Job (in)accessibility in the Parkstad region

About the impact of transport affordability on accessibility for low-income households and the unemployed

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TU Delft

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by

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Preface

I could write the longest preface in history, for there are so many people I am grateful to. The journey has been long and without the support of my family, friends and colleagues, I would not be where I am now.

I would like to thank my **Graduation committee** for their guidance and providing me with feedback during these past 6 months. A special thanks go out to **Koen** and **Jan Anne**. If it hadn't been for them, I would probably still be analysing my data. I have had moments where I no longer knew where I was going and insecurities gained on me, but both of you have been nothing but patient, understanding and supportive. I left each meeting more optimistic than I entered and it meant the world to me.

I would most definitely like to thank my colleagues at **Grenspaal12** for the opportunity to do my master thesis with them and for giving me the freedom to make it completely my own. I am proud to be part of your team.

My deepest gratitude goes out to my husband, **Jelle**, who stood by me all these years and has been my biggest fan all along. I don't know how I will ever repay you for your unconditional love and support. I could not have done this without you. **Zeb** and **Polke**, you both are the sunshine to my days. I will continue to make this world a better place, for you.

L. Zweers
Bunde, May 31 2023

Summary

In the past few years, multiple research institutions in the Netherlands published reports on accessibility and transport poverty in the Netherlands. In these reports, they warn of declining accessibility for people living either in rural or suburban areas. As the locations of facilities and jobs have been particularly oriented to being accessible by car and, in addition, public transport has been increasingly reduced, a high degree of car dependency has been created. This has major consequences in particular for people who cannot afford a car or who are physically unable to travel by car, posing the threat of transport poverty for these target groups. In this regard, transport poverty means being excluded from participation in activities as a result of not being able to reach these activities. This can ultimately also contribute to more socio-economic consequences, such as unemployment as a result of the inaccessibility of jobs.

What these aforementioned reports have in common, is that they suggest accessibility standards and working with these standards to improve accessibility for all, taking into account all modalities and preventing transport poverty. Already in 2015, Karel Martens proposed a method for designing fair transportation systems, in which threshold values are included to allow for setting such accessibility standards. His method stems from a sufficientarism approach; if it is agreed that the threshold value is a minimum accessibility to which all people are entitled, then all groups below this value suffer from insufficient accessibility. He used the case of Amsterdam as his proof of concept, showing how the method can be applied. Ever since, other researches added case-studies and confirmed the usefulness of this method. What these studies have in common, however, is the focus on travel time as the main measure for the accessibility, despite transport affordability being an important aspect in the discussion about transport poverty, especially when it comes to accessibility for low-income groups. A new case study in which travel costs are part of the analysis as well, would add a new and interesting dimension, since it is expected that the accessibility for these specific target groups is even lower due to a limited travel budget.

Various studies have elucidated that the risk of transport poverty and poor accessibility is mainly located outside major cities and in rural areas, since car dependency is in particular high in these regions. Since research in such an area has not yet been done, a most interesting case study will be provided with the Parkstad region. Multiple factors make this region interesting to study in terms of accessibility and transport poverty. As in similar border regions, this region is experiencing population decline, which is associated with the decrease of amenities and, consequently, decreasing accessibility. In addition, income here is on average the lowest in the Netherlands and the unemployment rate the highest, creating a multitude of vulnerable target groups for social exclusion. For instance, in the municipality of Heerlen, almost 21% of households are part of the 10% lowest income groups in the Netherlands, living on average from a monthly (standardized) income of 830 euros. The working population in the Netherlands has been above 70% for the past 5 years, but is only 62% in the Parkstad region, and there are neighbourhoods where the job participation rate is as low as 38%. In addition, if the modal split in this region is also considered, it is found that car use in this region is also the highest in the Netherlands (60.7% versus 46.3%), which could indicate car dependency.

The mobility visions of various municipalities in the region show the desire to break through this pattern of travel behaviour and move people towards more sustainable transport options such as the bicycle or public transport. This transition provides a momentum, not only to design a more sustainable, yet also a more inclusive transport system; improving accessibility by other modes of transport than car, doesn't just mean adding a sustainable alternative for those who are already mobile, but also means tackling car dependency and including those who are suffering from inaccessibility.

Even though the Parkstad region is on many levels a region with a high risk for transport poverty, the municipalities lack the knowledge about the accessibility in the region, its distribution and which target groups suffer the most from insufficient accessibility for each mode. Due to the high unemployment rate and low incomes and the assumption that it is harder for people in this region to improve their economic situation, this study investigates the job accessibility in particular.

The main research question for this thesis is:
'To what extent can a job accessibility analysis from a sufficientarism perspective help identify transport poverty and guide municipalities in the Parkstad region in designing a more inclusive transport system for low-income households and the unemployed?'

The main objective of this research is to demonstrate the applicability of Martens' method with the extension of travel costs and to reveal the impact of transport affordability on the accessibility for low-income households and the unemployed in the Parkstad region. Furthermore, with the results of the analysis the municipalties are provided with meaningful results which they can use in future transport system design or transport policy. For this research, the methodology has been disaggregated into 4 phases.

1. Data preparation - Building the QGIS-model and data gathering.
2. Measurement - Calculating both the potential mobility and accessibility for all neighbourhoods in the region.
3. Analysis - Analysing the result of the previous phase, by means of a specific framework, calculating and ranking shortfall in job accessibility for all neighbourhoods and assigning this to specific target groups.
4. Evaluation - Performing a sensitivity analysis, identifying the causes of the transport poverty and identify meaningful interventions.

The QGIS model is based upon a fine-grained neighbourhood classification from the Dutch Bureau of Statistics (CBS) and allowed the region to be disaggregated in 199 zones, for which both socio-economic data as well as the number of jobs is known. Then, for each neighbourhood, both the Potential Mobility Index (PMI) and the job accessibility were calculated. The PMI is an indicator that expresses the quality of the transportation network and services by dividing the aerial distances to all other neighbourhoods by the travel times to those neighbourhoods. This resulted in a list of four potential mobility indices for each neighbourhood, which correspond with walking, cycling, public transport and car respectively.

The PMI calculations show that the average speed in the region to travel to all neighbourhoods by car, public transport and bicycle is 28.6, 8.4 and 14.2 km/h respectively. In other words, to cover the same aerial distance, it takes you on average more than three times as long by public transport when compared to car and cycling allows you to travel faster than public transport. Public transport calculations assumed not only buses but also trains, but since there are only 13 train stations in the region, the vast majority of neighbourhoods rely on buses, of which the speed is much lower. In addition, the total travel time by public transport includes, if applicable, the time needed to walk to bus stops and stations and transfer time. It has been verified that the model takes into account the height differences in the region, which can make a significant difference for travel times. If the average potential mobility index for all modalities, which is 13, were the standard, it is not met by public transport in any of the neighbourhoods, thus the public transport system scores insufficiently throughout the region.

Subsequently, a cumulative accessibility measure was used to determine how many jobs one can reach from a specific neighbourhood within a travel time limit of 30 minutes. There are a total of over 102 thousand jobs in the region, with a number of locations standing out where most jobs are located. These include the centre of Heerlen, centrally located in the region, but also a number of industrial estates located especially along the motorway and connected ring roads. Within 30 minutes, from each neighbourhood in the region, all 102 thousand jobs are available by car. By public transport, this is more than four times less on average. Accessibility by bicycle stands out in a positive sense; with an average accessibility of over 63 thousand jobs, you can reach more in the region by bicycle than by public transport. All neighbourhoods in the region from which the residents can reach more than 50% of all jobs by public transport, live in the vicinity of business parks or the city centre of Heerlen, which

are the epicentre of all jobs. In none of the neighbourhoods in the region is coverage by bicycle 100%, but there are neighbourhoods that achieve coverage as high as 92%, by public transport the maximum accessibility achieved is 67%.

Following this analysis, the calculation of the job accessibility with a cumulative measure was carried out again, only this time with a travel budget of 3 euros, the budget that a low-income household can spend on transport on average per day. To determine this maximum budget, statistics from the CBS on household spending was used, which show how much people from specific income groups spend annually on transport and to assume for low-income groups that they do not spend more than they can spend. For both walking and cycling, the travel costs were assumed to be zero, for car and public transport a price per kilometer was used to calculate the travel costs between all neighbourhoods. The price per kilometre for cars was provided by the National Institute for Budget Information (Nibud) and the price per kilometre for public transport was provided by the operator itself (Arriva).

Including the travel costs particularly impacts job accessibility by car, which is now down by 72% compared to the analysis which included only travel times. The decrease of the job accessibility by public transport is negligible (-0,24%) although the accessibility by car remains somewhat higher than by public transport. Job accessibility by car for low-income households is about a quarter of job accessibility by car for middle- and high-income households. Job accessibility by public transport, cycling and walking is the same for all. This was also to be expected for the active modes, since they are not sensitive to travel costs. However, the travel budget apparently also has no effect on job accessibility by public transport; what is within the range of 30 minutes travel time, is also within the range of a 3 euro travel budget.

Figure 1 shows how travel costs affect the job accessibility by car for low-income households and what accessibility by public transport is by comparison. The average job accessibility by car and public transport are not that different, but from these maps its evident that less neighbourhoods have sufficient job accessibility by public transport than by car.

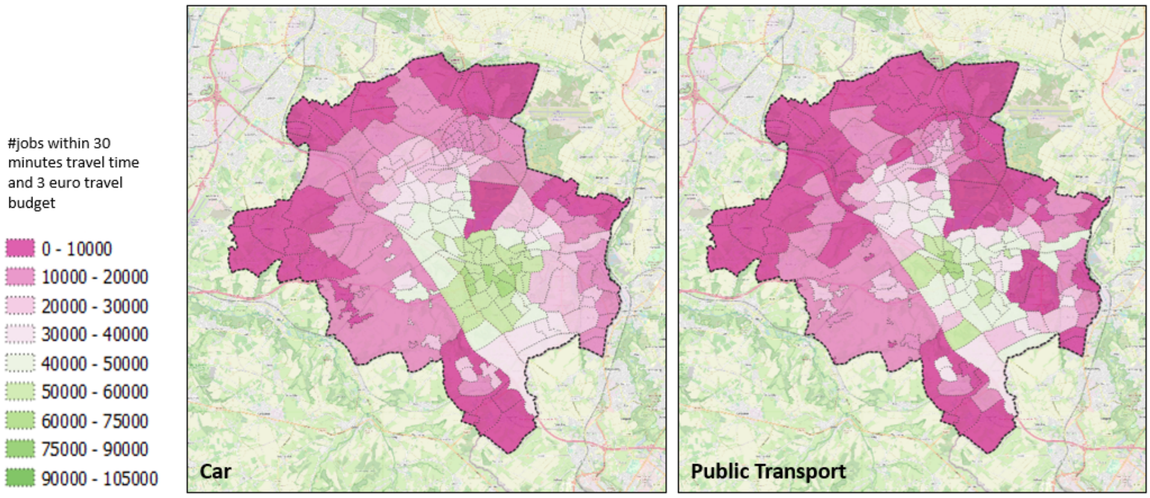

Figure 1: Number of jobs within 30 minutes travel time and 3 euro travel budget by car (left) and public transport (right) *(©OpenStreetMap, created with TravelTime API)*

The values found for all neighbourhoods, were used to build a 'Potential Mobility and Accessibility' framework, as presented in figure 2. Each color in this graph represents a mode and each dot a neighbourhood. On the y-axis is the number of jobs one can reach from a specific neighbourhood and the x-axis shows the related PMI. In this graph, two red dashed lines are added and suggest accessibility thresholds of 25% and 50% of all jobs.

With the help of these threshold values, neighbourhoods with job accessibility below these values can be identified. Since socio-economic data for all neighbourhoods is known, the number of households

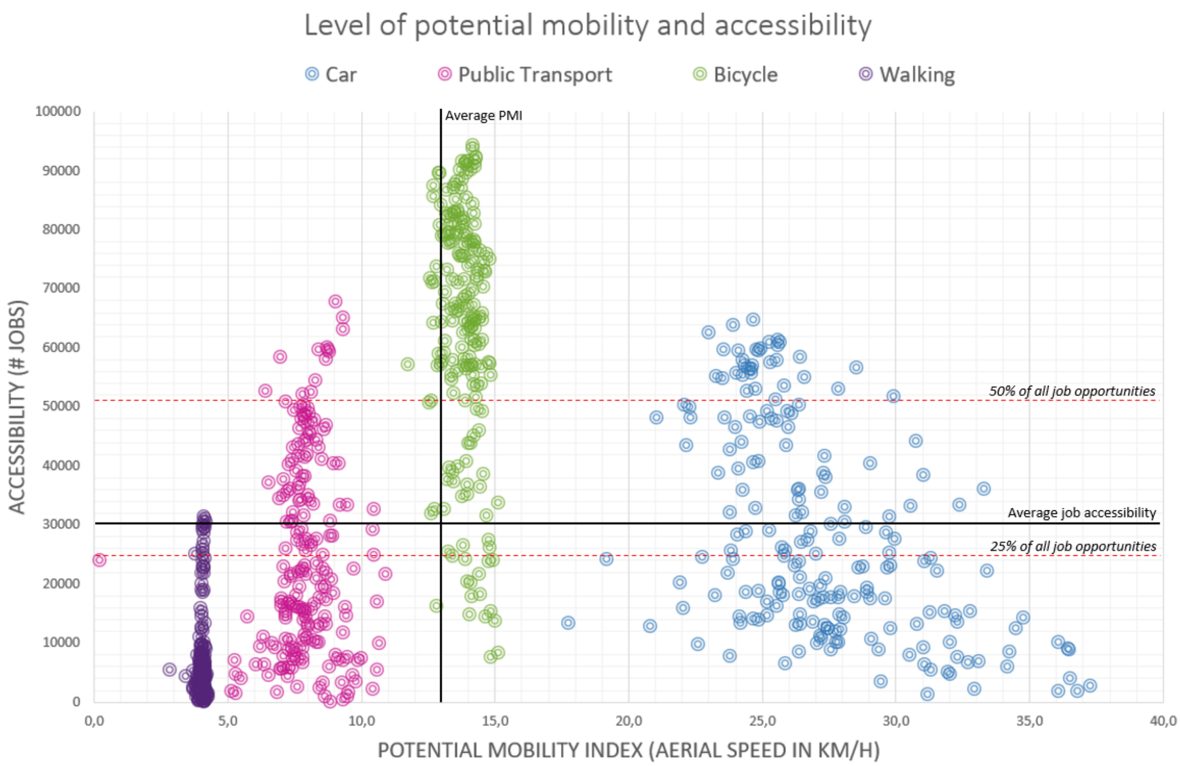

Figure 2: Potential Mobility and Accessibility graph - number of jobs within 30 minutes and 3 euro travel budget

with sufficient accessibility can be distinguished. The table in figure 3 summarizes this for the complete region. If the threshold value is 25%, for public transport between 53% and 58% of the more vulnerable target groups have sufficient job accessibility. This number decreases significantly with a threshold value of 50%, no more than 11% of the residents have sufficient accessibility by public transport. However, in comparison, middle or high income households have even lower job accessibility by public transport. Independent of threshold values, this can be concluded for accessibility by bicycle as well, a larger share of the vulnerable target groups have sufficient job accessibility by bike. This can be explained by the fact that the more rural municipalities have less accessibility by these modes and contain a smaller share of households with low income or unemployed residents. Household with higher income level can compensate for this low level of accessibility, by travelling by car, for which they have 100% of all jobs within reach.

	THR. 25% jobs			THR. 50% jobs			THR. 75% jobs		
	TT30+TC3			TT30+TC3			TT30+TC3		
Target group	PT	CAR	CYCLING	PT	CAR	CYCLING	PT	CAR	CYCLING
Lowest 10%	58%	61%	96%	11%	23%	84%	0%	0%	41%
Low income	55%	57%	94%	9%	22%	82%	0%	0%	39%
Unemployed	53%	53%	93%	8%	20%	81%	0%	0%	37%
	TT30			TT30			TT30		
Target group	PT	CAR	CYCLING	PT	CAR	CYCLING	PT	CAR	CYCLING
Middle income	51%	100%	91%	6%	100%	79%	0%	100%	36%
High income	45%	100%	87%	4%	100%	73%	0%	100%	33%

Figure 3: The percentage of people/households with sufficient job accessibility for threshold values of 25%, 50% and 75%

The 'Accessibility Sufficiency Index' (ASI) can be calculated, by multiplying the accessibility shortfall by the share of households suffering from this insufficiency. The ASI was used to determine how each neighbourhood contributes to the overall insufficiency of job accessibility in the region, by dividing the neighbourhoods' specific ASI by the regional ASI. This made it possible to identify specific neighbourhoods, for which the share of the insufficiency for low-income groups in the region is the highest. Especially areas close to the border with Germany, in the municipalities of both Kerkrade, Landgraaf and Brunssum stood out (negatively). The maps in figure 4 show the spatial pattern of the low job accessibility with public transport, whereas the map on the left is for all households and the map on the right for low income households.

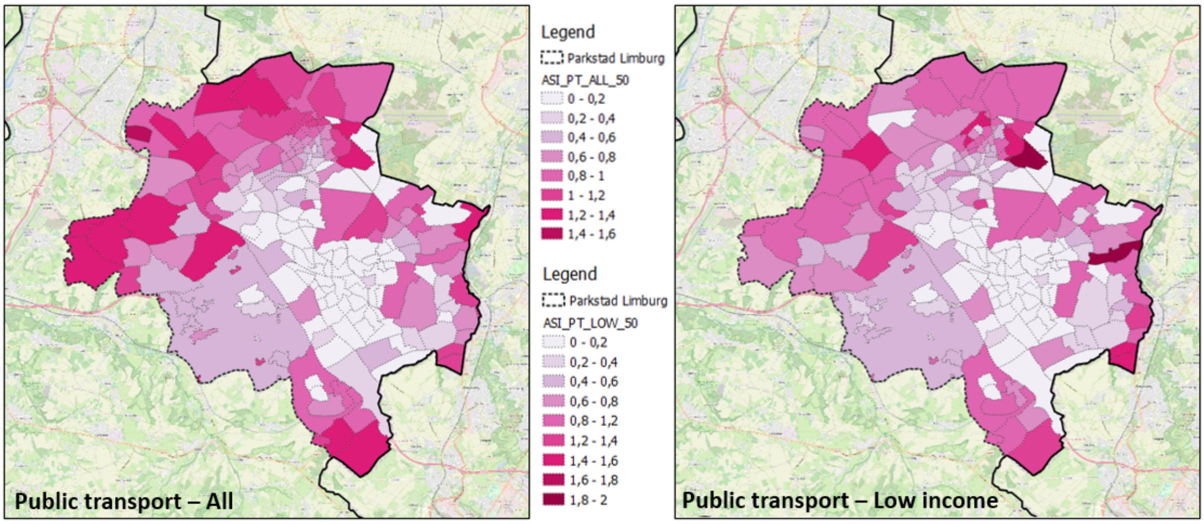

Figure 4: The changing spatial pattern of accessibility poverty by public transport for all households (left) and low income households (right) *(©OpenStreetMap, created with TravelTime API)*

After these analyses, a number of sensitivity analyses with travel costs and travel budget were conducted to test the results of accessibility with each modality. What is striking is that at least 63% of all jobs can already be reached within 15 minutes' travel time by car, but this requires a minimum travel budget of 5 euros, which is inaffordable for the majority of low-income households. Within their travel budget, accessibility to at least 60% of jobs in the region is only feasible with at least 45 minutes' travel time by public transport or 30 minutes' cycling. 100% coverage is already achieved by car with 30 minutes travel time, while 99% coverage is achievable by public transport and bicycle with a travel time of 90 and 60 minutes respectively. Taking into account only the travel budget, 100% coverage by car is possible with €12 and for public transport with €6. Accessibility by car is clearly limited by travel costs for low-income groups and with public transport the travel times are in particularly decisive.

The main conclusion on the overall job accessibility is that accessibility by public transport is low, for all. By car, the accessibility is really high, but for low-income groups, which are restricted by low travel budgets, their job accessibility by car is as low as by public transport. However by bicycle, for all except those living on the edge of the region, the potential job accessibility is high and more competitive with car. Furthermore, even though travelling by public transport is less expensive than by car, within the same travel budget of 3 euros, the accessibility is on average equal. And even more neighbourhoods have sufficient accessibility by car compared to public transport if the travel costs are included. Although the job accessibility by public transport is mostly limited by travel times, travel costs do influence the accessibility, even more for travel times larger than 45 minutes.

In a series of interviews with officials from the municipalities of Beekdaelen, Heerlen, Kerkrade and Brunssum, the results of the study were presented and evaluated. From these interviews it appears that in some municipalities the subject of transport poverty is high on the agenda and the interest in the results of this analysis was genuine. In the municipality of Landgraaf a motion recently passed, which will soon make free public transport available to people with an income up to 140% of the social minimum. If the aim is to increase the chance of a job, only providing free public transport is probably not the solution, given the performance of public transport in this region. An important detail here is that the free pass is only valid in off peak hours, which means that it is probably not suitable for all jobs. That the potential of the bicycle was evident from the results confirmed for them that there are opportunities to further improve accessibility by bicycle and compete with car accessibility. In this discussion, the current modal split of the region was brought up, which shows a low share of travelling by bicycle for commute (13% compared to a national average of 24%). Explanatory arguments for this are the high car accessibility and the differences in altitude in the region, which results in extra physical effort for people to travel somewhere by bicycle. E-bikes are considered a part of the solution in this regard, but these are to expensive for low-income households and the question is to what extent people also have suitable parking facilities for such an expensive bicycle. In the Parkstad region, there are already several hubs of an e-bike sharing system. Increasing the supply of hub locations (also specifically on job locations) and making these e-bikes accessible for people who experience low accessibility would increase their job accessibility. Perhaps a free pass for these e-bikes sharing systems could improve job accessibility more than a free pass for public transport would.

During these meetings, ideas emerged for more research and expansion of this research. Officials of the municipalities were in particular interested in expanding the research area, since including other employment locations in South-Limburg, most likely affect the job accessibility for municipalities located along the Western border. And due to the variety of socio-economic challenges in this region, an evaluation of the accessibility of other amenities was considered important as well. Also, the municipality of Brunssum has a mobility vision of a '10 - minute city', setting a threshold value of 10 minutes. This methodology could help identify neighbourhoods that fall below this threshold value and help this municipality in reaching her goal.

Recent research on the perception of accessibility indicated that people living in areas with lower accessibility don't necessarily perceive their accessibility as less. One of the explanatory arguments for this is related to residential self selection; people consciously choose to live somewhere which matches their preferred mode of transport. For some neighbourhoods in the region this is true, according to officials in the more rural municipality of Beekdaelen. People choose to live there, despite low accessibility, because they get a quiet living environment in return for this. The question is whether this applies to people with a low income; due to shortage in housing and the increase in house prices, one could argue that residential self selection is not applicable here. From the perspective of mobility poverty, there are also groups with limited accessibility that cannot be identified with the statistics provided by the CBS. This term is related to people who experience low levels of accessibility, due to a lack of sufficient transportation alternatives. This can be related to a physical disability or a more situational limitation, for people who for example depend heavily on a partner, which has also been confirmed by recent qualitative research.

The aim of the research was to demonstrate the applicability of Martens' method with the extension of transport costs. This study shows that it is possible to include the travel costs by means of a travel cost budget into the analysis and thus capture the accessibility of low-income households and the unemployed. This research proofed that, up to now, the accessibility by public transport for low-income households and the unemployed has been overestimated. Although the travel times have a larger diminishing effect on the job accessibility by public transport, the travel budget opposes a limitation as well.

The methodology can guide municipalities in identifying transport poverty in the region. The policymakers also saw opportunities to use these results to prioritise policy, value possible solutions (such as free public transport), identify neighbourhoods where further research would be justified and to promote bicycling. The inaccessibility of jobs can hinder people from finding or keeping employment or improving their economic status. Since the unemployment rates in this region are so high and the accessibility to jobs by public transport (and car) is very limited for the unemployed, it is justified to further explore to what extent there is a correlation between the two. Since there can be a variety of reasons for experiencing limited accessibility, beyond travel times and costs only, it is recommended to conduct qualitative research into this matter and involve the people affected, also to find the reasons behind the current travel behaviour. I highly recommend the municipalities to use to results to explore the feasibility of the proposed interventions and improve the job accessibility in the region for those who need this the most.

List of Figures

Contents

1 Introduction

In October 2022, the Netherlands Environmental Assessment Agency (PBL) published a report on accessibility in the Netherlands (Bastiaanssen and Breedijk, 2022). Currently, accessibility in the Netherlands is not yet measured structurally, despite there being several accessibility measures and a lot of data available these days to map it properly. The first results of the research done by PBL, show that in the big cities, there is higher accessibility by all modalities, due to the close proximity of amenities and jobs. People living in suburban areas or more rural areas have the lowest accessibility. People who have access to a car experience the highest accessibility in any area, especially compared to those who depend on public transport.

Already two years prior to this report, the Council for the Environment and Infrastructure (2020) wrote a report on accessibility related to urbanization and they warned about the diminishing accessibility for people living outside of cities. Both reports mention the need for developing accessibility standards, as this would help operationalising the concept. Even though policy makers often talk about improving accessibility, a lack of these standards, structural measuring and specific objectives have prevented the actual improvement of peoples accessibility (Bastiaanssen and Breedijk, 2022).

Several reports published in the past few years by research institutes in the Netherlands show that the issue is also on the agenda at government level and that the relationship between broad welfare and accessibility is also evident. The concept of transport poverty is also used several times in this context; experiencing social exclusion as a result of the absence of accessibility.

1.1. Problem statement

Recent research by PBL shows that in the municipality of Heerlen several neighbourhoods can be identified where there is an increased risk of transport poverty (Nijland et al., 2019). In the municipality of Heerlen, car use is high, and the use of both bicycles and public transport is rather low compared to the rest of the Netherlands. Not surprising, according to Ernst Adriaanse (2022), as the city is also very well accessible by car and has been designed traditionally to do so. Public transport here is also limited; recently, bus lines were removed as they were also rarely used. The municipality has formulated a mobility vision that aims to reduce car use and achieve a modal shift towards walking, cycling, public transport and shared mobility. This is motivated not only by the desire to be CO_2-neutral by 2040 but more so due to to current problems regarding the liveability and safety.

Meanwhile, the municipality is also facing other challenges around broad prosperity related to low incomes, high unemployment and population decline; factors that, according to research by Nijland et al.(2019) can indicate an increased risk of transport poverty and which affects at least 12% of households in Heerlen. With the municipality's renewed vision towards mobility, there is now also an opportunity to make the transport system not only more sustainable but also more inclusive. Providing more and more sustainable alternatives would not only mean offering choice to those who already travel, but also to those who are currently restricted in their travel options as a result of transport poverty. Within the municipality of Heerlen, it is known that there is an increased risk of transport poverty. However, it is not known exactly in which neighbourhoods this occurs, what the causes are and which population groups are particularly affected. Knowledge in this respect is essential to arrive at the right interventions.

1.2. Scope

For this study, the method of 'Designing fair transportation systems' (Martens, 2017) will be used to analyse the job accessibility of the Parkstad region. The method consists of 10 steps, but this research will limit itself to the analysis phase and end with identifying the causes of accessibility shortfalls by different population groups and proposing interventions, in collaboration with municipalities involved.
The scope of the study area includes the entire Parkstad region, where there is a cooperation between the 7 municipalities, of which Heerlen is the largest. Because more problems around broad welfare are addressed regionally, and previously mentioned risk factors for transport poverty also play a role in some surrounding municipalities, it was self-evident to consider all 7 municipalities in this study. In addition, amenities located in neighbouring municipalities also affect the accessibility of residents of Heerlen.

1.3. Research gap

In recent years, there has been an increasing focus on accessibility and also the lack of accessibility that has arisen particularly due to increased dependence on cars. As a result, studies have been done on possible transport poverty, which have focused mainly on looking for regional disparities in accessibility. Only a few studies showed that it distinguishes between the population groups that were particularly affected by these disparities. Using Martens' method, a number of case studies were carried out that looked not so much at disparities but at the extent to which a minimum accessibility standard was met. Accessibility by car and public transport are mainly the subject of comparison, which is probably related to the focus on larger travel distances, since most transport poverty occurs in suburban and rural regions. However, in the Netherlands, where it is more common to use bicycles over longer distances, active modes also play an important role in understanding the extent to which one can speak of transport poverty. Despite several studies showing that mostly low income groups suffer from transport poverty, due to transport affordability, all accessibility studies are conducted on the basis of travel time and not travel costs.

The gap in the literature that is clearly visible is a case study that examines to what extent, and which population groups suffer from transport poverty if we consider the travel costs. Since Martens' method allows population groups to be identified and also multiple modes to be compared, this method will be used in this case-study and active modes will be included as well. The case study of the municipality of Heerlen and the Parkstad Region is particularly interesting because figures show that here a high degree of car dependence in this region, despite being one of the poorest regions in the Netherlands.

1.4. Research objectives

The main objective of the study is to demonstrate the applicability of Martens' method with the extension of travel costs and to reveal the impact of transport affordability on the accessibility for low-income households and the unemployed in the Parkstad region.

