefore, this research also adopts an urban focus.

In essence, this research could have been conducted in any city. The goal of this research is not to generalise the findings of a mobility poverty map to a different city, but to explore how participatory mapping can improve the development of mobility poverty maps and their use. How planning is exercised is relatively similar in Dutch cities, which allows generalising the findings of the participatory mapping approach of this research from the cases to different Dutch cities. However, the explorative aim of this research demands some differences in issues to be present between different cases. This is required to investigate which aspects (indicators) are important and whether this selection is or is not affected due to different contexts as each city is unique. To allow generalisability but also to investigate differences, a comparative approach is taken in this research with two cities from the same planning regime that face different issues. Apeldoorn and Nijmegen, two cities in the province of Gelderland, fit these requirements. These differ in two ways.

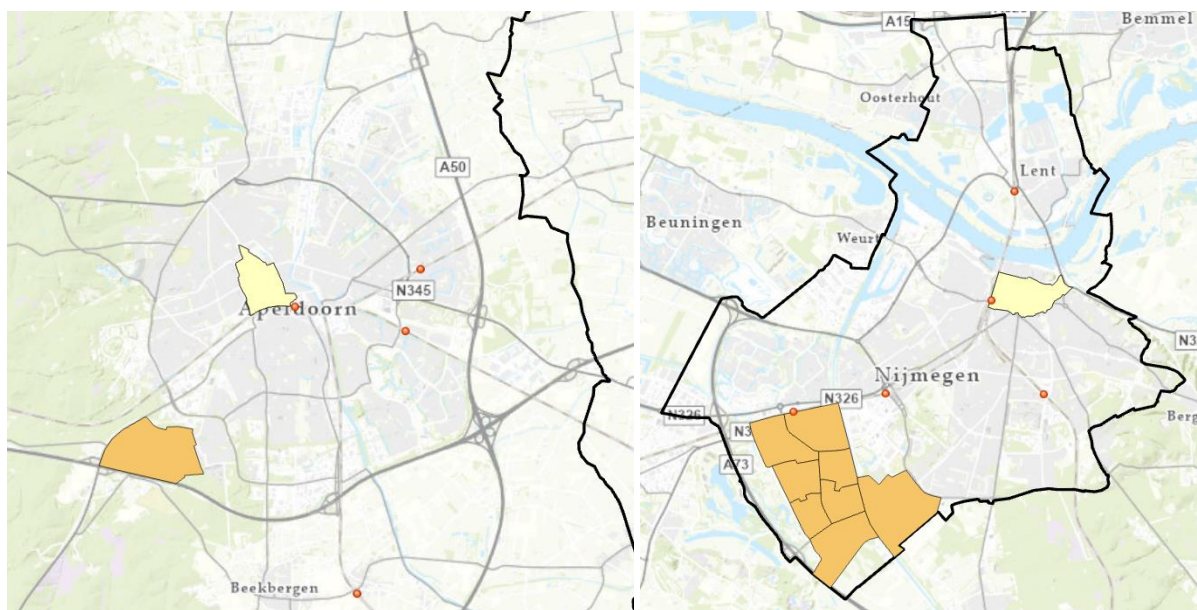
First, the municipalities differ in size and the amount of rural area (figures 4 and 5). The municipality of Apeldoorn has more rural areas than the municipality of Nijmegen. This might lead to a difference in which indicators are regarded as important. Many authors have already pointed out the relative inaccessibility of rural areas compared to urban areas. Moseley (1979)

for example highlights that the ‘rural accessibility problem’ occurs due to the limited availability of amenities and car dependency. It may be that these indicators are regarded as more important in Apeldoorn than in Nijmegen. Secondly, Jorritsma et al. (2018) highlight that Apeldoorn has a relatively old but wealthy population whereas Nijmegen faces a low social-economic situation. Similarly, this difference might also be reflected in a difference in important indicators in the bottom-up analysis.



Figures 4 and 5: Apeldoorn and Nijmegen

Despite that the focus of a lot of research in mobility poverty is on big cities (Kampert et al., 2019, Martens and Bastiaansen, 2019), this does not exclude Apeldoorn and Nijmegen from being good cases. Everywhere where people live mobility poverty can occur, but for every case, this is caused by different factors (indicators). As the goal of this research is that the approach to developing a mobility poverty map could also be applied to other cases this means that which case is selected does not matter, as long as the goal is to improve people’s living situation.



Figures 6 and 7: Ughelen and Dukenburg (orange), city centres (yellow) and train stations in Apeldoorn (left) and Nijmegen (right).

Two specific neighbourhoods reflect the different issues that Apeldoorn and Nijmegen face: Ugchelen (Apeldoorn) and Dukenburg (Nijmegen). Both neighbourhoods are located at the edge of the cities and are relatively distant from the train network (figures 6 and 7). Almost a third of the inhabitants of Ugchelen are 65+ (Allecijfers, 2021-1). Ugchelen houses a relatively wealthy population whereas Dukenburg houses a relatively poor population (Allecijfers, 2021-1; Allecijfers, 2021-4). It is interesting to investigate whether a different set of indicators of mobility poverty is important according to the interviewees as they come from different locations. It may be that in Ugchelen distance to public transport is considered an important indicator as this is important for a relatively old population whereas for Dukenburg skill in cycling or ICT skills to use bike-sharing are more important indicators as this is a cheap transport mode. However, without including practice, these differences remain unknown. It may well be that both cases show that the same set of indicators is important. To clarify this, some interviewees in this research will come from the micro-scale from both cases (chapter 3.3).

Furthermore, these neighbourhoods are also selected as they already house some approaches to reduce potential mobility poverty. It will be interesting to find out whether these approaches were indeed required by the mobility poverty situation or if these approaches were more needed elsewhere in the municipality. In Ugchelen, recently a buurtbus was introduced (De Stentor, 2021), where volunteers run a small-scale bus service that brings travellers from former bus stops currently outside the main bus network towards the city centre. This might especially help older people that cannot walk long distances. In Dukenburg, e-bike sharing in ehubs might be a cheap way for travellers to travel longer distances. Both approaches thus deal with the local situation, but these approaches were considered before the mobility poverty situation in these neighbourhoods was clarified. Was dealing with mobility poverty in these neighbourhoods appropriate, or was the situation in other neighbourhoods more pressing? If that is true, then in the future it might be better to first investigate mobility poverty thoroughly for the whole municipality, and afterwards deal with it. But also this is not yet known, which this research will investigate as well.

3.2: Research strategy

3.2.1: Philosophical standpoint

This research's research paradigm is constructivism. Constructivists claim that knowledge is constructed socially based on multiple viewpoints (Guba & Lincoln, 1984). Specifically, this research is based on Critical Realism (CR). The ontological viewpoint of critical realists is that there is a real-world that can be investigated. However, they claim that you can only observe the 'observable world' (Bal, 2020). Furthermore, this observable world only overlaps to some extent with the real world. So the ontological claims about mobility poverty are interpretations of the real world. Critical realists argue that the best research approach is to use multiple methods and multiple perspectives. This links well with the views of Knigge and Cope (2006) about grounded visualization. By using multiple viewpoints, the knowledge base of mobility poverty mapping evolves. Maps that do not show absolute truth is not a problem as long as they can communicate mobility poverty (the goal of the map).

3.2.2: Research strategy

The main research goal is to explore mobility poverty mapping and the potential uptake of mobility poverty in policy via a bottom-up approach. According to van Thiel (2014, p87), a case study is useful to explore cases in detail. The goal of this research is to bring depth to mobility poverty mapping and understanding how mobility poverty policy can benefit from the mobility poverty maps or different ways of mapping mobility poverty. The participatory take of this research rules out research strategies like documentary analyses that are not designed to interact with practice. In a case study, this is possible. This research fits in essence an experiment as in experiments the aim is to investigate a hypothesis about how adding a certain variable influences other variables (Van Thiel, 2014). A hypothesis can be that a grounded visualization approach benefits mobility poverty mapping. However, instead of testing hypotheses about pre-defined variables, this research is interested in studying mobility poverty and mobility poverty mapping as broad and in-depth as possible. A case study is then more logical. This research follows a multi-case study (Nijmegen and Apeldoorn) approach instead of a single case study approach. The reason for this is that this research, following its explorative nature, aims to explore whether a different case leads to different results. Stewart (2011, p70) highlights that a multi-case study instead of a single case study is more able to highlight key variables. In the case of this research, these key variables are indicators or perspectives that may be only present in one case, in none of the cases or in both cases. The multi-case study approach thus fits the explorative nature of this research.

3.3: Research methods

As mentioned in chapter 1, the following sub questions are central in this research.

- 1) What is mobility poverty and what are indicators of mobility poverty?
- 2) What indicators are most relevant in a mobility poverty map according to interviewees active in the public domain in Apeldoorn and Nijmegen?
- 3) What is the extent of mobility poverty in these two cities in Gelderland?
- 4) How do the same interviewees value the presented mobility poverty map?

The first sub question will be answered using a literature review of academic literature and policy documents. This is already done in chapters 2.1.3 and 2.1.4. Chapter 2.1.3 highlights the definition of mobility poverty. Chapter 2.1.4 highlights that several authors (e.g. Jorritsma et al., 2018; Kampert et al., 2019) already identified several indicators of mobility poverty. The second sub question consists of semi-structured interviews with interviewees from various scales relevant to the cities Nijmegen and Apeldoorn. Table 2 shows potential participants.

Participant	Scale	Number of interviews	Viewpoint
Province of Gelderland	Macro	2 (mobility and social domain)	Mobility and social policies (macro)
Transport company (RRReis in Apeldoorn, Breng in Nijmegen)	Macro	2 (1 per municipality)	Mobility, practice-based, public transport
GGD (Gelderland Noord-Oost and Gelderland-Zuid)	Macro	2 (1 per municipality)	Challenges of active mobility
Municipalities (Apeldoorn and Nijmegen)	Meso	4 (2 per municipality in mobility- and social domain)	Mobility and social policies (meso)
Neighbourhood manager	Micro	2 (1 per municipality in a specific neighbourhood)	Mobility poverty on the micro-scale
Housing association	Micro	2 (1 per municipality in a specific neighbourhood)	Challenges in housing, social-economic challenges
Desired number of interviews:			14 x 2 = 28 interviews with 14 interviewees

Table 2: Potential interviewees

Why is this list of potential interviewees relevant for this research? The approach of this research is to investigate mobility poverty from different viewpoints. The participants are chosen as they all shed a different light on mobility poverty, from public transport to active mobility and housing. It is important to use multiple viewpoints to avoid one-sidedness.

The first set of participants consists of public authorities from the mobility and social domain. These domains are present at the provincial and municipal public authorities. This will give a first impression of how current approaches and ideas about mobility poverty differ between the municipalities. The participants from the public authorities should at least have some affinity with the 'buurtbus' and with bike-sharing, concepts relevant to Ugchelen and Dukenburg.

The second set of participants consists of transport companies and the GGD that illustrate mobility poverty from a macro perspective. Both organisations deal with mobility poverty indirectly. Transport companies deal with the mobility side of mobility poverty. The GGD (Dutch regional health institute) can inform about the connections between mobility poverty and health. They can inform about active mobility, as active mobility can both reduce negative health effects and mobility poverty. Both organisations are required to limit the one-sidedness of consulting only public transport and active mobility that are both alternatives to people that do not have a car.

The final set of participants is directly involved with Ugchelen and Dukenburg. It is interesting to investigate whether important indicators differ between the macro and micro scales. If there are significant differences, then this would highlight that improved communication between participants from different levels is required to improve policy to reduce mobility poverty. However, as each neighbourhood is different from the other, careful interpretation of this is required. As mentioned in chapter 3.1, Dukenburg houses a larger share of inhabitants with lower incomes than Ugchelen. This difference might be reflected in the resulting important indicators.

Multiple micro-scale actors from the same neighbourhood are needed to give a complete overview of the important indicators of mobility poverty in a certain neighbourhood. In this research, these mainly concern housing associations and neighbourhood managers. Inhabitants are not potential participants. They can illustrate their personal experiences in mobility poverty (if they have those in the first place), but then more cases are needed to give an overview about mobility poverty in a certain neighbourhood. An overarching neighbourhood manager (employed by the municipality) already knows a lot about these inhabitants. Therefore a neighbourhood manager is an important actor in this research. Housing associations can also inform about mobility poverty on the micro-scale, especially from a social-economic point of view.

The mobility poverty risk in the two cases in this research will be compared with each other. The hypothesis is that per location different indicators are considered as important and that the important indicators differ from a purely theoretical constructed mobility poverty map. To find out whether this hypothesis is true, the interviews for answering the second sub question take 30-45 minutes and investigate the following questions:

- What is currently already done regarding mobility poverty within the organisation the interviewees are in?
- What are the attention points when considering mobility poverty? Interviewees might come up with indicators that are not yet on the indicator list.
- The interviewees are asked to explain the in their opinion important indicators of mobility poverty. If needed, the five categories in table 1 can provide fuel to the interview. Interviewees also rank these indicators on a Likert scale (1-5). Using all results, the most important indicators will be considered in the mobility poverty map. Furthermore, if one of those indicators stands out on importance, a certain weight will be used when the map layer 'risk of mobility poverty' will be made.

The abovementioned interviews point out that the interviews in this research are semi-structured. The semi-structured interview consists of an interview guide with open questions while leaving room for departure from the interview guide (attachment D). As the aim of this research is to explore what interviewees think of mobility poverty, openness in the semi-structured interview is very important. However, as the goal of the interviews themselves is to understand which indicators are important and to what extent, this requires some "closeness" in the interview guide. These questions need to be asked. Therefore, this research follows a semi-structured interview. A remark regarding this closeness is that to clarify the question regarding which indicators are important, the interviewees were given if needed, an example that was mentioned by other interviewees (often income or physical health). To keep the grounded character of this research, it was deliberately chosen to mention only one example indicator and to give an example that the interviewees likely would mention themselves given earlier questions and their relation to mobility poverty.

For the third sub question, a ranking of indicators will be made based on all interviews. This is the basis for the mobility poverty map of both cases. The most important indicators will be put individually in GIS. Also, these indicators will be bundled into one map layer showing mobility poverty risk. A weight factor used in the bundling process when one of the indicators stands out in importance is optional. The final sub question will consist of semi-structured interviews with the same interviewees from the second sub question and will investigate whether the interviewees recognize the mobility poverty situation from the GIS tool

(attachment E). This feedback is important, as it will highlight whether the analysis has been executed correctly or incorrectly and if some indicators are missing in the analysis. Furthermore, this sub question will be used to investigate what currently already is done to reduce mobility poverty and what is required to put mobility poverty more firmly on the policy agenda. Policy documents related to the province of Gelderland (in which the cases of Nijmegen and Apeldoorn are part of) will also serve as input regarding this final sub question to investigate what is already done to reduce mobility poverty.

A focus group has also been considered as a research method. Interviews are one-to-one and a focus group consists of more than two persons. A focus group might be of use to investigate how actors develop a shared vision to deal with mobility poverty. However, this goes beyond the scope of this research, as this research is mainly concerned with how mobility poverty can be mapped in the first place. Interviews are more in-depth than a focus group analysis (Schwab, 2020). This depth is relevant for this research as it investigates thoroughly what aspects of mobility poverty are important regarding different viewpoints. Interviews are then most suitable.

A survey has also been considered as a research method. A survey allows researchers to collect a lot of data on different subjects (Van Thiel, 2014). The focus of this research was however more on exploring mapping mobility poverty instead of gathering data on mobility poverty. This data is required to map mobility poverty but is also available as secondary data from monitors like the CBS. Despite the value of primary data, especially concerning data quality, due to the focus on mapping of this research, it was not chosen to undertake a survey. But a survey can in the future be a valuable addition to this research.

3.4: Data collection

Much of the data in this research is secondary data, such as academic literature and GIS data. The GIS data is partly personal and therefore privacy-sensitive. Therefore, the data will be presented on a neighbourhood level. The interviews provide primary qualitative data. The interview guide of the semi-structured interviews is highlighted in attachments D and E. The interviewees will be made anonymous. Further in this research, interviewees will be included in the form: interview 1 (MG) indicates... etc. The first M indicates that the interviewee is active in the mobility domain. The G indicates the geographical component, in this case, Gelderland. Sometimes more letters are used. A broader overview of the interviewees of this research is available in attachment B. In addition, interviewees have a say in the transcripts and can indicate whether they want to omit any parts. The transcripts will be deleted a few months after the research has been completed. Finally, interviewees may provide help in gathering the required GIS datasets.

3.5: Data analysis

3.5.1: GIS analysis

Data analysis of the mobility poverty maps will be mostly descriptive. The indicators have been grouped in paragraph 2.1.4 into different subgroups. For some indicators from the spatial circumstances and transport options categories, a buffer analysis is necessary for the GIS analysis. This logic behind the buffer analysis is based on the gravity-model. The gravity-model measures accessibility by making use of distances (Talen, 1998). Accessibility will be lower when distances to amenities or transport options are higher. This increases the risk of mobility

poverty. From the indicators from the subgroups social-economic circumstances, competences and economic circumstances, there is no direct data available on the risk of inhabitants on these indicators. This might require too personal data or unavailable data. These indicators are approached using aspects that determine these indicators. However, care must be taken to what aspects of these indicators can be mapped.

The next step is to scale the individual indicators to be able to compare them. A scale of 1 (low) to 3 (high) is used per indicator for mobility poverty. What is low and what is high will be different for each indicator and has yet to be determined. Earlier mobility poverty maps by, for example, the CBS (Kampert et al., 2019) help in determining these scales as these have already attempted to map mobility poverty in this way. In addition, a map layer will be added to the GIS tool in which an average score is shown. This layer shows in essence how each neighbourhood scores on mobility poverty risk. A weighted average where some indicators have a higher say in the extent to which mobility poverty risk comes forth is optional.

The second round of interviews will serve as feedback to the mobility poverty maps. It may well be that the interviewees acknowledge that some of the indicators are not well mapped. This may happen for example with the indicators that need to be approached as data is limitedly available. These indicators are then filtered out of the analysis. This iteration or reflection is also what this research aims to achieve. This will improve knowledge about mobility poverty maps.

3.5.2: Interviews

Interviews will be transcribed and afterwards analysed using the coding programme ATLAS.ti. Coding is used to evaluate and organize data to understand meanings in texts or images and helps with identifying categories and patterns (Knigge & Cope, 2006). While coding, the amount of data is reduced. Coding in this research consists of two cycles. The first cycle consists of categorising text into single words (descriptive coding) and counting how often these categories occur in the coded transcripts (magnitude coding) (Patel, 2014). The second cycle consists of bundling the previously formulated codes (pattern coding) and counting how often these bundles occur in coded transcripts (focused coding) (Patel, 2014). The results will be used as input for summaries of the interviews. These summaries can then be compared with each other or used as separate data sources for this research.

3.6: Reliability and validity

3.6.1: Reliability

Research is reliable, when the same research leads to similar results (van Thiel, 2014, p185), even in different spatial contexts. The used indicators and related GIS data sources will be documented clearly and transparently. However, as the interviews are the basis of this research, choosing different interviewees in different locations might lead to different indicators used and a different mobility poverty map. As finding these differences is key in this research, this does not affect the reliability of this research. More important regarding reliability is whether someone else can use the same approach in mapping mobility poverty. Therefore, this research will be as transparent as possible.