For this purpose, this method is extended so that not only travel time but also travel costs are included in the analysis. As the average income in the Parkstad region is lower than in the rest of the Netherlands, it is expected that travel costs in particular are a determining factor for people whether or not they make a trip, which is the main argument to add this to the methodology. A sub-objective for this research is the measurement of job accessibility in the region and providing municipalities with meaningful analysis which they can use in future transport system design.

And, since the aim of the researcher is also to arrive at a valuable contribution for practice, policymakers will be asked to evaluate the results and value the usefulness of the method. The researcher's wish is for the method to help policymakers design a more inclusive transport system, by revealing where the system falls short or which target groups are disadvantaged most.

1.5. Research questions

The following main research questions and sub-questions contribute to achieving the aforementioned objectives:

To what extent can a job accessibility analysis from a sufficientarism perspective help identify transport poverty and guide municipalities in the Parkstad region in designing a more inclusive transport system for low-income households and the unemployed?

1. What methods have already been developed and what research has already been done on (in)equity in accessibility?
2. What method is most suitable for identifying transport poverty and how can it be applied in this case-study?
3. What is known about the socio-demographics, travel behaviour, land-use and transport system in Heerlen and the Parkstad region?
4. What are the outcomes of the analysis?
5. How can policymakers use the results of the analysis and how do they value its applicability?

1.6. Methodology

As this is a study involving both geographical and socio-economic data, QGIS is used, because this software program allows the geographical visualisation of relevant data as well as the results. Also, TravelTime provides a plugin for QGIS that allows the calculation of (travel) distances and travel times with all modes between given locations. Research shows that the reliability of this plugin is very high; there is a significant correlation between the calculated accessibility of the largest cities in America and Europe using three different methods including this plugin (Conwell et al., 2023). In addition, TravelTime itself states that the coverage for all modes, including public transport, in the Netherlands is 100%.

1.7. Case-study

The Parkstad region is an interesting case for research on transport poverty for several reasons. Despite a certain degree of urbanisation in this region, causing similar problems to those in cities in the Randstad, the population here is not growing, but is in decline. In regions where population decline occurs, amenities disappear and the distance and hence travel time to amenities for residents increases. The distance to the next urban area is also higher here, as cities here alternate with large municipalities with a more rural character, which can be an indicator of car dependence in the region.

In addition, there are other areas in the Netherlands that show a similar profile and for whom this study has added value. The eastern border of the Netherlands shows several urban areas where incomes are low and where there is also population decline (van Algemene Zaken, 2021). Examples include Enschede, Groningen and Maastricht. And even though the employement rate in these cities is larger, a comparable percentage of households have to live on the social minimum.

2

Literature review

This chapter reviews literature on accessibility and more specifically, accessibility poverty. The table in figure 2.1 shows an overview of the literature used and how they where found. Based on both the methods snowballing and searching with more specific keywords, such as 'transport poverty', 'accessibility (poverty), 'transport affordability' and names of researchers, the literature was found. Three different categories can be distinguished in the table: sources that were already known before the literature search was carried out (marked with an asterisk *), literature found with keywords and by 'snowballing' (where the 'keywords' column is empty).

Literature research			
Author	**Title**	**Year**	**Keywords**
Bastiaanssen and Breedijk *	Toegang voor iedereen? Een analyse van de (on)bereikbaarheid van voorzieningen en banen in Nederland	2022	-
Snellen et al.	Brede welvaart en mobiliteit	2021	-
Raad voor de Leefomgeving en Infrastructuur (RLI)	Toegang tot de stad: Hoe publieke voorzieningen, wonen en vervoer de sleutel voor burgers vormen	2020	-
Van Wee, Geurs *	Accessibility evaluation of land-use and transport strategies: Review and research directions	2004	-
van Wee et al.	Accessibility measures with competition	2001	-
van Wee and Geurs	Discussing equity and social exclusion in accessibility evaluations	2011	'van Wee' AND 'Accessibility'
van Wee and Mouter	Evaluating transport equity	2021	'van Wee' AND 'Accessibility'
Van Wee	Accessibility and equity: A conceptual framework and research agenda	2022	'van Wee' AND 'Accessibility'
Chen et al.	Exploring the equity performance of bikesharing systems with disaggregated data: A story of southern tampa.	2019	-
Borowski et al.	Disparity of access: Variations in transit service by race, ethnicity, income, and auto availability	2018	-
Lucas et al.	A method to evaluate equitable accessibility: combining ethical theories and accessibility-based approaches	2016	-
Martens	Transport Justice: Designing Fair Transportation Systems	2017	-
Blanchard and Waddell	Assessment of regional transit accessibility in the san francisco bay area of california with urbanaccess	2017	-
Van der Veen et al.	Operationalizing an indicator of sufficient accessibility – a case study for the city of Rotterdam	2020	'Accessibility' AND 'Martens'
Benenson et al.	Public transport versus private car GIS-based estimation of accessibility applied to the Tel Aviv metropolitan area	2010	'Accessibility' AND 'Martens'
Fransen and Farber	Using person-based accessibility measures to assess the equity of transport systems	2019	'Accessibility' AND 'Martens'
Allen and Farber	Planning transport for social inclusion: An accessibility-activity participation approach	2020	-
Levine et al.	From Mobility to Accessibility: Transforming Urban Transportation and Land-Use Planning	2019	-
Martens and Bastiaanssen	An index to measure accessibility poverty risk	2019	'Accessibility poverty'
Lunke	Modal accessibility disparities and transport poverty in the Oslo region	2022	'Transport poverty' AND 'Disparities'
Singer et al.	Equity in Accessibility: Moving from disparity to insufficiency analyses	2023	'Transport poverty' AND 'Disparities'
Pritchard et al.	A new index to assess the situation of subgroups, with an application to public transport disadvantage in us metropolitan areas	2022	-
Lucas et al.	Transport poverty and its adverse consequences	2016	'Transport poverty' AND 'Transport affordibility'
Litman	Evaluating transportation affordability: Evaluation and improvement strategies	2013	'Transport poverty' AND 'Transport affordibility'
Cooper and Vanoutrive	Is accessibility inequality morally relevant?	2022	-
Kelobonye et al.	Measuring the accessibility and spatial equity of urban services under competition using the cumulative opportunities measure	2020	-

Figure 2.1: Table with sources included in the literature research

In order to formulate an initial definition on accessibility, explain its multidimensional nature and the ways in which it can be measured, the article by Geurs and van Wee (2004) was used. As the article was already written almost 20 years ago, a search for more recent literature by the authors resulted in a review of more recent research on accessibility.

The study published by the PBL in October 2022 on accessibility (Bastiaanssen and Breedijk, 2022) was the main motivation for this research. The report includes a section on transport poverty that also cites various sources on this matter, and since some of these have been studied in more detail, they were also added to this literature table.

2.1. Accessibility

Accessibility is a multi-dimensional concept that can be interpreted depending on the perspective chosen. The most widely cited article explaining accessibility is the one by Geurs and van Wee (2004), who defined accessibility as *" the extent to which **land-use** and **transport systems** enable (groups of) **individuals** to reach activities or destinations by means of a (combination of) mode(s)"*.

When we decompose this definition, four components can be identified, which will be explained separately. First, there is the land-use component, which describes both the spatial distribution and characteristics of activities such as retail or jobs. The interaction between the demand and supply of these activities becomes relevant when there are competition effects, which occur for example with jobs and hospital beds, for which supply is limited. Common indicators to describe the land-use component are the available amount of opportunities. The second element is the transport system, which reflects on the supply, characteristics and location of physical infrastructure and transport services. For this component the direct relationship with accessibility can be expressed in, for example, travel time and travel costs. The individual component describes the (groups of) individuals by their characteristics, such as income, gender or vehicle ownership. These characteristics influence the needs and desires for accessibility to opportunities. And although not directly visible in the definition, the fourth dimension of this definition does have significance; the temporal component represents the time restrictions, such as limited opening hours of the opportunities or availability of public transport (Geurs and van Wee, 2004).

2.2. Accessibility measures

Various accessibility indicators have been developed over the years, and within them, four types of measures can be identified: infrastructure-based, location-based, person-based and utility-based measures. Depending on the purpose of the accessibility analysis, each of these measures has its own application. The explanation below for each of these measures is therefore not comprehensive, but gives an idea of their main advantages and disadvantages (Geurs and van Wee, 2004).

1. **Infrastructure-based accessibility**: In particular, this measure is intended to assess the functioning of the transport system. Indicators such as travel times, congestion, vehicle loss hours and speed are used to determine the functioning of the system and are leading in determining interventions of improving accessibility from this perspective. This does not include the other three components of accessibility, which is then also the main shortcoming.

2. **Location-based accessibility**: There are several location-based measures, all of which have in common that they are able to include multiple aspects of accessibility in the analysis. In doing so, the relationship between the land-use component and transport component is particularly visible, and the individual component can also be added by including sensitivity to travel resistance in the analysis (Albacete et al., 2017).

3. **Person-based accessibility**: Person-based accessibility measures have their origins in the 1970s, where space-time graphs were used to describe travel patterns in time and space from an individual's perspective. This analysis is ideally suited for describing the relationships between individuals and the potential areas of activities that can be reached within a certain time window, but it requires a considerable and detailed amount of information, such as origin-destination ma-

trices of all individuals and travel diaries that provide an understanding of travel patterns (Fransen and Farber, 2019).

4. **Utility-based accessibility**: This measure describes accessibility as the attractiveness of the full set of transport choices a person has. Accessibility can therefore be defined as the 'maximum expected utility', where both land-use as well as transport-related factors can be part of the utility function. Main drawbacks of this approach seems to be the interpretability of the measure and the lack of including temporal effects.

Geurs and van Wee (2004) add that an accessibility measure ideally addresses all four components, but sensitivity to changes in transport and land-use systems should at least be part of the measure. Location-based measures, and in particular the potential accessibility measures perform well in their review: the possibility to include all four components and the ease with which it can be operationalised and interpreted explains why this accessibility measure, and refinements of it, are popular in the literature. The simplest location-based measurement is the cumulative accessibility measure, which counts the number of opportunities that can be reached from a particular zone, within a certain travel time or travel cost threshold. The potential accessibility measure is a refinement of this measure, by taking into account the diminishing influence of opportunities further away. Another variant of this measure is a potential accessibility measure with competition effects which is commonly used in research on job accessibility, due to the restriction in supply for this type of opportunity (van Wee et al., 2001).

For decades, infrastructure-based measures in particular have been used as indicators to measure transport system performance, with different indicators being used for the road network and the public transport network. As a consequence, policies have always focused on solving congestion by improving the road network and scaling down public transport due to a decline in users (Singer et al., 2023). According to Levine et al (Levine et al., 2019), it would only make sense to use indicators such as congestion and speed as the main performance indicators, when the main purpose of transport is the movement itself. However, from the perspective of accessibility, the goal has always been to enable people to reach their desired destinations. The awareness of this discrepancy between what is measured and what the actual purpose of the transportation system is, is becoming noticeable in the literature, due to increasing attention to accessibility standards and transport poverty.

2.3. Transport poverty

In October 2022, the Netherlands Environmental Assessment Agency (PBL) published a report on accessibility in the Netherlands (Bastiaanssen and Breedijk, 2022). The first results of the research done by PBL, show that in the big cities, there is higher accessibility by all modalities, due to the close proximity of amenities and jobs. People living in suburban areas or more rural areas have the lowest accessibility. People who have access to a car experience the highest accessibility in any area, especially compared to those who depend on public transport.

Already two years prior to this report, the Council for the Environment and Infrastructure (2020) wrote a report on accessibility related to urbanization and they warned about the diminishing accessibility for people living outside of cities. Both reports mention the need for developing accessibility standards, as this would help operationalising the concept. Even though policy makers often talk about improving accessibility, a lack of these standards, structural measuring and specific objectives have prevented the actual improvement of peoples accessibility (Bastiaanssen and Breedijk, 2022).

The reports published in the past few years by research institutes in the Netherlands show that the issue is also on the agenda at government level and that the relationship between broad welfare and accessibility is also evident. Not only in the Netherlands, but internationally, the concept of broad welfare is receiving increasing attention. Broad welfare goes beyond financial welfare alone and includes all aspects that contribute to the population's well-being, such as health, living environment, social connections and safety. From a mobility perspective, better accessibility can contribute to broad welfare by providing people with access to, for example, health care, social contacts, jobs and education. The lack of accessibility to these daily activities, can lead to a situation where people are (involuntarily) excluded from full participation in society, which is one of many definitions of transport poverty (Snellen, 2021).

Different definitions are used in the literature to describe transport poverty, often with some overlap. According to Lucas et al. (2016), transport poverty is a more overarching term, which include:

- mobility poverty: the lack of transport, which could be the result of absence of infrastructure or transport services, but also not owning a vehicle;
- accessibility poverty: the inability to reach certain activities, such as jobs, supermarkets, family or schools;
- transport affordability: the inability to pay for transport;

Mobility poverty is closely related to transport affordability, when it refers to people in low income groups that don't own a vehicle and have therefore less mode choices. Accessibility poverty also shows some overlap with transport affordability, which focuses on the extent to which people within a household can afford transport alternatives (Litman, 2013). This overlap in definitions is visualised in figure 2.2.

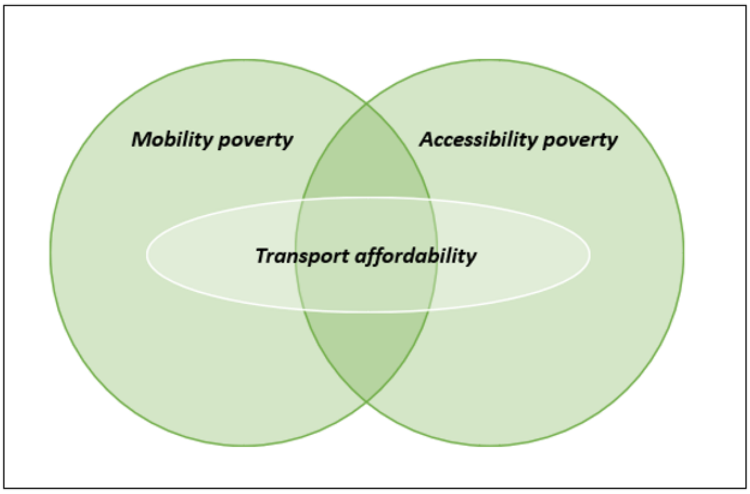

Figure 2.2: Transport poverty as an overarching definition for transport poverty, accessibility poverty and transport affordability. *Adapted from: Lucas et al., 2016*

2.4. Disparity and sufficiency

In research on transport poverty, different philosophical approaches are touched upon, to elaborate on the perspective from which a particular method was developed, of which egalitarianism and sufficientarism are most frequently used. From the perspective of egalitarianism, policymakers should focus on reducing the differences in levels of accessibility (van Wee and Mouter, 2021). Research from an egalitarian perspective focus on identifying disparities between, for example, accessibility by car and public transport (Lunke, 2022),(Blanchard and Waddell, 2017) or amongst different population groups (Chen et al., 2019), (Borowski et al., 2018) to evaluate the fairness in the transportation system.

From a sufficientarism perspective, the disparities are not that relevant, as long as everyone is provided with a certain standard of minimum accessibility. From this perspective, determining what is sufficient and finding consensus, in particular, is a recurring challenge and is highly context related (Cooper and Vanoutrive, 2022). An example of this are households living in rural areas by choice, accepting low accessibility levels, and where the people wouldn't appreciate accessibility measures from their (local) government. Determining accessibility threshold values would be an iterative process, in which a threshold value will have to be determined and then, based on empirical evidence, be further refined. In addition, understanding the impact of a certain level of accessibility in people's lives will help determine minimum accessibility levels.

Regardless of the approach chosen, from the perspective of equity analysis two distinctions are often made, which are the analysis of spatial equity or vertical equity (amongst different target groups, also referred to as social equity) (van Wee and Geurs, 2011). Due to the increase in available data and the possibility to map data by means of GIS-based models, several studies consider the distribution of accessibility spatially. Research by Benenson (2010) is an example of a disparity analysis, that examined the difference in accessibility by car and public transport in Tel Aviv. He displays that by using GIS-based data on travel times, the actual accessibility can be better estimated, in particular for public transport. There are however also researchers who study both social and spatial equity using regression analysis (Allen and Farber, 2020), or a more comprehensive spatial accessibility analysis, from a sufficientarism perspective, that also includes socio-economic target groups (van der Veen et al., 2020), (Singer et al., 2023). The latter examples all use a method developed by Karel Martens, 'Designing fair transportation systems'(Martens, 2017).

2.5. Discussion

The literature review focused on accessibility and transport poverty. Both are complex and multi-dimensional concepts that can be approached from different perspectives, which is why the variety of studies on combinations of both is considerable. Whereas research on accessibility has been carried out internationally for decades, research on transport poverty, in particular, is still in its early stages and may be the subject of more research. The examples of case-studies presented above have in common that they use location-based accessibility measures, although there is also research where other accessibility measures are the starting point, but this was beyond the scope of this literature review.

Location-based accessibility measures take into account the travel resistance, which is the travel time, travel cost and effort required to reach opportunities. What was noticeable was that in the presented case-studies, the accessibility measures only take into account travel times and not the transport costs, whilst transport affordability is an important concept in the transport poverty lexicon. In some research, the travel costs are considered implicitly, through assumptions about the capabilities of low income groups. Sometimes the assumption is that low-income people, do not have access to a car and thus solely rely on public transport. Others assume that only in neighbourhoods where car ownership is lower than 1, people depend on public transport (Pritchard et al., 2022). In both cases, the thought is that low-income people, whether they own a car or not, would benefit most from good accessibility with alternatives such as public transport, given the financial constraint of car ownership. What the difference in accessibility is as a result of the car travel costs is not precisely identified and neither are the financial constraints arising from travelling by public transport. The underlying assumption that public transport is always a valid alternative for low-income households, need not be true, especially in the Netherlands where public transport is known to be expensive.

In the approach of the evaluation of justice in the transportation systems, the main distinction that can be made is between disparity and sufficiency. The reports by several research institutes in the Netherlands point towards a need for accessibility standards, as they can help set objectives and ensure sufficient accessibility, which implies an approach from a sufficientarism perspective. Karel Martens proposes a method in which accessibility standards are included and the aim is to assess whether people experience (in)sufficient accessibility according to this standard. From his point of view, a transportation system is fair when all people have sufficient accessibility. He makes a strong case for choosing a sufficientarism approach above egalitarianism with two main arguments. For one, the results from disparity analysis are based on group averages which might give the impression that accessibility levels are high, whilst there are large in-group variations. But more importantly, these analysis don't provide an answer to the question, whether people experience sufficient accessibility or not. Research on job accessibility in the United States, where he compared the results from both an analysis on disparity and sufficiency, showed that the wrong conclusions would be drawn from merely a disparity analysis (Martens et al., 2022).

2.6. Conclusion

Although receiving more attention in the literature, accessibility and transport poverty are still underexposed research topics in the Netherlands. Several reports from dutch institutions refer to the need of accessibility standards to enhance the evaluation of accessibility, implying policy from a sufficientarism perspective.

The literature review reveals that depending on the context, transport poverty is explained in different ways, but three main concepts can be distinguished in general terms. Of these three, only mobility poverty and accessibility poverty are represented in the case studies. Travel costs are nowhere explicitly included to determine accessibility for people with limited travel budgets, instead, the assumption is that part of the population can't afford travelling by car and therefore is dependant on public transport. However, this is a limitation that additionally results in an inadequate perception of both car and public transport accessibility for low-income households.

An important note on the limitations in the research done so far concerns the type of case-studies conducted. Even though various studies have elucidated that the risk of transport poverty and poor accessibility is mainly located outside major cities, research on transport poverty in the Netherlands has so far concentrated on the two largest cities. A gap in the literature is most definitely a case-study of a region where the risk of transport poverty due to poor accessibility is more evident.

The conclusion on the gap in the literature based on this review, is that more research on the impact of travel costs on the accessibility for low-income households is desirable. Furthermore, this would preferably be from a sufficientarism approach, as such research would contribute to the discussion on accessibility standards. Finally, a case-study which is more representative for regions where there is an increased risk for transport poverty due to both the geographical and the socio-economic characteristics would add great value.

3
Methodology

In order to asses the sufficiency of the accessibility of jobs in the Parkstad region, method proposed by Karel Martens (Martens, 2017) is applied. In this chapter the methodology will be further explained, as well as the choices and assumptions that were made.

3.1. Step-by-step; A fair transportation system

The method towards a transportation system based on principles of justice, consists of a total of ten steps. For this research, the final step will not be carried out, which is the implementation of a solution and monitoring the impacts of this solution on the accessibility for the identified population groups. Instead, this research will finalize with a more theoretical assessment of the proposed solutions. Because a number of steps are strongly interrelated, all steps are distributed over 4 phases. Based on this phase structure, which is shown in figure 3.1 the methodology as well as the choices and assumptions made will be further explained.

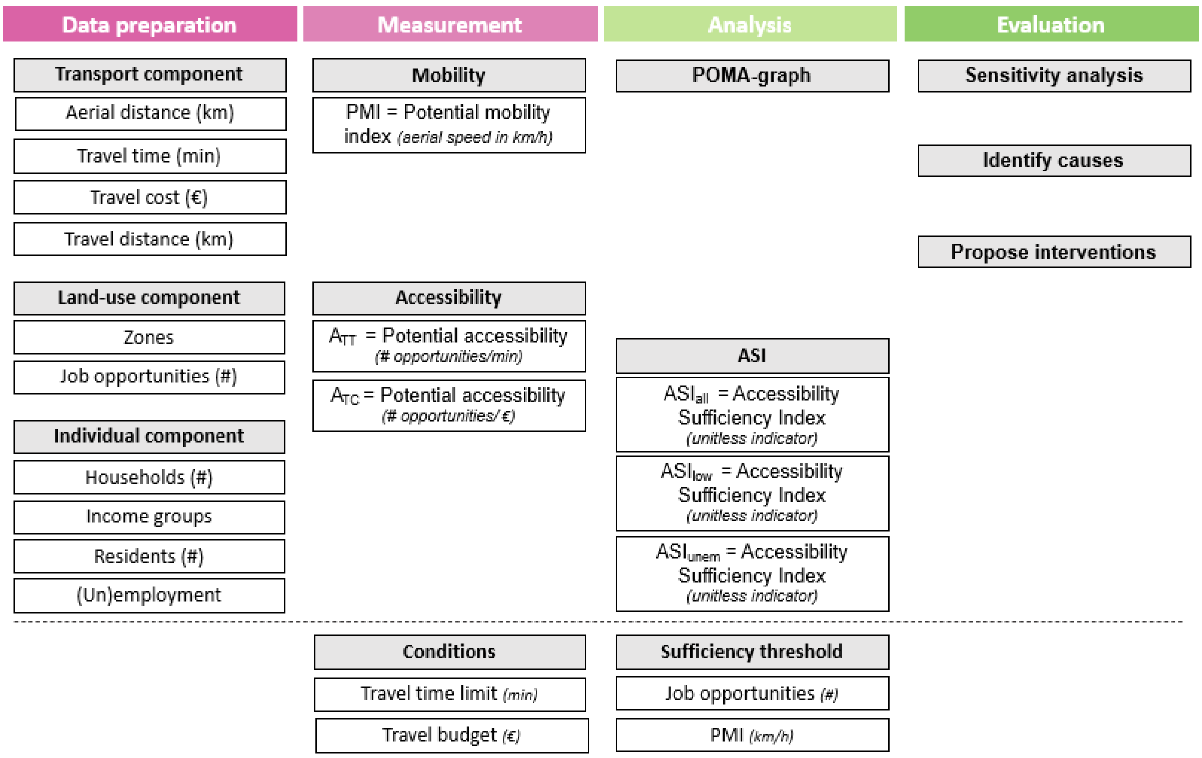

Figure 3.1: Conceptual model

3.1.1. Data preparation

In the first phase, the QGIS model for this region will be created, which actually represents the land-use component. This will initially require a bounded region and a division into zones for which accessibility will be calculated later. In addition, data on job locations is needed so that it can then be linked to the zones. For this study, only the jobs located in the Parkstad region are considered. Despite the fact that there are also jobs outside this region that are attractive to Parkstad residents, they are not included in this analysis. Particularly because the research area would then become too large and the competition of the bicycle as a means of transport would be more difficult to assess.

To perform the accessibility measurement, a number of matrices with information about the performance of the land-use and transport component is required. The TravelTime plugin for QGIS is used to calculate the following matrices: Aerial distance between all zones, travel times between all zones for all modalities and travel distance between all zones for car and public transport. The latter is important to calculate the matrices with travel costs between all neighbourhoods for both car and public transport.

The final step in this phase is to add meaning to the individual component by identifying different target groups, which are expected to experience different levels of accessibility. Martens (2017 refers to three characteristics that particularly influence accessibility, which are a person's place of residence, income and availability of modalities. By categorising the groups by residential location, accessibility from a particular neighbourhood can be linked to the target group. Or, in other words, the job accessibility of a neighbourhood, is the job accessibility for the people living in this neighbourhood. Classifying these groups by income is relevant for multiple reasons. Part of this study is the impact of travel costs on job accessibility and what one can spend on mobility depends on their income. In addition, relative to the rest of the Netherlands, income in this region is very low and the proportion of households living on low income is high and there is an increased risk of transport poverty among these groups.

As for the availability of modalities, there is insufficient data available to identify groups based on car ownership. It is known on average what car ownership is in a neighbourhood, but not how many households do not own a car and are more dependent on other modalities. In addition, research in the municipality of Heerlen has shown that there are neighbourhoods, where car ownership is high, but people hardly use their car, presumably due to the additional cost in its usage. Nevertheless, as travel costs will be included in this study, the difference in accessibility by car between different income groups will become apparent.

As an additional characteristic, the (un)employement rate is also considered; according to CBS and PBL (Bastiaanssen and Breedijk, 2022), the unemployed have an increased risk of transport poverty. There is some overlap between people who are unemployed and belong to the low-income group, but the analysis will be conducted for this specific group separately. The unemployment rate is higher in this region than in the rest of the Netherlands, which justifies conducting the analysis for this specific population as well.

3.1.2. Measurement

In the second phase, all the data gathered in the precious phase, will be used to measure the performance of the transportation system and assess the job accessibility.

To assess the transport network, the Potential Mobility Index (PMI) is calculated for each mode with equation 1 This index is calculated by dividing the aerial distances between neighbourhoods by the travel time, thus taking into account not only the speed on the network, but also the network structure itself. The index is calculated for each modality separately and the average from one neighbourhood to all other 198 neighbourhoods in the region, becomes the potential mobility indicator for this neighbourhood and modality specifically.

$$PMI_{im} = \sum_{i=1}^{n} \frac{d(i,j,..n)}{T(i,j,..n)} \tag{1}$$

Where, PMI_{im} is the average aerial speed for zone i and mode m, $d(i,j...n)$ is the aerial distance between zone i and zone j and $T(i, j...n)$ is the travel time of mode m between zone i and zone j.

The accessibility measure chosen for the assessment of the job accessibility, is a cumulative accessibility measure. This measure allows for the estimation of the total number of jobs that can be reached within a given travel time or travel cost threshold. This measure is chosen, since it is both easy to compute and interpret and data requirements are rather modest (Kelobonye et al., 2020). In this research, a distinction is made between the accessibility within a given travel time limit ($A_T T$) and the accessibility within both a given travel time limit and a travel budget ($A_T C$). Equations 2 and 3 show the equations for these two cumulative accessibility measures.

$$A_{TT} = \sum_{i=1}^{n} E_i \cdot tt \tag{2}$$

$$A_{TC} = \sum_{i=1}^{n} E_i \cdot tt \cdot tc \tag{3}$$

In these equations, the variables tt and tc can take on the value of 1 or 0. A value of 1 means that the jobs in a specific zone are within the boundary conditions of travel time and/or travel budget and are included in the total number of accessible jobs. If the condition(s) is/are not met, the value is 0.

To do these calculations, boundary conditions for both travel time and travel cost are also required. The average time commuters in the Netherlands travel was found to be 26 minutes. Since the area this region covers can be reached by car from all neighbourhoods within 30 minutes travel time, the starting condition for the travel time limit will be 30 minutes. This will set an interesting benchmark to evaluate the job accessibility by all other modes.

Data on households and spending patterns show that the lowest income groups use between 6.5 - 12.9% of their income for transportation purposes. For middle- and high-income groups, this percentage increases to up to 17.9% of their total income. Translate this into what people spend at most on transport every day, and for the lowest income group this equals €5,20 (CBS, 2023a)(CBS, 2023b). In order to set a condition, it is assumed that what people spend daily on mobility amongst the lowest income households is equal to what they can afford and is thus their daily travel budget. Half of this figure is then the maximum one-way travel budget. The table in figure 3.2 shows that there is some variation in the travel budget among low-income households. Using the number of households per income group as a weight factor, an average travel budget of €3,53 was determined. Because the determination of the daily budget assumes that people only spend money on commute, this budget is slightly overestimated. In the analysis, the travel budget will therefore be rounded off to 3 euros.