3.6.2: Validity

A valid research is representative of the real world (van Thiel, 2014). As explained in chapter 3.2.1, the observed world overlaps the real world somewhat. The real world is represented by mobility poverty indicators, but not fully as not all indicators are in view due to the young age of mobility poverty (Lucas et al., 2016). Furthermore, not all indicators concern spatial data or contain too sensitive information and can therefore not be taken up in the mobility poverty map. Similarly, although scaling of indicators (1 to 3) is a simple way of representing and comparing indicators care must be taken that this has been done in a fair way. Also, care must be taken when weight is given to certain indicators based on how important the interviewees state these indicators are. According to Kampert et al. (2019), these notions can lead to an over or undershoot of the mobility poverty risk. They state that overshooting can occur due to missing indicators or due to indicators adding up to the risk despite that these do not affect an individual situation. For example, an older person without a car can still let groceries be delivered and thus do not experience mobility poverty, whereas theory suggests that when someone is older and does not have a car this leads to a high risk of mobility poverty. Undershooting can occur when some indicators are not included.

Is the research then not valid? According to Talen (1998), not capturing complexity is still legitimate. This research still adds to the partial knowledge already known. Information from practice gives a new perspective to mobility poverty mapping. This link with practice puts mobility poverty mapping into a different perspective and will increase the validity of making mobility poverty maps as a whole.

Finally, what does not capturing complexity mean for the interpretation of the map? The map does not present absolute knowledge. After all, a map is a social construction in itself (McKinnon & McCallum Breen, 2020). Furthermore, maps are interpreted based on the own perspective of the person that interprets the map. Therefore, multiple interviews are conducted in this research to avoid a single-minded interpretation of the mobility poverty maps developed in this research. By allowing the interpreters of the map to investigate individual indicators and combinations of indicators of mobility poverty, the GIS maps in this research help in discovering patterns that remain otherwise hidden (McKinnon & McCallum Breen, 2020), which thereby increases the validity of this research.

4: Results

This chapter will highlight the results of this research. The chapter is split into three parts, chronologically following the approach of this research (chapter 3.3). First, the results of the conducted interviews prior to the mapping exercise will be presented. This section will elaborate on whether mobility poverty is currently known amongst the participants, how their organisations are already addressing mobility poverty, whether the map can be of added value in dealing with mobility poverty and, most importantly, which indicators are most important in explaining mobility poverty. Secondly, the mapping process itself will be presented. This section will elaborate on how and which indicators are mapped in GIS and what the resulting maps look like. Finally, this chapter will present the potential of mobility poverty maps, further research into mobility poverty and policy recommendations based on the opinions of the interviewees on the developed mobility poverty map in this research.

4.1: First round of interviews

This section will present the most important results of the interviews conducted before the mapping exercise. Attention is devoted to the familiarity of the interviewees with mobility poverty, current approaches within their respective organisations to reduce mobility poverty risk, the value of the mobility poverty map and the indicators of mobility poverty.

4.1.1: The interviewees

Information about the consulted interviewees can be found in appendix B. Only 10 interviewees have been consulted instead of the intended 14 (chapter 3.3). This had partly to do with time constraints. Care was taken that at least all different perspectives from chapter 3.3 (micro vs macro, governmental vs non-governmental) were included in the analysis. This resulted in for example that only 1 instead of 2 GGD's was consulted. Furthermore, no housing association was consulted, contrary to what is outlined in chapter 3.3. The expected bottom-up perspective of housing associations on mobility poverty was also present in the neighbourhood employee (opbouwwerker) and neighbourhood manager that have been consulted in this research. Both the housing associations and the opbouwwerker have insight into how people in a local specified area might experience mobility poverty. The opbouwwerker has likely a broader perspective on mobility poverty, due to which this is regarded as a more important interviewee in this research. However, the opbouwwerker (interview 10, SNO) consulted in this research expresses housing associations as a partner in improving loneliness, a potential consequence of mobility poverty, which shows the connection between the opbouwwerker and housing associations.

Bottom-up experiences were also notable in interview 4 (MU), not from a social perspective as in interview 10 (SNO) but from a mobility perspective. Interview 4 (MU) consisted of volunteers from a local volunteer-based bus service (the buurtbus). The buurtbus is a local volunteer-driven bus service. In Ugchelen the buurtbus replaces a now closed bus service that was not volunteer-driven. This interview was not originally intended, but it contributes to knowledge about mobility poverty in a local neighbourhood from a solution-based point of view. This interview illustrated how important a bus service is in reducing mobility poverty.

4.1.2: Familiarity with mobility poverty

Most interviewees explained that they were prior to the interviews unfamiliar with the term mobility poverty. An exception were the interviewees from the mobility domain. Interview 7 (MN) noticed for example that mobility poverty was addressed in the mobility policy of the municipality of Nijmegen. The unfamiliarity with mobility poverty might be due to mobility poverty being a relatively new research topic (chapter 2.1.2). However, after mobility poverty was explained to the interviewees, the interviewees were able to inform about actions of their organisations that might reduce mobility poverty risk (see chapter 4.1.3). The interviewees expressed the potential negative consequences of mobility poverty. Interview 10 (SNO), who works at a very local level with inhabitants and thus was aware of the topic of mobility poverty, stressed for example that mobility poverty can lead to loneliness and nuisance due to people “searching for meaning” on the streets. The interviewees stressed the importance of being able to reach activity locations so that they remain able to participate in society (interview 8, SN). The interviewees also imagined reasons why people might experience mobility poverty. Interviewees mentioned for example the closure of neighbourhood centres where people can meet (interview 10, SNO), people’s physical and mental health situation (interview 3, SGGD), having a low income (interview 8, SN) and the closure of bus services (interviews 2, MC and 4, MU) as reasons for people to experience mobility poverty. These answers reflect the domains or activities these interviews are attending in their daily practices. The interviewees thus already were aware of mobility poverty, despite that most of them were prior to the interview unfamiliar with the term itself.

4.1.3: Current approaches to mobility poverty

As expected because of the unfamiliarity of interviewees with the term mobility poverty, few interviewees expressed that their organisation had an approach tailored specifically at reducing mobility poverty risk. However, the interviewees were able to link some actions or programs of their organisations with mobility poverty. Although it was not often stated in the goals of these actions or programs to reduce mobility poverty, these actions likely reduce mobility poverty risk. The interviewees were often involved in these actions and programmes or they were aware of them because they were active in the same domain. However, the interviewees expressed that they were unaware of all potential mobility reducing actions within their organisations. Furthermore, some interviewees from the governmental organisations claimed that they are not always aware of actions or programs related to mobility poverty from other domains from within the same organisation. Therefore, the interviewees mostly mentioned actions from their own domain. Interviewees from both the societal and mobility domain stress the importance of cooperation with multiple domains to effectively deal with mobility poverty (for example, interviews 3, SGGD and 5, MA) as mobility poverty has a social- and mobility-related component. They recognize that this can be improved.

Some of these actions are presented in the following paragraphs. This shows to some extent how mobility poverty is already addressed. First, several approaches within the social domain are presented that might reduce mobility poverty. Most of these actions are organized by the municipalities. An example is doelgroepenvervoer (interview 6, SA). This concerns a subsidized bus service that brings children with a disorder (like Autism) to and from school. This reduces mobility poverty for children and their parents who have more time to perform other activities. This program only serves some inhabitants. Programs such as Automobiel and

‘Vervoersvoorziening De Kap’ are volunteer-based programs aimed at moving elderly people (interview 6, SA). In the Automobiel program, volunteers use their own private vehicles to move other people from A to B (ANWB, n.d.). Another example in the municipality of Nijmegen is the ‘Busvoordeel abonnement’ (interview 8, SN), where inhabitants with low incomes can get tickets for public transport at a reduced price. The reduced prices of the Busvoordeel abonnement, Automobiel and the Vervoersvoorziening De Kap reduce the income barrier for travel and thus reduce mobility poverty. NGOs are also active in reducing mobility poverty from a social perspective. Interview 8 (SN) also mentioned Stichting Leergeld, which is an NGO with the goal of reducing social exclusion amongst families with children with low incomes (Leergeld, 2021). This organisation for example finances bikes for children. This also reduces the risk of mobility poverty.

Municipalities typically arrange places where inhabitants can find programs where they can receive help. However, people must understand the native language and must know which programs they can apply to and where they can do this (interview 8, SN). Friends and relatives can help with this. To stimulate the sharing of information between inhabitants about these types of programs, municipalities organize projects where inhabitants can get in touch with each other. A housing corporation is a network partner that can help in this process (interview 10, SNO).

Secondly, several approaches from the mobility domain were mentioned by the interviewees. Mostly, these alternatives reduce the dependency of people on the car. This is helpful, especially for people with low incomes and people with low health conditions. Some of these projects increase the accessibility of transport. In the municipality of Apeldoorn, this is done for example by improving the accessibility of bus stops for people with a wheelchair or a visual impairment or by increasing the number of parking spots for disabled people (interview 5, MA).

Other examples improve the provision of transport. Public transport is not everywhere at every time available. For a public transport operator, “a bus must have enough travellers, efficiency is very important related to the high costs involved in providing public transport” (interview 2, MC). This means that some people have limited access to public transport. In some neighbourhoods, like in Ugchelen, the bus service does not drive through the neighbourhood anymore but drives at the 50 km/h road at the borders of this neighbourhood. This is understandable from an efficiency-related viewpoint, but this can negatively affect mobility poverty since some people in the neighbourhood have to walk further to the bus stop. This is problematic, especially for people with poor health (including elderly people) (interview 5, MA). The municipality can subsidize the public transport operator to keep the bus service available (interview 5, MA). But the budget of the municipality, the province (who is responsible for the transport network) and the public transport operator is not endless.

Alternative systems are available that are either less expensive or that can move people that do not live within close distance of public transport. Examples are shared mobility (interview 7, MN), the Buurtbus (interviews 2, MC and 4, MU) or the Haltetaxi (interview 1, MG). The Haltetaxi is a heavily subsidized form of public transport where people can use a small taxi service aimed at first or last mile transport towards a more sizable public transport hub (like a station). The subsidies make this mode of transport affordable to the user. The Buurtbus is

a volunteer-based bus service with a small bus (typically with a maximum of 8 seats). Using voluntary bus drivers reduces the costs of this alternative system drastically for the transport operator. This means that there are no large amount of travellers needed to keep up with the costs of the system. Therefore, the Buurtbus system is considered a stable, self-sustainable system (interviews 1, MG and 2, MC). The Buurtbus also has social benefits as people can get out of their homes and as the Buurtbus is not bounded to predefined bus stops (interview 4, MU). Next to these alternative systems, there are also some subsidized pilot projects available. However, many of these projects are not self-sustainable in the long term when the subsidies for the project are halted (interview 1, MG and 9, MAG).

Finally, a lack of access to transport modes is not the only reason that people have difficulties in reaching activity locations. Interviews 3 (SGGD), 7 (MN) and 10 (SNO) also acknowledge the importance of spatial circumstances. The provision of cycling paths or the densification of amenities (and thus reducing distances) are examples of how spatial circumstances can help in reducing mobility poverty.

4.1.4: Value of the map

The main purpose of the mobility poverty map is to highlight where mobility poverty might occur. This is recognized by the interviewees as well. Interviews 5 (MA) and 6 (SA) noticed that the map concerns risks and not statements about how many people experience mobility poverty. As outlined in the previous section, there are many programs or approaches already present that in some way reduce mobility poverty risk. Unfortunately, many of these actions and programs are organized in a fragmented fashion. Instead of fragmented actions and programs, an integral approach can lead to a more effective, orchestrated set of actions. This integral, efficient and effective approach leads to a so-called 'collective impact' (interview 3, SGGD). To reach this collective impact, more intensive cooperation between relevant domains is important (interview 5, MA). A further step can be to also cooperate with other partners and inhabitants (interview 3, SGGD). The mobility poverty map is seen as a valuable communication tool to improve this communication and cooperation (for example interview 10, SNO).

Even before the map was being developed the interviewees already imagined its benefits. For example, interview 9 (MAG) sees the mobility poverty map as a valuable tool in light of the buurtbus system. The Buurtbus system is when realised, often available in neighbourhoods with high organizational power. Organizational power depends in this respect on income and education levels. Neighbourhoods with lower organisational power can be highlighted in the mobility poverty map. The municipality or the province can, if there is enough budget available, respond to this by aiding these neighbourhoods in organizing a Buurtbus service.

4.1.5: Relevant indicators

The various perspectives of the variety of interviewees consulted in this research results in a large variety of mobility poverty indicators. The 10 interviewees came up with 31 indicators. Table 3 shows the list of indicators mentioned by the interviewees, how frequently they are mentioned by the interviewees and how these indicators are connected to mobility poverty.

Indicator	Times mentioned	Link with mobility poverty
Physical health	9	Poor physical health conditions increase the risk of mobility poverty
Accessibility of activity locations (shopping centres, sports locations, music schools, friends and family, education, city centre, nature and recreation, healthcare, personal health, meeting places for youngsters and neighbourhood centres)	8	Poor accessibility to activity locations increases the risk of mobility poverty
Income	7	A lower income increases the risk of mobility poverty
Elderly people (as target group)	7	Due to a decrease in health, this group is at risk of mobility poverty
Public transport costs	6	Higher public transport fares increase the risk of mobility poverty
Owning a bike	6	Not owning a bike increases the risk of mobility poverty
Owning a car	6	Not owning a car increases the risk of mobility poverty
Distance to public transport	6	A large distance to public transport increases the risk of mobility poverty
Physical accessibility of transport modes	5	Poor physical accessibility of transport modes (for example a lack of wheelchair-friendly bus stops) increases the risk of mobility poverty
Social isolation	5	Mobility poverty increases the risk of experiencing a form of social isolation
Understanding transport options	4	Poor understanding of transport options increases the risk of mobility poverty
Bicycle-related costs	4	Higher costs of bikes and repairs increase the risk of mobility poverty
Mental health	4	Poor mental health conditions increase the risk of mobility poverty
Digital accessibility of transport modes	3	Poor digital accessibility of transport modes (for example not owning or understanding a smartphone) increases the risk of mobility poverty
Having a driver's license	3	Not having a driver's license increases the risk of mobility poverty
Owning a scooter	2	Not having a scooter increases the risk of mobility poverty

Availability of transport	2	General term. Having a lack of transport options increases the risk of mobility poverty
Transport costs	2	General term. Higher transport costs increase the risk of mobility poverty
Language level	2	Having a limited understanding of the language in the country of residence increases the risk of mobility poverty
Skill in cycling	1	Having limited skill in cycling increases the risk of mobility poverty
Owning a smartphone	1	Important for accessing shared mobility or travel apps.
Effort to travel	1	People experiencing that travel requires a lot of effort have a relatively high risk of mobility poverty
Weather	1	Bad weather conditions decrease the comfort of the bicycle which increases the risk of mobility poverty
Frequency of public transport	1	Public transport with a low frequency increases the risk of mobility poverty
Distance between activity locations and parking spots for disabled people	1	A larger distance increases the risk of mobility poverty
Distance between activity locations and bike sheds	1	A larger distance increases the risk of mobility poverty
Distance between activity locations and parking spots	1	A larger distance increases the risk of mobility poverty
Shame	1	People with low incomes might feel shame for that situation. This decreases the likeliness to apply for programs as the Nijmegen busvoordeel abonnement, which increases the risk of mobility poverty
Car-related costs	1	Higher costs of cars and repairs increase the risk of mobility poverty
Availability of shared mobility	1	Availability of shared mobility decreases the risk of mobility poverty
Subjective safety	1	Feeling unsafe in travel increases the risk of mobility poverty

Table 3: List of indicators

As mentioned in chapter 3.3, the interviewees were given, if needed, an example of an indicator (like income or physical health) to clarify the question of which indicators they think are important regarding mobility poverty. Despite that these example indicators were chosen by carefully considering an example that the interviewees were likely to mention, this might have affected the order in the indicator list (table 3) somewhat. However, most interviewees understood this question and only the indicators that were already often mentioned and

therefore likely to be mapped anyways were mentioned as examples to those that did not understand this question.

The indicators most mentioned are considered as the most important indicators of mobility poverty. The interviewees had difficulties in making a ranking of indicators themselves, with income and health as exceptions. These two indicators are concerned to be the most important indicators of mobility poverty is income (for example interviews 5, MA and 8, SN).

The main reason that ranking the indicators is difficult is that mobility poverty is in essence personal (or individual) (interviews 5, MA and 6, SA). For each individual, a different combination of and different severity of indicators makes them experience mobility poverty. For example, someone may experience mobility poverty mainly due to a considerable distance to public transport, whereas someone else may experience mobility poverty mainly due to not understanding regulations related to acquiring cheap public transport tickets. The interviewees also agreed that no indicators can determine mobility poverty as the indicators highlight a risk of mobility poverty. This is in line with the definition of mobility poverty in chapter 2.1.3.

In chapter 2.1.4, five categories of mobility poverty indicators are presented. These are transport options, spatial circumstances, social-economic circumstances, competences and emotional circumstances (table 1). Of these categories, competences and emotional circumstances were only limitedly mentioned by the interviewees. All indicators matched with the categories of indicators. This means that there is no need to include more categories in the working definition of mobility poverty in chapter 2.1.3. The working definition of mobility poverty thus holds. The list of indicators (table 3) overlaps to a great extent with the list of indicators defined prior to the interviews (attachment A).

The indicators income and health might be regarded as most important by the interviewees because they determine other indicators in table 3. For example, there are links between health and the elderly and the physical accessibility of transport modes. Older people have often a poorer health situation than younger people, impacting the physical accessibility of transport modes and therefore increasing the mobility poverty risk. Similarly, there are also links between income, owning vehicles and costs of transport. Accessibility of activity locations is also mentioned often. This indicator in the category of spatial circumstances is also regarded as very important by the interviewees.

Not all indicators in the list can be explained using income, health or spatial circumstances as the basis. An example is understanding transport options. This indicator is partly based on people's language level and on having friends or relatives that can help in understanding transport options. Another example is loneliness. This indicator does not determine mobility poverty, but loneliness is rather determined by mobility poverty. Nevertheless, it is remarkable that most indicators have some link with income, health or spatial circumstances.

4.1.6: Comparative analysis

In this section, four comparisons are made regarding which indicators are important. These comparisons are mobility domain – social domain, macro-scale – micro-scale, Nijmegen – Apeldoorn and Ugchelen – Dukenburg. There were only slight differences in which indicators

are regarded as important. Regarding the two neighbourhoods that were central in this research, there were no notable differences in which indicators were regarded as important in Ugchelen and Dukenburg. A notable difference between Nijmegen and Apeldoorn is that in Nijmegen there seems to be slightly more focus on dealing with social themes as income and knowledge of transport (including language level and digital skills) whereas in Apeldoorn there seems to be slightly more focus on elderly people. This is precisely in accordance with Jorritsma et al. (2018) who highlighted that Apeldoorn has a relatively old but wealthy population whereas Nijmegen faces a low social-economic situation.

The comparison macro-micro highlighted only a slight difference in indicators, where isolation and loneliness were according to the micro interviewees more important as was considered by macro interviewees. This does point out that when making mobility poverty policy on the macro scale (province, municipality), it is recommended to consult micro-scale stakeholders (e.g. neighbourhood managers) about whether the policy fits local neighbourhoods. The comparison mobility domain – social domain highlights that some indicators are more important according to interviewees from the social domain than according to interviewees from the mobility domain. Physical accessibility of public transport, loneliness, understanding public transport, mental health, having a driver's license and being able to afford a bike are more often mentioned by interviewees in the social domain than in the mobility domain. The focus on public transport was however more often mentioned in the mobility domain. This highlights that when dealing with mobility poverty in the future both domains can learn from each other.

4.2: Mapping mobility poverty

This section will describe the results of the mapping process. The list of indicators of mobility poverty (table 3) will serve as a basis for mapping mobility poverty. Not all indicators in table 3 are mapped due to a lack of data of the indicators on a neighbourhood level, due to these indicators being mentioned only by a few interviewees or due to these indicators being combined with other indicators that are mapped. After this, the maps of the individual indicators of mobility poverty and the combined layer of these indicators (showing mobility poverty risk) will be presented. Finally, the main remarks of the mapping process are described in this section.

4.2.1: Mapped indicators

Table 3 shows which indicators are mentioned by the interviewees, how often they are mentioned and how they relate to mobility poverty. Table 4 shows which of these indicators have been mapped in this research.

Indicator	Mapped	Merged into	Reason not mapped
Physical health	Yes	1. Health	
Accessibility of activity locations	Yes	2. Amenities	
Income	Yes	3. Income	
Elderly people	Yes	4. Socio-economic category	
Public transport costs (financial)	No		Lack of geographical differences on a neighbourhood level
Owning a bike	Yes	5. Bike ownership	
Owning a car	Yes	6. Car ownership	
Distance to public transport	Yes	7. Public transport	
Physical accessibility of transport modes	No		Lack of geographical data
Social isolation	Yes	8. Loneliness	
Understanding transport options	No		Lack of geographical data
Bicycle-related costs	No		Lack of geographical differences on a neighbourhood level
Mental health	Yes	1. Health	
Digital accessibility of transport modes	No		Lack of geographical data
Having a driver's license	Yes	9. Having a driver's license	
Owning a scooter	No		Lack of geographical data
Availability of transport	No		Too general. Merged into bike ownership, car ownership and public transport
Transport costs	No		Lack of geographical differences on a neighbourhood level
Language level	No		Lack of geographical data
Skill in cycling	No		Mentioned only a few times
Owning a smartphone	No		Mentioned only a few times
Effort to travel	No		Mentioned only a few times
Weather	No		Mentioned only a few times
Frequency of public transport	Yes	7. Public transport	
Distance between activity locations and parking spots for disabled people	No		Mentioned only a few times
Distance between activity locations and bike sheds	No		Mentioned only a few times

Distance between activity locations and parking spots	No		Mentioned only a few times
Shame	No		Mentioned only a few times
Car-related costs	No		Mentioned only a few times
Availability of shared mobility	No		Mentioned only a few times
Subjective safety	No		Mentioned only a few times

Table 4: Mapped indicators

Table 4 shows that many indicators are not mapped. Most of these are only mentioned a few times (table 3), which is why they are left out of the analysis. However, these indicators are still valuable for further research, as some of these can serve as inspiration for the development of potential approaches to deal with mobility poverty. For example, a municipality can initiate a program to improve people's skill in cycling. Another example of a municipal program is the "Medon regeling" in Nijmegen assist people financially so that they can get for example driving lessons (interview 8, SN). These are examples of how mobility poverty can be reduced. Sometimes geographical differences in some indicators are so small that mapping these indicators is not logical. Public transport fees for example are in Apeldoorn and Nijmegen almost the same. Furthermore, some of the indicators in table 4 are not mapped due to a lack of geographical data. A lack of geographical data implies that there is no data available that directly measures the indicator and that approaching this indicator using other factors is not possible. An example of this is understanding travel options. No dataset has measured this directly. It was also not possible to measure this using other factors, although this was tried. The interviewees regarded the way of approaching this indicator as not logical. This is an iterative example of this research. The discussion section (chapter 6) will go into more detail on this topic.

Some indicators are combined in the analysis with other indicators. The frequency of public transport is combined with distance to public transport. Similarly, physical and mental health are combined into the indicator 'health'. These two factors are combined as geographical data on health was also available only as a combination of these two aspects. With these combinations, 9 (groups of) indicators are present in the mobility poverty map.

4.2.2: Mapped mobility poverty indicators

This section will highlight the mapping process. As highlighted in chapter 3.5.1, the identified indicators of mobility poverty have been mapped individually and together in one layer (the layer mobility poverty). Despite some differences, the mapping process was the same for each indicator. Each indicator is bundled into 3 risk categories. For each neighbourhood, geographical data have been used to estimate an average risk on the scale from 1 (low) to 3 (high). Attachment C will give a calculation example. The combined layer is an average of the 9 indicators of mobility poverty used in this research. The following section will review of each indicator the used geographical data and how the indicators are mapped. This section will conclude with some remarks on the quality of the data used, which will be further discussed in the reflection.

1. Health

Used data

The indicator health concerns a combination of physical and mental health conditions. To find out how neighbourhoods score on health, three factors have been considered in this analysis. The first one is whether people feel limited in their life due to their health. Information on this indicator was available in the Gezondheidsmonitor (public health monitor) of the RIVM (RIVM, 2020-2). This subjective information is substantiated with two other factors with more concrete information about the health situation in neighbourhoods. The reason for that is that relying solely on subjective information might lead to an overshoot of the real health situation in neighbourhoods. Schneider et al. (2004) for example state that despite the real health (objective health) situation of elderly people is decreasing, people's self-rated health (subjective health) is not decreasing at the same rate. Therefore, also some objective health indicators have been considered in this research. The second factor in this category are inhabitants with a WMO indication. The WMO is a Dutch law established in 2015 where municipalities aid inhabitants so that they can live independently and so that they can keep on participating in society (Zorgwijzer, n.d.). For example, people can get help in doing groceries or cleaning but also can be moved via a dedicated taxi service (WMO-vervoer). A similar but more intensive form of help is given in WLZ-indications (ciz, 2022). People with a WLZ or WMO indication can get help in going places. However, as they are dependent on this help these people have difficulties in for example arranging spontaneous activities and spontaneous encounters. Therefore, these two factors do give some indication of whether people are mobile in a neighbourhood or not. The geographical data of WMO-indications is available in the Wijken and Buurten monitor of the CBS (CBS, 2019). WLZ-indications were only available on the municipal level (ciz, 2020).

Risk categories

The following risk categories have been identified (table 5). Note that people with WLZ-indications need care more intensively, which is why people in this category have a higher risk of experiencing mobility poverty than people with WMO-indications.

Risk	Health
1 (low)	Not limited in the health situation
2	Limited in the health situation and WMO-indications
3 (high)	Very limited in the health situation and WLZ-indications

Table 5: Risk categories health

Result

Figures 8 and 9 show the risk maps concerning the indicator health. The lighter coloured neighbourhoods at the edge of the cities of Apeldoorn (for example the northeast corner) and Nijmegen (for example in Lent) are neighbourhoods with a relatively young population. Similarly, the dark coloured neighbourhoods have a relatively older population. The maps confirm therefore the expectations of some of the interviewees (for example from interviews 8, SN and 9, MAG).

Health

Health risk

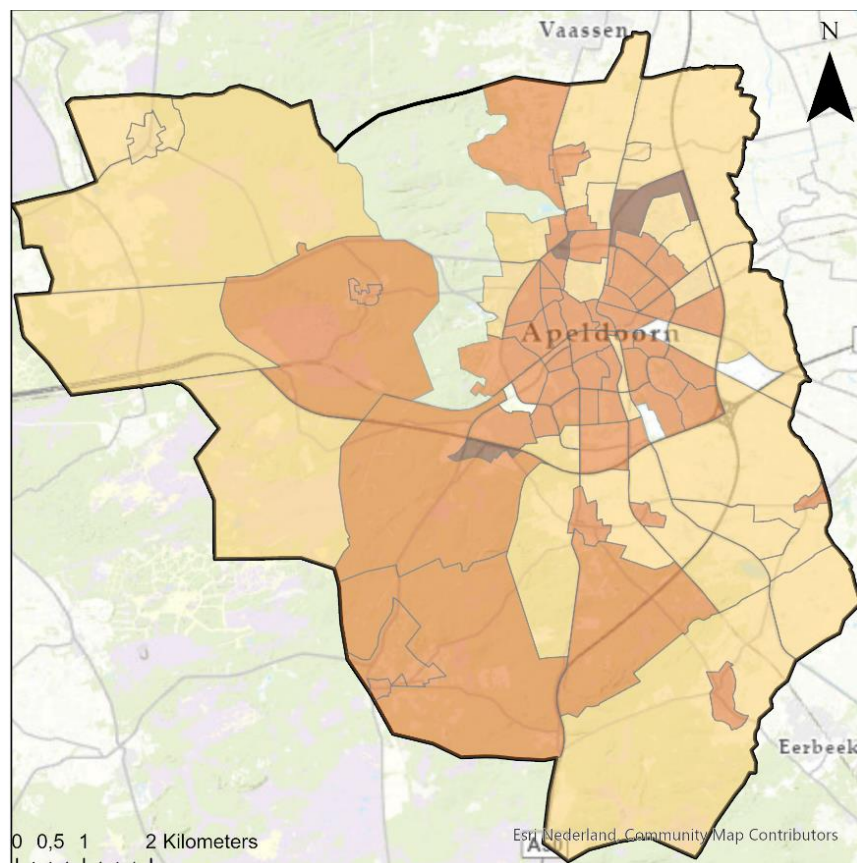
1,0 - 1,2

1,2 - 1,4

1,4 - 1,6

1,6 - 1,8

Apeldoorn_en_Nijmegen



Health

Health risk

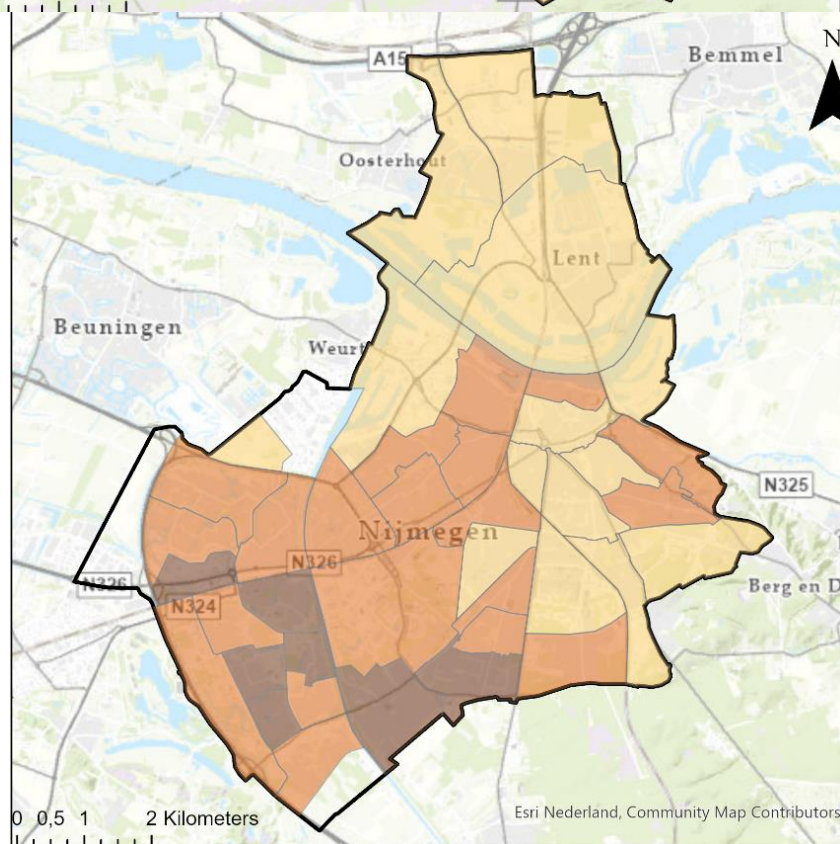
1,0 - 1,2

1,2 - 1,4

1,4 - 1,6

1,6 - 1,8

Apeldoorn_en_Nijmegen



Figures 8 and 9: Health risk maps

2. Amenities

Used data

The amenities in table 6 were mentioned by the interviewees as activity locations. The activity locations were selected as general amenities that should ideally be within walking or cycling distance. Since work locations are logically far away for people, these are not in the analysis. Not all amenities were input of the GIS analysis. This has to do with a lack of geographical data. Various geographical datasets from the Esri-cloud were used in gathering the required geographical data. Some amenities should ideally be located within walking distance, whereas others are allowed to be located somewhat further. Therefore, table 6 makes a distinction between walking and cycling amenities.

Amenity	In GIS?	Walking/cycling amenity	Data source
Supermarket	Yes	Walking amenity	Esri cloud
Sport	No (data availability)		
Music school	No (data availability)		
Friends and family	No (too sensitive information/data availability)		
Education	Yes (distinction between primary and higher education)	Primary education (walking amenity) and higher education (cycling amenity)	Esri cloud
City centre	Yes	Cycling amenity	Google Maps analysis
Nature/recreation	No (data availability)		
Public health	Yes (distinction between general practitioners and hospitals)	GP (walking amenity) and hospitals (cycling amenity)	Google Maps analysis
Daycare	No (data availability)		
Hairdresser	No (data availability)		
Youth meeting places	No (data availability)		
Neighbourhood centres	No (data availability)		

Table 6: Amenities

Risk categories

The geographical data of the amenities in table 6 is input for a buffer analysis. A buffer is drawn around each amenity to investigate to what extent inhabitants can reach these amenities. The buffer radiuses are identified using maximum acceptable walking and cycling distances. Beyond these maximum acceptable distances, people are regarded to have to walk or cycle too long distances which means they have a high risk of experiencing mobility poverty. The CROW has identified the maximum acceptable walking distance as a range between 450 and 1000 meters (CROW, 2021). Verkeersnet.nl (2016) identified the maximum acceptable cycling distance as 7.5 kilometres. Combining this information leads to the following risk categories (table 7):

Risk	Distance to walking amenity	Distance to cycling amenity
1 (low)	0 – 450 meters	0-1 kilometres
2	450 – 1000 meters	1-7,5 kilometres
3 (high)	1000+ meters	7,5+ kilometres

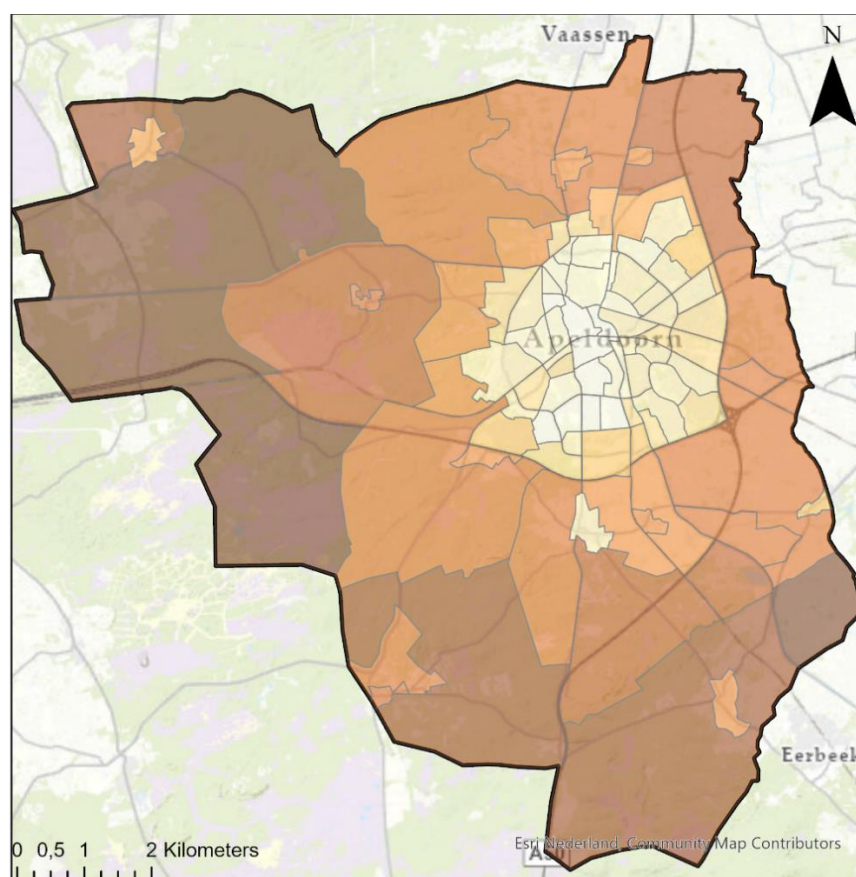
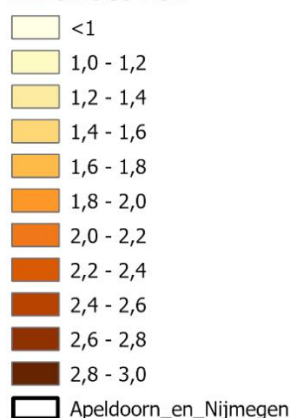
Table 7: Risk categories amenities

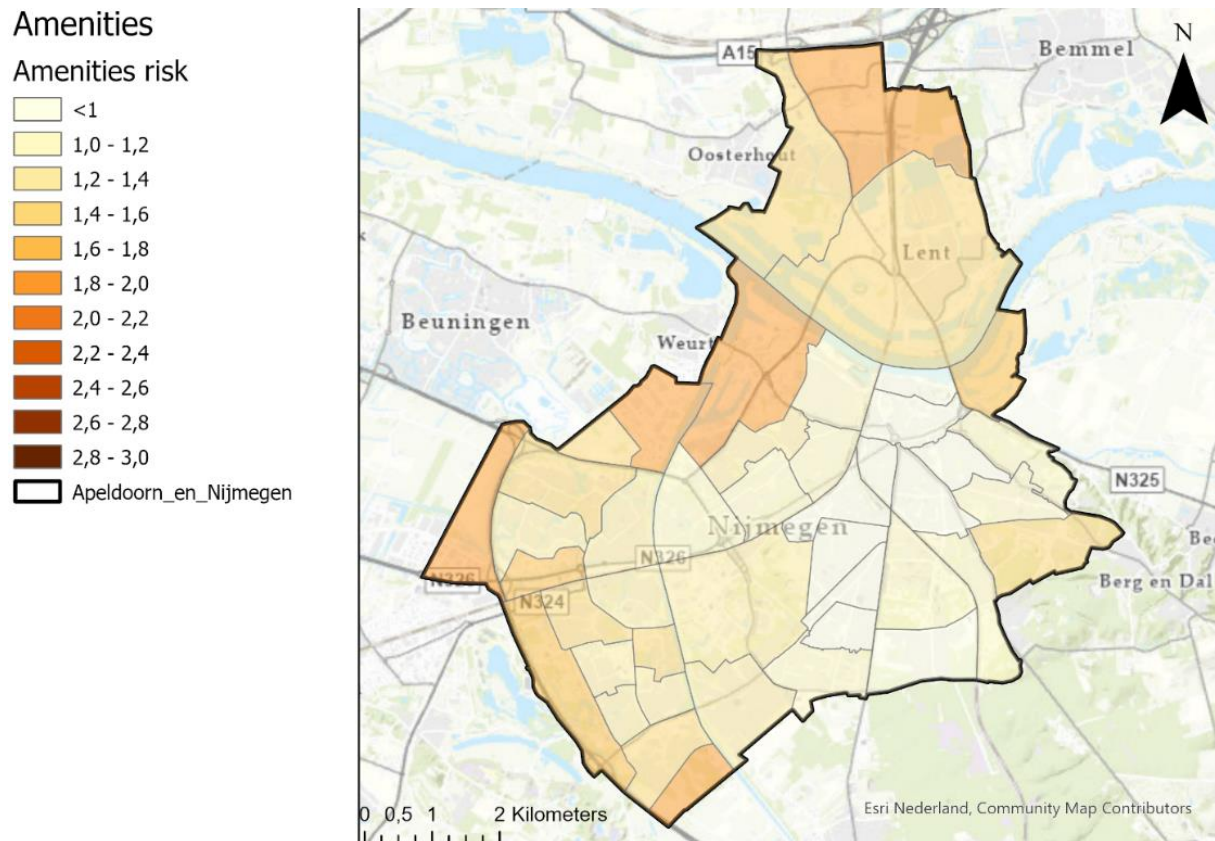
Result

Figures 10 and 11 show the risk maps concerning the indicator amenities. The neighbourhoods in the central parts of the cities Apeldoorn and Nijmegen are within walking distance of almost all types of amenities. This is reflected in the maps. Neighbourhoods at the edge of the cities have a higher risk of mobility poverty as they are located more distant from amenities. Figure 10 shows that especially the rural parts of this municipality have low coverage of amenities. However, only a few people live in these areas. Therefore, attention to access to amenities should be paid especially to neighbourhoods at the edge of the cities. Interview 10 (SNO) for example mentioned that access to the city centre is an issue in Dukenburg (south-west of Nijmegen), which is reflected by a higher risk of mobility poverty concerning this indicator in figure 11.