	Average budget (€/year)	Travel budget (€/day)	Travel budget (€/trip)	Number of households	Weighted average
1e 10%-groep	1300	€ 5,20	€ 2,60	11875	€ 30.875,00
2e 10%-groep	1400	€ 5,60	€ 2,80	16880	€ 47.264,00
3e 10%-groep	1800	€ 7,20	€ 3,60	16580	€ 59.688,00
4e 10%-groep	2500	€ 10,00	€ 5,00	15253	€ 76.265,00
			€ 3,53	60588	€ 214.092,00

Figure 3.2: Travel budget for low income groups

3.1.3. Analysis

The third phase is the actual analysis of the job accessibility and the performance of the transportation system, which starts with placing the values found in a so-called 'Potential Mobility and Accessibility

(POMA) - framework (Martens, 2015). This framework allows one to assess the accessibility from both the land-use and transport system perspective simultaneously. Figure 3.3 shows an adaption of the original framework he presented.

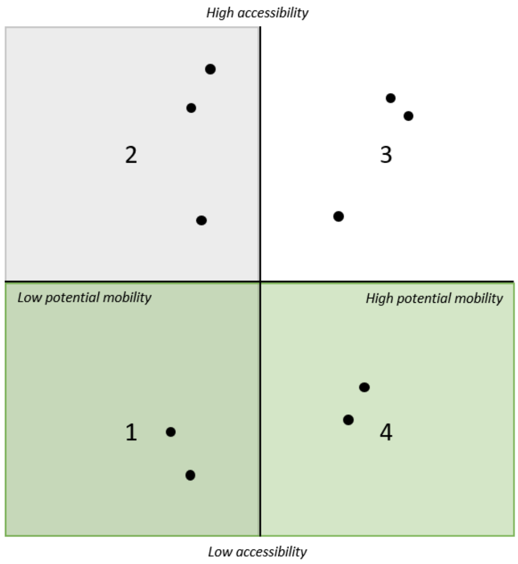

Figure 3.3: POMA-framework for the assessment of accessibility and potential mobility. *Adapted from: (Martens, 2015)*

This framework is divided into four quadrants using threshold values for accessibility and mobility. For threshold values for the accessibility, Martens (2017) argues the necessity of knowledge on the actual distribution in order to come to a threshold value with practical relevance. After assessing the potential mobility and accessibility, the sufficiency threshold values for both the potential mobility as well as the accessibility can be determined based on the results. For this purpose, numbers such as averages, standard deviations, upper and lower limits can be used to indicate an area in which accessibility is still sufficient and where it is not. For example, in his case study, Veen et al. (2020) used average car accessibility outside rush hour as an upper limit to compare the accessibility of other modes of transport against. The lower limit was half of this value and all that was below this line was classified as insufficient. The average speed of the car was used to determine the threshold value for potential mobility. Based on the results of the analysis, it will be determined what are practical thresholds in this case study.

Once it is clear what the threshold values are, it is also possible to determine from which neighbourhoods and with which mode, there is insufficient accessibility. In this context, the term transport poverty applies to neighbourhoods where there is insufficient job accessibility. This is true for all neighbourhoods below the threshold value, also those who have a potential mobility index above the threshold value for mobility. For those neighbourhoods, the mode specific shortfall in accessibility can be calculated with equation 4.

$$X_{im} = \left(\frac{z - y_{im}}{z}\right)^2 \tag{4}$$

Where, X_{im} is the shortfall in job accessibility for zone i and mode m, z is the threshold value for job accessibility and y_{im} is the number of jobs one can reach from zone i with mode m. The outcome of this equation is a value between 0 and 1, where the closer to 1 means the more severe the shortfall in job accessibility for that neighbourhood with that mode is. For middle- and high-income households, shortfalls are calculated with accessibility based on travel time only. For low-income households, the shortfall is calculated using accessibility within both travel time and travel budget.

The methodology proposes the Accessibility Sufficiency Indicator (ASI) as an indicator to determine the severity of the accessibility for specific target groups. The ASI can be calculated using equation 5 and the result is a normalised value between 0 and 1, where a high value means that many people in that neighbourhood experience insufficient job accessibility by a specific mode. In this equation, N is the total group size (for example all household in the region) and n is the size of the group for which the ASI is calculated (the number of households in a specific neighbourhood). For this study, the ASI will initially be determined at the neighbourhood level, to obtain a list where neighbourhoods are ranked according to this indicator. In addition, a separate ASI will also be determined for low-income groups in order to compare these groups geographically.

$$ASI_i = \frac{1}{N}\sum_{i=1}^{n} n_{ij} \cdot \left(\frac{z - y_{im}}{z}\right)^2 \tag{5}$$

Finally, a neighbourhood's contribution to the overall job inaccessibility in the region can be expressed,by dividing a neighbourhood's ASI by the sum of ASI values in the overall region.

3.1.4. Evaluate

In this phase, the results of the analysis will be evaluated, considering all intermediate results. A sensitivity analysis for travel time, travel budget and the sufficiency thresholds will be carried out first. In the Netherlands, the average commute times amongst different age groups differ and travel times up to 70 minutes are considered acceptable. The sensitivity analysis will cover this variation by evaluating the job accessibility with travel times of 15, 45 and 60 minutes in addition to the initial travel time of 30 minutes. The table in figure 3.2 shows some variation in the travel budget amongst the low-income households. For the sensitivity analysis, a travel budget of 2, 4 and 5 euros will be used to include this variation in the analysis. Finally, the initial threshold value for the accessibility, is 50% of all jobs in the region, but threshold values of 25% and 75% of all jobs will be explored here as well.

Finally, well prepared interview sessions with municipalities, in which both the methodology and the results are being discussed, will lead to an evaluation that includes expert opinions and context. Municipalities are informed in advance of the results at the regional level and are invited to discuss the results for their municipality specifically. Presentations are prepared to present results that are specific for the municipality, with which the meeting takes place. During these sessions, the results are used to discuss the topic of job accessibility and transport poverty but also the meaning of the results and what they consider causes and possible interventions to improve accessibility in their municipality. As far as there are already plans for interventions or officials see opportunities to solve insufficient accessibility locally, these proposals will also be evaluated here.

4

The case-study

In this chapter, the case-study for this research will be introduced, which is the Parkstad region. This will be done using three main elements that contribute to understanding the region's accessibility, namely the transportation system, the land-use and the socio-demographic and socio-economic data to provide content to the individual component. Furthermore, information about travel behaviour in this region will provide some more understanding about how people use the transportation system.

4.1. The Parkstad region

The Parkstad region is located in the province of Limburg, consists of 7 different municipalities and covers the area known as the eastern mining region up until the mid-1970s. Of the 13 mines that operated in the Netherlands, 11 were located in this region. The work opportunities and welfare this entailed meant that, particularly in the early 20th century, Heerlen transformed from a small village of 6,000 inhabitants into a city, now home to over 86,000 people. To accommodate this growth during those periods of prosperity, neighbourhoods were built between existing small villages and along the mines to accommodate workers and provide all necessary amenities. This has created an elongated area that is fairly densely populated and which does not always seem to have a clear structure.

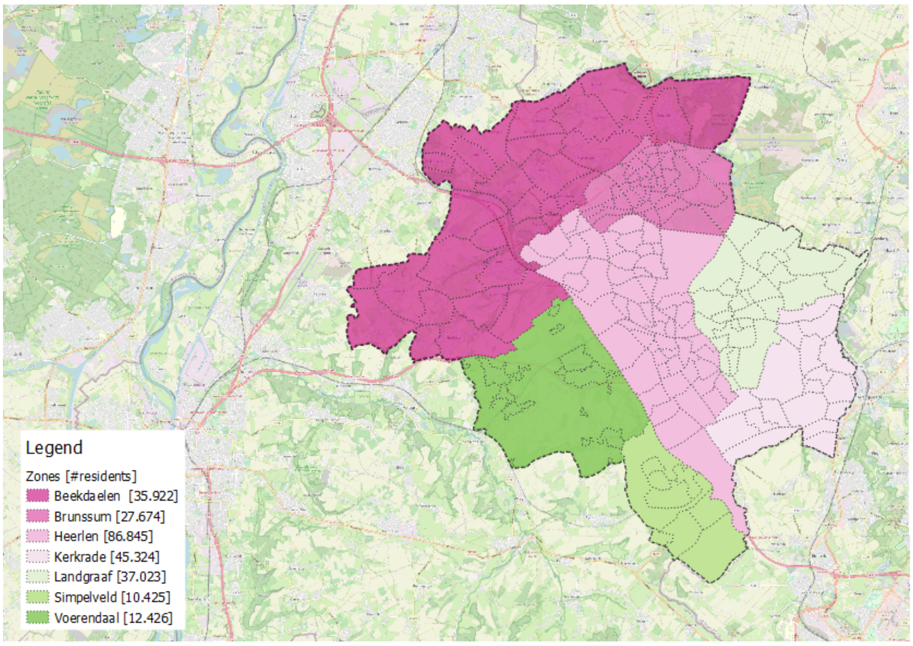

Figure 4.1: Municipalities in the Parkstad region *(©OpenStreetMap, created with TravelTime API)*

Figure 4.1 shows the names of the 7 municipalities and the number of residents (CBS, 2022). Municipalities surrounding Heerlen on the right (Kerkrade, Landgraaf and Brunssum) have the highest population density in this region after Heerlen, also due to the former presence of one or more mines. The final three more rural municipalities of Beekdaelen, Voerendaal and Simpelveld complete the Parkstad region on the left. The collaboration of these municipalities exists for over 20 years. At the regional level, these municipalities currently work on three themes, namely sustainability, cross-border cooperation and attention for the region's socio-economic problems. Within these themes, various objectives have been formulated to improve the broad welfare of the region. More recently, the designation of South-Limburg as a NOVI area as part of a national program enhanced this collaboration. The government acknowledged the South of Limburg as an area of national importance, in which the national government, province, municipalities, companies, knowledge institutions and citizens will have to work together on the broad welfare of all residents in the area (Provincie Limburg, 2022).

4.2. Transportation system

This section will further explain the Parkstad transport network, focusing in particular on the road structure and public transport in the region.

4.2.1. Road network

The three largest municipalities in the South of Limburg, Maastricht, Heerlen and Sittard-Geleen, are well connected by highways, as indicated on the map in figure 4.2 with the dark red lines, which form a triangle shape in the centre. The road network is drawn up to the national borders, but in reality provide access to major cities in Belgium and Germany as well.

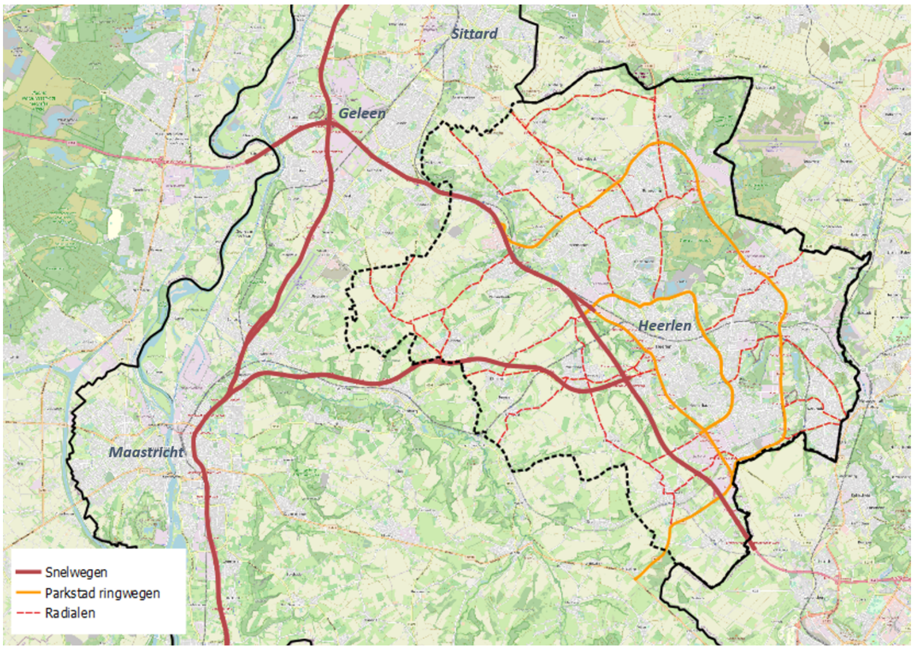

Figure 4.2: Road network in the Parkstad region *(©OpenStreetMap, created with TravelTime API)*

Zooming in on the infrastructure of Heerlen, it can be noticed that it is designed primarily for car traffic. The traffic structure involves a number of ring roads connected to each other and surrounding villages, by a number of radials. These ring roads are fairly new and have been put into use about 8 years ago. As a result of this structure the car accessibility improved and liveability in the neighbourhoods improved, because traffic is now routed along these main roads and no longer go through the centres of villages. In addition, this has also improved the connection to already existing highways and roads to Germany.

4.2.2. Public transport

The largest cities in this part of Limburg are also connected by railway. From the North two different NS intercity trains enter this region, one of which has the destination Maastricht and the other Heerlen. On this route, another railway operator, Arriva, provides a train connection that stops at every intermediate stations. On the railway track between Heerlen and Maastricht, only an Arriva stopping train is operated, which stops at all intermediate stations.

No metros or trams are operated in this region. Besides the stopping train, Arriva also offers a bus service in this region. Maps of the buslines in the region show that the routes all go through the city centre of Heerlen. This provides a high accessibility by public transport in Heerlen but also means that residents in the Parkstad region nearly always have to pass through Heerlen regardless of their destination.

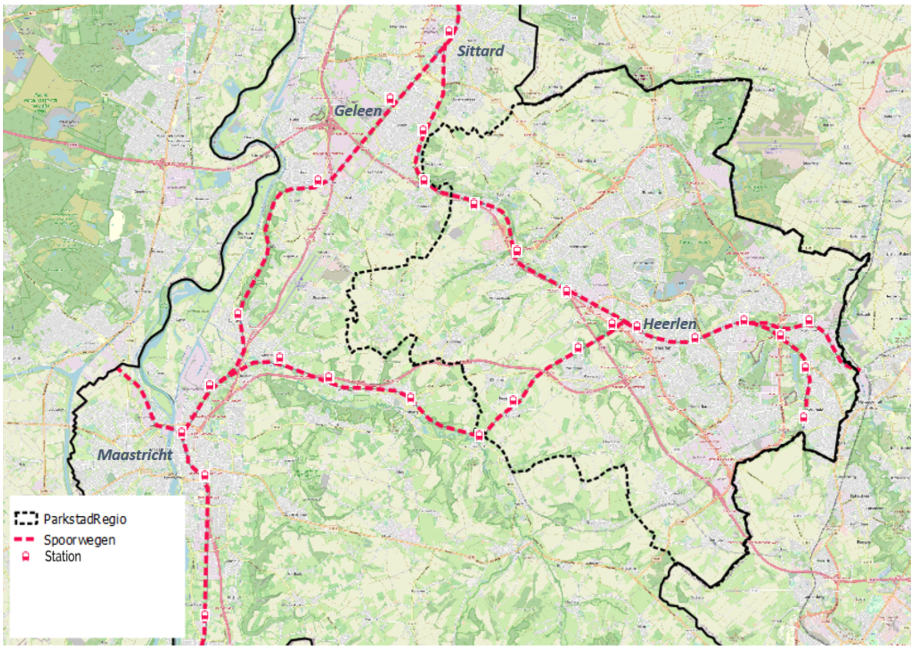

Figure 4.3: Rail network in the Parkstad Region *(©OpenStreetMap, created with TravelTime API)*

4.2.3. Cycling network

Limburg has an extensive cycling network. The area, with its nature that is unique in the Netherlands, is also a tourist attraction, resulting in many recreational cycling routes. The biggest challenges for cyclists here are the differences in altitude that one also has to make in this hilly landscape. Currently, several municipalities in South-Limburg are collaborating with each other to develop bicycle highways that are not only meant for recreational purposes, but also to encourage cycling for commuting.

4.3. Land-use

In this paragraph, the land-use component of accessibility will be described, which is the allocations of opportunities and for this case more specific, job opportunities.

Parkstad itself has over a hundred thousand jobs, of which some are scattered (such as jobs in education, healthcare or government) and some are centred in a number of locations (business parks). In figure 4.4 the map on the left shows the job opportunities in business parks ("Bedrijventerreinen provincie Limburg", n.d.) and the map on the right shows all job opportunities in the region. The share of jobs from business parks is clearly visible on the map on the right as well, since these locations are responsible for about 40% of all jobs opportunities in the region. The large amount of jobs in the city centre of Heerlen are related to the city hall, hospital and the high density of shops and restaurants in the city centre as well.

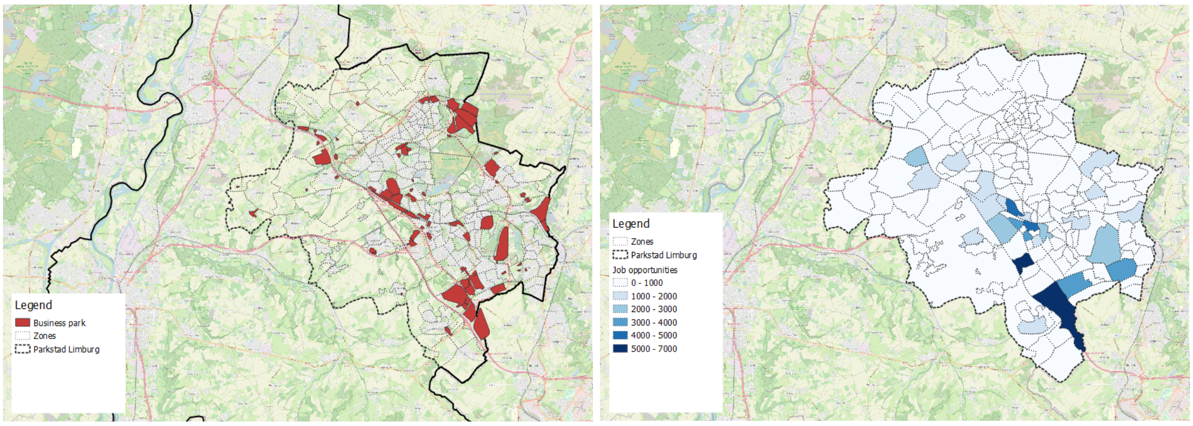

Figure 4.4: Job opportunities from business parks (left) and all job opportunities in Parkstad (right) *(©OpenStreetMap, created with TravelTime API)*

4.4. Socio-demographic and economic data

After Maastricht and Sittard-Geleen, Heerlen is the largest city in the South of Limburg with over 86 thousand residents. Heerlen and Kerkrade are the most densely populated cities outside the Randstad after Maastricht (figure 4.5 (right)). As in the rest of Limburg, the municipalities of this region also have an ageing population; on average 25% of the population is over 65. This also partly explains why this region's population is declining, despite a nationwide trend of urbanisation actually causing growth in cities (van Algemene Zaken, 2021).

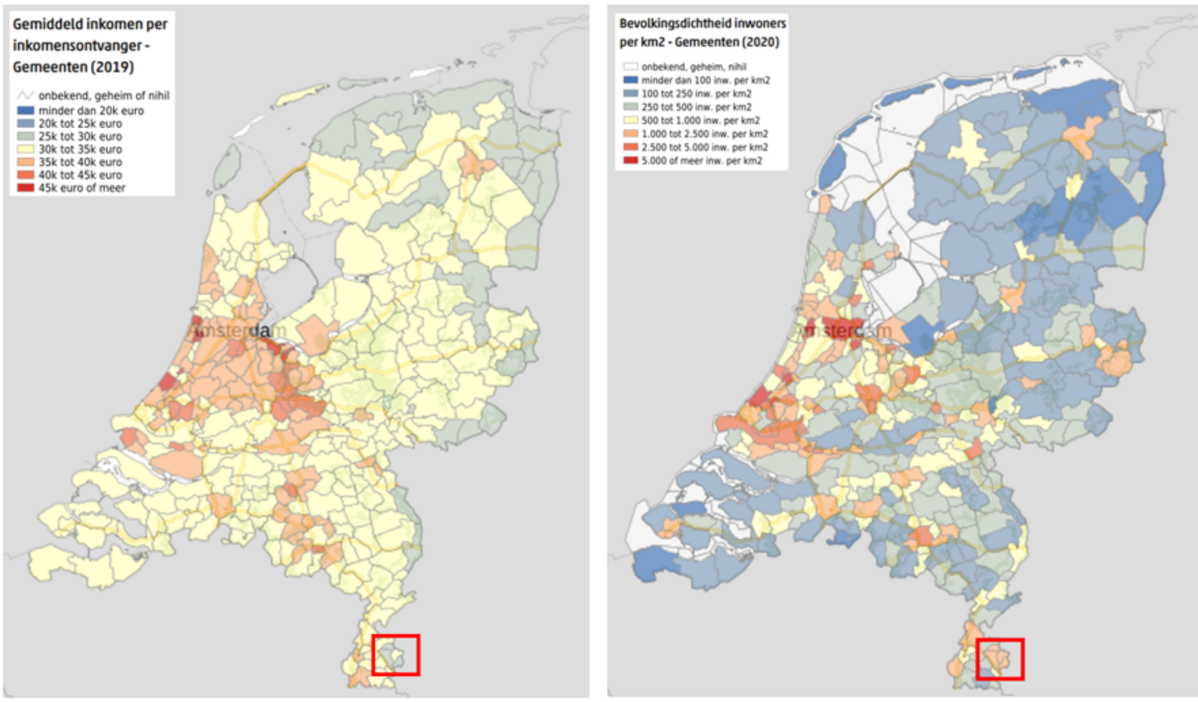

Figure 4.5: Average household income (left) (CBS, 2019a) and population density (right)(CBS, 2020)

Figure 4.5 (left) shows the average income per income recipient in the Netherlands. From this figure, it can be seen that there is a particularly large difference between the Randstad and areas located along the northern, eastern and south-eastern borders of the Netherlands. This also applies to Heerlen and the Parkstad region, which lies in the area in the red square. Unlike many other areas along the border with a low average income, it does have a high population density. The employment rate in the Parkstad region is lower compared to the rest of the Netherlands, which is often attributed to a certain degree of inheritance of unemployment that occurred after the closure of the mines. The combination of low average incomes and low labour participation results in an average high number of households living on an income below or around the social minimum (figure 4.6 (right)).

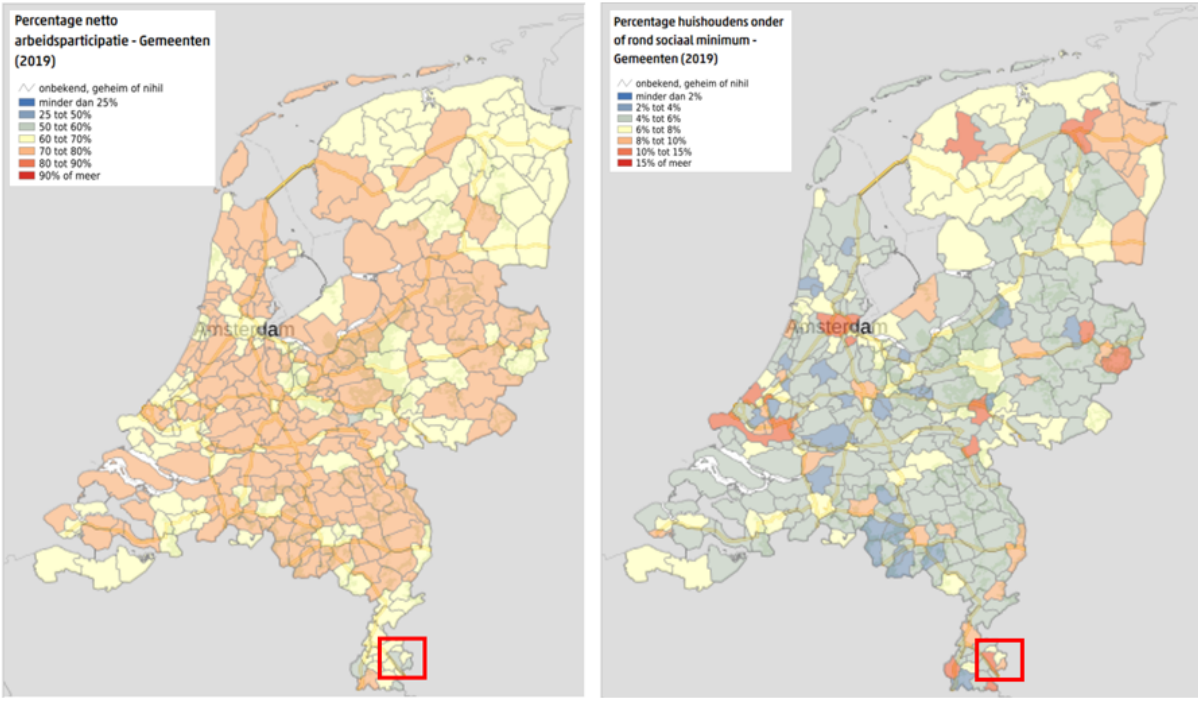

Figure 4.6: Employement rate (left)(CBS, 2019b) and percentage of households below social minimum (right)(CBS, 2019c)

4.5. Travel behaviour

Every year, the Statistics Netherlands (CBS) conducts research ('Onderweg in Nederland', ODiN) about the daily mobility of the population in the Netherlands, from which information can be extracted about travel motives, distances travelled and the modal split. The table in figure 4.7 shows figures about travel behaviour in Parkstad, the province of Limburg and the Netherlands. The figures on the left show how people travel in general, the figures on the right are more specific for commuting. Apparently, car use in Parkstad is high and the use of bicycles and public transport in this region is lower than both the provincial and the national average. The use of public transport is even so limited, that when the data is sorted by travel motive, there is insufficient data to determine the exact modal share. Walking, instead, is on average more popular in this region, even for commuting, than in the rest of the Netherlands.

	Modal split - complete			Modal split - commute		
Transport mode	Parkstad	Limburg	NL	Parkstad	Limburg	NL
Car	61%	55%	46%	65%	61%	53%
Public transport	3%	4%	6%	-	-	-
Bicycling	12%	21%	28%	13%	21%	24%
Walking	19%	17%	16%	6%	4%	4%

Figure 4.7: The modal split in the Parkstad region compared with both provincial and national averages (CBS, 2022)

5 Results

In this chapter the results of the analysis for the Parkstad region are presented, in accordance with the conceptual model as presented in figure 3.1.

5.1. Data preparation

To conduct the accessibility analysis, several data sets were required, of which some were readily available and other needed to be edited to make them more suitable. This subsection will elaborate on the building of the QGIS-model, the data preparation and the identification of the target groups.

5.1.1. Land-use component

A fine-grained area classification is essential when public transport, cycling and walking are also part of the accessibility analysis (Benenson et al., 2010). Therefore, the CBS neighbourhood classification was used, allowing a distinction to be made between a total of 199 areas. Based on the neighbourhood geometry, centres of gravity, centroids, are assigned to each neighbourhood, from where the accessibility calculations for that neighbourhood will be performed (figure 5.1 shows the neighbourhoods with centroids on the left). For 33 neighbourhoods, this centroid was manually replaced because it was not located near households, but in the middle of a nature reserve or grassland, for which some examples are visible in figure 5.1 on the right. This significantly affected the accessibility results, due to the extra travel time caused by first having to walk to a road or bus stop from where the journey can be continued by any of the modalities. A complete list of neighbourhoods where centroids where replaced can be found in appendix B.

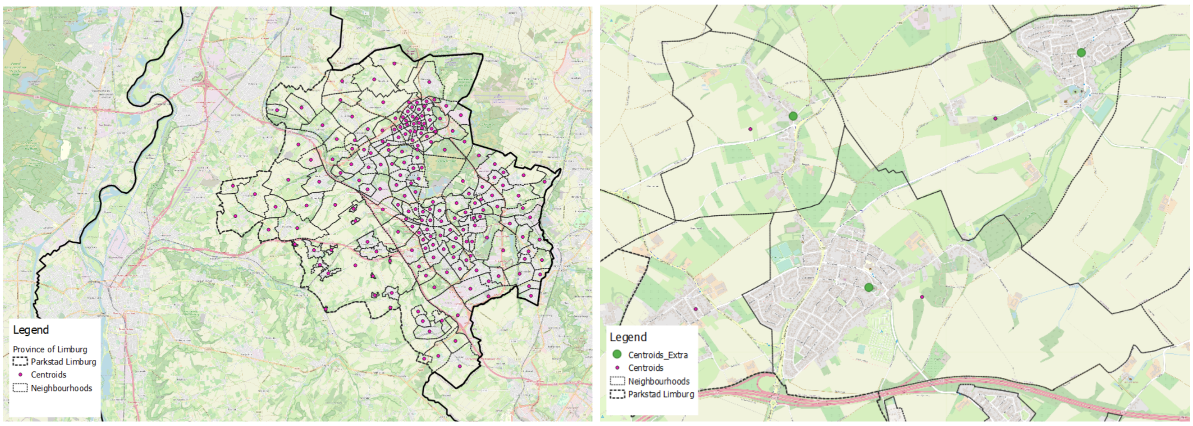

Figure 5.1: Neighbourhood classification and centroids (left) centroid replacement for selected neighbourhoods (right) *(©OpenStreetMap, created with TravelTime API)*

To be able to calculate the job accessibility, data on the number of jobs in each neighbourhood is required. In the traffic model of the province of Limburg all the jobs in the Parkstad region are assigned to a specific zone. The traffic model has a classification based on 118 zones, where part of the zones could be translated one on one to a neighbourhood from the CBS classification. In addition, for each neighbourhood was examined of which zone it is part of, with which other neighbourhoods this zone is shared and how the jobs of this zone are distributed over these neighbourhoods. To do so, information from Google Maps on locations of schools, shops and healthcare were used to distribute the jobs in these sectors. Furthermore, as mentioned before, the Province of Limburg provides GIS data about the location of business parks and the number of jobs located there, which already accounted for over 40% of the jobs in the region. Figure 4.4 in chapter 4 shows the locations of all job opportunities. A list of all neighbourhoods, the corresponding zone of the traffic model and the number of jobs located here, can be found in appendix C.