Amenities

Amenities risk





Figures 10 and 11: Amenities risk maps

3. Income

Used data

The average household income is not useful to arrive at the risk categories for this indicator. An average only limitedly highlights people with low incomes as these are levelled with people with high incomes. Therefore, the risk categories in this research are based on income groups. The Wijken and Buurten monitor of the CBS (CBS, 2019) has information about the percentage of households in the neighbourhood below the social minimum (which is the minimum income necessary for a living), and of the percentage of households with a low income. The low income group is defined as 40% of the Dutch inhabitants with the lowest incomes.

Risk categories

The risk categories are as follows (table 8):

Risk	Income
1 (low)	Middle or high income
2	Between low income and social minimum
3 (high)	Below the social minimum

Table 8: Risk categories income

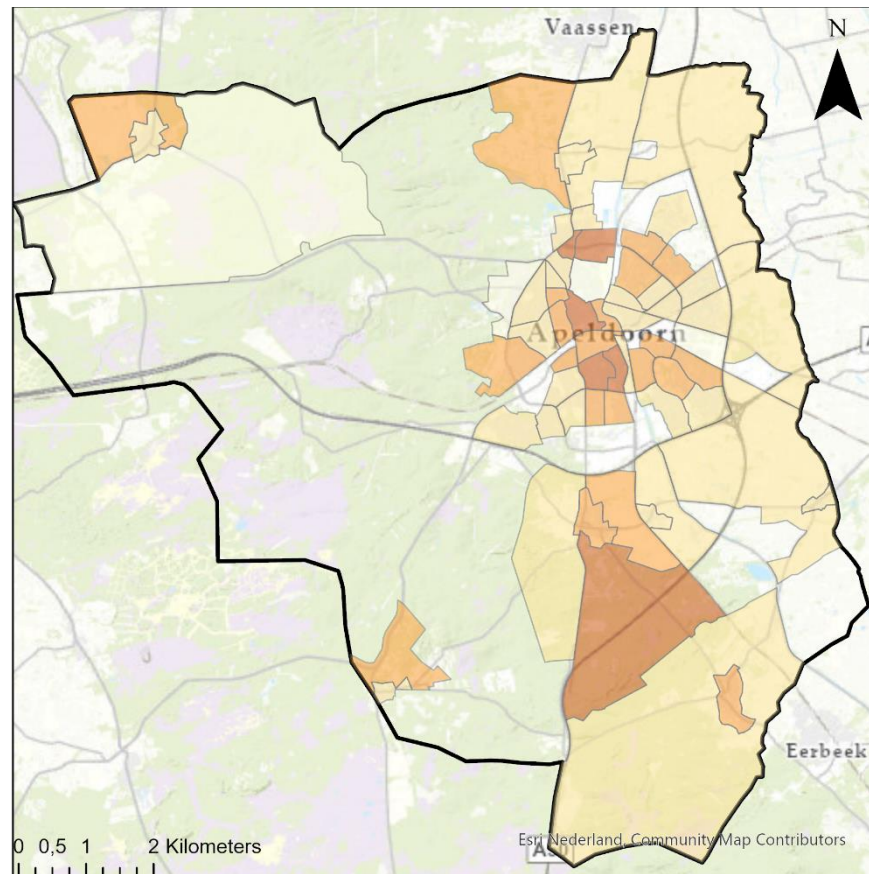
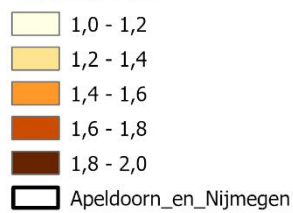
Result

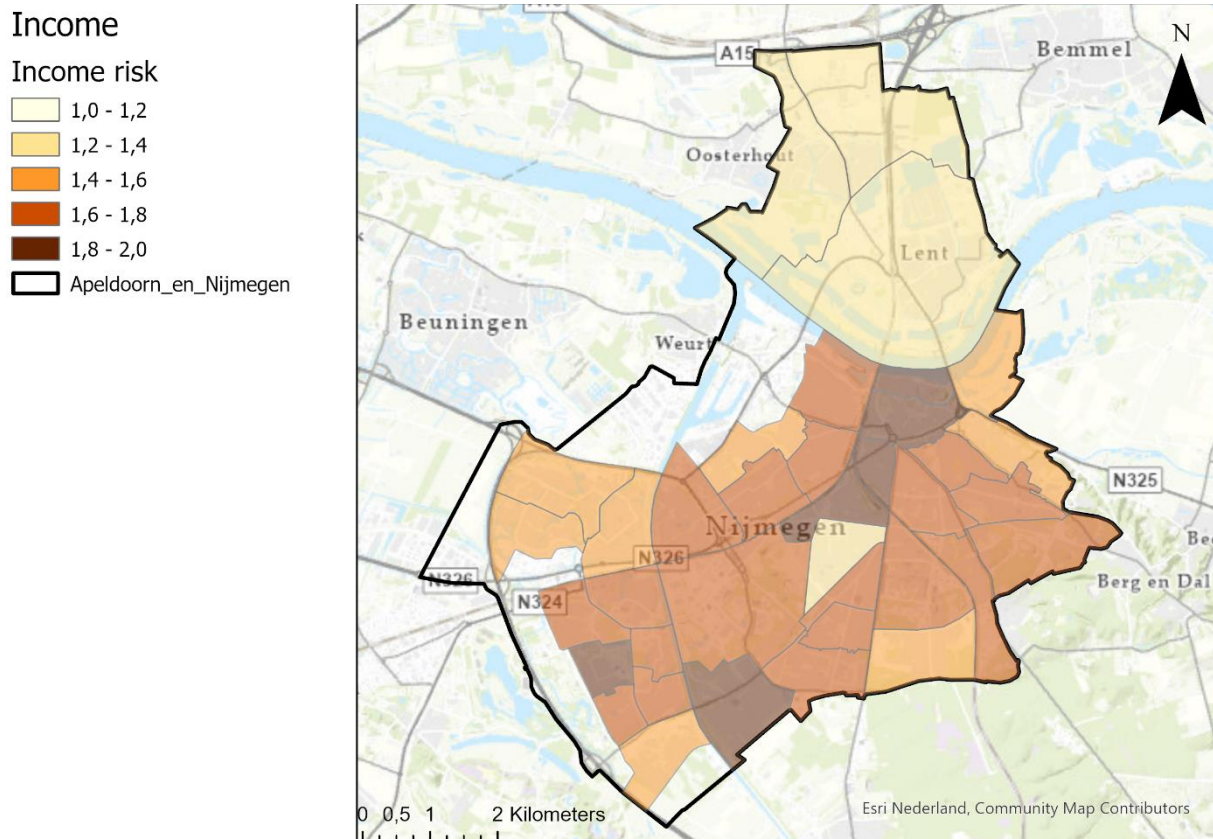
Figures 12 and 13 show the risk maps concerning the indicator income. The neighbourhoods with the highest risk on the indicator income are confirmed by the interviewees as being neighbourhoods with a high share of households with low incomes (for example interviews 8, SN and 9, MAG). An exception are the relatively wealthy neighbourhoods in the east of Nijmegen that have contrary to expected in figures 12 and 13 a relatively high risk on the

indicator income. Furthermore, interview 10 (SNO) was surprised by the colour differences in Dukenburg (southwest Nijmegen). It can well be that these neighbourhoods differ only limitedly in absolute terms, despite that the colours in the map show a different picture. For example, the map is insensitive to relative differences like in the scenario where one neighbourhood may score 1,79 whereas a different neighbourhood scores 1,80. The map rather divides the data in chunks of 0,2. This aspect that also matters in the case of the other mapped indicators requires attention. Also, note the lack of data in some parts in especially the municipality of Apeldoorn (figure 12). There were too few inhabitants in these areas which meant that this information was not available due to ethical reasons.

Income

Income risk





Figures 12 and 13: Income risk maps

4. Socio-economic category

Used data

This category relieves some of the flaws of the indicator income. For example, students and retired people often have a low income, but they might still have the means to travel. Students in the Netherlands for example can travel for free with public transport. Therefore, they have a relatively low risk of mobility poverty. Retired people have some budget that they have earned over the years which they can use to stay mobile. However, as they may have difficulties in travel due to poorer health conditions they have a slightly higher risk of mobility poverty as students. Two final groups in this indicator are people who work or people that receive a payment. People who work are regarded as having a low risk of mobility as they earn likely enough to be mobile. People that receive payment are however at risk of mobility poverty since they are dependent on this payment.

Unfortunately, information about students per neighbourhood was not available. However, the CBS (2015) has information about students per municipality. This information was used to estimate the number of students per neighbourhood based on the total inhabitants of the municipality and the inhabitants of the neighbourhoods. The Wijken and Buurten monitor of the CBS (CBS, 2019) has information about the AOW-indications. Most retired people receive an AOW payment. This information is used to estimate the number of retired people per neighbourhood. Finally, the Wijken and Buurten monitor of the CBS (CBS, 2019) also has information about payments, through which the groups 'people who work' and 'people that receive a payment' could be estimated.

Risk categories

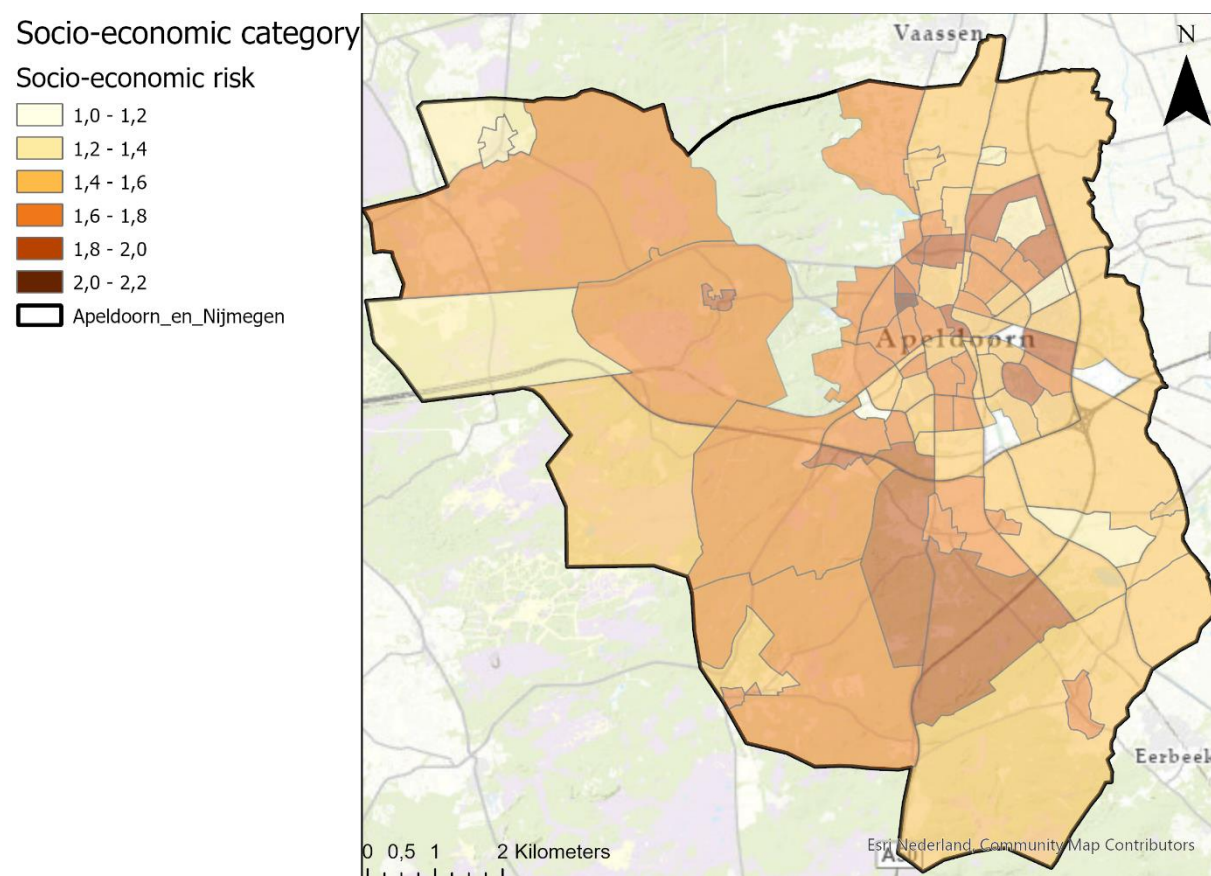
The following risk categories are present (table 9):

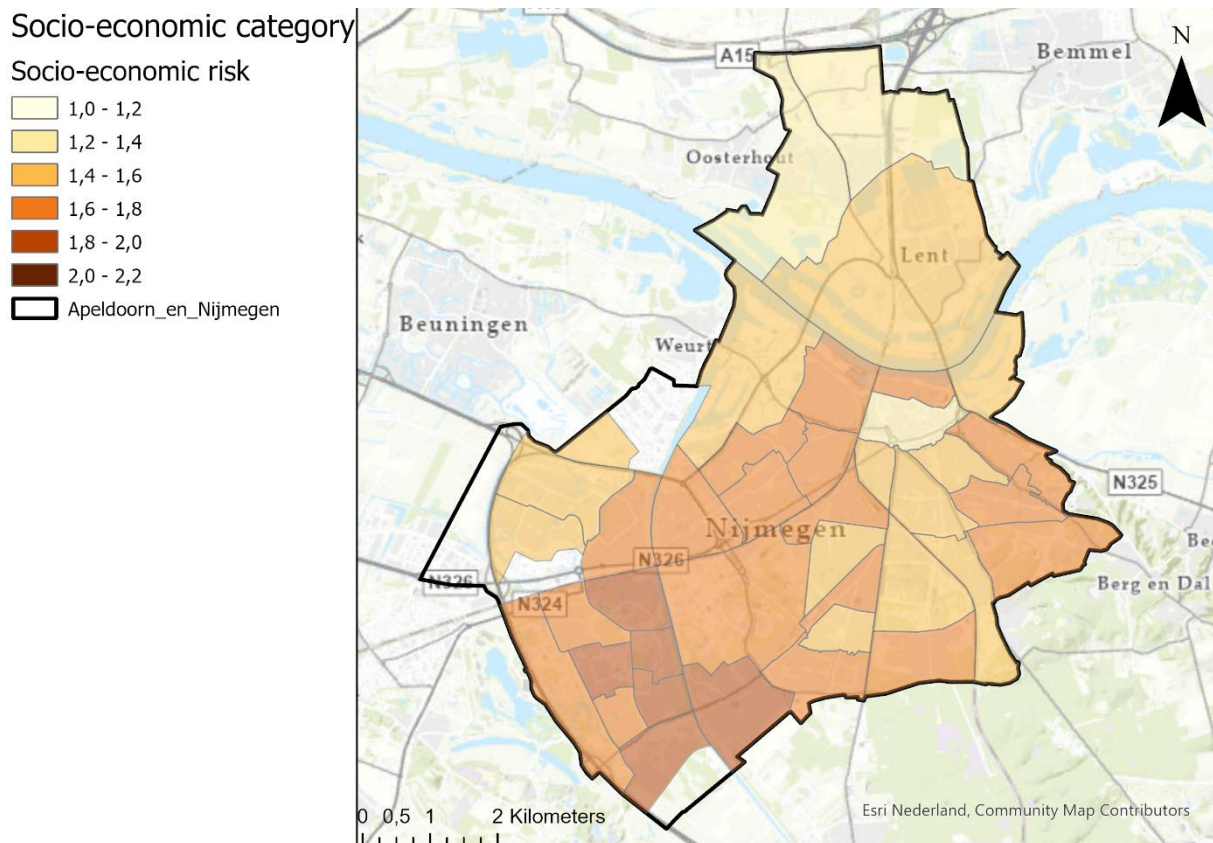
Risk	Socio-economic category
1 (low)	People who work and students
2	People who are retired
3 (high)	People who receive a payment

Table 9: Risk categories socio-economic category

Result

Figures 14 and 15 show the risk maps concerning the indicator socio-economic category. For Nijmegen (figure 15), the dark neighbourhoods in the southwest of Nijmegen were expected. However, the maps are somewhat more difficult to interpret as multiple factors are used as input for figures 14 and 15.





Figures 14 and 15: Socio-economic category risk maps

5. Bike ownership

Used data

Gathering data on bike ownership is challenging as bikes are, unlike cars, not registered. Consequently, this indicator was approached using other relationships. Two factors were used to approach bike ownership. The first is income. In general, the higher the income the higher bike ownership. According to Gulikers (2020), in the Netherlands, 79% of the people with low incomes owns a bike, 88% of the people with middle incomes owns a bike and 92% of the people with higher incomes owns a bike. The second factor to approach bike ownership is migration background. Dutch people cycle more often than people with a migration background. According to the KiM (de Haas & Hamersma, 2020), 27.5% of Dutch people cycle, 28% of people with a Western migration background cycle and 25% of people with a non-Western migration background cycle.

Risk categories

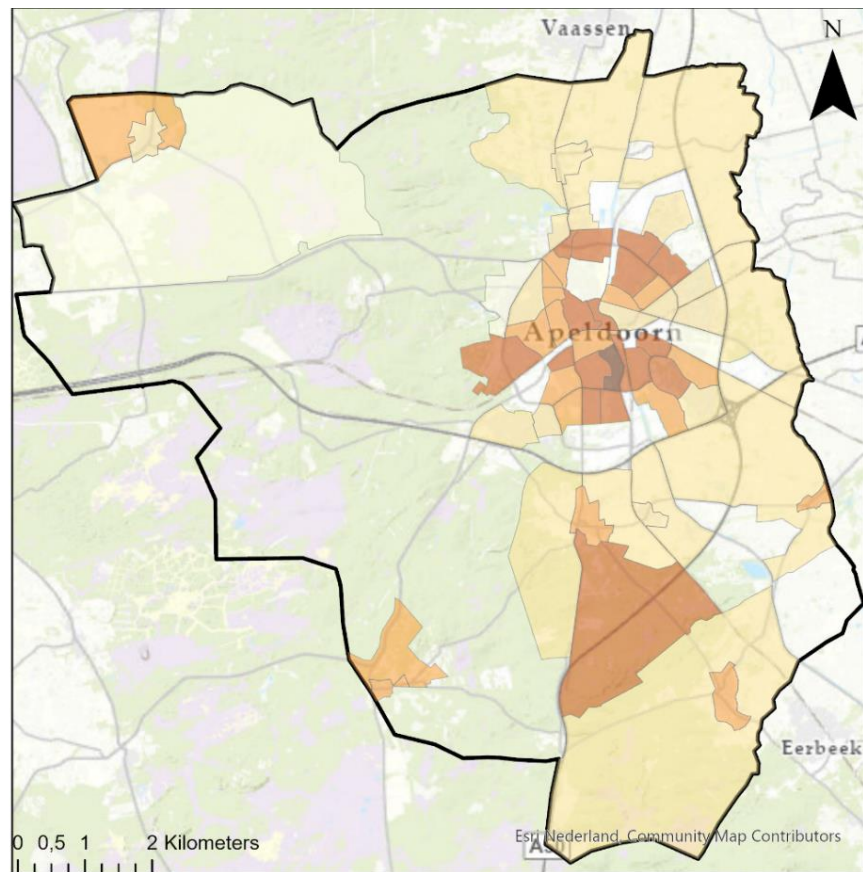
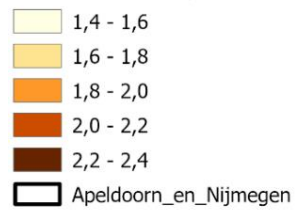
No risk categories were used for this indicator, as people either have or do not have a bike. However, as information about the Netherlands was available as well, the neighbourhoods were compared against this national average. A neighbourhood scoring 2 on this indicator means that bike ownership is as high as the Dutch national average.

Result

Figures 16 and 17 show the risk maps concerning the indicator bike ownership. The maps show great similarity with the income risk maps (figures 12 and 13). This is logical, as income is part of the indicator bike ownership.

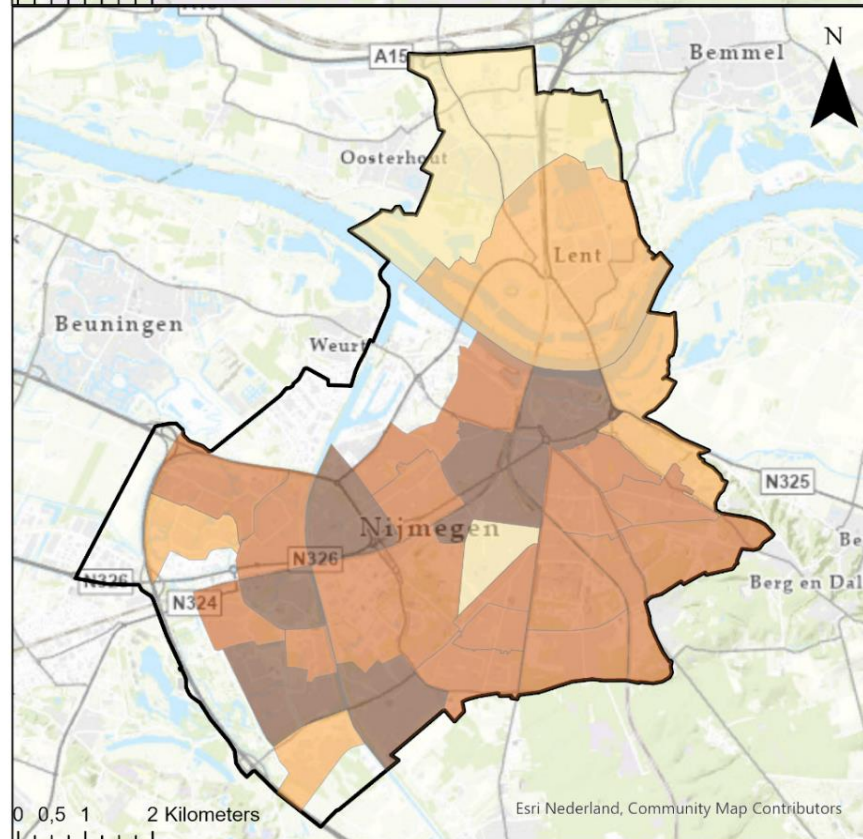
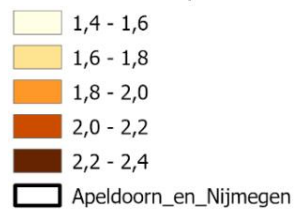
Bike ownership

Bike ownership risk



Bike ownership

Bike ownership risk



Figures 16 and 17: Bike ownership risk maps

6. Car ownership

Used data

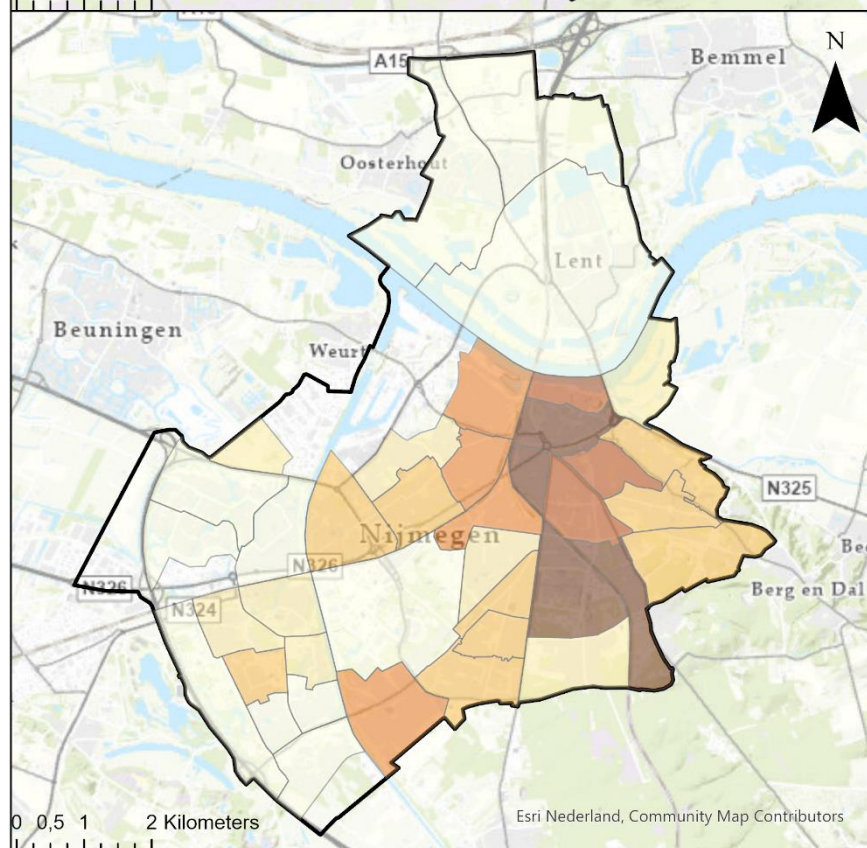
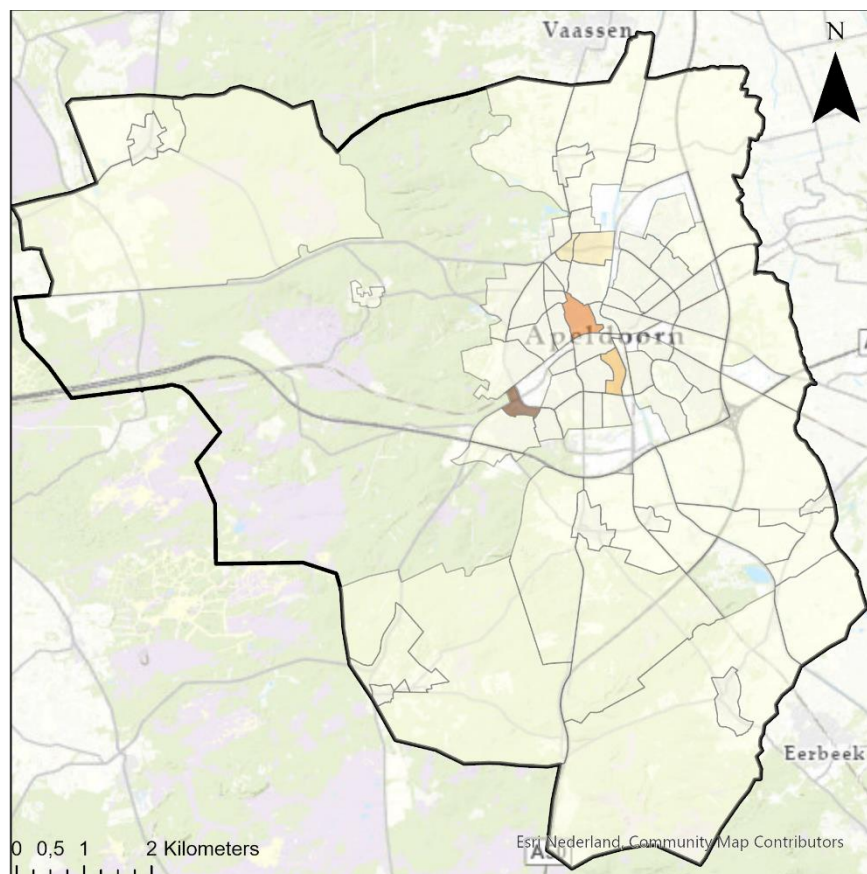
Contrary to bicycles, cars are registered. Therefore, data about car ownership was available on a neighbourhood level. For each neighbourhood, the Wijken and Buurten monitor of the CBS (CBS, 2019) presents the average amount of cars per household. However, since this is an average, it can well be that when the average amount of cars per household is 1, 50% of the households have no car whereas the other half has two cars. This affects the quality of the data, but unfortunately, this is the best figure in estimating the risk on the indicator car ownership.

Risk categories

Similarly to the indicator bike ownership, no risk categories were used for this indicator, as people either have or do not have a car. However, as information about the Netherlands was available as well, the neighbourhoods were compared against this national average. A neighbourhood scoring 2 on this indicator means that car ownership is as high as the Dutch national average.

Result

Figures 18 and 19 show the risk maps concerning the indicator car ownership. In Apeldoorn, the car ownership risk is almost the same in each neighbourhood. Some exceptions are the neighbourhood in the south-west (where few inhabitants live which impacts the risk score), the city centre (where access to other modes of transport and amenities is good) and some neighbourhoods in the north and south of Apeldoorn where incomes are somewhat lower. In Nijmegen, similar to Apeldoorn, the city centre also shows high risks in the category of car ownership.



Figures 18 and 19: Car ownership risk maps

7. Public transport

Used data

Similarly to the indicator amenities, the indicator public transport uses the maximum acceptable walking distances. The CROW (2021) identified the maximum acceptable walking distance to public transport to be 400 meters. However, people are willing to walk somewhat further to bus stops where busses stop more frequently (HOV bus stops) and to train stations. Van der Blij et al. (2010) identified the maximum acceptable walking distance to HOV bus stops as 800 meters. The CROW (2021) identified the maximum acceptable walking distance to train stations as 1000 meters.

Risk categories

Also similar to the indicator amenities, a buffer analysis with a visual inspection has been performed to investigate of each neighbourhood the accessibility (based on distance) towards public transport. The following risk categories have been identified (table 10):

Risk	Public transport
1 (low)	Within 400 meters of a public transport stop
2	Within 800 meters of an HOV stop or within 1000 meters of a train station
3 (high)	Other

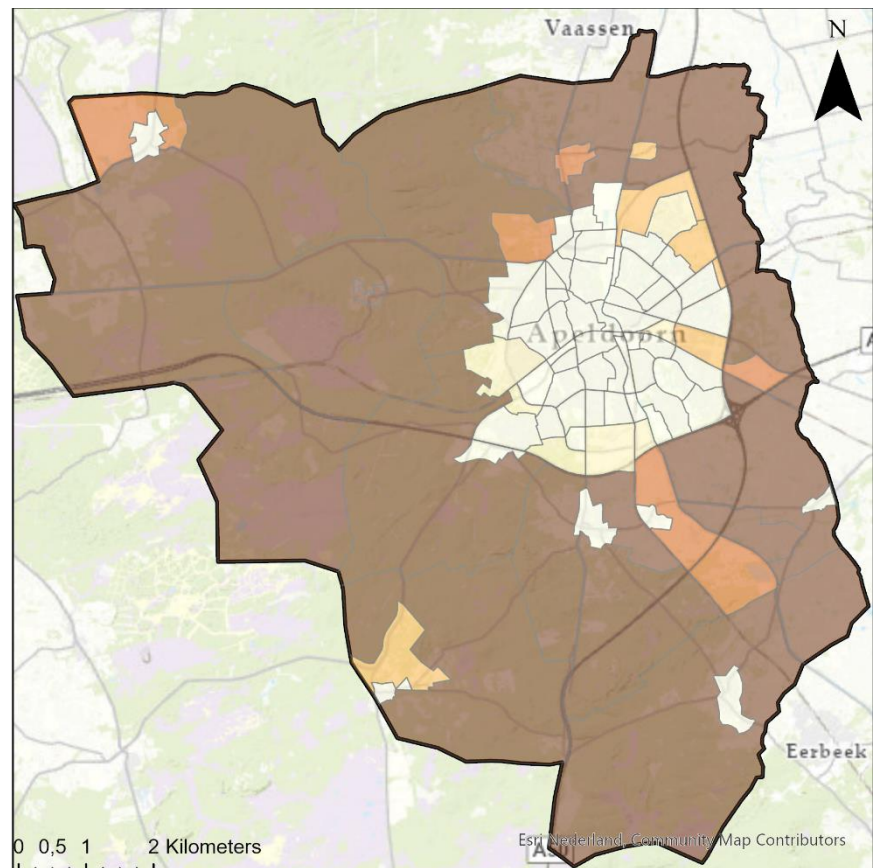
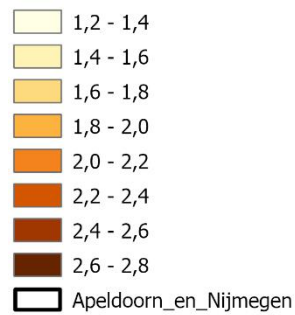
Table 10: Risk categories public transport

Result

Figures 20 and 21 show the risk maps concerning the indicator public transport. These figures show that the neighbourhoods in the cities are well connected to public transport, whereas the neighbourhoods at the edge of the cities and (in the municipality of Apeldoorn) the areas outside the cities are less connected to public transport. This result was expected by the interviewees. Fortunately, only a few people live in the areas outside the city of Apeldoorn where the coverage of public transport is low.

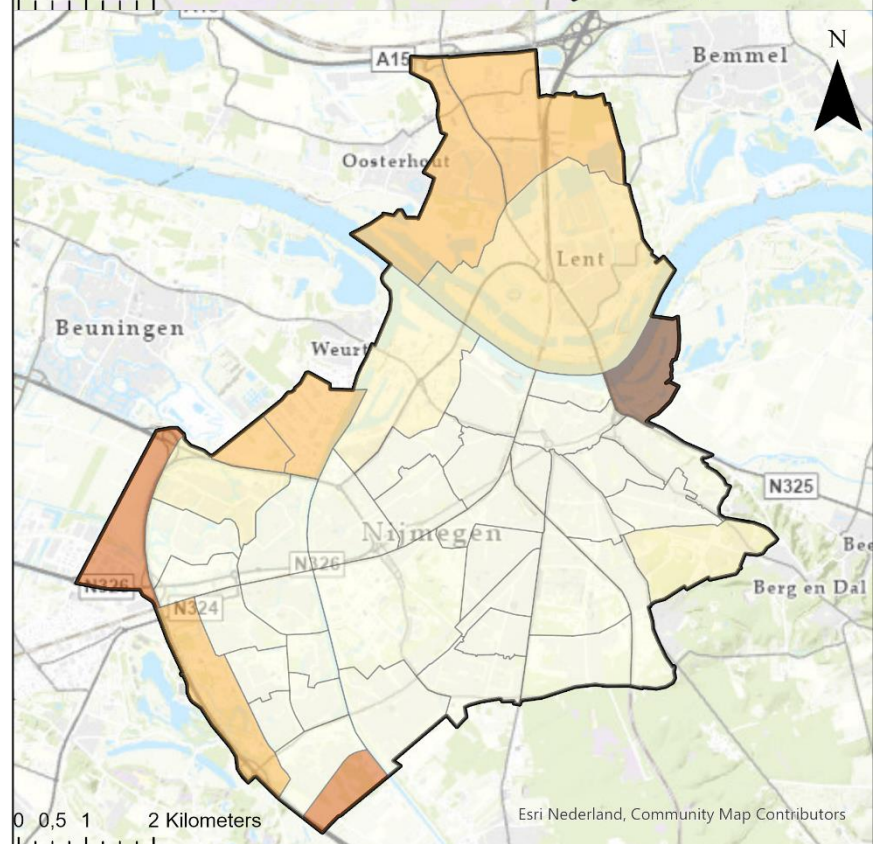
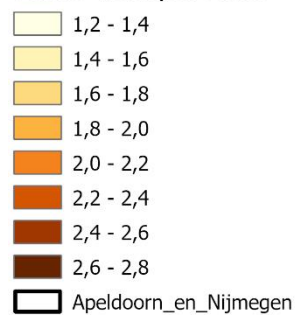
Public transport

Public transport risk



Public transport

Public transport risk



Figures 20 and 21: Public transport risk maps

8. Loneliness

Used data

Loneliness is a potential consequence of mobility poverty. The Dutch RIVM (2020-1) did a monitor on a neighbourhood level, asking inhabitants about whether they experience loneliness. They distinguish between not feeling lonely, feeling lonely and feeling very lonely.