5.1.2. Transport component

For all modes, travel times matrices between all centroids were constructed with the TravelTime plugin for QGIS. For travelling by car, the time of day chosen was a Friday afternoon, to avoid any delays during rush hours. For public transport the Friday morning was chosen as the time of day, to avoid delays due to less frequent public transport supply. The assumption for all modes is thus the travel time under the best possible conditions, e.g. free-flow travel times. For walking, cycling and the car, a simple time filter search was sufficient, with a time window of 4 hours travel time, which is a limitation of the tool. This resulted in gaps only in the matrices for walking, for neighbourhoods whose travel time on foot exceeds 4 hours. These have been manually complemented with Google maps, using the exact locations of the centroids. For public transport a more advanced time filter was used, which allowed more settings to be adjusted, such as the search range width. By expanding this range the algorithm creates a departure interval in which it searches for the best time to start the journey and avoids creating extra travel time at the very beginning of the journey. Furthermore the maximum walking time to and from stations/bus stops was extended, because otherwise there were neighbourhoods that appeared to be inaccessible.

Simultaneously with the creation of travel time matrices, the plugin constructs travel distance matrices, which are required for both car and public transport for the travel cost calculations. Aerial distances between all neighbourhoods were also required, but for this QGIS is equipped with a tool which creates distance matrices. For both the travel distance and the aerial distances, the distances are measured from the centroids from each neighbourhood.

An additional step taken here, was validating the travel times and (travel) distances. This was done by comparing the travel time matrices for travelling car, bicycle and on foot with travel times from Google maps and for public transport with 9292OV. There were sometimes slight deviations in the travel times and travel distances by car; Google maps often provides multiple route options and the preferred option in Google maps was not always the option given as a result in QGIS. The deviations found in travel time by car were no more than 3 minutes (maximum 10% is compared with the longest travel time by car in the Parkstad region). Travel times by bicycle and walking also appeared to match well with Google maps. In addition, it could be validated that the calculation of travel times to and from neighbourhoods that were uphill or, on the contrary, in a valley takes into account bridging these height differences. Validating travel times with 9292OV for public transport showed that on average the deviation was no more than 11%, with some outliers up to 28%. These outliers showed that travel times with 9292OV for these cases were a lot longer, so it can be assumed that the travel times used for the rest of the analysis assume the most favourable situation with public transport. There will therefore be an overestimation rather than an underestimation of accessibility by public transport.

5.1.3. Individual component

A major advantage of the area classification of the CBS is that both socio-demographic and socio-economic data at this level is made available by the CBS, allowing for the analyses for specific target groups. This makes it possible to define different target groups and also link them to specific neighbourhoods. For all neighbourhoods, the number of households located there and to which income groups they belong was extracted. In the Netherlands, income statistics distinguish 10% groups, making a total of 10 groups, each containing the same number of households (almost 800,000) and ranked by income. The lowest 10% group contains the 10% poorest households in the Netherlands, the highest

10% contains the 10% richest households in the Netherlands. CBS also refers to the lowest 40% as the low-income groups, which live on a standardised income of up to 24,000 euros. For the lowest 10% group, this is at most half of this income (and on average only 10,000 per year). A standardised income means that the household size has been corrected for and this income applies to a one-person household, which makes it possible to compare different household compositions.

Of all neighbourhoods in the Parkstad region, the distribution of households across all 10% groups is known. This makes it possible to determine different target groups for each neighbourhood and classify them by income level. A distinction has been made into 4 target groups; group 1 contains the households belonging to the 10% lowest incomes, group 2 the remaining households belonging to the lowest income groups, group 3 the middle-income households belonging to the 50-80% group and group 4 then contains the households belonging to the 20% households with the highest income. The table in figure 5.3 shows the distribution of these 4 income groups over the municipalities and how these numbers relate to national averages. For example, the share of households living on low income is relatively high in Heerlen, Kerkrade and Landgraaf in particular, with Heerlen standing out with 20% of the households belonging to the 10% lowest income group in the Netherlands. However, the averages of Beekdaelen and Voerendaal show a different picture; in these municipalities, income levels are higher on average and more households also belong to the middle and high income groups. A complete list of the number of households and to which income groups these households belong, can be found in appendix D.

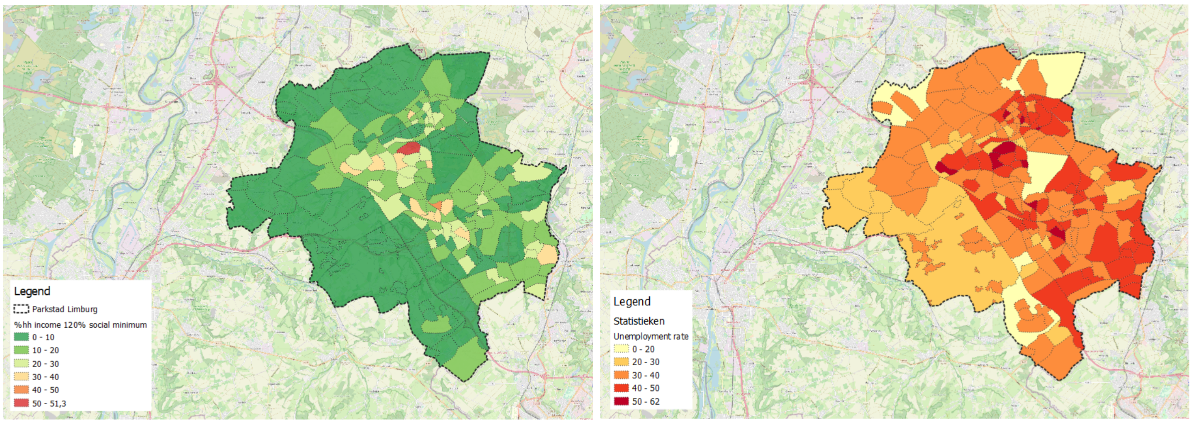

Figure 5.2: Share of households with a maximum income of 120% social minimum (left) and unemployment rate in the Parkstad region (right) *(©OpenStreetMap, created with TravelTime API)*

Of the 199 neighbourhoods, there are eight in which either the number of households or the number of inhabitants is 0 according to statistics. However, these zones are included in the analysis because they are mostly neighbourhoods with interesting destinations, such as jobs. In addition to these 8 neighbourhoods, there were another 36 neighbourhoods where the number of households was less than 100, so for privacy reasons no household income information is shared by the CBS. For these neighbourhoods, the distribution by income was assumed to be equal to the average of the 4-digit postal code area in which this neighbourhood belongs. The same method was also applied to other socio-economic data that were missing, such as the unemployment rate.

Figure 5.2 (left) shows the percentage of households in a neighbourhood living from an income of no more than 120% of the social minimum. In the Netherlands, this is about 10% of the households, but in most of the neighbourhoods in the denser areas of the Parkstad region, this percentage is much higher, which is consistent with previously shown figures that confirmed the region's relative low income. A map of the region with the unemployment rate (figure 5.2 (right)) shows a similar pattern, with the highest unemployment occurring in the 4 municipalities with the highest population density and with the northern part of Heerlen in particular turning darker red on the map. A complete list of the number of residents and the (un)employment rates, can be found in appendix E.
The table in figure 5.3 summarizes the distinction made in population groups for this research. It is important to note that the data on income groups are distinguished at the household level while

Municipality	#hh	#res	#res(15-65)	Group 1	Group 2	Group 3	Group 4	Unemp (%)
Heerlen	45325	86845	55375	20,9%	33,9%	36,1%	9,1%	41,0%
Kerkrade	22930	45324	27970	17,6%	31,8%	41,8%	8,8%	41,0%
Landgraaf	17675	37023	22965	14,4%	28,4%	44,0%	13,2%	39,0%
Brunssum	14875	27674	17185	13,1%	28,5%	48,4%	10,1%	38,0%
Simpelveld	4920	10425	6205	10,8%	29,1%	45,1%	15,0%	33,0%
Voerendaal	5600	12426	7315	7,7%	24,1%	48,1%	20,2%	33,0%
Beekdaelen	16240	35922	21700	9,6%	24,6%	46,1%	19,7%	34,0%
Parkstad	**127565**	**255639**	**158715**	**15,9%**	**30,2%**	**41,9%**	**12,0%**	**38,7%**
Nederland				*10%*	*30%*	*40%*	*20%*	*20%*

Figure 5.3: Socio-demographic and economic data on the municipality level

unemployment rates are distinguished at population level.

5.2. Measurement

The this second phase, the potential mobility and the accessibility for all neighbourhoods in the region will be calculated. The assessment of the job accessibility requires preset conditions about the travel time limit and travel budget. In line with previous statements about these conditions, the accessibility will be calculated for a travel time limit of 30 minutes and a travel budget of 3 euro.

5.2.1. Potential Mobility Index

The potential mobility index is calculated for each neighbourhood in the region and for all modalities. Figure 5.4 shows the PMI index for the car (left). What the map shows is also what one might expect; the aerial distances travelled from the neighbourhoods on the outskirts of Parkstad are larger on average, and because from here motorways and provincial roads are used more often, the PMI is therefore higher. The distances from the centre of Parkstad to each neighbourhood is smaller because, there will always have to be driven first from more densely populated areas where speeds are lower and delays due to intersections occur. The average PMI for the car is around 30 km/h, but the distribution is wide with aerial speeds varying between 21 km/h and 39 km/h.

For public transport and cycling this is lower, 8.4 km/h and 14.2 km/h respectively. In other words, the potential mobility for residents in Parkstad is lower by public transport than by bicycle. For public transport, this is mainly due to transfer times and walking distances to stops included in the calculation of travel time. And although the travel time calculations do take into account the possibility to travel by train, there are only 13 train stations in the region, thus most neighbourhoods rely on buses, of which the speeds are lower. If the average potential mobility index for all modalities, which is 13, were the standard, it is not met by public transport in any of the neighbourhoods, thus the public transport system scores insufficiently throughout the region.

For cyclist the travel times are calculated based on data on actual travel speeds and data on road conditions and geographical conditions. For this region, that means it also includes the height differences that cyclists have to overcome to arrive at neighbourhoods that are located at higher altitudes. This explains the variations in the potential mobility indices on the map in figure 5.4 (right). Note that the calculations assumed the average speed of a cyclist on a normal bicycle, i.e. not an e-bike or speed pedelec, which is also reflected in the average PMI of approximately 14 km/h.

5.3. Potential accessibility

This section will present the job accessibility within 30 minutes travel time and 3 euro travel budget for the whole region. First, the accessibility within 30 minutes is calculated, which is in principal the accessibility for anyone who has no limitations, such as a lack of a vehicle or a limited travel budget. The second subsection describes how the accessibility is affected when a limited travel budget is added.

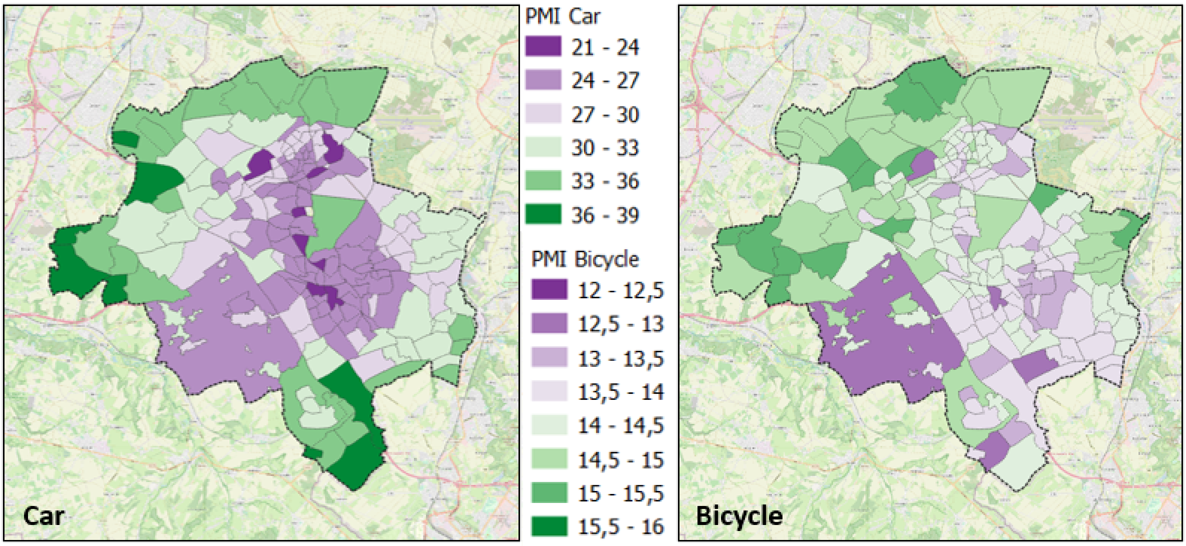

Figure 5.4: Potential Mobility Index - Car (left) and Bicycle (right) *(©OpenStreetMap, created with TravelTime API)*

5.3.1. Travel time = 30 minutes

The first analysis was carried out with a 30-minute travel time limit, because the coverage by car for each neighbourhood in the region is 100% of all jobs and this allows us to benchmark the other modes. Figure 5.5 visualizes the job accessibility within a travel time limit of 30 minutes for both car, public transport and bicycle. By public transport, job accessibility is only 24% on average and the highest accessibility is from neighbourhoods in and around the centre of Heerlen, from where between 60-70% of jobs can be reached by public transport.

Accessibility by bicycle is much higher than by public transport, on average almost three times as many jobs can be reached by bicycle as by public transport. The coverage by bicycle is nowhere 100%, but there are neighbourhoods that achieve an accessibility of around 90% of the total number of jobs and these too are mainly located in and around the centre of Heerlen. Coverage by bicycle and public transport is low along the edges of Parkstad, with the municipalities of Beekdaelen and Simpelveld standing out in particular, which are located in the north and south of the region. In these municipalities, the job accessibility for most neighbourhoods is less then 10% of all the jobs in the region.

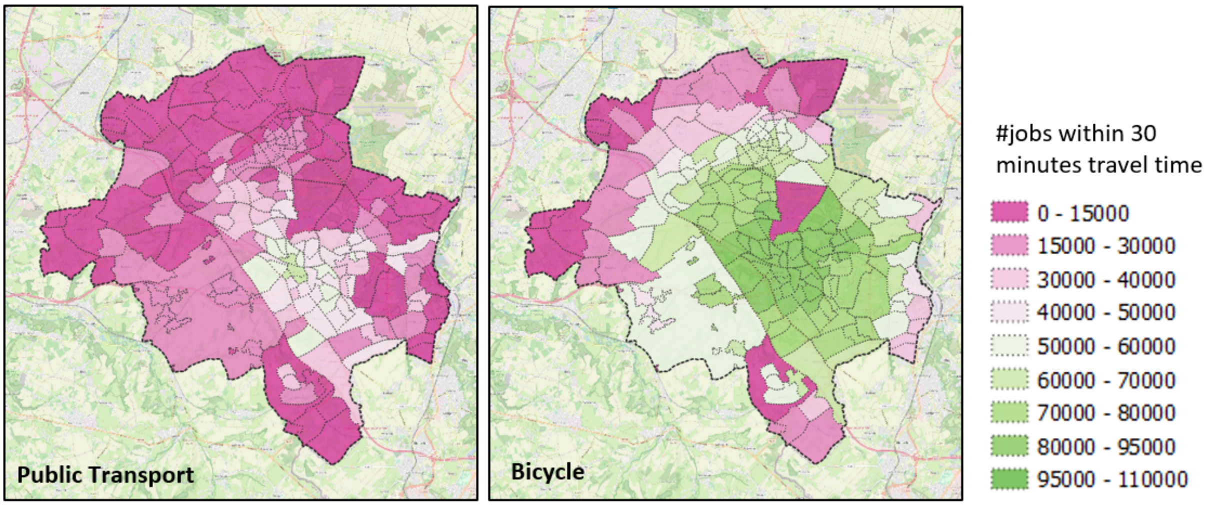

Figure 5.5: Number of jobs within 30 minutes travel time by public transport (left) and bicycle (right) *(©OpenStreetMap, created with TravelTime API)*

5.3.2. Travel budget = 3 euro

For the second analysis, a 3 euro travel budget was added to determine the accessibility within 30 minutes for low-income people. This travel budget corresponds to what low-income people have on average to spend daily on transportation purposes. It is assumed that there are only travel costs associated with travelling by car or public transport; for cycling and walking there are no additional travel costs.

The costs of travelling by car is based on a price per kilometre, which represents not only fuel costs but also insurance, maintenance and depreciation costs. Depending on the type of car, the cost vary between 45 and 58 cents per kilometre. The costs considered are on the more conservative side; a small mid-range car is assumed with a price per kilometre of 48 cents (Nibud, 2022). A travel distance matrix for travelling by car is constructed with the TravelTime plugin in QGIS. Multiplying all these distances with the price per kilometre, results in a cost matrix for and to all neighbourhoods in the region.

The costs of travelling by public transport is based on a price per kilometre as published by the public transport operator Arriva. There is a starting fare of 1,08 and additionally a price per kilometre of 0,204 euros on the bus and 0,22 euros on the train. This difference in price of 1,6 cents per kilometre is neglected, as it is not possible to tell from the matrices when travelling by bus or train occurred. What was inconvenient was that the distance matrix for public transport also does not distinguish between distances walked and distances actually travelled on a bus or train. This would mean that the travel costs for residents who have to walk longer distances are overestimated if these distance matrices are used. Therefore, it was decided to use the aerial distances between neighbourhoods, even though this means an underestimation. Distances are naturally higher in reality, the bus rarely travels directly, but more often via detours through village centres. To compensate for this underestimation, the aerial distances were multiplied by a factor 1,3. This conversion factor is not arbitrary; with the help of the public transport travel planner 9292OV, for different origins and destinations, this factor is validated. The purpose was to get as close as possible to the prices published on the 9292OV website, while alternating between origins and destinations that are located in both the centre of the region as well as near the boundaries.

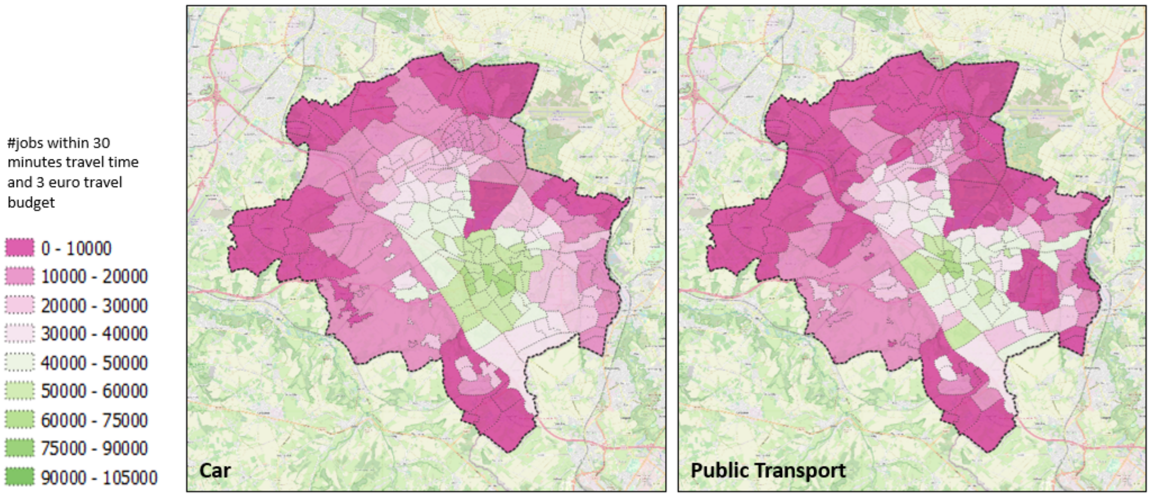

Figure 5.6: Number of jobs within 30 minutes travel time and 3 euro travel budget by car (left) and public transport (right) *(©OpenStreetMap, created with TravelTime API)*

After a travel distance of 5 km, travel costs by car are higher than by public transport. The greatest distance that can be travelled if the aerial distances are considered, is almost 20 km, so on average, public transport is less expensive than car. Figure 5.6 visualizes the results of the accessibility within 30 minutes travel time and 3 euro travel budget. As a result of adding travel costs and limiting the travel budget, car accessibility decreases significantly; instead of 100%, the average job accessibility by car is now only 28%. Thus, for low-income households with a car, the number of jobs they can reach within their travel budget is a lot lower than one would assume based on travel time alone. Although the accessibility is a lot less, it is still somewhat larger than by public transport, which is practically unchanged; what was accessible within 30 minutes travel time also seems to fall within a budget of 3 euros. There are more neighbourhoods with sufficient accessibility by car, compared to public transport. What is also noticeable is that the neighbourhoods with good accessibility by car are mainly located along the highway or have quick access to the Parkstad ring roads. In terms of accessibility by public transport, you can see that the eastern part of the region has slightly better accessibility due to the train connectivity. For both modes, accessibility is actually highest in the centre of Heerlen and south of the city centre, since the job opportunities are mainly located here. Taking all modes into account, the average job accessibility for the whole region is about 30%; in comparison, without adding travel costs, this was almost 50% of all jobs. Accessibility by walking and cycling has not changed because these are insensitive to travel costs.

5.4. Analysis

Using the results found for potential mobility and accessibility, a number of analyses can now be carried out. First, the results will be put into a graph in order to assess the overall accessibility per mode and determine threshold values. The threshold values then enable the use of the ASI to determine which population groups across the region suffer from low job accessibility.

5.4.1. Threshold values for sufficient accessibility and mobility

To identify threshold values for sufficient accessibility and mobility, the values found in the previous subsection are placed in a Potential Mobility and Accessibility graph. The results of the accessibility within 30 minutes travel time result in the graph in figure 5.7, where each colour represents a modality, and each dot represents one of the 199 neighbourhoods.

Figure 5.7: Potential Mobility and Accessibility graph - number of jobs within 30 minutes

The average PMI and average accessibility divide this graph into four quadrants and help identify the cause of the level of accessibility. Everything in the first and second quadrants (on the left of the average PMI) is less well served by the transport system because the PMI index is below average. Neighbourhoods here that do experience above-average accessibility to jobs by public transport have this mainly because the jobs are located nearby. There are also neighbourhoods where this applies to cycling, where despite a lower PMI due to height differences or a less well-designed cycling network, high accessibility to jobs is still achieved. There are also neighbourhoods where the PMI is above average for cycling, but the job accessibility is still low (quadrant 4); for these neighbourhoods, the distance to job opportunities is too far to travel within 30 minutes.

Quadrant 3 contains the neighbourhoods that have above-average PMI and accessibility; the more desired situation. This applies to most of the neighbourhoods for accessibility by bicycle, but especially for accessibility by car. The PMI is not only high, but from all neighbourhoods one can also reach all jobs within 30 minutes. What has not yet been mentioned is the job accessibility on foot. The dispersion in the average speed on foot is low, and is around 4.1 km/h for all neighbourhoods and the job accessibility here is particularly dependent on the proximity of the jobs.
Figure 5.8 shows a Potential Mobility and Accessibility graph, with the results of the analysis after adding a travel budget of 3 euros. The decrease in accessibility by car is evident from this graph. The potential mobility for car in this region is high, but if we add the travel costs, job accessibility by car decreases for neighbourhoods that are located further away from the job opportunities.
This graph is divided into 4 quadrant as well, however, the average accessibility is a lot lower due to the decrease in accessibility by car. If the average accessibility is chosen as a threshold value, this would mean that for different target groups, different threshold values would apply. Instead, in both graphs two red, dotted lines have been added representing a sufficiency threshold for the accessibility of 25% and 50% of all jobs.

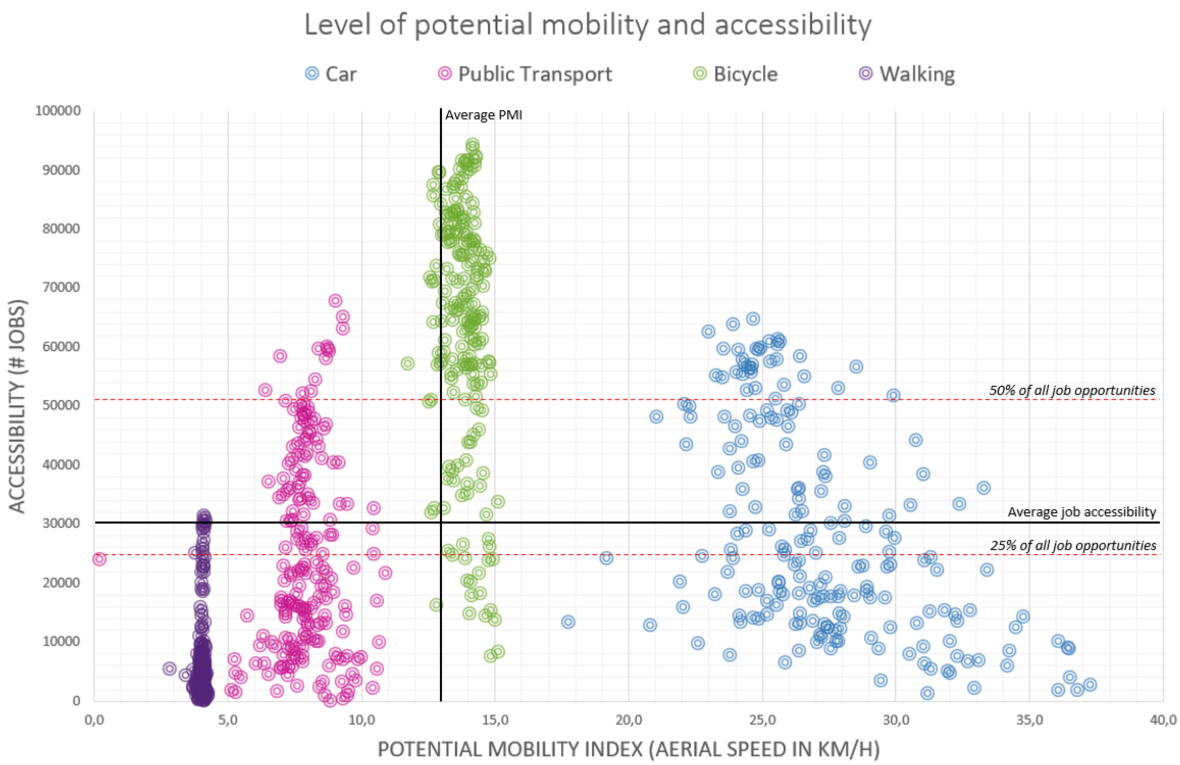

Figure 5.8: Potential Mobility and Accessibility graph - number of jobs within 30 minutes and 3 euro travel budget

Both graphs make clear that from a majority of the neighbourhoods, accessibility of 50% of jobs by public transport is not feasible and for a threshold value of 25% it is about half. By bicycle, the 50% threshold is met by the majority of neighbourhoods, with the exception of those along the region's border. If only travel times are considered, the accessibility by car is sufficient for all neighbourhoods. But after adding the travel budget, the majority of the neighbourhoods are unable to meet the threshold value of 50%. And for all modes applies, the lower the threshold value, the more neighbourhoods show a sufficient job accessibility.

The table in figure 5.9 shows the share of different target groups that have sufficient job accessibility by different transport modes and threshold values. A distinction was made between low-income or jobless target groups above, and middle- and high-income target groups below. If the threshold value is 25%, for public transport between 53% and 58% of the more vulnerable target groups have sufficient job accessibility. This number decreases significantly with a threshold value of 50%, when no more than 11% of the residents have sufficient accessibility by public transport. However, in comparison, middle or high income households have even lower job accessibility by both public transport and bicycle, independent of threshold values. This can be explained by the fact that the more rural municipalities have less accessibility by these modes and contain a smaller share of households with low income or unemployed residents. Households with higher income levels can compensate for this low level of accessibility, by travelling by car, for which they have 100% of all jobs within reach, which low income groups can't. Even with the lowest threshold value of 25% of all jobs, only between 53% and 61% of the more vulnerable target groups have sufficient accessibility by car.