Risk categories

The following risk categories can be imagined (table 11):

Risk	Loneliness
1 (low)	Not feeling lonely
2	Feeling lonely
3 (high)	Feeling very lonely

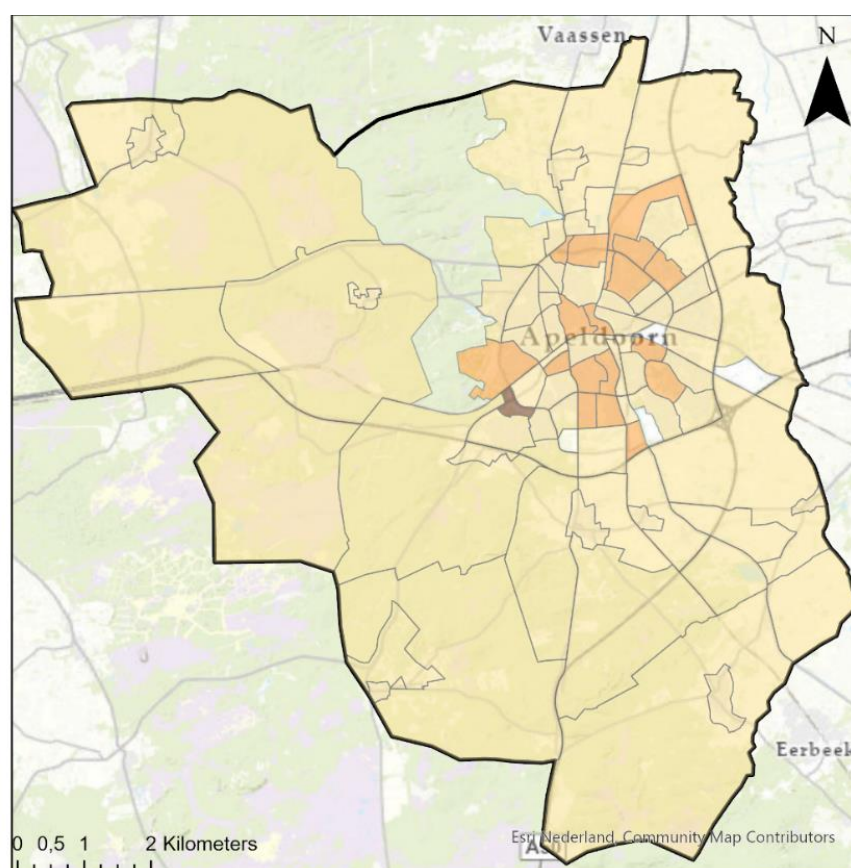
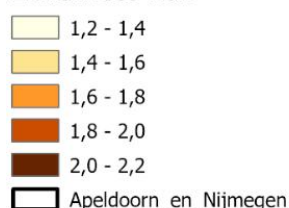
Table 11: Risk categories loneliness

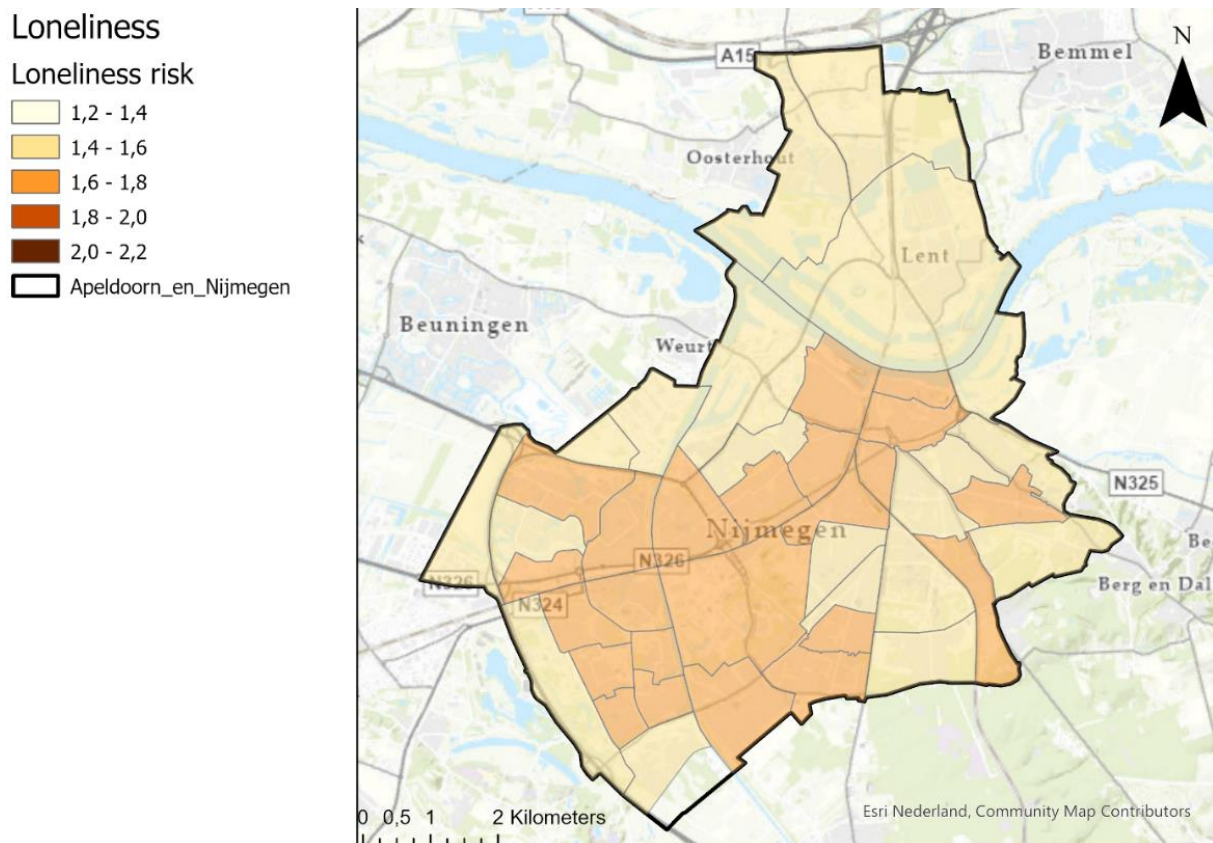
Result

Figures 22 and 23 show the risk maps concerning the indicator loneliness. The maps show little differences overall. The darker coloured neighbourhoods are also amongst the neighbourhoods with high risks on the indicators of health (figures 8 and 9) and income (figures 12 and 13). Despite that there are multiple reasons why people might feel lonely, health and income are reasons why people have difficulties in doing activities and thus of meeting other people.

Loneliness

Loneliness risk





Figures 22 and 23: Loneliness risk maps

9. Having a driver's license

Used data

Having a driver's license can be useful even for people that do not own a car. People with a driver's license can make use of shared mobility like in the case of the eHubs in Nijmegen. This indicator was not available at a neighbourhood level. However, it was possible to use age to find out the risk on the indicator 'having a driver's license'. The CBS (2021) has information about the percentage of driver's licenses amongst different age groups in the province of Gelderland. Using this information (table 12), and the composition of age groups in the neighbourhoods, which is available in the Wijken and Buurten monitor of the CBS (2019), for each neighbourhood the percentage of people with a driver's license can be calculated. This can be compared with the average of the province of Gelderland, which is visualized on the map.

Age groups	15-25	25-45	45-65	65+	Total
Having a driver's license (%)	48.2	88.5	90.2	76.5	67.7

Table 12: People with a driver's license in the province of Gelderland (CBS, 2021).

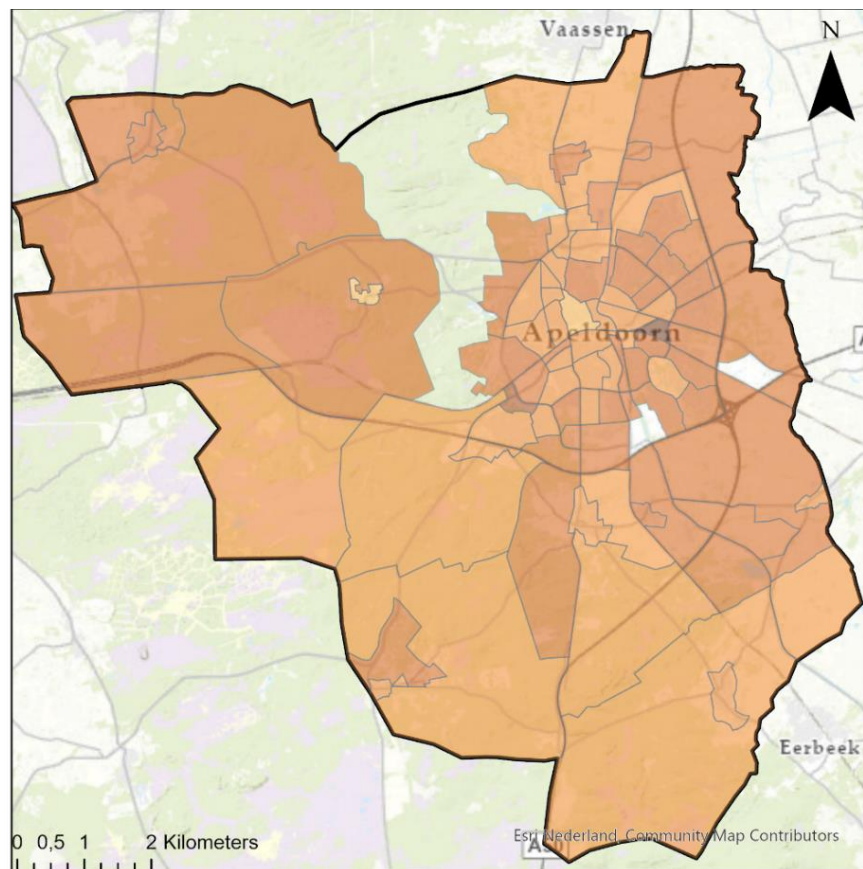
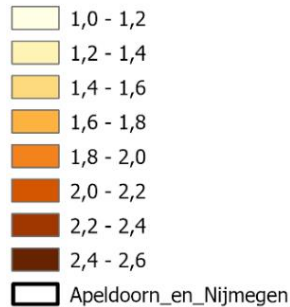
Result

Figures 24 and 25 show the risk maps concerning the indicator driver's license. Table 12 shows that the age group 15-25 has the least amount of people with a driver's license. The darker coloured neighbourhoods reflect this. This research only considers age as an explaining factor of having a driver's license but ignores for example that people with lower incomes might not have the opportunity to get a driver's license, something that interview 8 (SN) stressed.

Therefore, this map is difficult to interpret. A neighbourhood scoring 2 on this indicator means that having a driver's license in that neighbourhood is as high as the Dutch national average.

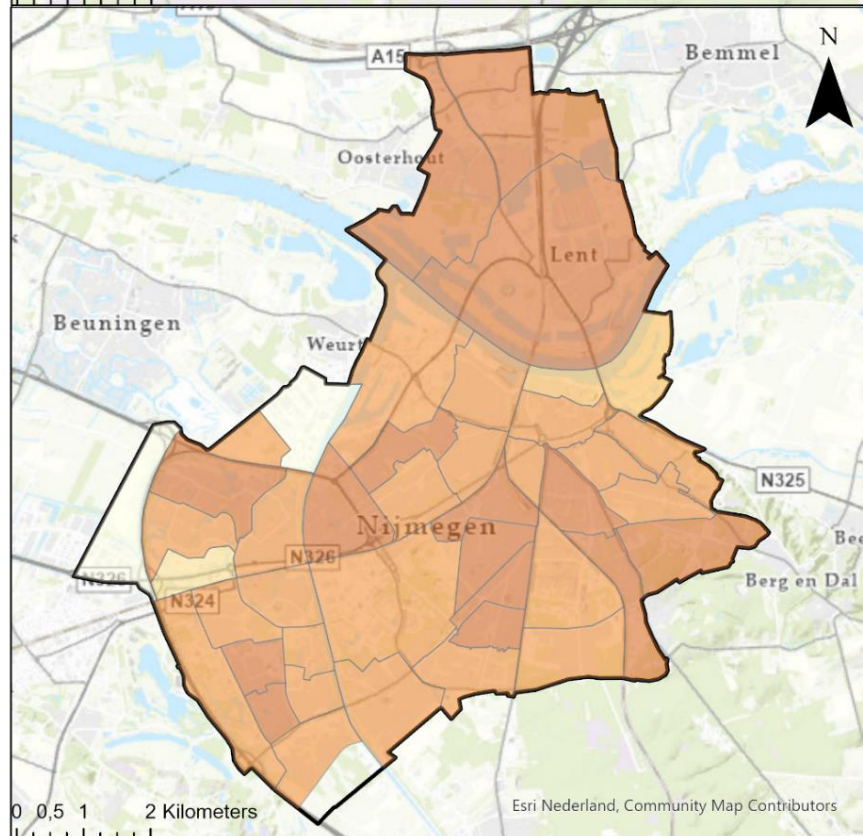
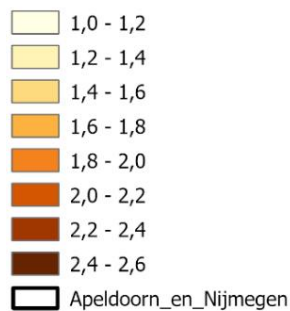
Driver's license

Driver's license risk



Driver's license

Driver's license risk



Figures 24 and 25: Driver's license risk maps

4.2.3: Layer quality

To develop mobility poverty maps of good quality, data should be available and of sufficient quality (Martinez, 2009). Several remarks regarding the availability and quality of the data used in the development of the mobility poverty maps can be made. An overview of these remarks is presented in table 13. First, data on the indicators 'health' and 'socio-economic category' was not available on a neighbourhood level, but on a municipality level. This data had to be spread over all neighbourhoods in this municipality by using the number of inhabitants as mediating factor.

Second, the indicators amenities and public transport required a buffer analysis and visual inspection. Some mistakes may have been made during the visual inspections. Visual inspections were performed to investigate the percentage (in chunks of 20%) of coverage of each neighbourhood by the buffers in table 7. For example, a neighbourhood covered in reality for 43% by the 400 meters buffer of primary schools may be scaled wrongly in this research as being 20-40% covered. Unfortunately, there was no tool available in ArcGIS Pro to calculate this coverage. Furthermore, this visual inspection is only based on coverage of the total area and should be nuanced by considering where in these neighbourhoods actually the inhabitants live.

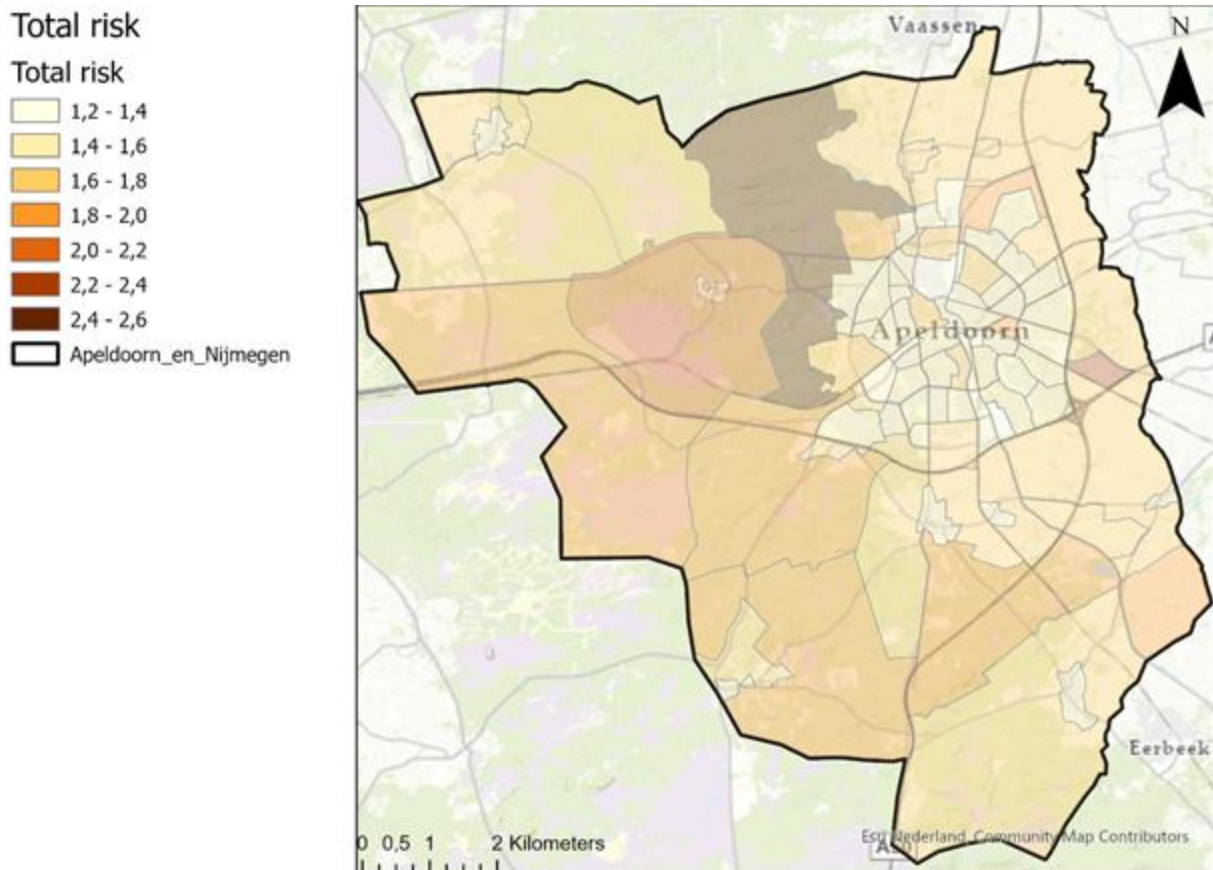
Finally, some indicators had to be approached using other factors. Given the data available, approaching indicators is logical (interview 1, MG). However, this 'approaching' does affect the quality of this layer and the combined layer showing mobility poverty as effectively something else than the indicator is measured. Chapters 5 and 6 dive deeper into this.

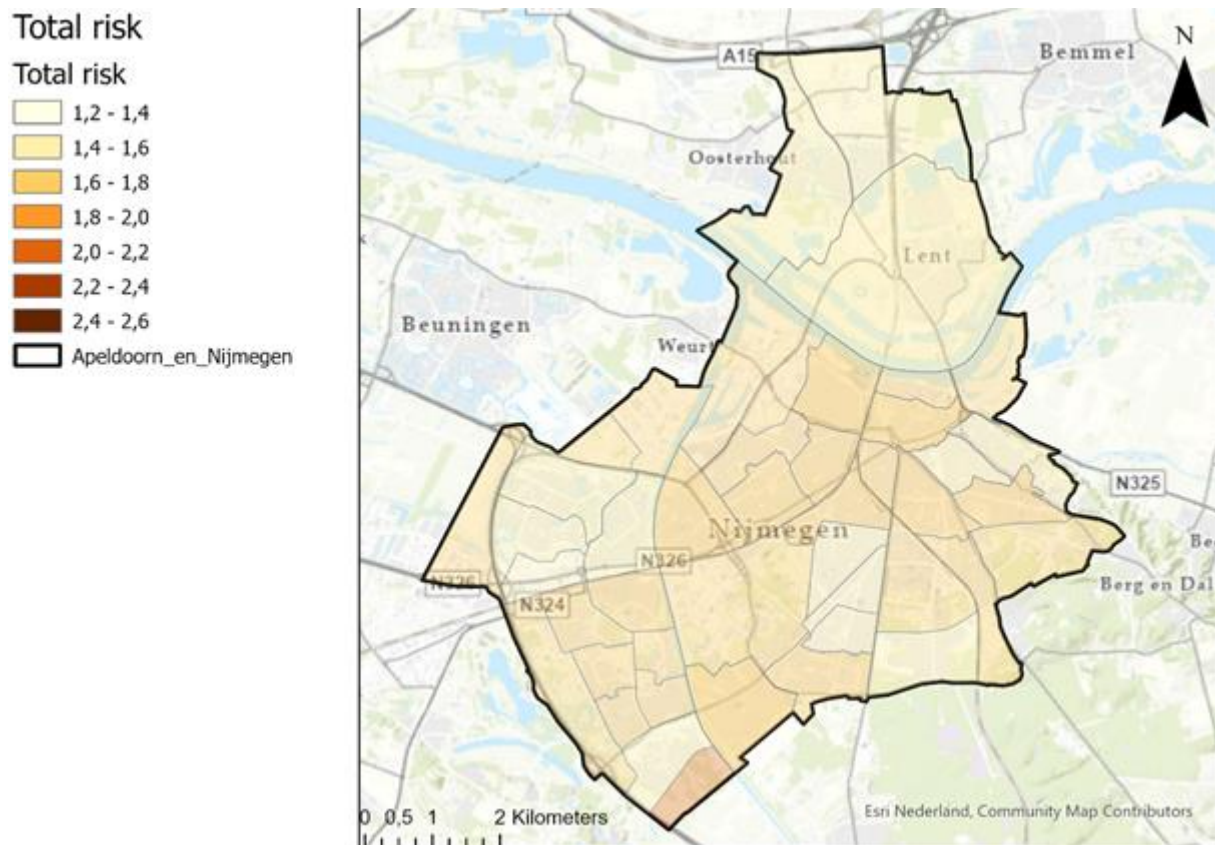
Indicator	Layer quality (own interpretation)	Remarks
Health	Relatively good	WLZ data on a municipality level instead of on a neighbourhood level
Amenities	Relatively good	Minor mistakes in secondary data, visual inspections to calculate coverage
Income	Good	Secondary data measured directly by the CBS (CBS, 2019)
Socio-economic category	Relatively good	Student data on a municipality level instead of on a neighbourhood level
Bike ownership	Debatable	Approached via income and migration background
Car ownership	Relatively good	Secondary data measured directly by the CBS (CBS, 2019) but it is still a question of how many households have or do not have a car
Public transport	Relatively good	Visual inspections to calculate coverage
Loneliness	Good	Secondary data measured directly by the Dutch health organisation (RIVM, 2020-1)
Having a driver's license	Debatable	Approached via age

Table 13: Quality of the mapped indicators.

4.2.4: Combined map layer

Figures 26 and 27 show the combined maps that highlight mobility poverty. The scores on the 9 indicators used in this analysis have been averaged in figures 26 and 27. Especially visible in Nijmegen (figure 27) is that differences between neighbourhoods are very small. This was contrary to expectations, where it was expected that some neighbourhoods would score significantly different than others. The differences may appear small because averaging might level out the differences. It appears that using this set of indicators, the risk of mobility poverty is almost equal in each neighbourhood. Figures 26 and 27 show that mobility poverty is a relatively invisible topic when considering multiple factors. There is no big difference in the mobility poverty situation of Apeldoorn compared to Nijmegen. However, examining the results more closely reveals that relative differences are nonetheless present. Ugchelen for example has a total risk score of 1,488 whereas Hatert, a neighbourhood in Dukenburg, has a total risk score of 1,729. This mainly had to do due to Ugchelen being a more wealthy neighbourhood than Hatert. So, the map is useful in highlighting relative differences.





Figures 26 and 27: Mobility poverty risk maps

4.3: Second round of interviews

In this section, two parts are central. The first part investigates the opinions of the interviews on the presented mobility poverty maps (chapter 4.2). The second part discusses the future of mobility poverty maps and potential alternative approaches to gain insight into mobility poverty. Furthermore, this part will also discuss which organisation(s) is/are responsible for dealing with mobility poverty and how mobility poverty can become a theme on the agenda of these different organisations.

4.3.1: Interpretation of the maps

Due to the few relative differences between the neighbourhoods in figures 26 and 27, the interviews argue (for example interview 1, MG and 7, MN) that this can lead to false conclusions (for example amongst politicians) about whether mobility poverty exists in a municipality. The map currently may look like an expression of a non-existing problem. However, some of the interviewees point out that the mobility poverty risk maps also highlight the invisibility of mobility poverty. There are thus different opinions about the combined map layer showing mobility poverty.

Despite that, the interviews agree that some of the individual indicator maps confirm expectations about the real situation. Interview 9 (MAG) for example mentioned that the neighbourhoods at risk on the indicator health in Apeldoorn are also the neighbourhoods where a large share of older inhabitants live. Elderly people are expected to state more often than younger inhabitants that their health situation limits them in their mobility. This is

reflected in figures 8 and 9. Furthermore, the neighbourhoods with low scores on the indicator income (figures 12 and 13) are already attention points of poverty policy in Nijmegen (interview 8, SN). However, interview 10 (SNO), also from the social domain, points out as an expert in the neighbourhood of Dukenburg that careful interpretation of the maps is always required. For example, some programs to decrease poverty in Dukenburg had been aimed at some neighbourhoods that were in the analysis in this research not neighbourhoods with a very high risk on the indicator income. In other words, locally, the information of the municipalities differed slightly from the maps. This means that when using the map to deal with mobility poverty, communication with local stakeholders is beneficial to come to an efficient approach.

It remains unclear which and how many people experience mobility poverty (interviews 1, MG and 6, SA). For example, access to amenities due to large distances might be a problem in the neighbourhoods at the edge of the city. However, as interview 5 (MA) noted, these people often have a car to travel due to which these people might not experience mobility poverty. However, the maps at least highlight where the risk of mobility poverty is high.

Interpretations of the maps differed between the interviewees. For example, the maps concerning access to public transport show that the neighbourhoods in the centre of the cities are most connected to public transport. This matches the expectations of the interviewees (interview 1, MG). However, interview 8 (SN) noticed that this layer is insensitive to the actual use of public transport, which depends on income for example. Some interviewees also note that some indicators are missing, like digital skills (interview 7, MN). The different interpretations are also rooted in the respective domains that the interviewees are in. They thus can learn from each other to improve mobility poverty policy uptake.

Approaching indicators using different factors might be a reason that these differences in interpretations occur. This does not give the full picture (interviews 2, MC, 7, MN and 9, MAG). For example, when approaching bike ownership via income and migration background, income and migration background are in fact mapped (interview 7, MN). Given the data availability, this approaching of indicators is logical (interview 1, MG), but it reduces the quality of these individual map layers and the combined total result. Future mobility poverty maps might improve or remove these approached indicators or use weights to give a better picture of the mobility poverty situation. Furthermore, in-depth surveys might give more clarity to this. However, the interviewees agree that the maps are a valuable tool to start the discussion about mobility poverty.

4.3.2: Further map improvements

Several interviewees noted that despite figures 26 and 27 (the combined mobility poverty maps) show only limitedly the differences between the neighbourhoods, they have had some expectations about in which neighbourhoods mobility poverty would occur (for example interviews 2, MC and 6, SA). When asked directly about which indicator is most important, most interviewees respond with loneliness (interviews 8, SN and 10, SNO) and income (interviews 7, MN and 8, SN). This concerns not only interviewees from the social domain, but also interviewees from the mobility domain. This highlights that the interviewees can think beyond their domain. When reducing poverty, many other social problems are also likely to be reduced (interview 8, SN). Furthermore, loneliness is regarded as a layer that might come

very close to mobility poverty as loneliness can be a direct consequence of mobility poverty. To improve future mobility poverty maps, these indicators can get a greater weight (interview 2, MC).

4.3.3: Alternative approaches to measure mobility poverty

Next to map improvements, several interviewees point out that there are alternative ways to measure mobility poverty. The interviewees notice that using multiple methods is necessary to be able to formulate future mobility poverty policy. The first is to investigate further into groups that have a high chance of experiencing mobility poverty. It is important to investigate who these groups are, what they experience (interviews 6, SA and 8, SN) and what help they need (interview 1, MG). A GIS analysis can be done to map those identified groups. The groups that are unlikely to experience mobility poverty (like people that own a car) can be filtered from the analysis (interview 5, MA). A second approach to further investigate mobility poverty is to perform surveys as a follow up of the mobility poverty maps (for example interviews 1, MG, 3 and 10, SNO). These surveys can be performed in neighbourhoods where mobility poverty is expected to occur (interviews 1, MG and 3). In these surveys, inhabitants can be asked about the indicators found during the interviews in this research (table 3). This research had to approach several indicators (like bike ownership). This is then not necessary anymore. This can give great quantitative support to the question of how much mobility poverty occurs. A final way of measuring mobility poverty is to not only do surveys in a neighbourhood where mobility poverty is expected but also to ask inhabitants about experiences regarding mobility poverty (interviews 6, SA and 8, SN). As searching for experiences is a social exercise, it is logical that interviews from the social domain highlighted this aspect. Local knowledge and knowledge of the social domain is useful to contact these inhabitants and to investigate a certain neighbourhood's mobility poverty situation more thoroughly (interview 5, MA).

4.3.4: Responsibility

There are multiple opinions about who is responsible for reducing mobility poverty. As mobility poverty is both a social and a mobility-related theme, in essence, the responsibility of dealing with mobility poverty responsibility should be shared between the involved domains (interview 8, SN). Governmental organisations need to make many choices as there are many pressing issues. Some of these issues might be regarded as more important than mobility poverty (interview 9, MAG). This is a political question. However, as stressed multiple times in this research, mobility poverty is in the context of Social Justice and the Just City (Fainstein, 2009) (chapter 2.1.1) nevertheless a fair thing to pursue.

As striving for the Just City is best off when multiple organisations strive for this goal, ideally, responsibility is also shared amongst different organisations. This also fits the collective impact model (interview 3, SGGD). Unfortunately, achieving this is not simple. Every organisation has its own goals, opinions, agendas and budgets. As an example, there are different opinions regarding the provision of public transport. Public transport is not at all times at every location available. Examples of locations where public transport is not always available are industrial areas, villages and social movements between neighbourhoods (interview 2, MC). On the one hand, inhabitants often consider public transport as an essential good. Public transport companies on the other hand are bounded by their financial budgets in making schedules to give access to public transport for all inhabitants. Public transport companies focus therefore mostly on efficient systems that can move large streams of

travellers (interview 5, MA). The province has a position in between the ends of this spectrum, dealing with both the social wishes of the inhabitants and the financial budget of the public transport company. This example about the provision of public transport shows that opinions, budgets and agendas differ between involved stakeholders. Mobility poverty, of which the provision of public transport is one aspect, is better off when an orchestrated approach with these stakeholders is established, instead of laying the responsibility to one of these parties solely (for example the province). Achieving this is not easy, but in the following sections, concrete measures to reduce mobility poverty and policy recommendations are presented that increase the sharing of responsibility regarding mobility poverty.

4.3.5: Mobility poverty reducing measures

There are concrete measures proposed by the interviewees that reduce mobility poverty risk. First, interviews 3 (SGGD), 7 (MN) and 10 (SNO) suggest that the accessibility of activity locations can be improved. When people can better reach these locations or can get multiple transport options so they can choose a preferred mode of transport then this reduces mobility poverty risk. Examples are improved cycling paths or the densification of amenities (reducing distances). Second, there are many social programs thinkable that can reduce mobility poverty risk. Notable examples of these are the Busvoordeel-abonnement in Nijmegen where respondents can get bus tickets for a reduced fee (interview 8, SN) or the Medon-regeling which respondents can use to finance driving lessons (interview 8, SN).

Third, there are also several alternative public transport systems thinkable that can potentially reduce mobility poverty when regular public transport is not available. These systems typically spread out responsibility over different organisations, whilst simultaneously reducing the risk of mobility poverty. The first alternative system concerns doelgroepenvervoer. In this, for example, elderly people, people with a handicap or people with Autism can be picked up from their homes and brought to their destinations (interview 5, MA). This doelgroepenvervoer is subsidized by public authorities. The Haltetaxi system is another system that transport people from bus stop to bus stop, but not necessarily on the same bus route. These systems are relatively expensive for the province and the public transport companies, as they move only a small number of people. Therefore, these systems are meant for those for whom other modes of transport are not an option. A more cost-effective system is the Buurtbus. In this, no professional bus drivers are required. The bus drivers are volunteers, which saves expenses due to a reduced amount of loans that have to be paid (interview 2, MC). Responsibility is shared between the volunteers, province and public transport company.

Despite these methods, a more orchestrated approach to dealing with mobility poverty can lead to an even more efficient approach to deal with mobility poverty. Doelgroepenvervoer is somewhat more expensive than the Haltetaxi system. Interview 1 (MG) points out that several of the people in the doelgroepenvervoer can also be moved by the Haltetaxi system. This would be less costly. The buurtbus system is in some cases established following the closure of a “normal” bus service. An example is the buurtbus in Ugchelen. Ugchelen is a neighbourhood with a high organisational capacity as the educational background and incomes are relatively high in this neighbourhood. Interestingly, buurtbus services appear also in other neighbourhoods with a relatively high organisational capacity (interview 6, SA). But what about those neighbourhoods with lower organisational capacity? The mobility poverty map might signal this so that the municipality can respond to this.

These examples show that dealing with mobility can be improved when multiple organisations actively communicate with each other. But how can that be realised when many political choices have to be made? And how can that be realised as some of the interviewees acknowledge that they are unaware of what policy measures or alternative transport systems there are available, even within their own organisation? The next section will give some policy recommendations to improve this orchestration in measures and to put mobility poverty more prominently on the political agenda.

4.3.6: Policy recommendations

As mentioned earlier, the lack of differences in the combined mobility poverty maps (figures 26 and 27) shows the invisibility of mobility poverty which makes it challenging to make mobility poverty policy (interview 7, MN). More quantitative information (for example using surveys) can make mobility poverty more tangible (interview 5, MA). This does not mean that the mobility poverty maps in this research are not valuable in communicating mobility poverty. Mobility poverty maps are useful in the orientation phase. These maps can be useful to start the discussion about mobility poverty and to set up an integrated approach with multiple domains and organisations to deal with mobility poverty (interviews 3, SGGD and 8, SNO). In addition, it is valuable when using these maps to consult local stakeholders more often (opbouwwerkers, neighbourhood managers, and inhabitants) about whether the maps are in accordance with reality (interview 10, SNO). Fortunately, municipalities devote increasingly more attention to this link with practice. For example, the municipality of Nijmegen has its own statistical service that issues social monitors of neighbourhoods in Nijmegen. Consultations with local stakeholders are performed to give nuance to these monitors (interview 10, SNO).

This process of connecting these multiple domains and organisations can be strengthened when mobility poverty is communicated step by step (interview 7, MN). This means that first the consequences of mobility poverty should be communicated, then the reasons why this occurs and then who are at risk. Another suggestion might be to link mobility poverty to current policy. Durability, loneliness or space uptake are themes where mobility poverty can simultaneously be addressed (interview 7, MN). Content-wise, this makes sense. Consider for example cycling. Cycling is durable, has low space uptake and reduces mobility poverty as people might see the bike more as a reliable option. Simultaneously, more themes at the same time can be approached.

This bundling of multiple themes at the same time can in the Dutch context be achieved via the future Omgevingswet, Omgevingsvisie and Omgevingsplan (interviews 3, SGGD and 10, SNO). The Omgevingswet is a new Dutch spatial planning law that bundles several separate spatial planning laws. The Omgevingsvisie and Omgevingsplan are translations of this Omgevingswet to a municipal or regional level. The Omgevingsvisie is an ambition document that highlights the main policy directions a municipality would like to go. The Omgevingsplan is a more regulatory expression of these ambitions.

Mobility poverty can be one of the themes in the Omgevingsplan and Omgevingsvisie. Currently, mobility poverty is not very prominent in these planning documents, but the municipalities and the province in this research give some suggestions on how mobility

poverty might be reduced. In the Omgevingsvisie of Apeldoorn for example, the municipality will focus in the following years on amenities on walking distance and the preservation of amenities in rural villages (Gemeente Apeldoorn, n.d.). In the Omgevingsvisie of Nijmegen, the municipality also focuses on amenities within walking distance (especially for elderly people) (Gemeente Nijmegen, 2020). The municipal Mobiliteitsvisie, which will be integrated into the Omgevingsvisie, expresses that transport poverty (which relates to mobility poverty) should be reduced (Gemeente Nijmegen, 2019). They acknowledge that this can be done via for example shared mobility, alternative public transport systems like the buurtbus and active mobility. They even highlight which neighbourhoods they will focus on as they expect transport poverty to be high as they are distant from the city centre and have a limited quality of public transport (Gemeente Nijmegen, 2019). These neighbourhoods (for example Dukenburg and Hatert), were also considered by the interviews in this research as neighbourhoods with a high risk of mobility poverty.

The focus on active mobility highlights potential synergies with other themes as active mobility is durable, active and accessible to almost everyone (Gemeente Nijmegen, 2019). This integral approach is aimed at in the Omgevingsvisies (Gemeente Apeldoorn, n.d.). The paragraphs above highlight that mobility poverty gets some attention in these policy documents, but if this is pronounced even more firmly then this can lead to better uptake of mobility poverty in policy. These policy documents often concern multiple domains. Making reducing mobility poverty a clear goal in these documents can increase communication between different domains and organisations and thus can potentially lead to a reduction in mobility poverty.

5: Conclusion

This research investigated mobility poverty mapping from a practice-driven perspective. The goal of this research was to find out how practice-driven mobility poverty mapping can improve mobility poverty maps and their uptake in policy. The definition of Jorritsma et al. (2018) was used to define mobility poverty. Social justice and the just city (Fainstein, 2009) were the ethical base of this research. Despite increased recent attention to mobility poverty (source), relevant actors able to deal with mobility poverty (a mix of non-governmental and governmental actors from different levels) require both a more clear picture about where and to what extent mobility poverty occurs and what current approaches (“best practices”) there are already available of dealing with mobility poverty (OFL, 2018).

To increase knowledge about mobility poverty mapping and its potential use in policy, this research took a bottom-up perspective. This is rooted in constructivism, which claims that knowledge is constructed socially based on multiple viewpoints (Guba & Lincoln, 1984). Grounded visualization was the key methodological term in this research, where maps are inductively constructed using data that concerns multiple viewpoints (Knigge & Cope, 2006). This bottom-up approach sets this research apart from previous mobility poverty mapping attempts. The development of mobility poverty maps and the interpretation of mobility poverty maps improves when a map is scrutinised to multiple perspectives instead of a one-sided viewpoint. Furthermore, a bottom-up approach was useful in exploring what issues the current uptake of mobility poverty in practice faces and what policy approaches are possible to reduce mobility poverty.