	THR. 25% jobs			THR. 50% jobs			THR. 75% jobs		
	TT30+TC3			TT30+TC3			TT30+TC3		
Target group	PT	CAR	CYCLING	PT	CAR	CYCLING	PT	CAR	CYCLING
Lowest 10%	58%	61%	96%	11%	23%	84%	0%	0%	41%
Low income	55%	57%	94%	9%	22%	82%	0%	0%	39%
Unemployed	53%	53%	93%	8%	20%	81%	0%	0%	37%
	TT30			TT30			TT30		
Target group	PT	CAR	CYCLING	PT	CAR	CYCLING	PT	CAR	CYCLING
Middle income	51%	100%	91%	6%	100%	79%	0%	100%	36%
High income	45%	100%	87%	4%	100%	73%	0%	100%	33%

Figure 5.9: The percentage of people/households with sufficient job accessibility for threshold values of 25, 50 and 75%

5.4.2. Accessibility shortfall

For all neighbourhoods below the threshold value for accessibility, the shortfall is calculated. The table in figure 5.10 shows the average shortfall for each municipality for different modes and situation. The first column is the average shortfall for public transport with a travel time limit of 30 minutes. The average shortfall is largest in Beekdaelen, the more rural municipality in the north of the region, and smallest for Heerlen, the municipality with the highest job density and well served by public transport compared to other municipalities. The second columns shows the average shortfall if travel costs are considered and there is hardly any difference in the outcome. Thereafter, figures follow for public transport with 45 minutes travel time with and without budget, car with 30 minutes travel time with and without budget and bicycle with 30 and 45 minutes travel time.

Municipality	PT TT30	PT TT30 TC3	PT TT45	PT45 TC3	CAR TT30	CAR TT30 TC3	CYCLE TT30	CYCLE TT45
Beekdaelen	0,723	0,752	0,162	0,367	0,000	0,632	0,238	0,004
Brunssum	0,500	0,503	0,086	0,115	0,000	0,435	0,015	0,000
Heerlen	0,090	0,090	0,001	0,001	0,000	0,040	0,000	0,000
Kerkrade	0,332	0,342	0,001	0,020	0,000	0,290	0,015	0,000
Landgraaf	0,330	0,331	0,015	0,026	0,000	0,231	0,005	0,000
Simpelveld	0,584	0,584	0,090	0,146	0,000	0,551	0,156	0,000
Voerendaal	0,484	0,485	0,073	0,115	0,000	0,450	0,057	0,000

Figure 5.10: The average shortfall in accessibility for each municipality with a threshold value of 50%

5.4.3. Accessibility Sufficiency Index (ASI)

The Accessibility Sufficiency Index is calculated for each neighbourhood for different modalities under different circumstances. The complete analysis of the ASI is summarized on the municipality level in the table in figure 5.11. The effect of the ASI for public transport is in particular well visible for the municipality of Beekdaelen where the ASI is significantly lower for low-income groups, due to the fact that low-income households are less prevalent here.

Municipality	PT TT30	PT TT30 TC3	PT UNEMPL	PT TT45	PT45 TC3	PT UNEMPL	CAR TT30	CAR TT30 TC3	CAR UNEMPL	CYCLE TT30	CYCLE TT45
Beekdaelen	0,504	0,227	0,242	0,117	0,104	0,117	0,000	0,187	0,204	0,238	0,004
Brunssum	0,226	0,189	0,165	0,023	0,032	0,028	0,000	0,175	0,151	0,010	0,000
Heerlen	0,039	0,049	0,039	0,000	0,000	0,000	0,000	0,022	0,018	0,000	0,000
Kerkrade	0,163	0,175	0,142	0,000	0,010	0,008	0,000	0,147	0,120	0,015	0,000
Landgraaf	0,184	0,116	0,114	0,008	0,008	0,008	0,000	0,081	0,078	0,005	0,000
Simpelveld	0,378	0,206	0,184	0,059	0,050	0,046	0,000	0,195	0,175	0,156	0,000
Voerendaal	0,339	0,146	0,158	0,053	0,032	0,038	0,000	0,129	0,149	0,057	0,000

Figure 5.11: The average Accessibility Sufficiency Index for each municipality with a threshold value of 50%

However, the figures in this table give a limited picture of the total results of all neighbourhoods. A spatial pattern of public transport ASI as in figure 5.12 helps to get a better picture of the differences in job accessibility by public transport at the neighbourhood level. In a number of neighbourhoods, the share in the total ASI increases when low income households are distinguished. Several neighbourhoods in Brunssum now stand out, and in Landgraaf, Kerkrade and Heerlen, too, a bit more colour contrast arises locally because more low-income households live here. The share in the ASI of areas on the edge of the region decreased, but is certainly still present.

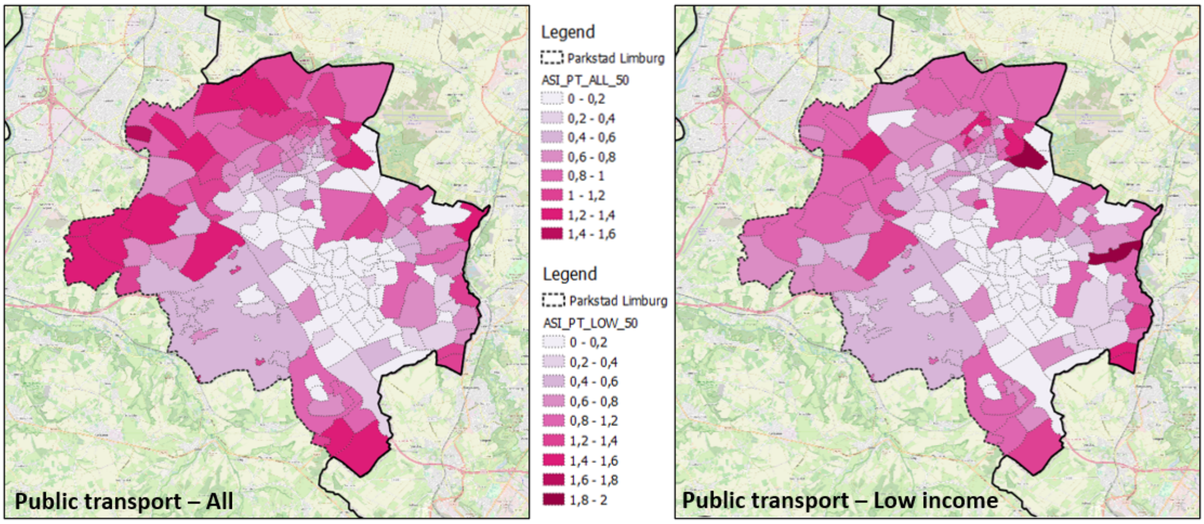

Figure 5.12: The changing spatial pattern of accessibility poverty by public transport for all households (left) and low income households (right) *(©OpenStreetMap, created with TravelTime API)*

A spatial pattern of the ASI for each neighbourhood was created also to assess car accessibility for low income groups and accessibility by bicycle for all households (as this is the same for everyone), see figure 5.13. Apart from exceptions, the map for car accessibility shows a similar pattern as accessibility by public transport for low income households. A limited number of neighbourhoods has a job accessibility by bicycle lower than the threshold value, hence the large share (percentage of up to 16%) for some of the neighbourhoods on the edge of the region.

The main conclusion on the overall job accessibility is that accessibility by public transport is low, for all. Car accessibility in the region is high, but for low-income groups, which are restricted by low travel budgets, their job accessibility by car is on average equal to the accessibility by public transport. By bicycle, for all except those living on the edge of the region, the potential job accessibility is high and more competitive with car. And even though travelling by public transport is less expensive than by car, within the same travel budget of 3 euros, the accessibility is on average equal. And even more neighbourhoods have sufficient accessibility by car compared to public transport if the travel costs

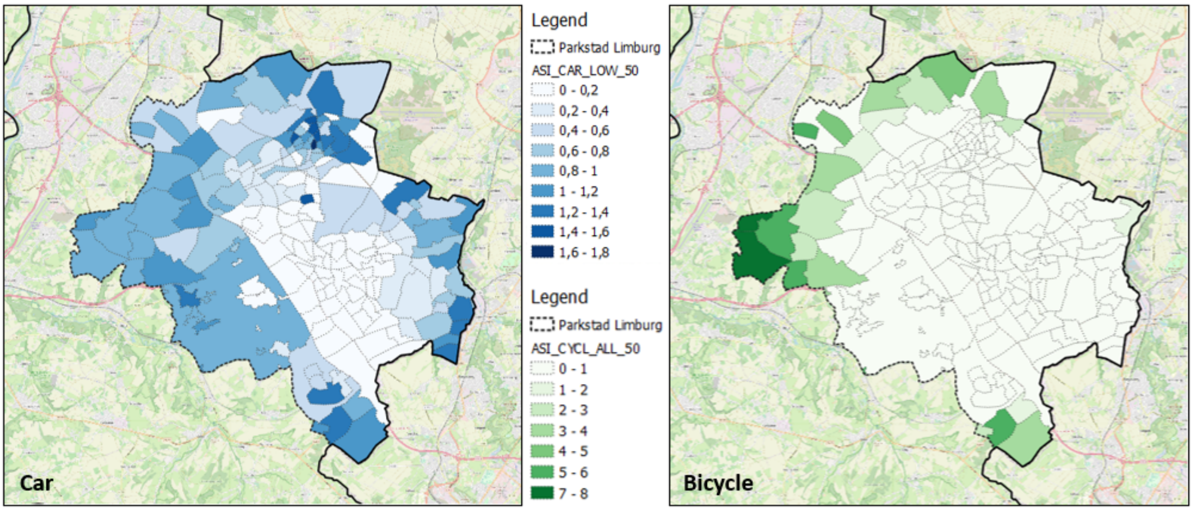

Figure 5.13: The changing spatial pattern of accessibility poverty by car for low income households (left) and by bicycle for all households (right) *(©OpenStreetMap, created with TravelTime API)*

are included. The different threshold values show that the share of low-income households and the unemployed with sufficient job accessibility is extremely low, by both car and public transport, which contrast greatly with the high car accessibility for middle and high income households.

5.5. Evaluation

In this section, the results of the analysis will be evaluated, both quantitative and qualitative. This starts with describing the sensitivity analysis for travel time, travel cost and the threshold values. Both the method and the results were presented to the officials of municipalities in the Parkstad regio, and with their expertise the results were put into context and further interpreted.

5.5.1. Sensitivity analysis

A sensitivity analysis was carried out for both travel time and travel costs, to explore how sensitive all modes are to an increase or decrease in available travel time or travel budget.

The table in Appendix H shows the accessibility, expressed in the number of jobs that can be reached on average by each modality, under different boundary conditions. By varying the travel time between 15, 30, 45 and 60 minutes it was possible to determine the job accessibility under different conditions. It is then noticeable that 63% coverage is already achieved by car within 15 minutes travel time; a coverage that is only achievable by public transport within 45 minutes, or by bicycle within 30 minutes. In the end, the 100% coverage by public transport is only achieved with at least 90 minutes travel time. Extending the available travel time thus particularly affects accessibility by public transport and bicycle. To determine job accessibility based on the travel budget, the travel budget was varied between 2, 3, 4 and 5 euros. Travel costs are particularly limiting for accessibility by car, this is clearly more expensive than public transport. Up to a budget of 2 euros, the job accessibility by public transport and car are comparable, after that it mainly increases considerably for public transport. In the end, a budget of 6 euros showed to be sufficient to provide accessibility to all jobs for all residents by public transport and 12 euros by car. Cycling and walking are insensitive to travel costs.

Only assessing travel costs gives a somewhat misleading picture of actual accessibility, as travel time is not unlimited. Combining different travel times and travel costs gives a more realistic picture of the job accessibility. That car accessibility is very much determined by travel costs can be seen in the combinations for a 15-minute travel time. This was 63% based on travel time alone, but with a budget of up to 5 euro, it is limited by travel costs. With public transport, the increase in accessibility depends on the increase in travel time. It is only from a travel time of 45 minutes and onwards that it is visible that too small a budget can limit job accessibility by public transport as well.

The analysis of sensitivity to travel costs and travel time is also visualised in two different graphs. The graph in figure 5.14 shows the sensitivity for travel time. For all four modes a line shows how the job opportunities increase with increasing travel times. Two dashed lines are added to show how job opportunities for both car and public transport increase with increasing travel time if there is also a limitation of a travel budget of 3 euros. Accessibility by car does not increase and is limited to around 28% of jobs. The accessibility of jobs by public transport still increases, and eventually stops at 61%.

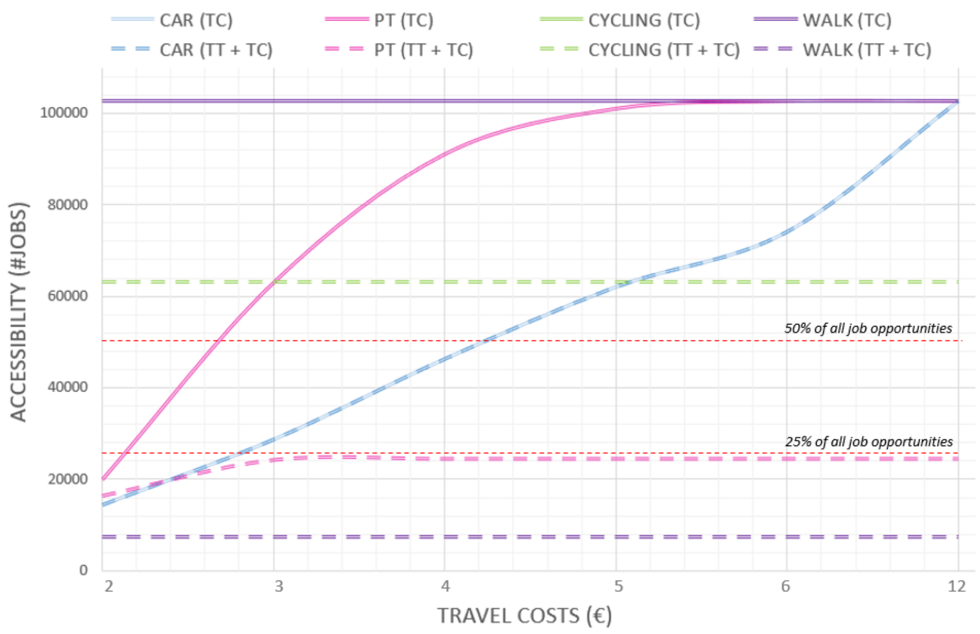

Figure 5.14: Sensitivity analysis for travel time within a 3 euro travel budget

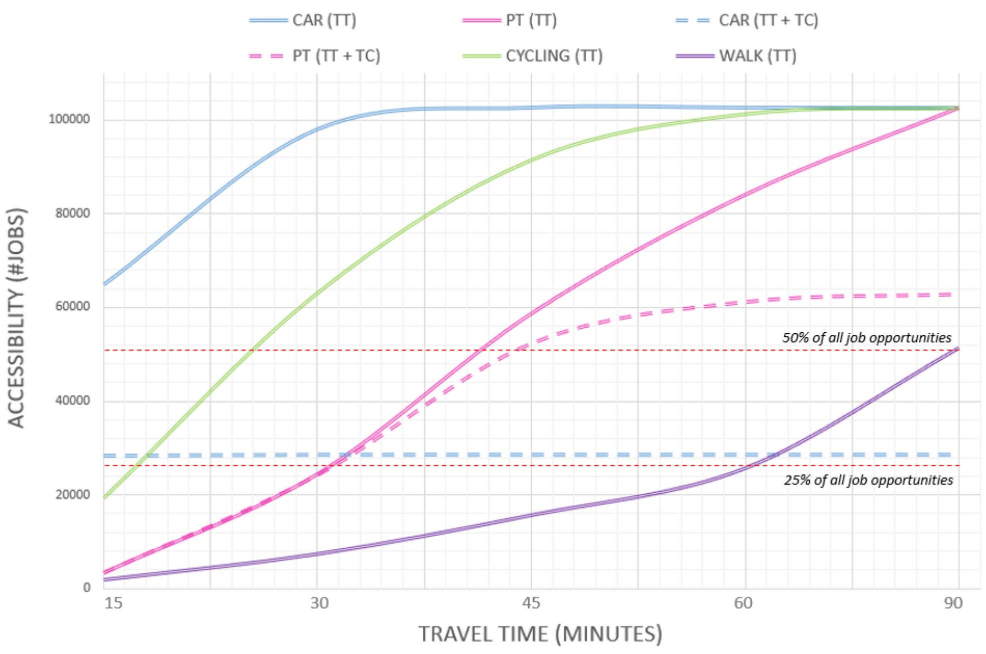

Figure 5.15: Sensitivity analysis for travel costs within 30 minutes travel time

The graph in figure 5.15 shows the sensitivity for travel costs. For all four modes a line shows how the job opportunities increase with increasing travel budget. Two dashed lines are added to show how job opportunities for both car and public transport increase with increasing travel budget if there is also a travel time limit of 30 minutes. Accessibility by car keeps increasing with increasing travel budget, but requires a 12 euro budget. The job accessibility by public transport, cycling and walking is clearly restricted by the travel time limit of 30 minutes and does not increase with increasing budget.

Besides sensitivity for travel time and travel costs, the threshold values can be considered as well. The analysis was carried out with a threshold value of 50% of all jobs, but the threshold value of 25% was present in the graphs as well. Maps of the Accessibility Sufficiency Index of car accessibility for households with low income, with a threshold value of 25% and 50% are shown in figure 5.16. What this map shows, is what all maps show if the threshold values is lowered. Of the threshold value is lower, more neighbourhoods have sufficient accessibility, thus less neighbourhoods suffer from transport poverty, according to the analysis. This means, that the contribution of these neighbourhood to transport poverty in the region increases, which is evident from the legend.

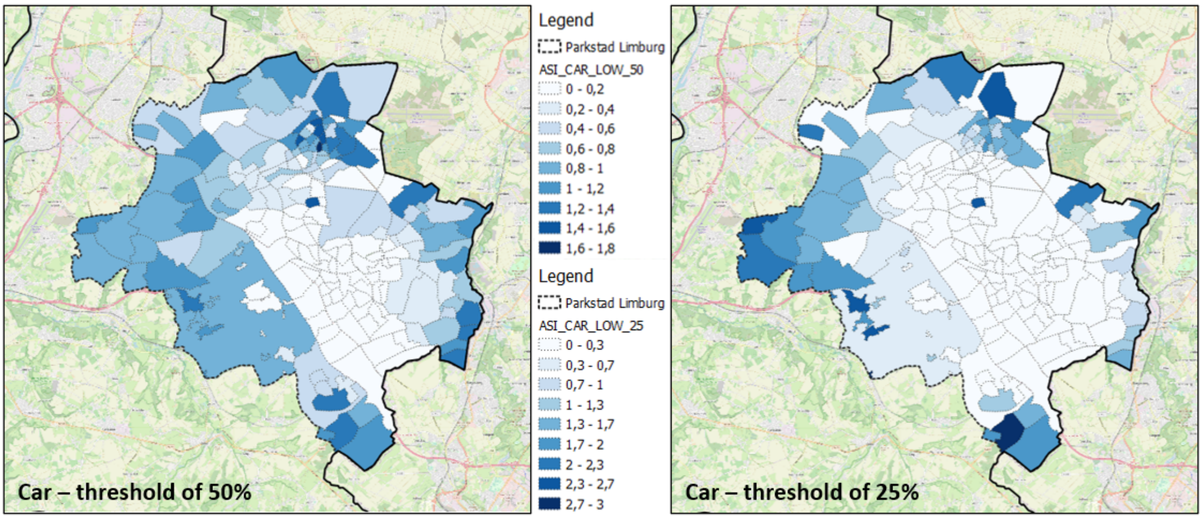

Figure 5.16: The car ASI for each municipality with a threshold value of 25% (right) and 50% (left) *(©OpenStreetMap, created with TravelTime API)*

5.5.2. Identify causes and promising interventions

In a series of interviews with officials from the municipalities of Beekdaelen, Heerlen, Kerkrade and Brunssum, the results of the study were presented and evaluated. A table with a summary of results presented and discussed, is shown in figure 5.17. This table shows the neighbourhoods which have the largest ASI scores for job accessibility by public transport, car and bicycle for low-income households and the unemployed. If a figure is red, this means that it is 1 out of the 20 highest scoring neighbourhoods in a specific column. Where a high score means that a neighbourhood contributes significant in the overall ASI in the region. The columns 'LOW HH Rate' and 'UNEM rate' represent the percentage of low income households and unemployed residents in a neighbourhood. The values are red if the figures are above national averages. The final two columns are the summation of the ASI values for low-income households and the unemployed, whereas the complete table is sorted by the column for the low-income households. Apparently, if we consider all modes, the neighbourhood 'Hendrik en omgeving' in Brunssum contributes to transport poverty in the region the most. With this table, the 'least accessible' neighbourhoods for low-income households and unemployed residents can be identified and compared with the socio-economic characteristics.

From themeeting with officials of the municipalities, it appears that transport poverty is high on the agenda in a number of municipalities in the region, and interest in the results is high. In the municipality of Landgraaf a motion recently passed, which will soon make free public transport available to

Municipality	Neighbourhood	PT LOW	PT UNEMPL	CAR LOW	CAR UNEMPL	CYCLE LOW	CYCLE UNEMPL	LOW HH Rate	UNEM Rate	SUM ASI LOW	SUM ASI UNEMPL
Brunssum	Hendrik en omgeving	0,512	0,000	0,296	0,000	0,000	0,000	54%	42%	0,808	0,000
Simpelveld	Bocholtz	0,373	0,308	0,265	0,219	0,140	0,116	39%	32%	0,778	0,644
Brunssum	Houserveld	0,411	0,316	0,328	0,252	0,028	0,022	56%	43%	0,767	0,590
Brunssum	Merkelbeekerdal	0,439	0,338	0,308	0,237	0,012	0,009	56%	43%	0,758	0,584
Brunssum	Kleikoelen	0,443	0,327	0,315	0,232	0,000	0,000	71%	52%	0,758	0,559
Kerkrade	Bleijerheide	0,415	0,315	0,297	0,225	0,042	0,032	57%	43%	0,754	0,572
Brunssum	Lemmender	0,397	0,286	0,345	0,249	0,000	0,000	81%	58%	0,742	0,535
Beekdaelen	Schinveld	0,310	0,275	0,303	0,269	0,118	0,105	42%	37%	0,731	0,649
Simpelveld	Bocholtzerheide	0,297	0,299	0,282	0,284	0,144	0,145	31%	31%	0,723	0,728
Heerlen	Weggebekker	0,549	0,413	0,165	0,124	0,000	0,000	82%	62%	0,714	0,537
Kerkrade	Rolduckerveld	0,366	0,242	0,311	0,205	0,036	0,024	71%	47%	0,713	0,472
Brunssum	Bouwberg	0,342	0,350	0,264	0,270	0,104	0,106	41%	42%	0,711	0,727
Brunssum	De Heide	0,390	0,302	0,304	0,236	0,000	0,000	54%	42%	0,694	0,538
Landgraaf	Waubach	0,331	0,272	0,359	0,295	0,000	0,000	55%	45%	0,690	0,567
Kerkrade	Nulland	0,395	0,320	0,262	0,212	0,030	0,025	53%	43%	0,688	0,557
Beekdaelen	Schinnen	0,388	0,334	0,239	0,206	0,052	0,045	44%	38%	0,679	0,585
Voerendaal	Fromberg	0,275	0,339	0,262	0,322	0,140	0,172	28%	34%	0,677	0,833
Brunssum	Rozengaard	0,321	0,259	0,317	0,255	0,000	0,000	57%	46%	0,639	0,514
Kerkrade	Holz	0,287	0,200	0,275	0,192	0,044	0,031	56%	39%	0,606	0,422
Brunssum	Rode Beek	0,299	0,306	0,255	0,261	0,043	0,044	41%	42%	0,597	0,611
Landgraaf	Rimburg	0,293	0,302	0,243	0,250	0,051	0,053	35%	36%	0,587	0,606
Simpelveld	Simpelveld	0,280	0,174	0,297	0,184	0,000	0,000	60%	37%	0,577	0,358
Landgraaf	Abdissenbosch	0,283	0,249	0,287	0,253	0,000	0,000	42%	37%	0,570	0,501
Brunssum	De Eggen	0,244	0,193	0,307	0,243	0,000	0,000	57%	45%	0,551	0,436
Heerlen	Terschuren	0,336	0,336	0,215	0,216	0,000	0,000	53%	53%	0,551	0,552
Brunssum	Hofpoel	0,203	0,146	0,343	0,246	0,000	0,000	61%	44%	0,546	0,392
Brunssum	Centrum	0,149	0,112	0,388	0,291	0,000	0,000	73%	55%	0,537	0,403
Beekdaelen	Sweikhuizen	0,216	0,306	0,196	0,277	0,113	0,160	22%	31%	0,525	0,743
Beekdaelen	Swier	0,348	0,244	0,159	0,112	0,000	0,000	37%	26%	0,507	0,355
Landgraaf	Lauradorp	0,312	0,267	0,185	0,159	0,000	0,000	46%	39%	0,497	0,426
Beekdaelen	Tervoorst en omgeving	0,240	0,310	0,189	0,243	0,057	0,073	26%	34%	0,486	0,626
Kerkrade	Haanrade	0,286	0,303	0,169	0,179	0,004	0,004	39%	41%	0,459	0,486
Landgraaf	Buitengebied Brunssum	0,324	0,306	0,122	0,115	0,000	0,000	43%	41%	0,446	0,421
Voerendaal	Klimmen	0,108	0,104	0,278	0,267	0,000	0,000	34%	33%	0,386	0,372
Brunssum	Ora et Labora	0,000	0,357	0,000	0,270	0,000	0,055	0%	42%	0,000	0,682

Figure 5.17: Table with results for neighbourhoods with high ASI score

people with an income up to 140% of the social minimum. Other municipalities in the region are now also looking at this, or as one policymaker aptly said: 'when a motion like this is passed at one of the municipalities in Parkstad, it will most likely turn end up on the agenda of other municipalities in the region as well'. Despite the fact that people are not directly against the proposal, there were some critical voices, which were mostly related to the purpose of this motion. If the aim is to increase the chance of a job, only providing free public transport is probably not the solution, given the results of this research. An important detail here is that the free pass is only valid in off peak hours, which means that it is probably not suitable for all jobs.

This opened up a discussion about what might be the solution here. People from the municipality of Heerlen were in particular glad to see that the potential of the bicycle was evident from the results, while at the same time the lack of accessibility by public transport concerned them. However, the municipalities' influence on public transport is limited and decisions are made at provincial level. Based on the graphs showing the potential mobility and accessibility, it was immediately clear to them that there are opportunities to further improve accessibility by bicycle and compete with car accessibility. In this discussion, the current modal split of the region was brought up, which shows a low share of travelling by bicycle. When asked for explanatory arguments for this, the high car accessibility in the region was mentioned in particular. In addition, the differences in altitude in the region are believed to play a role, and the extra effort it takes for people to travel somewhere by bicycle. E-bikes are considered a part of the solution in this regard, but these are to expensive for low-income households. However, in the Parkstad region, there are already several hubs of an e-bike sharing system. Increasing the supply of these locations (also specifically on job locations) and making these e-bikes accessible for people who experience low accessibility would increase their job accessibility. Perhaps a free pass for these e-bikes could improve job accessibility more than a free pass for public transport.

Awareness of the individual component is also essential here. Where for one target group an e-bike may be a solution, other people would be more pleased with free or improved public transport, which also has to do with (physical) capabilities. The analysis is very quantitative and to identify possible transport poverty and propose useful interventions, it is also important to know what is prevalent among residents. For example, an official of the Kerkrade municipality said he was surprised that the neighbourhood Gracht did not emerge as a neighbourhood with limited accessibility to jobs, because it is precisely from this neighbourhood he receives complaints about poor accessibility to jobs. This neighbourhood is south of the region, near many jobs and even right next to the neighbourhood with the highest jobs density, which is why Gracht scores reasonably well on accessibility. Apparently, people living in Gracht, don't work here, but somewhere they can't reach with public transport. In the discussion that followed, it became clear that having a good idea of where people work but also the extent to which people also have access to jobs for which their level of education is also adequate, is equally important. An in-depth analysis on this analysis calculating the accessibility of jobs of different education levels or industries could provide more understanding. But maybe more qualitative research, which includes involving the people affected, can also help to understand the results.

At the municipality of Beekdaelen, officials were very interested to see the results, as they had not seen a study before, which connected job accessibility and transport poverty, and these are issues that are of concern to this municipality. Public transport accessibility as currently mapped for Beekdaelen is expected to decrease; as a result of tightening measures, bus routes in this municipality will be removed from village centres, further increasing travel times to bus stops at various locations. That the results of this study show that job accessibility is rather low in this municipality makes these developments all the more concerning. Nonetheless, policymakers were very pleased to see that bike accessibility is very promising; encouraging cycling for commute has the attention of this municipality, given the plans for a bicycle highway.

To conclude this section, a number of reasons for the limited accessibility has been mentioned. For one, public transport has been scaled down further in recent years and is currently in a downward spiral, with less and less supply, because people use it less and less, because supply is less and less, and so a downward spiral has been developed. Improvements in the public transport network weren't even mentioned, not only because this is not in the direct sphere of influence, but one could sense a feeling of despondency related to this subject. The accessibility by bicycle was only low for neighbourhoods located at the outskirt of the regions, and at least in the north, there are already plans for improving the cycling network. And even though the potential accessibility is high, the share in bicycle use is low, and officials questioned whether people with a low income own a bike, or at least one that is decent enough to travel the hills in this region. For these specific groups, providing a bicycle, possibly through an e-bike sharing system, will help increase the job accessibility.

It is expected that free public transport will have limited effect on the accessibility of jobs. There is a limitation on job accessibility by public transport for people with a small travel budget after a 45-minute travel time due to increasing travel costs. Thus there will be some improvement when public transport is free, but the difference is limited and the accessibility will be well behind job accessibility by car and bicycle even. The sensitivity analysis also revealed that for job accessibility by public transport, the travel times are the main cause for limited accessibility. However, for neighbourhoods located near public transport and in the vicinity of jobs, such as Kerkrade, Heerlen and even some neighbourhoods in Landgraaf, commute by public transport is more attractive and for households located here it, free public transport might be a solution. The discussions were conducted with officials who are particularly involved with mobility. Therefore, the solutions that were put forward were directly related to mobility, although the method also allowed for solutions from the perspective of land-use. For instance, employment in this region is located along the main access roads and where access by public transport is not adequate. By taking into account infrastructure other than that of cars when assigning locations for employment, the accessibility of jobs can also be improved. It should also be noted that public transport in this region performs really poor and that improvements would have a direct impact on the accessibility of many, especially if combined with making public transport free for specific target groups.

6 Discussion

The aim of this chapter is to discuss the method and results, which can help to further improve research into this area, as this research has limitations on its own. The chapter is divided into three section and covers a discussion first about the methodology, then the implications for practice and finally there will be a broader discussion which involves other research as well. In addition, the results of the analyses were also shared with policy makers of the municipalities and their perspectives have also been incorporated into this discussion.

6.1. Methodology

A major advantage of the methodology is that it allows for numerous design choices, allowing the method to be adapted to any given context. This flexibility has already emerged from previous case studies where it was already mentioned that the possibilities are numerous by varying the area size, destination or target groups, as long as sufficient data is available (van der Veen et al., 2020). The additional risk that more selective research of sufficient accessibility can lead to an analysis that does not do justice to the method, is being challenged with this research. Even the results of a study with a limited scope can be valuable, provided that the researcher is aware of the limitations of the study and interprets the results in a nuanced way.

The limitations of this research will be discussed here and to what extent these affected the results. The conceptual model shows that choices about the travel time limit, travel budget and threshold values, among others, affect the results of the calculations directly. The choice for the travel time limit is based upon the average commute travel time by car. But this travel time limit might be different if commute travel times by bicycle or public transport had been considered; figures on distances travelled by bicycle and public transport for commuting are lower on average, and if this is set against the speed at which these distance are travelled, this would lead to a travel time limit of around 20 minutes by bicycle and 45 minutes by public transport. If we take the mode specific travel time limits into account, this would mean that job accessibility by public transport is better than by bicycle, although the willingness to travel longer distances by bike might be greater with e-bikes. Furthermore, despite the average travel times by car being almost 30 minutes, journey times of up to 70 minutes are considered acceptable and the same phenomenon could occur with other modes where longer journey times are considered acceptable, especially if this brings a multitude of jobs within reach.

An important variable in the calculation of the travel costs, are the price per kilometre for travelling by car. According to Litman (2013) there are multiple items that affect transport affordability, such as vehicle purchase costs, insurance fees, fuel prices and parking fees. He states that a complete analysis of transport affordability should include all cost component rather than individual cost components. Therefore the choice in this study was to include more costs than just the usage costs in determining the fuel prices. These results have been discussed amongst colleagues and from these conversations it is noticeable that people assume the cost of fuel mainly, when they compare travel costs of different modes. As a result, people do not perceive public transport as the cheaper mode, if compared with travelling by car. It would have made quite a difference to the results if only fuel prices had been assumed for the price per kilometer by car. On the other hand, the travel budget would also have been a lot smaller, as the fixed costs of a vehicle are part of the annual mobility expenditures CBS statistics calculated.

The statistics considered for low-income households, are on the household level. This brought a number of advantages, such as information on incomes which are available at the household level. However, transport poverty is more likely to occur in individuals than in households (Lucas et al., 2016), where one member of a household experience limited accessibility and the other not. For example a household where one member can use the car and the other is dependant on the partner or other modalities. But there are numerous household compositions that can be considered, with family members who each have their own desires regarding activities they want to participate in. Since the scope of this research is limited to job accessibility, these details are not considered in this research.

Not only the variables and threshold values affected the outcome of the analysis, so did the accessibility measure chosen. Of the location-based measures mentioned, the cumulative accessibility measure was chosen, since the data requirements are modest and the calculations easy to calculate and communicate with the officials of the municipalities. Although considered, more advanced measures, with job competition or distance decay functions are not applied. Job competition effects would most likely affect the accessibility of jobs located near the city centre of Heerlen, where there is not only a high density in jobs, but also more competition due to the high accessibility for most residents in this region, with all modes.

The use of distance decay functions in the accessibility calculations would most likely have had a limited affect on the accessibility by car. On average, commute travel time in the Netherlands is 26 minutes and up to 70 minutes is considered acceptable. By car, all jobs can be reached within 30 minutes, which is why a distance decay function would not affect the outcome for job accessibility by car. In addition, accessibility within 30 minutes was initially considered, which actually implicitly takes into account that jobs located further away are less attractive. It is therefore expected that using a distance decay function would mainly affect the results of the sensitivity analyses with travel times of 45 and 60 minutes. For public transport, accessibility will then show slightly lower job accessibility than at present. For cycling and walking it could well be that the limit for acceptable travel times is lower, thus for these two modes, a decrease in job accessibility may occur sooner. The expectation here is, that adding a distance decay function, might only change the perception on how severe transport poverty is, not where transport poverty occurs or how the different modes perform relative to one another. But maybe an even more important reason for not applying more refined accessibility measures, is that this would require more disaggregate data as well. Applying an accessibility measure with job competition effects, would be inappropriate on this regional scale whilst considering a homogeneous labour market and employees. There was no distinction made on educational level or the type of employment sector since this data was not available.

The job accessibility was calculated for four different modes, and although job accessibility on foot was determined, little was done with the results, since walking is not really competitive with the other modes. Nevertheless, the results have been left in the analysis; for possible future research on the accessibility of other facilities and when walkability of neighbourhoods becomes more relevant. An example is the municipality of Brunssum, which aims to have all basic amenities within 10 minutes' travelling time for everyone, and it becomes interesting to see whether this is also feasible on foot. By including walking in the analysis, however, the average PMI became lower than if it would have been left out. If walking was not part of the analysis, the average PMI would have been 16 and for all neighbourhoods, accessibility by bicycle would have fallen anywhere in the first or second quadrant of the graph. But since all neighbourhoods falling below the threshold of sufficient accessibility are included in the analysis, regardless of the PMI index, this does not make any difference to the final result. In the discussion with municipalities about the results, it does not appear to matter either, since no one gave the impression that the potential mobility of bicycles in this context was considered sufficient. Indeed, there is even a clear show of ambition to improve bicycle accessibility and compete with car accessibility even more.

Finally, an important step in determining the Accessibility Sufficiency Index is multiplying the severity of the shortfall by the number of households suffering from this insufficient accessibility. The results you get from this can help prioritise policies. However, sometimes neighbourhoods where proportionally a smaller amount of low-income households live, but accessibility is very poor, might not be taken into account, and the question here is, whether that is entirely fair. When Martens proposed the ASI as an indicator, his argument was, that it would not be entirely fair to spend a lot of public money to improve the accessibility levels of a really small group of people, but that is directly opposed to the statement that accessibility should be considered a basic right in transport planning (Donkers, 2017). In addition, what must be taken into account is that in larger neighbourhoods, which may have proportionally fewer low-income residents, it could be more if you consider the absolute numbers, and the ASI is thus not infallible. It is therefore recommended to always take into account the severity of the shortfall and the statistics of a neighbourhoods population next to the ASI as well.

6.2. Practice

To achieve results that will also be used in transport policy by policymakers and planners, it is important to come up with accessibility indicators that are both easy to interpret as well as easy to communicate (Geurs and van Wee, 2004). Based on the presentations given to the municipalities and the discussions that followed, it appears that this method succeeds in doing so. The only drawbacks that emerged had to do with the scope of the study, which included the geographical scope and the type of amenities included, which both can easily be extended as desired using this method.

As for the geographical scope, only the jobs located within the boundaries of the Parkstad region where part of the accessibility measurement. Because the municipality of Beekdaelen is located along the Northern border of the region, accessibility to jobs in the Parkstad region is low, but residents of this municipality are also focused on jobs outside this region. Officials at the municipality indicated that they cooperate a lot with the western mining region (municipality of Sittard-Geleen) and that many large employers are also located there, such as Chemelot and VDL. For the municipality of Beekdaelen, in particular, an extension of this research to the rest of South-Limburg would be valuable, but it has also been mentioned by officials of other municipalities.

The second limitations of the scope is related to to the assessment of job accessibility only, but accessibility to amenities elsewhere in the region are considered equally interesting. Several officials have asked what opportunities there are to expand this further, by adding more amenities and examine accessibility for other target groups. For instance, population aging plays a role in this region, so an investigation into accessibility of basic facilities for the elderly could be a next step.

6.3. Academic

Recent research on the perception of accessibility indicated that people living in rural areas where accessibility is lower, don't perceive their accessibility as worse off compared to people living in areas with higher levels accessibility. One of the explanatory arguments is the residential self selection; people choose where they want to live and match this with their preferred modality, and most people living in areas with lower accessibility can compensate the lower level of accessibility by the use of their car (Jorritsma et al., 2023). It was an argument of an official of the municipality of Beekdaelen as well, in relation to some of the rural neighbourhoods on the map with low accessibility, where the residents consciously choose to live here, because these locations often have other advantages, such as a quiet living environment or lots of nature. This is off course true and probably applies to a lot of the neighbourhoods in municipalities such as Beekdaelen and Voerendaal, where most of the resident belong to medium and high income groups. However, the question is whether this is an argument when we discuss groups of people with very low incomes and who are also sometimes involuntarily unemployed. These people do not always have a choice in housing and sometimes have to accept what they are offered. Something that has most likely even increased in recent years, due to the housing shortage and the rise in house prices.

in addition, you may wonder to what extent people are capable of self-reflecting on their accessibility. If you already experience a certain degree of accessibility throughout your life, you will eventually start to find this acceptable. People have a way of adapting an accepting their situation, but this does not make it fair. Martens (2017) points out that there is currently no justice in mobility, because that would mean that people have a basic right to some predefined level of accessibility and would be allowed to call out their (local) government for not fulfilling their obligations. That is what also initiated the discussion about accessibility standards, because these would help determine the extent to which people also get what they are entitled to. The sufficiency thresholds set in this study are a starting point.

The accessibility standards used in this study provided a starting point, but practice will have to show what is not only fair but also achievable. None of the municipal officials could reflect on the sufficiency threshold values and found it difficult to specify to what extent a standard of 25% or 50% of all jobs is justified. It does help that this provides insight into where accessibility is low, and transport policy could be evaluated against this value, by showing by how much percent accessibility increases with a given measure.

Looking at the possible solutions proposed, they range from free public transport to improving the bicycle network and offering bicycles to people who lack one. Before these solutions are put into practice, however, it is important to first determine what the aim of the intervention is and reason from the perspective of the people themselves. There are examples of more qualitative research which provided novel insights on what are the barriers of people who experience less accessibility (Krabbenborg and Uitbeijerse, 2023)(Bastiaanssen and Martens, 2013), which can help to put possible interventions into perspective. Examples are people who are physically unable to cycle because they have never learned to do so or who do not own a bicycle because they lack suitable parking facilities. There is even sometimes a clear mismatch between supply and demand of public transport, by not providing public transport for people who have less common working hours, or by not connecting to locations where jobs are located (Bastiaanssen and Martens, 2013). When the figures of the analysis of this study were being discussed, officials' comments on what is prevalent among residents helped in interpreting the results, and endorsed the necessity of qualitative research to interpret the figures.

There are also more specific target groups which are not visible in CBS statistics and therefore hard to find in quantitative research. These are people who suffer from mobility poverty and experience, for various reasons, less accessibility because they have less options in transportation. Consider people with a physical disability, but also people who are situationally limited because they depend heavily on a partner to go places. These groups of people have less freedom of choice because they have fewer alternatives at their disposal (Lucas et al., 2016). This limitation in freedom of choice or the impossibility of choosing among alternatives to travel is also referred to by mobility poverty. There is also a growing population of people who experience a certain degree of mobility poverty despite being able to fully participate in social activities. They are highly dependant on their car because they lack alternatives, might consider their car-dependency a burden and having more alternatives and a free mode choice would add value for them. Larger investments such as improvements in public transport supply and physical infrastructure for cyclists would also help people who are already mobile by offering them an alternative to the car and this could also be key in the transition to not only a more fair, but also a more sustainable transport system.

7

Conclusion & recommendations

The main objective of this research was to analyse to what extent the job accessibility in the Parkstad region is sufficient, identify the population groups that are in particular affected by insufficient accessibility and identify the causes and come meaningful interventions. For this, the methodology for designing fair transportation systems was applied in a case-study, the Parkstad region, and results were discussed with officials of the municipalities. In this chapter, the answers to the sub-research questions will be presented first and these will lead to answering the main research question. There will also be elaborated on how this study contributes to science whilst at the same time offers new leads for more research.

7.1. Sub-research questions

This section aims to answer the five sub-research questions of this study abnd will build up to answering the main research question in the following section.

1. What methods have already been developed and what research has already been done on (in)equity in accessibility?
For decades, there has been research on accessibility which ranges from building a lexicon to developing various accessibility measures and providing case-studies. Attention for the extent to which there is also equity in accessibility has taken off in recent years, which is also reflected in the literature. In particular, many studies can be found in which disparities in accessibility are considered, which focuses on the differences in levels of accessibility between different modalities (Lunke, 2022), (Blanchard and Waddell, 2017) or across different population groups (Chen et al., 2019). Recent research by Bastiaansen et al. (2022) being an example of a case-study in the Netherlands, in which the disparities in accessibility between different regions and modalities were mapped for all kinds of activities. Due to an increasing need to formulate standards and bring equity into transport policy, research from a sufficientarism perspective emerged. Martens (2017) developed a method from the perspective of sufficientarism and several case studies, both in the Netherlands and abroad have shown the usefulness of this method. What research from both the perspective of disparities and sufficientarism have in common is the use of location-based measures where travel times are being used to measure the number of amenities one can reach from a specific location, considering different populations groups, geographical scopes, modalities and amenities.

2. What method is most suitable for identifying transport poverty and how can it be applied in this case-study?
In his research on job accessibility in the USA, Martens et al. (2022) make a strong case for using methods from a sufficientarism approach rather than disparities. If, within a given context, the differences are very small, but an entire population experiences insufficient accessibility, the system might be evaluated as equitable from an egalitarianism approach. The growing discussion on the need of accessibility standards in the Netherlands implies a sufficientarism approach and thus makes the methodology developed by Martens most suitable to asses transport poverty in the Parkstad region.

Due to the use of this methodology, transport poverty is defined by the sufficiency threshold value, where populations groups living in neighbourhoods where accessibility is below this value suffer from transport poverty. Nonetheless, some nuance is appropriate here. In the literature, a broadly accepted definition of transport poverty is when people are involuntarily excluded from participating in social activities due to limited accessibility to these activities. The causes of inaccessibility can be many; absence of infrastructure or services, the physical inability to drive or cycle or transport affordability to name a few. By extending the measure and include both travel times and travel costs, this methodology allows to identify where transport poverty is caused by the lack of infrastructure, services or due to high transport costs. The scope of the research is limited to job accessibility, which means that the transport poverty found is related to jobs only and does not provide information about the accessibility to other amenities on this level. This is also a main advantage of the method, it can be customised to a specific case; for the Parkstad region, where unemployment rates are very high and incomes are very low, the addition of travel costs and scoping on job accessibility make this research even more relevant.

3. What is known about the socio-demographics, travel behaviour, land-use and transport system in Heerlen and the Parkstad region?
The Parkstad region is located in the South of Limburg, consists of seven municipalities of which Heerlen is the largest with over 86 thousand residents. The region is known for its variety of socio-demographic challenges such as population decline, high unemployement rates and the largest share of low-income households in the Netherlands. Its geographical characteristics are unique in the Netherlands; the hills with their forests, valleys and nature parks attract many tourists to this part of the country every year.

Job opportunities are located throughout the region, but several business parks provide a larger share (together about 40%). These business parks are mainly located along the highway coming from Sittard-Geleen, entering the region on the North and leaving in the South towards Aken. This highway and the highway between Maastricht and Heerlen are the main road infrastructure for this region, connecting the region with the largest municipalities in the South of Limburg. The road network in the Parkstad region is centered around Heerlen, where the radials of several ring roads connect surrounding villages to the city centre of Heerlen. The public transport services in the region are also Heerlen-oriented and regardless their destination, residents nearly always have to pass the city-centre. A total of 13 train stations are located in this region and most neighbourhoods are dependant of a bus service. There are no additional public transport modalities such as light rail or subways. A cycling network is present and is being expanded with 'bicycle highways' to improve the network for commuters mainly. Due to the geographical characteristics, cycling is more challenging in this region.

The modal split in this region shows a high car use, 61%, which is high in comparison with the national average of 46%. Share of the use of public transport (3%) and bicycling (12%) are significantly lower than national averages (6% and 28% respectively).

4. What are the outcomes of the analysis?
The analysis provide results on different elements, which will be elaborated on in the following order: the performance of the transportation system, the job accessibility based on travel times and on both travel times and travel costs and how these figures relate to the sufficiency threshold values and for specific target groups.

The Potential Mobility Index is an indicator to evaluate the performance of the transport system and represents the average speed over aerial distances. This PMI was calculated for each mode and each neighbourhood and showed values between 21 and 39 km/h for travelling by car, where speeds where lower in more densely populated areas. The PMI for cycling was larger than for public transport, which means that to travel the same aerial distance, on average, one would be faster by bicycle, than by public transport.

The potential job accessibility within 30 minutes travel time was calculated for each neighbourhood and showed that by car, from all neighbourhoods people can reach 100% of jobs in the region. On average, this is 25% by public transport and 61% by bicycle. And although coverage by bicycle is never 100%,

there are neighbourhoods from where around 90% of the jobs can be reached; for public transport neighbourhoods with the highest job accessibility can reach between 60-70% of the jobs.
If we include travel costs into the calculation to evaluate the impact of travel costs for car and public transport for low income households, the job accessibility by car is significantly lower. The average job accessibility by car dropped to about 28%, but the number of jobs accessible by public transport within 30 minutes is also accessible within a 3 euros travel budget.

The figures for job accessibility where compared with the sufficiency threshold value of 50% of the jobs in the region. With this threshold value, only 22% of the households with a low income have sufficient accessibility by car and 10% of the households have sufficient accessibility by public transport. For residents who are unemployed, only 8% have sufficient accessibility by both car and public transport. For these aforementioned target groups, over 80% has sufficient accessibility by bicycle, which emphasises on the potential of this modality, whilst at the same time exposing the poor functioning of public transport. For households with a medium or high income, the share with sufficient accessibility by public transport and bicycle is a little lower, but this is compensated with 100% accessibility by car.

The results of the analysis were also visualized on a map, which provided a spatial pattern of the transport poverty in the region. These maps show that in the more rural neighbourhoods on the edges of the region, the job accessibility by public transport and bicycle is lower. This explains the larger share of medium and high income households having lower accessibility by these modes, since this population can be found in these neighbourhoods. Furthermore, several neighbourhoods along the eastern border, in the municipalities of Brunssum, Landgraaf and Kerkrade showed the most severe transport poverty by both public transport and by car.

5. How can policymakers use the results of the analysis and how do they value its applicability?
In separate sessions, the results were presented for and discussed with the municipalities involved. The interest in the results was high and provoked in-depth discussions about the severity of the shortfall in job accessibility and its causes. The results of the analysis were easy to communicate and provided the municipalities with lists of neighbourhoods where job related transport poverty is high and where also difference for low-income households or the unemployed were evident. The policymakers found the results insightful and saw opportunities to use these results to prioritise policy, value possible solutions (such as free public transport), identify neighbourhoods where further research would be justified and to promote bicycling. The applicability was valued high and multiple officials of municipalities has asked whether I would present these results on more governmental layers, as they are eager to work on this topic on a regional or provincial level.

7.2. Research question

The main research question of this study is:

To what extent can a job accessibility analysis from a sufficientarism perspective help identify transport poverty and guide municipalities in the Parkstad region in designing a more inclusive transport system for low-income households and the unemployed?

This question consists actually of two parts; on the one hand, there is the method by which possible transport poverty can be detected, and on the other hand, there is the case of the Parkstad region and the municipalities that would benefit from a method and results that they can use.

To start with the first part of this question, the method proofed to be valuable in identifying transport poverty in the region, considering transport poverty is defined as having a lower level of accessibility than a predefined threshold value. Setting this threshold value is the main challenge in this method. You can do this by starting with neighbourhoods having an accessibility of less then 10%, 20%, or 50%, this process is rather arbitrary. The higher the threshold value, the more regions and groups you will find, which makes it more difficult to set priorities. However, making the value to low, might lead to not including areas that have a low accessibility, but not low enough for the threshold value set, which might lead to underestimating inaccessibility. So there is also a more practical downside when choosing the threshold values to low or to high, which should be taken into account.

For some of the neighborhoods where job related transport poverty was found, officials confirmed these are the neighbourhoods they would suspect transport poverty as well, although the severity of the shortfall was not known. The ASI was found valuable since it allowed for the identification of the neighbourhoods were a larger share of low-income households or unemployed people are located. Unemployment rates are high in this region, and during the sessions, some officials were wondering to what extent transport poverty causes people to remain unemployed.
There were also neighbourhoods not showing up on the shortlist although expected, or neighbourhoods showing up of which the officials know that people who live here, choose to live here and probably do have enough resources to travel. So an important conclusion here is, that this type of knowledge aids the interpretation of the quantitative results and is equally important to identify actual transport poverty.

From the sessions with the municipalities it can also be concluded, that the results of the analysis provided a lot of starting points for discussion. There are several intermediate results and these can be presented in a way, that all people understand the meaning of the figures. An example for this is the Potential Mobility Index, which resulted in a discussion about interventions to improve the aerial speed for the bicycle. But also the ASI proofed to be an interesting indicator, which led to discussions about different population groups and how this indicator could help to identify neighbourhoods where the severity of transport poverty is considerable. For the municipality of Heerlen the ASI values confirmed what they already knew, which is valuable as well, because these results can support them in their arguments.
The second part of the question is more related to the possibility of the method to guide the municipalities into designing more inclusive transport systems, for which two main arguments in favor of the method will be mentioned here. First of all, what is very helpful in this methodology, is the POMA-framework that offers the possibility to distinguish the cause of low accessibility; are adjustments in the transport system needed here or is the lack of proximity to jobs the cause? In this case-study, for public transport, it was evident that the transport system here does not function adequately, due to low supply and supply to the wrong locations (not necessarily work locations). And for low-income groups, accessibility by car was no longer affordable at some point, which was clearly related to the larger distance to jobs (and thus an increase in travel costs).

Second, due to the analysis and the intermediate results, possible causes for inaccessibility at specific locations were identified. Without going through these steps, the possible interventions would not have been brought up or would interventions that are currently under discussion been openly criticised. Also, the discussion about the topic and the insights that were obtained about what you can achieve when you analyse the transport system from the perspective of accessibility, made officials enthusiastic. Several municipalities indicated that they would like to see this research taken up on a larger scale and even taken up regionally (South-Limburg).

7.3. Contribution to science

Up to this moment, the accessibility by public transport for low-income households has been overestimated. This research revealed how transport costs affect the job accessibility for low-income households and the unemployed and that there are not only limitations in car-use but also in the use of public transport. Even though researchers show awareness of the impact of transport affordability on transport poverty for low-income households, so far accessibility has only been measured by taking into account travel times and by assuming these target groups are dependant on public transport.

It is almost self-evident that new accessibility studies are conducted in larger or more (internationally) known cities; this will most likely help raise awareness and for these case-studies more information may also more often be available. Nevertheless, taken into account the important societal purpose of conducting research, it is also of high value to conduct research in other type of cases. This study provides new knowledge about a lesser-known region, which does have many accessibility problems, diminishing public transport services and a multitude of socio-economic challenges reinforcing the risk of transport poverty as well.

7.4. Recommendations

In this section, some recommendations are listed. These recommendations are split in two sections, one consist of recommendations for further research, other are more practical recommendations for policy makers.

7.4.1. Academic recommendations

The focus for this research was on the accessibility of jobs. The measure chosen to access the accessibility, was a more simple cumulative accessibility measure, which allows one to add up all the jobs that are within reach. For job accessibility, more advances accessibility measures have been applied before, which include job competition effects. It would be interesting to see what will happen with the job accessibility if these competition effects are added to the case, especially since most jobs here are located in areas were the population is rather dense, such as in the vicinity of the city-centre of Heerlen. Also, education level, or the type of jobs (that require high or low education levels) have not been included in this analysis, but could help to better identify the accessibility of jobs on a more disaggregated level.

The Accessibility Sufficiency Index allows to not only take into account the severity of a shortfall, but also the number of people suffering from this shortfall. However, the differences in shortfall were sometimes really large, compared to the number of people living in a neighbourhood and in some other areas the shortfall was not that large but a lot of people from a specific target group was living there. In the final index, this difference is not clear, but could be important for more practical reasons. Also, the sensitivity to these values and to what extend they determine how high or low a neighbourhood enters the final list, has not been tested. But the final results do show that most neighbourhoods on the edges of the regions have the largest share in the insufficiency index, but these are not necessarily the areas were most low-income groups live.

7.4.2. Practical recommendations

The main advantage of the method is, that it can help municipalities prioritise their policies. Neighbourhoods where accessibility for specific target groups is very low could receive more attention. From the perspective of broad welfare, accessibility can make a difference and improve the conditions of peoples life. Previous qualitative research in Rotterdam showed that the inaccessibility of jobs can even hinder people from finding or keeping employment (Bastiaanssen and Martens, 2013). Since the unemployment rates are so high in this region, and the accessibility to jobs by public transport is very limited it seems justified to wonder to what extent limited accessibility also directly contributes to the unemployment in this region. It is therefore recommended that municipalities in this region further study the correlation between the unemployment in this region and the limited job accessibility.

This could very well be a more qualitative study, involving people belonging to these target groups and living in neighbourhoods with limited access to employment locations. Recent research showed that there are reasons for limited accessibility beyond travel times or costs, which can not be found by quantitative research like this. Research on the perception of accessibility showed that despite accessibility being significantly lower in some regions, it is not always perceived as such by residents. I would recommend the municipalities to use the results of this study to start the discussion with their residents and find out whether or not they experience low (job) accessibility and social exclusion in their everyday life. These conversations could help to further interpret the results and add a 'human size' to the numbers.

The results may also guide further research into accessibility by bicycle and public transport. After all, the municipalities would like to further improve sustainability and encourage its inhabitants to make other choices. The poor accessibility by public transport is reflected in the very low modal split for this mode in the region. However, accessibility by bicycle is considerably high, but nowhere in the Netherlands the bicycle-use is so little as in this region. It would be worth investigating what the reason is for not choosing this mode despite the high accessibility; are the bicycle paths unsafe, are the height differences really an obstacle, or do people not have a proper bike or parking facilities?

The method has the potential to identify the accessibility of all kinds of destinations. For example, the accessibility of basic facilities (such as healthcare or supermarkets) for people of old age could also be studied, or the accessibility of schools for children and students. One of the municipalities recently published a mobility vision of a '10 - minute city' and thereby set a standard for the accessibility; all basic amenities should be accessible within 10 minutes by either public transport, bicycle or on foot. This method could also help identify neighbourhoods that fall below this threshold value and help this municipality in reaching their goal.

A
Scientific paper

The following pages contain the scientific paper for this master thesis. As this article was submitted for the 'Nationaal Verkeerskundecongres' (NVC 2023), it was written using the paper requirements of this congress. This means that the article does not exceed 3000 words and is written according to the following structure: Introduction, research question, research method, results, conclusion and recommendations.