Practice was used to investigate the indicators of mobility poverty, to provide feedback on the mobility poverty maps and to explore current policy approaches of mobility poverty. Semi-structured interviews provided the data. These interviews were conducted with local and regional policy-makers from the mobility and social domain, public transport companies and a regional health organisation, and micro actors as a local Buurtbusvereniging and neighbourhood managers (employed by the municipality) that were aware of issues of inhabitants in a specific neighbourhood. These inhabitants themselves were not part of this research. This would have made this research even more bottom-up. A challenge of including inhabitants in this research is that a large enough sample is required to illustrate the issues of a local community. Therefore, neighbourhood managers were more valuable actors in this research to include the viewpoints of local communities.

In the context of Apeldoorn and Nijmegen, mobility poverty was unknown to most of the interviewees in this research. However, the interviewees were able to understand the concept and were able to mention approaches to reduce mobility poverty that their organisations were undertaking. It was notable that the interviewees mentioned indicators mostly from within their own domains, but they were also able to mention indicators from outside their domains. The working definition of mobility poverty in chapter 2.1.3 does not have to be changed, as the interviewees did not mention any new categories of indicators that affect or are caused by mobility poverty. The most important indicators according to the interviewees were income, health and loneliness as the resulting mobility poverty maps of these indicators matched expectations of the interviewees. This was especially the case for interviewees from the meso and macro levels. The interviewees from the micro-level were able to question the

maps based on their own experience. This highlights that when using mobility poverty maps it is worth questioning the maps by taking into account experiences from the neighbourhood level.

The interviewees expressed some doubt on some of the individual mobility poverty maps, as these were approached using other factors. Further research can improve these individual mapped layers. The combined map layer showed for both cases limited differences concerning mobility poverty risk between different neighbourhoods. This may be a methodological issue that can be improved using a weight for the most important indicators or by filtering target groups that are unlikely to experience mobility poverty (like students) out of the analysis. However, the differences in the data matched expectations somewhat about where mobility risk should be highest. This was the case in both Nijmegen and Apeldoorn. Therefore, they consider the mobility poverty maps as a valuable orientation tool to realize better uptake of mobility poverty in policy.

In-depth surveys or interviews with inhabitants in neighbourhoods where mobility poverty is likely to be high can provide more understanding about where and to what extent mobility poverty occurs somewhere. This requires commitment by policymakers and politicians. The map can lead to more motivation amongst these stakeholders. An integral approach where mobility poverty is dealt with simultaneously with other themes and multiple domains, for example in the new Dutch Omgevingsvisie, can be useful to put mobility poverty more firmly on the policy agenda and can help in orchestrating various measures to deal with mobility poverty that are currently fragmented.

Next to policy recommendations, this research also contributes to current theory of mobility poverty. The participatory, grounded visualization approach in the context of mobility poverty research is currently relatively unexplored. This research shed light via a practice-based viewpoint on mobility poverty indicators, mobility poverty maps, current approaches related to mobility poverty and potential use of mobility poverty maps in policy. The iterative nature of grounded visualization was present in this research. Originally, the mobility poverty map consisted of 10 instead of 9 indicators. The indicator “understanding transport options” was originally in this analysis, which was approached using age and level of education. It was assumed that the higher one’s level of education, understanding travel options would have been easier. It was also assumed that the higher one’s age, understanding travel options would have been easier. However, these assumptions are not always true. For example, elderly people often have limited digital skills. The interviewees in this analysis, therefore, doubted the quality of this layer, due to which this layer has been removed from the analysis. This highlights that the quality of the mobility poverty map can be improved by scrutinizing it with practice.

The grounded visualization approach contributes to current knowledge about mobility poverty mapping. Specifically, the bottom-up approach contributed to the quality of the indicator list, which turned out to match current research on indicators. Furthermore, the bottom-up approach also informs about current approaches to reduce mobility poverty maps and whether mobility poverty maps or other research into mobility poverty can help the uptake of mobility poverty in policy. However, not only theory of mobility poverty mapping benefits from grounded visualization, but the grounded visualization approach also

highlighted the benefit of a bottom-up approach for future use of mobility poverty maps in practice. The feedback interviews showed that a grounded visualization approach helps in interpreting and criticizing the map results (see the previous paragraph). Furthermore, including practice also highlights that a multidisciplinary and multilevel approach is required to develop effective policies to reduce mobility poverty, where mobility poverty maps are potential tools to provide the required knowledge. This fits the view of Ghose and Huxhold who state that maps can present a baseline of information to relevant stakeholders, and can in that way assist and inspire the creation of new policy (2002). The grounded visualization approach that sets this research apart thus benefited both theory about mobility poverty maps and knowledge about the benefits of a bottom-up approach in reducing mobility poverty in general. This research demonstrated that mobility poverty maps can be a valuable tool to reduce mobility poverty.

6: Discussion

In this research, it is claimed that the contribution of this research to current knowledge of mobility poverty mapping is the grounded visualization approach. To what extent matches this research the inductive and explorative components of grounded visualization (Knigge & Cope, 2006)? First, only 10 interviews were conducted in this research. From some organisations, only 1 interview was conducted. More interviews from the same organisations might have led to a clearer overview of what approaches this organisation already has in dealing with mobility poverty. Nevertheless, actors that already were active with mobility poverty and thus able to mention a lot of these approaches have been spoken to. Several other viewpoints were also not included in this research, like inhabitants or housing associations. Despite the practical reasons that caused this, this may have impacted the results of this analysis. However, the conducted interviews did result in a balanced mix of viewpoints, resulting in a balanced mix of results. Care should be taken in future research to not put too much emphasis on one level. This research avoided this. But, all in all, conducting more interviews might have improved the quality of the end result.

Second, this research might be somewhat less grounded as intended as sometimes an example indicator was given to the interviewees to clarify the question of which indicators they think are important concerning mobility poverty. In chapter 4 it is stated that this might only slightly impacted the order in the indicators list (table 3). However, it might have also led the interviewees to come up with related indicators. This cannot be excluded.

Multiple suggestions for further research can be made to make mobility poverty more tangible and to enable it to be put more firmly on the political agenda. The first is to compare this research with a different geographical context. This research was conducted in the Netherlands. However, it may well be that different indicators are regarded as important in a different country. Also, some concrete recommendations already made in this research like the buurtbus might not work in a different country. The recommendations and indicators are bounded to the Dutch context. It is questionable whether the results can be transferred to a different geographical context. Therefore, further research in a different geographical context can be conducted to gain more understanding about the transferability of this research to a different geographical context. Within the Dutch context, the research findings (indicators, recommendations) can however be transferred to a different region or municipality as they are present in the same country. This research was conducted in Apeldoorn and Nijmegen, but it could have been conducted in different municipalities in The Netherlands.

The most important remark regarding this issue of transferability is that a mobility poverty map should be developed and interpreted in cooperation with (local) stakeholders. A bottom-up approach can question the presented mobility poverty maps, which is necessary as the maps show risks and not absolute cases of mobility poverty. Also, actors from practice are crucial to consider which potential approaches are possible within their organization or geographical context and how they can motivate local politics to deal with mobility poverty. If both these actors from practice and politicians are motivated to deal with mobility poverty, mobility poverty might be reduced in the future. The fact that the interviewees in this research were enthusiastic about the term reflects that they can be motivated to see the relevance of this topic.

As mentioned several times in this research, some of the layers in the mobility poverty map had to be approached using other factors. Despite that this can be regarded as best practice, this does affect the quality of the mobility poverty map (see chapter 4.2.3). Further research is required into how these approached indicators can be improved. Some interviewees pointed out that more quantitative information regarding mobility poverty can make mobility poverty more tangible for them and politicians. A survey or interviews with inhabitants for some neighbourhoods where inhabitants are asked directly about the indicators that are approached in this research can be a form of further research. It will be interesting to investigate whether this leads to a different picture of mobility poverty than the maps developed in this research would suggest.

Finally, is dealing with mobility poverty really needed? The interviewees in this research had different opinions about this. This research highlighted, using the Just City as an ethical foundation, that mobility poverty should be reduced. Martens (2015) for example mentions that the ultimate goal of the transport network should be to move all individuals. However, despite this importance, there are other social pressing themes where choices have to be made. Politicians and policymakers are the ones who make these choices. This research only highlights the importance of dealing with mobility poverty. Mobility poverty can most effectively be reduced (somewhat) if it is combined with other social pressing themes (like durability or sustainability) in an integral approach, where it is ultimately up to the policymakers and politicians to decide how much they focus on this topic. An approach exclusively aimed at dealing with mobility poverty is undesired as politicians and policymakers might still regard these other issues as more important. An integral approach is more effective in putting mobility poverty on the policy agenda. However, also in an integral approach care should be taken that in this combining with different themes, mobility poverty is not overlooked. The most effective way to put mobility poverty on the policy agenda can be investigated in further research. Finding out this was not the goal of this research. The participatory approach of this research only scratched the surface of this by highlighting the importance of mobility poverty and the development and potential use of mobility poverty maps, which increases the local stakeholders' decision-making capacity (Akbar et al., 2021). In other words, this research aided in acquiring a more clear picture of where and to what extent mobility poverty occurs that is needed according to the OFL (2018).

7: References

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8: Attachments

Attachment A: Potential indicators of mobility poverty

Table A1 shows the indicator list developed prior to the interviews in this research, based on several authors.

Indicator	Description	Type of data	Author
<i>Transport options</i>			
Owning a motorized vehicle	Without a motorized vehicle, it is challenging to reach destinations	Open data	Kampert et al. (2019); Martens en Bastiaansen (2019); Jorritsma et al. (2018)
Owning a bike	Without a bike, it is challenging to reach destinations	Open data	Kampert et al. (2019)
Distance to the nearest bus stop	If this distance is large then it is challenging to reach destinations. Timetables can also be included in this indicator	Open data	Kampert et al. (2019)
Distance to the nearest train station	The scope of destinations becomes larger when using the train compared to the bus. If this distance is large then it is challenging to reach destinations. Timetables can also be included in this indicator	Open data	Kampert et al. (2019)
Accessibility of public transport	Aspects as safety (subjective) and user-friendliness can increase the attractiveness of public transport	Not open data, interviews may be a potential data source	Lucas (2012); Jorritsma et al. (2018)
Public transport fares	If this is high then it can decrease the attractiveness of public transport	Open data	Jorritsma et al. (2018)
<i>Spatial circumstances</i>			
Distance to supermarket	Living closer to the supermarket reduces the risk of mobility poverty	Open data	Kampert et al. (2019)
Distance to healthcare	Living closer to healthcare reduces the risk of mobility poverty. A distinction can be made between for example	Open data	Lucas (2012); Jeekel &

	general practitioners and hospitals		Martens (2017)
Distance to education	Living closer to education reduces the risk of mobility poverty A distinction can be made between for example primary and higher education.	Open data	Lucas et al. (2016); Jeekel & Martens (2017)
Distance to family and relatives	Being unable to visit family and relatives negatively impacts social wellbeing. Furthermore, these people can help in reaching destinations.	Not open data, also a challenge due to ethical reasons	Kampert et al. (2019)
Distance to work locations	Living closer to work locations reduces the risk of mobility poverty	Open data. But how to define work locations?	Martens en Bastiaansen (2019)
<i>Social-economic circumstances</i>			
Household income	In general, the lower the income the higher the risk of mobility poverty. There are exceptions however, such as students	Open data	Kampert et al. (2019); Jorritsma et al. (2018)
Social-economic circumstances	These circumstances have some influence on mobility poverty. An example is the life phase	Open data (for example age)	Kampert et al. (2019); Jorritsma et al. (2018)
Migration background	Understanding the native language makes it easier to understand how to travel in that country	Open data	Kampert et al. (2019); Lucas (2012)
Public Health	Having bad physical and mental health makes it challenging to reach desired destinations	Potentially difficult to find. In the Netherlands, this may be investigated by looking at WLZ or WMO payments	Kampert et al. (2019); Jorritsma et al. (2018)
Household composition	People may get help from people from their households	Open data	Kampert et al. (2019); Jorritsma et al. (2018)
<i>Competences</i>			
Skill in cycling	The better one's skill in cycling, the less risk of mobility poverty	Data may be challenging to find	Kampert et al. (2019)
ICT skills	With better ICT skills, more activities can be performed online which results in a reduction of mobility poverty risk	Data may be challenging to find	Lucas et al. (2016)

Acquired skills related to understanding rules and regulations	Having a driver's license or understanding rules and regulations related to transport reduces the risk of mobility poverty	Having a driver's license is open data, understanding rules and regulations may be challenging to find	Jorritsma et al. (2018)
Acquired skills related to understanding how the public transport system works	Knowing this makes it more comfortable to travel with these modes of transport. If people do not know this, they might be afraid of public transport	How to get tickets, finding and understanding schedules, how switching trains data may be hard to find	Jorritsma et al. (2018)
Skill in fixing transport modes or understanding how to let them be fixed	Prerequisite for travel	Data may be hard to find	Jorritsma et al. (2018)
<i>Emotional circumstances</i>			
Subjective traffic safety	Experiencing traffic as unsafe might be a reason to choose different modalities, different times of travel or rather not to travel at all.	According to the SWOV (2012), there is no open data or quantitative base for this indicator. But it is assumed that this aspect influences transport choices.	SWOV (2012)
Social safety	Can influence movements of people	Data may be hard to find	CROW (2007)

Table A1: Potential indicators for the mobility poverty map

Attachment B: Interviewees

Table B1 shows the interviews conducted in this research.

Interview	Organisation	Domain	Times participated
1 (MG)	Province of Gelderland	Mobility	Both interviews
2 (MC)	Connexxion	Mobility	Both interviews
3 (SGGD)	GGD Gelderland-Zuid	Social	Both interviews
4 (MU)	Buurtbusvereniging Ugchelen	Mobility	First interview
5 (MA)	Municipality of Apeldoorn	Mobility	Both interviews
6 (SA)		Social	Both interviews
7 (MN)	Municipality of Nijmegen	Mobility	Both interviews
8 (SN)		Social	Both interviews
9 (MAG)	Area manager Apeldoorn (gebiedsmanager)	Mobility	Both interviews
10 (SNO)	Neighbourhood employee Nijmegen (opbouwwerker)	Social	Both interviews

Table B1: Interviews of this research

Attachment C: Calculation example GIS

This attachment presents the steps of how the risk of a neighbourhood for a given indicator (in this case income) is calculated in this research.

Step 1: Define for the individual indicator three risk groups. Example: The indicator income has the following risk groups: Risk 3 (high) = % households below the social minimum. Risk 2 = % households between the social minimum and the 40% households with low incomes boundary. Risk 1 (low) = % households below the 40% with low incomes boundary. The risk categories are based on the available data, in this case, the Wijken and Buurten monitor of the CBS (CBS, 2019) (see chapter 4.2.3).

Step 2: Calculate the risk per neighbourhood on these individual indicators. Example: Consider the indicator income in neighbourhood A. Suppose that we have the following information (table C1):

Risico	1 (low)	2	3 (high)
Percentage households	40%	40%	20%

Table C1: *Incomes of households within example neighbourhood A*

The income risk for neighbourhood A can be calculated as follows:

$$0,40 \cdot 1 + 0,40 \cdot 2 + 0,20 \cdot 3 = 1,8.$$

Repeat this step for every neighbourhood in the analysis. Repeat this for every indicator in the analysis. It is important that each neighbourhood scores on every indicator between 1 (low) and 3 (high) to allow the development of a combined layer that shows the mobility poverty risk. Weights can be used when combining different indicators into this total mobility poverty risk layer.

Attachment D: Interview guide 1 (prior to mapping mobility poverty)

This attachment presents the interview guide for the first round of interviews. The questions asked during the interviews might depart somewhat from this guide. However, care has been taken during the interviews that all these questions were discussed.

Start:

- [Welcome] Thank you for participating in this research. Let me introduce myself: I am Evert-Jan, a master's student in urban and regional mobility at the Radboud Nijmegen. I am doing my internship at Mobycon, where I am doing my master thesis on mapping mobility poverty. The subject really appeals to me as it is socially relevant. But it is a challenge. There is still much to be gained in mapping mobility poverty.
- [Rights interviewees] Before the introduction I would like to point out some practical matters: The interview will be recorded. You have the right to stop this interview at any time. You have the right to see my transcripts after the interview, where you can

indicate that you would rather not share certain things. The data will be deleted before the next academic year.

Introduction:

- In this section, the interviewees were informed about the aims and organization of this research.

Warm-up questions:

- Are you familiar with mobility poverty? If not, the researcher will explain this to the interviewee.
- What is already being done to reduce mobility poverty within your organisation? To what extent do you deal with mobility poverty yourself?

Sensitive questions:

- Is mobility poverty for you an important topic? Why is that?
- Is this noticeable in the approach of dealing with mobility poverty within your organisation? In what way? Do you regard this approach as positive or negative? Why is that? Can this approach be improved in the future?
- [Indicators] What are, according to you, attention points when dealing with mobility poverty? (this might point to some indicators already).
- What are according to you important factors/indicators that point to mobility poverty? (the interviewee can be presented some indicators as an example to guide them in the right direction, for example income or health). Can you rank these on importance from 1 to 5?

Final questions:

- What do you think of the list of indicators that we just discussed? Are all important indicators in this list?
- Are you satisfied with the ranking you made (considering that this ranking has been made)? Which indicator is most important? Which indicator is least important?
- Do you think that it is realistic to map these indicators?
- Is there anything else you would like to mention? What did you think of the interview, do you have any points for improvement? Thank you very much for your participation in this interview!

Attachment E: Interview guide 2 (after mapping mobility poverty)

This attachment presents the interview guide for the second round of interviews. The questions asked during the interviews might depart somewhat from this guide. However, care has been taken during the interviews that all these questions were discussed.

Start:

- [Welcome] Thank you for participating in this research again.
- [Rights interviewees] Before the introduction I would like to point out some practical matters: The interview will be recorded. You have the right to stop this interview at any time. You have the right to see my transcripts after the interview, where you can indicate that you would rather not share certain things. The data will be deleted before the next academic year.

Introduction:

- In this section, the interviewees were once again informed about the aims and organization of this research.

Warm-up questions:

- You have mentioned the following indicators as being important indicators of mobility poverty. Can you recall why you mentioned these?
- The indicators in green have been mapped. These are not mapped in this research (explain why). Will this influence the mobility poverty map?
- What do you think of the presented maps of the individual indicators? Do these maps match expectations that you have had before the maps were shown to you?
- This map layer shows the total mobility poverty map. Do these maps match the expectations that you had before it was shown to you?
- Have you seen any areas for improvement on the map? Does this have to do with the visualisation, the quality of the data or are there indicators missing in the analysis in your opinion?

Sensitive questions:

- What are current approaches to reduce mobility poverty, for example within your organisation? Can these approaches be improved in your opinion and if so, how?
- Would you like a clearer picture of mobility poverty? Would you like to have for example survey data?

Final questions:

- Are you satisfied with the presented mobility poverty maps? Do you think the maps be of value for you considering reducing mobility poverty?

- Is there anything else you would like to mention? What did you think of the interview, do you have any points for improvement? Thank you very much for your participation in this interview!