Job (in)accessibility in the Parkstad region - *About the impact of transport affordability on accessibility for low-income households and the unemployed*

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To obtain the degree of master of science at the Delft University of Technology

Abstract - There is increasing attention in the Netherlands in the topic of transport poverty and accessibility, with several publications discussing the need for accessibility standards to indicate injustice in the transportation system. Numerous case studies can be found where accessibility has been measured and assessed for fairness in the transport system, assuming that low-income households rely on public transport. This research reveals that up to now, the accessibility by public transport for low-income households and the unemployed is overestimated. Transport costs do not only have a diminishing effect on the accessibility by car, but also limits the accessibility by public transport. By means of the methodology 'Designing fair transportation systems' [1] it was possible to evaluate the job accessibility in the Parkstad region, a region where income on average is the lowest in the Netherlands and the unemployment rates the highest. The limited job accessibility by both car and public transport raises the question to what extent transport poverty contributes to the high unemployment rates in this region. Municipalities are recommended to use these results to further explore what the population groups suffering from transport poverty need and propose interventions to improve job accessibility for those who need this the most.

Keywords: Job accessibility, case-study, transport justice, sufficiency, transport affordability

I. Introduction

In the past few years, multiple research institutions in the Netherlands published reports on accessibility and transport poverty in the Netherlands ([2])([3]). For decades the focus of transport and planning policies has been on improving road networks to alleviate congestion and choosing the locations of facilities and jobs to ensure that they are primarily accessible by car. A car dependant society has been created where, in addition, public transport has been increasingly reduced leaving a higher risk of transport poverty. In the literature, one out of many definitions of transport poverty is 'the lack of accessibility to daily activities, which can lead to a situation where people are (involuntarily) excluded from full participation in society' ([4]). Transport poverty can also be explained as a more overarching term which includes *mobility poverty*, *accessibility poverty* and *transport affordability* ([5]).

The aforementioned reports from the PBL and Rli raise the possibility of an accessibility standard, which could enhance the structural measuring and improvement of peoples accessibility, implying policy from a sufficientarism approach, where everyone is provided with a certain standard of minimum accessibility. Case-studies found from a sufficientarism perspective were comprehensive spatial accessibility analysis which also included socio-economic target groups ([6]), ([7]) and both made use of the methodology proposed by Martens (2017). What most quantitative research in the evaluation of justice in the transport system have in common, is the use of location-based measures where travel times are being used to measure the number of amenities one can reach from a specific location. In neither of the case-studies, the travel costs are explicitly included to determine accessibility for people with limited travel budgets. Instead, the assumption is that part of the population can't afford travelling by car and is therefore dependant on public transport. However, this is a limitation that additionally results in an inadequate perception of both car and public transport accessibility for low-income households.

This study aims to demonstrate the applicability of Martens' method with the extension of travel costs and to reveal the impact of transport affordability on the accessibility for low-income households and the unemployed. The main research question for this study is:

To what extent can a job accessibility analysis from a sufficientarism perspective help identify transport poverty and guide municipalities in the Parkstad region in designing a more inclusive transport system for low-income households and the unemployed?

Since various studies have elucidated that the risk of transport poverty and poor accessibility is mainly located outside major cities and in rural areas an appropriate case-study will be provided with the Parkstad region. This region shows characteristics indicative of regions with an increased risk of transport poverty due to its geographical position and the multitude of socio-economic challenges, such as high unemployment rates and a large share of low-income households, which also determined the scope on job accessibility.

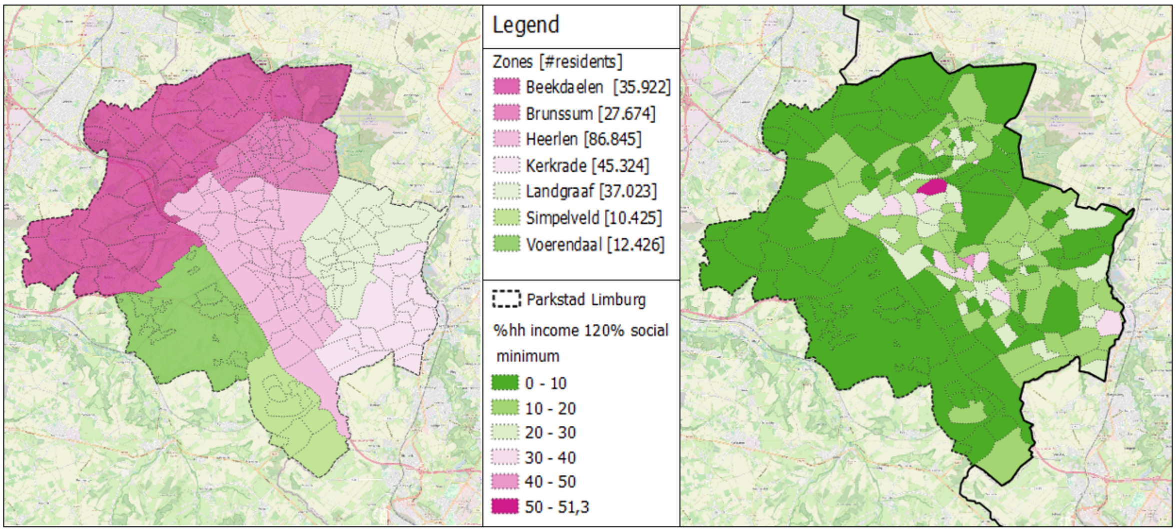

Figure 1. The Parkstad region with the seven municipalities (left) and households living from a maximum of 120% social minimum(right). ***(©OpenStreetMap, created with TravelTime API)***

In addition, there are other areas in the Netherlands that show a similar profile and for whom this study has added value. Along the eastern border of the Netherlands several urban areas are located where incomes are low and where there is also population decline, such as Enschede and Groningen ([8]).

In order to asses the sufficiency of the accessibility of jobs in the Parkstad region, the method proposed by Karel Martens ([1]) is applied. Because a number of steps are strongly interrelated, all steps are distributed over 4 phases. Based on this phase structure, which is shown in figure 2 the results will be presented. The final phase was realised in cooperation with several municipalities, with whom the results of the study were evaluated. As this study involves both geographical and socio-economic data, QGIS is used, because this software program allows the geographical visualisation of relevant data as well as the results. Also, TravelTime provides a plugin for QGIS that allows the calculation of (travel) distances and travel times with all modes between given locations.

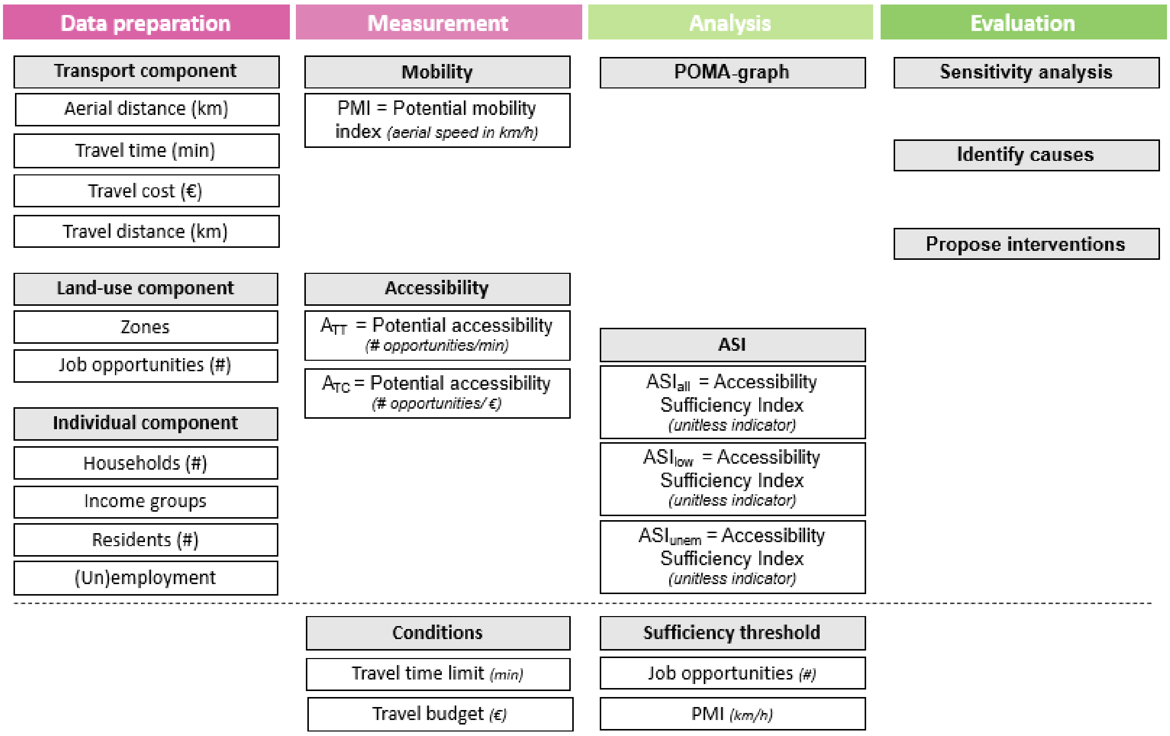

Figure 2. Conceptual model

II. Analysis

This section is structured by means of the methodology 'Designing fair transportation systems' and consists of 4 phases. The subsections will elaborate on the methodology, main assumptions and the results for each of those phases.

A. Data preparation

The QGIS model is based upon a fine-grained neighbourhood classification from the Dutch Bureau of Statistics (CBS) and allowed the region to be disaggregated in 199 zones, for which both socio-economic data as well as the number of jobs is known. With the TravelTime plugin for QGIS the matrices of the travel times, travel distances and aerial distances between all 199 neighbourhoods, by all modes are constructed.

B. Measurement

To assess the transport network, the Potential Mobility Index (PMI) is calculated for each mode. This index is calculated by dividing the aerial distances between neighbourhoods by the travel time, thus taking into account not only the speed on the network, but also the network structure itself. The average PMI in the region to travel to all neighbourhoods by car, public transport and bicycle is 28.6, 8.4 and 14.2 km/h respectively. In other words, to cover the same aerial distance, it takes you on average more than three times as long by public transport when compared to car, and cycling allows you to travel faster than public transport. The total travel time by public transport includes the time needed to walk to bus stops and stations and transfer time.

Calculations of travel time by bicycle takes into account the height differences in the region, which can make a significant difference for travel times.

The accessibility measure chosen for the assessment of the job accessibility, is a cumulative accessibility measure. This measure allows for the estimation of the total number of jobs that can be reached within a given travel time or travel cost threshold. This measure is both easy to compute and interpret and data requirements are rather modest. The initial condition for travel time is 30 minutes, which is close to 26 minutes, the average commute time in the Netherlands and the travel time in which the complete region can be reached by car. There are a total of over 102 thousand jobs in the region, with a number of locations standing out where most jobs are located. These include the centre of Heerlen, centrally located in the region, but also a number of business parks located especially along the highway and connected ring roads. Within 30 minutes, from each neighbourhood in the region, all 102 thousand jobs are available by car. By public transport, this is more than four times less on average. Accessibility by bicycle stands out in a positive sense; with an average accessibility of over 63 thousand jobs, you can reach more in the region by bicycle than by public transport. All neighbourhoods in the region from which the residents can reach more than 50% of all jobs by public transport, live in the vicinity of business parks or the city centre of Heerlen, which are the epicentre of all jobs.

Following this analysis, the calculation of the job accessibility was repeated, only this time with a travel cost budget. The initial condition for the travel cost budget is based on statistics on what low-income households spend on transport annually [9][10]. Under the assumption that the expenditure for low-income households is equal to what they can afford, a travel budget of 3 euros per day was estimated. For car and public transport a price per kilometer was used to calculate the travel costs between all neighbourhoods (provided by Nibud and Arriva respectively).

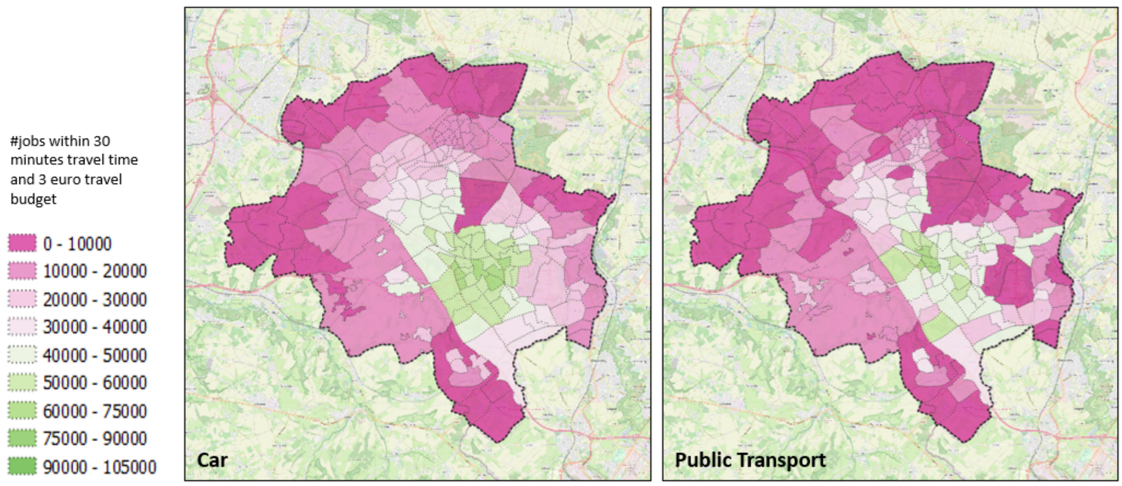

Figure 3. Job accessibility by car (left) and by public transport (right) for low-income households. ***(©OpenStreetMap, created with TravelTime API)***

Figure 3 shows how travel costs affect the job accessibility by car for low-income households and what accessibility by public transport is by comparison. The average job accessibility by car and public transport are not that different, but from these maps its evident that less neighbourhoods have sufficient job accessibility by public transport than by car. Including the travel costs particularly impacts job accessibility by car, which is now down by 72% compared to the analysis which included only travel times. The travel budget apparently has no effect on job accessibility by public transport; what is within the range of 30 minutes travel time, is also within the range of a 3 euro travel budget.

C. Analysis

The third phase is the analysis of the job accessibility, which starts with placing the values found in a so-called 'Potential Mobility and Accessibility (POMA) - framework [11], which can be found in figure 4. Each color in this graph represents a mode and each dot a neighbourhood. On the y-axis is the number of jobs one can reach from a specific neighbourhood and the x-axis shows the corresponding PMI. In this graph, two red dashed lines are added and suggest accessibility thresholds of 25% and 50% of all jobs and aid in identifying neighbourhoods below the threshold value.

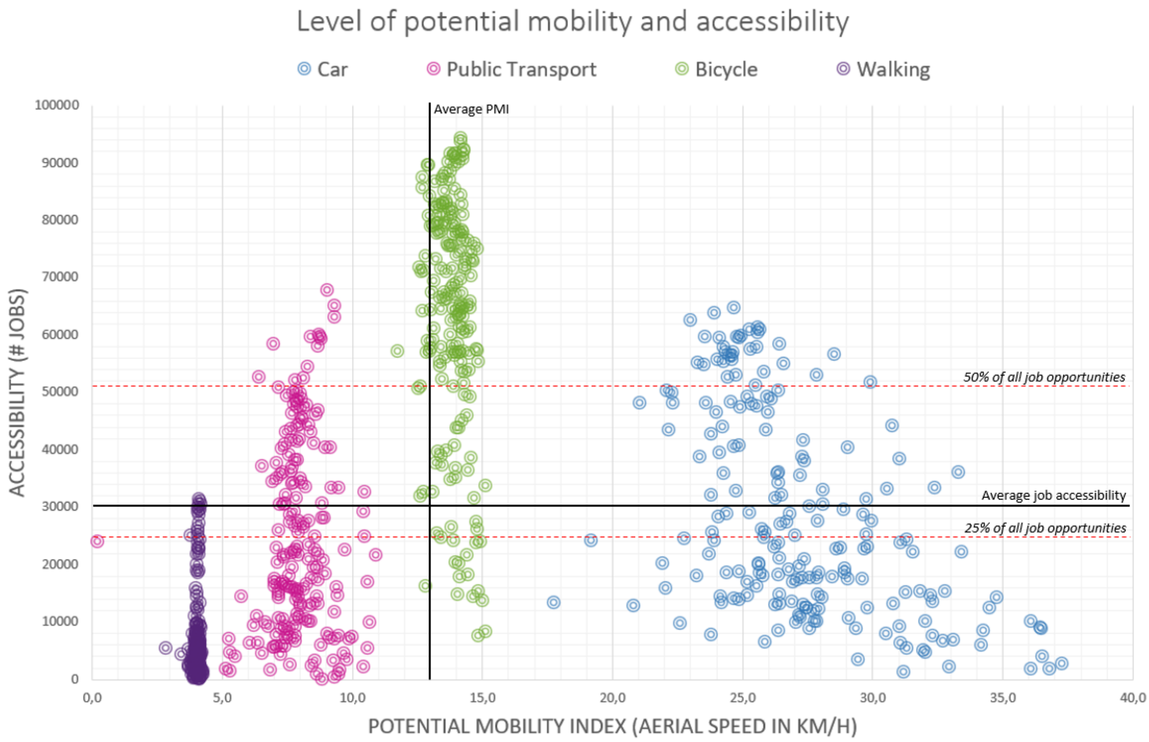

Figure 4. Potential Mobility and Accessibility within 30 minutes travel time and 3 euro travel budget

The methodology proposes the Accessibility Sufficiency Indicator (ASI) as an indicator to determine the severity of the accessibility for specific target groups. A neighbourhood's contribution to the overall job related transport poverty in the region can be expressed, by dividing a neighbourhood's ASI by the sum of ASI values in the overall region. Figure 5 shows these values for transport poverty by car for low income groups (left) and bicycle (right). The larger share in transport poverty by car on the east side of the region (Brunssum, Kerkrade, Landgraaf) is due to the higher share of low-income households. The figure on the right shows that most neighbourhoods are provided with sufficient job accessibility by bicycle and that mostly neighbourhoods located on the edges of the region have insufficient job accessibility by this mode due to the larger distances to job opportunities.

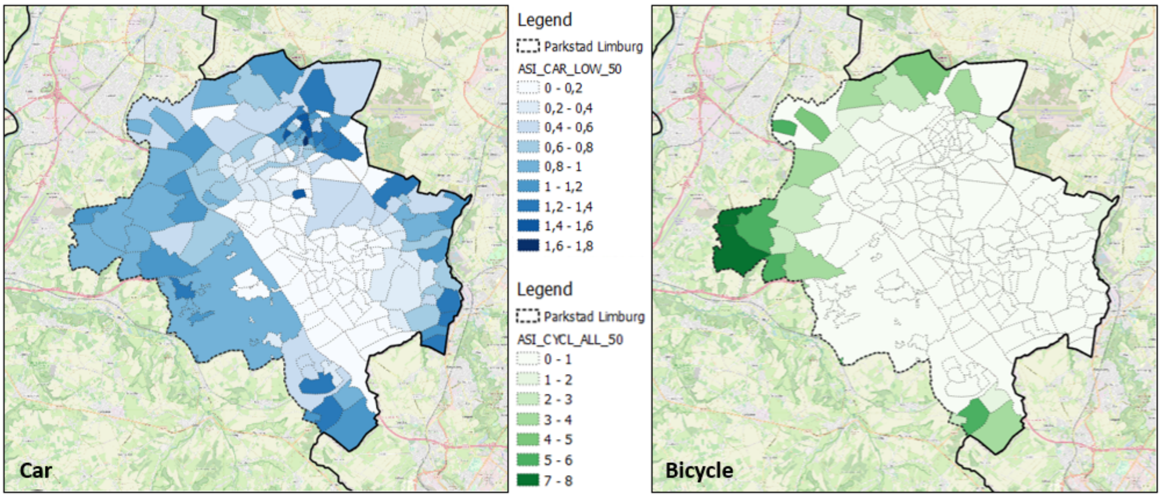

Figure 5. The spatial pattern of the ASI by car (left) and bicycle (right) under a threshold value of 50%. *(©OpenStreetMap, created with TravelTime API)*

With the ASI values it is also possible to determine the share of people suffering from transport poverty, which was calculated with a sufficiency threshold value of 25%, 50% and 75%. With a threshold value of 50%, only 22% of the households with a low income have sufficient accessibility by car and 9% of the households have sufficient accessibility by public transport. For residents who are unemployed, only 20% and 8% of the people have sufficient accessibility by car and public transport respectively. For all the aforementioned target groups, over 80% has sufficient accessibility by bicycle, which emphasises on the potential of this modality, whilst at the same time exposing the poor functioning of public transport. For households with a medium or high income, the share of households with sufficient accessibility by public transport and bicycle is a little lower, but this is compensated with 100% accessibility by car.

	THR. 25% jobs			THR. 50% jobs			THR. 75% jobs		
	TT30+TC3			TT30+TC3			TT30+TC3		
Target group	**PT**	**CAR**	**CYCLING**	**PT**	**CAR**	**CYCLING**	**PT**	**CAR**	**CYCLING**
Lowest 10%	58%	61%	96%	11%	23%	84%	0%	0%	41%
Low income	55%	57%	94%	9%	22%	82%	0%	0%	39%
Unemployed	53%	53%	93%	8%	20%	81%	0%	0%	37%
	TT30			TT30			TT30		
Target group	**PT**	**CAR**	**CYCLING**	**PT**	**CAR**	**CYCLING**	**PT**	**CAR**	**CYCLING**
Middle income	51%	100%	91%	6%	100%	79%	0%	100%	36%
High income	45%	100%	87%	4%	100%	73%	0%	100%	33%

Figure 6. The percentage of people/households with sufficient job accessibility

D. Evaluation

The evaluation phase consists of two steps, which are a sensitivity analysis and evaluation sessions with officials of the municipalities in the Parkstad region.

The graph in figure 7 shows the sensitivity for travel costs. For all four modes a line shows how the job opportunities increase with increasing travel budget. Travel costs are particularly limiting for accessibility by car; a budget of 6 euros showed to be sufficient to provide accessibility to all jobs for all residents by public transport and 12 euros by car. Two dashed lines are added to show the cost sensitivity under a travel time limit of 30 minutes. The job accessibility by public transport, cycling and walking is clearly restricted by the travel time limit of 30 minutes and does not increase with increasing budget.

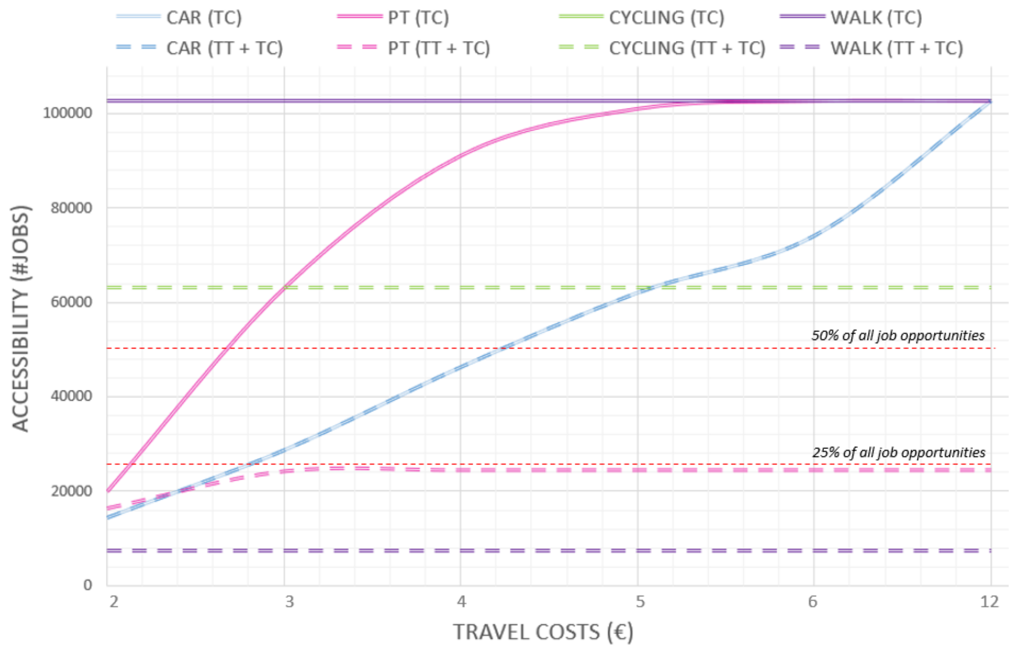

Figure 7. Sensitivity for travel time within a 3 euro budget

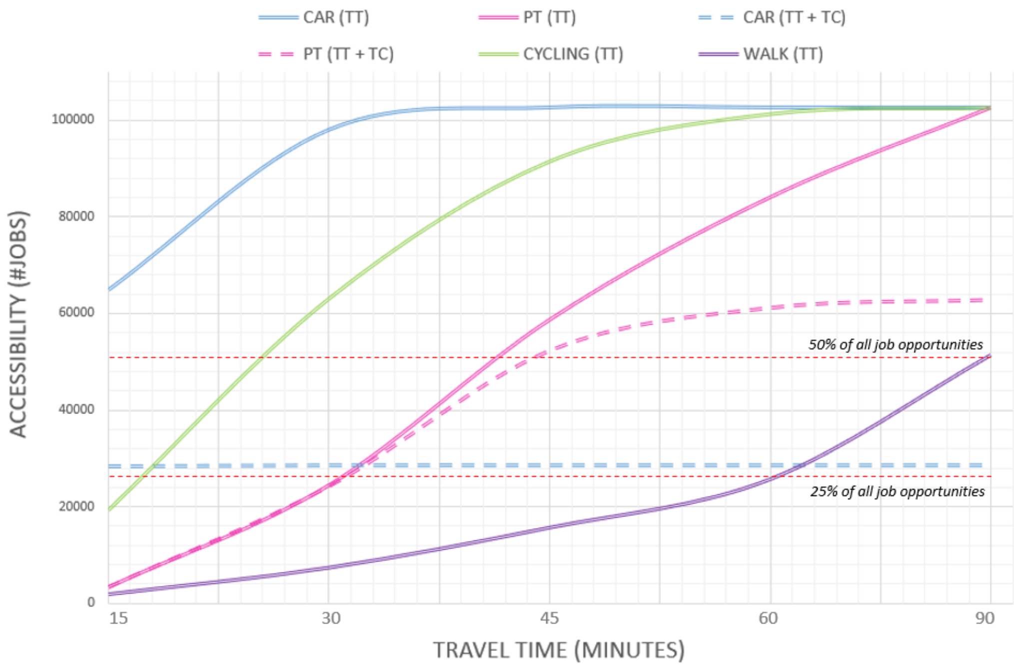

Figure 8. Sensitivity for travel time within a 3 euro budget

The graph in figure 8 shows the sensitivity for travel time. For all four modes a line shows how the job opportunities increase with increasing travel times. Two dashed lines are added to show how job opportunities for both car and public transport increase with increasing travel time if there is also a limitation of a travel budget of 3 euros. Accessibility by car is now limited to around 28% of jobs and 61% for public transport. So eventually, within a travel time budget of 3 euro, and 45 minute travel times, low-income households have on average a job accessibility of 61%. Mind you that these are averages and this is not correct for all low income households in this region. Further analyses showed that with a threshold value of 50%, within 45 minutes travel time and a 3 euro travel budget, up to 29% of low-income households and 31% of the unemployed still have insufficient accessibility by public transport.

In a series of interviews with officials from the municipalities of Beekdaelen, Heerlen, Kerkrade and Brunssum, the results of the study were presented and evaluated. In the municipality of Landgraaf a motion recently passed, which will soon make free public transport available to people with an income up to 140% of the social minimum. If the aim is to increase the chance of a job, only providing free public transport is probably not the solution, given the performance of public transport in this region. An important detail here is that the free pass is only valid in off peak hours, which means that it is probably not suitable for all jobs. That the potential of the bicycle was evident from the results confirmed for them that there are opportunities to further improve accessibility by bicycle and compete with car accessibility. In this discussion, the current modal split of the region was brought up, which shows a low share of travelling by bicycle for commute (13% compared to a national average of 24%, ([12])). Explanatory arguments for this are the high car accessibility and the differences in altitude in the region, which results in extra physical effort for people to travel somewhere by bicycle. E-bikes are considered a part of the solution in this regard, but these are to expensive for low-income households and the question is to what extent people also have suitable parking facilities for such an expensive bicycle. In the Parkstad region, there are already several hubs of an e-bike sharing system. Increasing the supply of these locations (also specifically on job locations) and making these e-bikes accessible for people who experience low accessibility would increase their job accessibility. Perhaps a free pass for these e-bikes sharing systems could improve job accessibility more than a free pass for public transport would.

III. Conclusion & recommendations

The aim of the research was to demonstrate the applicability of Martens' method with the extension of transport affordability. For this purpose a threshold value for a travel cost budget was added as an additional restriction into the analysis. This study shows that it is possible to include travel costs in the calculation of (job) accessibility and thus capture the accessibility of vulnerable target groups even better. The results show that if a limited travel budget is taken into account, the accessibility by both car and public transport is restricted at some point, demonstrating how accessibility by public transport for low income households has been overestimated thus far.

In separate sessions, the results were also presented for and discussed with the municipalities involved. The results provoked in-depth discussions about the severity of the shortfall in job accessibility, its causes and possible interventions. The results of the analysis were easy to communicate and provided the municipalities with lists of neighbourhoods where job related transport poverty is high. It can therefore be concluded that this methodology can guide municipalities towards designing transport systems that include low-income households and unemployed people as well. Due to the limited scope of this research, multiple officials of municipalities even asked whether the research could be expanded to include a larger area or other amenities for different target groups to gain even more information about accessibility and transport poverty in the region.

The policymakers also saw opportunities to use these results to prioritise policy, value possible solutions (such as free public transport), identify neighbourhoods where further research would be justified and to promote bicycling. An important note here is that, where for one target group an e-bike may be a solution, other people would be more pleased with free and improved public transport. More qualitative research, which includes involving the people affected, can also aid in understanding the results and come to useful interventions. A recent study of Krabbenborg et al. ([13]) shows that the obstacles people face to reach destinations are not only limited by travel times and costs, but for example, physical capabilities or unsafe infrastructure as well.

Previous qualitative research in Rotterdam showed that the inaccessibility of jobs can hinder people from finding or keeping employment ([14]). Since the unemployment rates are so high in this region, and the accessibility to jobs by public transport, based on both travel times and costs, is very limited it seems justified to wonder to what extent limited accessibility also directly contributes to the unemployment in this region. I would therefore recommend the municipalities to use the results and propose interventions that improve (job) accessibility for those who need this the most.

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B

Neighbourhoods with new centroids

Neighbourhoods	Distance between old and new centroids (m)
Aalbeek	344
Amstenrade	441
Beitel	588
Bingelrade	449
Brandenberg	504
Brunssumerheide (1)	471
Brunsummer Heide	690
Buitengebied	292
Buitengebied Brunsummerheide (2)	499
Gracht	264
Groenstraat	494
Hendrik en omgeving	424
Hulsberg	416
Imstenrade	556
Jabeek	772
Kakert	217
Klein-Doenrade	414
Merkelbeek_Douvergenhout	706
Nieuw Lotbroek-Noord	376
Ora et Labora	329
Prickart-Broek	284
Rimburg	182
Rolduckerveld	347
Schiffelerveld	155
Ten Esschen	409
Terworm	696
Thull	437
Uterweg	66
Vaesrade	588
Verspreide huizen Dentgenbach	152
Waubach	613
Waubacherveld	293
Wijnandsrade	833

C

Neighbourhoods - number of jobs

Neighbourhood	Zone_VML	Jobs (#)
Aalbeek	353	32
Aarveld	395	328
Abdissenbosch	332	1.554
Achter de Haesen	377	61
Achter de Put	313	0
Achter den Winkel	378	492
Amstenrade	308	645
Amstenraderveld	309	206
Arensgenhout	385	59
Baneheide	512	0
Beersdal	350	122
Beitel	483	6.621
Bekkerveld	395	1.049
Benzenrade	436	54
Bexdelle	306	126
Bingelrade	281	138
Bleijerheide	449	272
Bocholtz	512	919
Bocholtzerheide	512	0
Bouwberg	298	687
Brandenberg	321	0
Brunssumer Heide	323	0
Brunssumerheide (1)	332	0
Buitengebied	301	17
Buitengebied Brunssumerheide (2)	344	0
Burettestraat en omgeving	357	380
Caumerveld	400	100
Centrum	293	942
Chevremont	401	659
Colmont	460	0
Craubeek	409	0
De Dem en omgeving	333	543
De Dormig	356	543
De Eggen	297	0
De Heide	305	96
De Hemelder	313	0
De Kattekoelen	298	0
De Kling	302	16
De Koumen	347	1.594
De Streek	302	0
De Streep	355	0
De Struiken	323	155
Douve Weien	406	429
Douvenberg	323	508
Dr. Nolensplein en omgeving	383	684
Dr. Schaepmanplein en omgeving	390	530
Egstraat en omgeving	412	20
Eikenderveld	375	2.680
Eiske	388	426

Emma	320	805
Erenstein	408	196
Exdel	344	5
Eygelshoven-Kom	361	1.074
Fromberg	422	60
Giezenveld	412	0
Gracht	455	418
Grasbroek	370	763
Gravenrode	397	508
Groenstraat	348	432
Groot Rennemig	350	18
Groot-Doenrade	285	168
Haanrade	393	45
Haansberg	318	43
Haasdal	379	302
Heerlen-Centrum	384	4.461
Heerlerbaan-Oost	412	886
Heerlerbaan-West	424	336
Heerlerheide Kom	342	0
Heilust	434	542
Heistraat	397	25
Heksenberg	341	371
Hellebeuk	409	0
Hendrik en omgeving	310	88
Het Heufken	306	24
Hoefveld	363	182
Hoensbroek-Centrum	336	607
Hofpoel	293	0
Holz	428	367
Hommert (gedeeltelijk)	327	0
Hommert (gedeeltelijk)	308	0
Hopel	372	86
Hoppersgraaf	370	1.102
Houserveld	293	197
Huls	490	0
Hulsberg	380	860
Hulsveld	490	0
Husken	354	1.237
Imstenrade	436	27
In de Cramer	375	597
Industrieterrein De Horsel	330	2.360
Jabeek	272	95
Kaalheide	434	389
Kakert	355	256
Kerkeveld	312	34
Kerkrade-Centrum	426	3.126
Kleikoelen	305	0
Klein-Doenrade	300	7
Klimmen	409	447
Klingbemden	293	0

Klingelsberg	306	0
Klinkerkwartier	377	0
Koutenveld	293	612
Kruisberg	313	184
Kunderberg	422	0
Kunrade	387	404
Langenberg	323	0
Lauradorp	348	215
Leenhof	355	139
Lemmender	302	291
Lichtenberg	356	437
Lindeveld	384	3.274
Maria Gewanden	338	1.248
Mariarade-Noord	326	704
Mariarade-Zuid	326	334
Meezenbroek	366	267
Merkelbeek-Douvergenhout	292	191
Merkelbeekerdal	293	0
Mijnbuurt	388	25
Mingersborg	460	0
Molenbergpark	383	2.201
Molsberg-Rodeput	490	57
Musschemig	362	883
Nagelbeek-Hegge	322	188
Namiddagsche Driessen	332	0
Nieuw Lotbroek-Noord	349	507
Nieuw Lotbroek-Zuid	349	401
Nieuw-Einde	328	185
Nieuwenhagerheide	344	497
Nulland	447	421
Nuth	346	1.387
Oeloven	297	343
Oensel	352	20
Oirsbeek	300	573
Op de Kamp	356	597
Op de Nobel	384	534
Op de Vaard	313	0
Op de Vos	316	161
Op den Haan	293	0
Op gen Hoes	297	0
Ora et Labora	298	44
Oud Nieuwenhagen	351	1.020
Palemig	357	0
Parkheide	332	40
Passart	334	582
Prickart-Broek	512	0
Pronsebroek	342	538
Puth	294	222
Ransdaal	433	167
Retersbeek	371	0

Rimburg	345	174
Rode Beek	297	441
Rolduckerveld	393	294
Rozengaard	293	0
Rumpener Beemden	312	544
Schaesberg Centrum	377	1.917
Schaesbergerveld	373	414
Schandelen	370	83
Schelsberg	350	397
Schiffelerveld	390	258
Schimmert	352	445
Schinnen	311	998
Schinveld	280	720
Schuttersveld	305	0
Simpelveld	490	1.234
Spekholzerheide	445	3.419
Sweikhuizen	296	94
Swier	358	0
't Loon	384	1.684
Ten Esschen	365	1.058
Termaar	409	0
Terschuren	338	0
Tervoorst en omgeving	343	75
Terwinselen	419	983
Terworm	392	2.895
Thull	311	50
Treebeek-Noord	320	13
Treebeek-Zuid	320	14
Ubachsberg	460	289
Uterweg	328	0
Vaesrade	327	485
Versiliënbosch	341	0
Verspreide huizen Dentgenbach	398	2.662
Verspreide huizen Voerendaal	422	0
Vijverpark	312	844
Vink	393	302
Voerendaal	387	1.186
Vondelstraat	323	0
Vrieheide	337	187
Waubach	348	343
Waubacherveld	367	56
Weggebekker	325	206
Welten-Dorp	407	568
Weustenrade	371	79
Wijnandsrade	358	341
Winthagen	422	0
Zeswegen	369	4.240
Ziekenhuis	407	5.466
Total # jobs in Parkstad		**102.584**

D

Neighbourhoods - households and income groups

(yellow)	Average based on 4-digit postal code
(red)	No households/residents in this neighbourhood

	Average		17%	31%	40%	12%
	Total	126130	20898	39394	50484	15355
Municipality	**Neighbourhood**	**#hh**	**group 1**	**group 2**	**group 3**	**group 4**
Beekdaelen	**Aalbeek**	110	7	20	49	34
Heerlen	**Aarveld**	710	149	287	206	68
Landgraaf	**Abdissenbosch**	625	100	163	269	93
Landgraaf	**Achter de Haesen**	290	85	111	77	16
Brunssum	**Achter de Put**	190	9	64	81	36
Landgraaf	**Achter den Winkel**	540	70	134	286	50
Beekdaelen	**Amstenrade**	750	113	233	296	108
Brunssum	**Amstenraderveld**	185	5	24	77	80
Beekdaelen	**Arensgenhout**	215	13	39	107	57
Simpelveld	**Baneheide**	65	6	17	31	11
Heerlen	**Beersdal**	760	96	241	341	82
Heerlen	**Beitel**	30	2	8	15	5
Heerlen	**Bekkerveld**	765	61	178	337	189
Heerlen	**Benzenrade**	90	6	23	45	16
Brunssum	**Bexdelle**	175	22	53	82	18
Beekdaelen	**Bingelrade**	365	33	77	165	89
Kerkrade	**Bleijerheide**	2115	472	728	753	163
Simpelveld	**Bocholtz**	1915	201	540	866	308
Simpelveld	**Bocholtzerheide**	210	16	49	102	43
Brunssum	**Bouwberg**	60	8	16	31	5
Brunssum	**Brandenberg**	0	0	0	0	0
Brunssum	**Brunssumer Heide**	0	0	0	0	0
Landgraaf	**Brunssumerheide (1)**	0	0	0	0	0
Brunssum	**Buitengebied**	80	15	29	30	5
Landgraaf	**(2)**	50	7	14	22	6
Heerlen	**Burettestraat en omgeving**	235	102	100	31	2
Heerlen	**Caumerveld**	585	11	59	267	248
Brunssum	**Centrum**	440	95	227	104	14
Kerkrade	**Chevremont**	1605	398	587	491	128
Voerendaal	**Colmont**	35	3	8	18	6
Voerendaal	**Craubeek**	80	5	17	41	17
Heerlen	**De Dem en omgeving**	1755	377	607	644	126
Landgraaf	**De Dormig**	380	63	92	157	68
Brunssum	**De Eggen**	710	158	246	279	28
Brunssum	**De Heide**	5	1	2	2	0
Brunssum	**De Hemelder**	495	7	71	282	135
Brunssum	**De Kattekoelen**	0	0	0	0	0
Brunssum	**De Kling**	305	35	71	153	46
Heerlen	**De Koumen**	195	29	63	82	21
Brunssum	**De Streek**	445	67	164	183	31
Landgraaf	**De Streep**	515	84	175	192	64
Brunssum	**De Struiken**	545	53	134	271	87
Heerlen	**Douve Weien**	2190	309	858	780	243
Brunssum	**Douvenberg**	0	0	0	0	0
Heerlen	**Dr. Nolensplein en omgeving**	700	177	224	244	55
Heerlen	**Dr. Schaepmanplein en omgeving**	835	317	276	227	15

Heerlen	**Egstraat en omgeving**	910	45	215	495	156
Heerlen	**Eikenderveld**	1505	358	626	467	54
Landgraaf	**Eiske**	730	120	199	324	88
Brunssum	**Emma**	490	57	116	213	104
Kerkrade	**Erenstein**	855	235	300	258	62
Landgraaf	**Exdel**	240	30	49	96	64
Kerkrade	**Eygelshoven-Kom**	1190	259	445	388	98
Voerendaal	**Fromberg**	10	1	2	5	2
Heerlen	**Giezenveld**	855	137	240	334	144
Kerkrade	**Gracht**	975	119	301	487	68
Heerlen	**Grasbroek**	670	123	238	259	50
Landgraaf	**Gravenrode**	25	3	7	12	3
Landgraaf	**Groenstraat**	430	35	117	190	89
Heerlen	**Groot Rennemig**	1535	358	484	591	103
Beekdaelen	**Groot-Doenrade**	485	23	100	237	125
Kerkrade	**Haanrade**	985	127	254	480	124
Brunssum	**Haansberg**	415	61	126	171	57
Beekdaelen	**Haasdal**	330	10	65	151	103
Heerlen	**Heerlen-Centrum**	1880	367	951	493	70
Heerlen	**Heerlerbaan-Oost**	2195	579	944	606	66
Heerlen	**Heerlerbaan-West**	725	46	189	289	201
Heerlen	**Heerlerheide Kom**	1835	488	745	532	70
Kerkrade	**Heilust**	1240	340	420	408	72
Landgraaf	**Heistraat**	225	5	24	103	94
Heerlen	**Heksenberg**	1120	139	364	525	92
Voerendaal	**Hellebeuk**	40	3	8	20	8
Brunssum	**Hendrik en omgeving**	5	1	2	2	0
Brunssum	**Het Heufken**	370	77	118	151	24
Landgraaf	**Hoefveld**	615	33	120	326	136
Heerlen	**Hoensbroek-Centrum**	1975	685	749	462	79
Brunssum	**Hofpoel**	535	112	216	167	40
Kerkrade	**Holz**	1230	241	448	410	132
Beekdaelen	**Hommert (gedeeltelijk)**	440	15	72	227	126
Kerkrade	**Hopel**	1035	111	284	552	89
Heerlen	**Hoppersgraaf**	720	233	289	174	25
Brunssum	**Houserveld**	20	4	7	7	1
Simpelveld	**Huls**	150	10	34	82	24
Beekdaelen	**Hulsberg**	1410	86	334	684	306
Simpelveld	**Hulsveld**	710	53	160	388	109
Heerlen	**Husken**	580	24	131	325	100
Heerlen	**Imstenrade**	10	1	3	5	2
Heerlen	**In de Cramer**	5	1	2	2	0
Beekdaelen	**Industrieterrein De Horsel**	10	1	3	4	1
Beekdaelen	**Jabeek**	320	31	78	156	55
Kerkrade	**Kaalheide**	1315	241	391	567	117
Landgraaf	**Kakert**	785	153	179	328	125
Brunssum	**Kerkeveld**	200	41	58	81	20
Kerkrade	**Kerkrade-Centrum**	2630	444	1023	923	239
Brunssum	**Kleikoelen**	120	44	40	35	0
Beekdaelen	**Klein-Doenrade**	70	0	0	70	0
Voerendaal	**Klimmen**	805	67	209	359	170

Brunssum	**Klingbemden**	225	4	29	139	53
Brunssum	**Klingelsberg**	260	20	59	152	30
Landgraaf	**Klinkerkwartier**	420	18	92	236	73
Brunssum	**Koutenveld**	170	9	65	86	10
Brunssum	**Kruisberg**	545	43	171	269	62
Voerendaal	**Kunderberg**	10	1	3	5	2
Voerendaal	**Kunrade**	1550	127	405	685	333
Brunssum	**Langenberg**	625	24	191	330	79
Landgraaf	**Lauradorp**	1480	185	488	694	112
Landgraaf	**Leenhof**	350	14	106	207	23
Brunssum	**Lemmender**	735	243	348	135	8
Landgraaf	**Lichtenberg**	855	211	255	320	69
Heerlen	**Lindeveld**	430	52	140	148	89
Heerlen	**Maria Gewanden**	1860	407	591	711	151
Heerlen	**Mariarade-Noord**	920	147	297	373	103
Heerlen	**Mariarade-Zuid**	705	94	201	328	82
Heerlen	**Meezenbroek**	1495	502	528	420	45
Beekdaelen	**Merkelbeek-Douvergenhout**	695	58	139	348	150
Brunssum	**Merkelbeekerdal**	45	9	17	17	3
Landgraaf	**Mijnbuurt**	845	75	203	471	96
Voerendaal	**Mingersborg**	15	1	3	8	3
Heerlen	**Molenbergpark**	580	124	125	179	152
Simpelveld	**Molsberg-Rodeput**	415	23	90	201	101
Heerlen	**Musschemig**	430	51	113	204	62
Beekdaelen	**Nagelbeek-Hegge**	435	34	101	211	88
Landgraaf	**Namiddagsche Driessen**	490	33	92	275	90
Heerlen	**Nieuw Lotbroek-Noord**	850	105	282	378	85
Heerlen	**Nieuw Lotbroek-Zuid**	1170	241	322	504	103
Heerlen	**Nieuw-Einde**	730	193	240	247	49
Landgraaf	**Nieuwenhagerheide**	1525	235	436	697	157
Kerkrade	**Nulland**	1435	267	495	561	112
Beekdaelen	**Nuth**	2275	384	733	901	257
Brunssum	**Oeloven**	360	13	62	220	64
Beekdaelen	**Oensel**	50	2	10	24	14
Beekdaelen	**Oirsbeek**	1600	106	354	790	350
Landgraaf	**Op de Kamp**	460	78	185	170	27
Heerlen	**Op de Nobel**	655	148	233	178	97
Brunssum	**Op de Vaard**	255	35	86	92	42
Brunssum	**Op de Vos**	630	49	148	353	80
Brunssum	**Op den Haan**	355	55	124	145	31
Brunssum	**Op gen Hoes**	105	4	32	60	9
Brunssum	**Ora et Labora**	0	0	0	0	0
Landgraaf	**Oud Nieuwenhagen**	1720	311	590	657	162
Heerlen	**Palemig**	300	44	73	146	38
Landgraaf	**Parkheide**	725	54	88	349	233
Heerlen	**Passart**	1055	362	345	305	43
Simpelveld	**Prickart-Broek**	115	7	25	54	29
Heerlen	**Pronsebroek**	365	46	125	170	24
Beekdaelen	**Puth**	880	77	194	397	213
Voerendaal	**Ransdaal**	400	25	88	192	95
Voerendaal	**Retersbeek**	35	3	9	16	7

Landgraaf	**Rimburg**	315	31	79	139	66
Brunssum	**Rode Beek**	20	3	5	10	2
Kerkrade	**Rolduckerveld**	1290	397	520	312	61
Brunssum	**Rozengaard**	645	144	225	243	33
Brunssum	**Rumpener Beemden**	565	132	241	132	60
Landgraaf	**Schaesberg Centrum**	1535	209	531	619	177
Heerlen	**Schaesbergerveld**	1295	240	431	486	139
Heerlen	**Schandelen**	960	304	348	266	41
Heerlen	**Schelsberg**	120	15	27	54	23
Heerlen	**Schiffelerveld**	80	0	0	80	0
Beekdaelen	**Schimmert**	995	47	217	454	278
Beekdaelen	**Schinnen**	745	105	224	285	132
Beekdaelen	**Schinveld**	2105	276	602	899	328
Brunssum	**Schuttersveld**	520	77	212	212	18
Simpelveld	**Simpelveld**	1265	220	535	386	124
Kerkrade	**Spekholzerheide**	1735	338	619	616	161
Beekdaelen	**Sweikhuizen**	265	10	48	130	77
Beekdaelen	**Swier**	145	10	44	64	27
Heerlen	**'t Loon**	505	48	221	215	21
Heerlen	**Ten Esschen**	65	16	21	24	5
Voerendaal	**Termaar**	315	18	54	152	91
Heerlen	**Terschuren**	240	84	43	79	34
Beekdaelen	**Tervoorst en omgeving**	360	24	71	165	100
Kerkrade	**Terwinselen**	1720	119	473	877	251
Heerlen	**Terworm**	5	0	1	3	1
Beekdaelen	**Thull**	65	7	17	29	11
Brunssum	**Treebeek-Noord**	665	35	150	366	114
Brunssum	**Treebeek-Zuid**	895	214	337	285	60
Voerendaal	**Ubachsberg**	645	60	157	299	129
Heerlen	**Uterweg**	850	193	295	298	65
Beekdaelen	**Vaesrade**	470	61	127	206	76
Heerlen	**Versiliënbosch**	320	111	135	66	8
Kerkrade	**Verspreide huizen Dentgenbach**	10	1	3	5	1
Voerendaal	**Verspreide huizen Voerendaal**	140	2	27	60	51
Brunssum	**Vijverpark**	75	14	27	28	6
Kerkrade	**Vink**	1085	116	286	501	181
Voerendaal	**Voerendaal**	1390	131	409	589	261
Brunssum	**Vondelstraat**	105	0	25	56	24
Heerlen	**Vrieheide**	725	131	265	297	33
Landgraaf	**Waubach**	1505	307	516	528	154
Kerkrade	**Waubacherveld**	480	44	102	246	88
Heerlen	**Weggebekker**	205	105	64	35	1
Heerlen	**Welten-Dorp**	1870	144	503	877	346
Voerendaal	**Weustenrade**	100	8	26	46	20
Beekdaelen	**Wijnandsrade**	605	47	132	298	128
Voerendaal	**Winthagen**	30	2	6	16	5
Heerlen	**Zeswegen**	1140	377	352	361	49
Heerlen	**Ziekenhuis**	0	0	0	0	0

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Neighbourhoods - residents and (un)employment rates

	Average based on 4-digit postal
	No households/residents in this

	Average				61%		39%
	Total	255795	158715	97440		61185	
Municipality	**Neighbourhood**	**#res**	**#(15-65)**	**#employed**	**%empl.**	**#unemployed**	**%unempl.**
Beekdaelen	**Aalbeek**	270	175	124,25	71%	51	29%
Heerlen	**Aarveld**	1185	870	591,6	68%	278	32%
Landgraaf	**Abdissenbosch**	1380	830	522,9	63%	307	37%
Landgraaf	**Achter de Haesen**	565	360	183,6	51%	176	49%
Brunssum	**Achter de Put**	390	240	165,6	69%	74	31%
Landgraaf	**Achter den Winkel**	1155	505	262,6	52%	242	48%
Beekdaelen	**Amstenrade**	1670	920	588,8	64%	331	36%
Brunssum	**Amstenraderveld**	475	330	227,7	69%	102	31%
Beekdaelen	**Arensgenhout**	515	310	223,2	72%	87	28%
Simpelveld	**Baneheide**	150	80	54,4	68%	26	32%
Heerlen	**Beersdal**	1610	1060	657,2	62%	403	38%
Heerlen	**Beitel**	65	45	26,55	59%	18	41%
Heerlen	**Bekkerveld**	1575	990	702,9	71%	287	29%
Heerlen	**Benzenrade**	195	130	94,9	73%	35	27%
Brunssum	**Bexdelle**	345	215	133,3	62%	82	38%
Beekdaelen	**Bingelrade**	810	510	341,7	67%	168	33%
Kerkrade	**Bleijerheide**	4105	2725	1553,3	57%	1172	43%
Simpelveld	**Bocholtz**	4185	2610	1774,8	68%	835	32%
Simpelveld	**Bocholtzerheide**	485	315	217,35	69%	98	31%
Brunssum	**Bouwberg**	115	95	55,1	58%	40	42%
Brunssum	**Brandenberg**	0,0	0	0	69%	0	31%
Brunssum	**Brunssumer Heide**	0,0	0	0	69%	0	31%
Landgraaf	**Brunssumerheide (1)**	0,0	0	0	64%	0	36%
Brunssum	**Buitengebied**	125	30	17,1	57%	13	43%
Landgraaf	**(2)**	110	80	47,2	59%	33	41%
Heerlen	**Burettestraat en omgeving**	355	185	79,55	43%	105	57%
Heerlen	**Caumerveld**	1390	835	592,85	71%	242	29%
Brunssum	**Centrum**	630	270	121,5	45%	149	55%
Kerkrade	**Chevremont**	3025	1910	1107,8	58%	802	42%
Voerendaal	**Colmont**	90	60	40,2	67%	20	33%
Voerendaal	**Craubeek**	195	120	80,4	67%	40	33%
Heerlen	**De Dem en omgeving**	3405	2215	1306,9	59%	908	41%
Landgraaf	**De Dormig**	1105	635	412,75	65%	222	35%
Brunssum	**De Eggen**	1505	1000	550	55%	450	45%
Brunssum	**De Heide**	10	10	5,8	58%	4	42%
Brunssum	**De Hemelder**	1215	870	626,4	72%	244	28%
Brunssum	**De Kattekoelen**	0	0	0	58%	0	42%
Brunssum	**De Kling**	685	390	234	60%	156	40%
Heerlen	**De Koumen**	360	235	148,05	63%	87	37%
Brunssum	**De Streek**	815	565	367,25	65%	198	35%
Landgraaf	**De Streep**	1020	585	362,7	62%	222	38%
Brunssum	**De Struiken**	1220	840	562,8	67%	277	33%
Heerlen	**Douve Weien**	3695	2320	1531,2	66%	789	34%
Brunssum	**Douvenberg**	0	0	0	69%	0	31%
Heerlen	**Dr. Nolensplein en omgeving**	1400	820	459,2	56%	361	44%

Heerlen	**Dr. Schaepmanplein en omgeving**	1765	1080	518,4	48%	562	52%
Heerlen	**Egstraat en omgeving**	2040	1465	996,2	68%	469	32%
Heerlen	**Eikenderveld**	2565	1740	974,4	56%	766	44%
Landgraaf	**Eiske**	1520	965	598,3	62%	367	38%
Brunssum	**Emma**	1260	715	521,95	73%	193	27%
Kerkrade	**Erenstein**	1630	1020	571,2	56%	449	44%
Landgraaf	**Exdel**	510	300	171	57%	129	43%
Kerkrade	**Eygelshoven-Kom**	2145	1240	731,6	59%	508	41%
Voerendaal	**Fromberg**	30	20	13,2	66%	7	34%
Heerlen	**Giezenveld**	1800	1185	770,25	65%	415	35%
Kerkrade	**Gracht**	2040	1285	771	60%	514	40%
Heerlen	**Grasbroek**	1330	870	522	60%	348	40%
Landgraaf	**Gravenrode**	50	35	21,35	61%	14	39%
Landgraaf	**Groenstraat**	985	605	429,55	71%	175	29%
Heerlen	**Groot Rennemig**	3120	2240	1388,8	62%	851	38%
Beekdaelen	**Groot-Doenrade**	1100	650	422,5	65%	228	35%
Kerkrade	**Haanrade**	1950	1205	710,95	59%	494	41%
Brunssum	**Haansberg**	880	615	424,35	69%	191	31%
Beekdaelen	**Haasdal**	805	505	358,55	71%	146	29%
Heerlen	**Heerlen-Centrum**	2545	1640	967,6	59%	672	41%
Heerlen	**Heerlerbaan-Oost**	3940	2165	1125,8	52%	1039	48%
Heerlen	**Heerlerbaan-West**	1535	770	523,6	68%	246	32%
Heerlen	**Heerlerheide Kom**	3315	1840	975,2	53%	865	47%
Kerkrade	**Heilust**	2515	1580	821,6	52%	758	48%
Landgraaf	**Heistraat**	565	415	336,15	81%	79	19%
Heerlen	**Heksenberg**	2325	1580	995,4	63%	585	37%
Voerendaal	**Hellebeuk**	85	55	36,85	67%	18	33%
Brunssum	**Hendrik en omgeving**	5	0	0	58%	0	42%
Brunssum	**Het Heufken**	675	450	265,5	59%	185	41%
Landgraaf	**Hoefveld**	1345	785	463,15	59%	322	41%
Heerlen	**Hoensbroek-Centrum**	3425	2040	1020	50%	1020	50%
Brunssum	**Hofpoel**	930	510	285,6	56%	224	44%
Kerkrade	**Holz**	2305	1400	854	61%	546	39%
Beekdaelen	**Hommert (gedeeltelijk)**	1100	725	522	72%	203	28%
Kerkrade	**Hopel**	2275	1550	992	64%	558	36%
Heerlen	**Hoppersgraaf**	1100	820	459,2	56%	361	44%
Brunssum	**Houserveld**	55	35	19,95	57%	15	43%
Simpelveld	**Huls**	320	205	133,25	65%	72	35%
Beekdaelen	**Hulsberg**	3175	1895	1345,5	71%	550	29%
Simpelveld	**Hulsveld**	1520	900	612	68%	288	32%
Heerlen	**Husken**	1300	950	693,5	73%	257	27%
Heerlen	**Imstenrade**	335	280	187,6	67%	92	33%
Heerlen	**In de Cramer**	5	5	3,05	61%	2	39%
Beekdaelen	**Industrieterrein De Horsel**	35	25	16	64%	9	36%
Beekdaelen	**Jabeek**	705	470	300,8	64%	169	36%
Kerkrade	**Kaalheide**	2770	1830	1116,3	61%	714	39%
Landgraaf	**Kakert**	1685	1085	661,85	61%	423	39%
Brunssum	**Kerkeveld**	405	275	159,5	58%	116	42%
Kerkrade	**Kerkrade-Centrum**	4690	2425	1309,5	54%	1116	46%
Brunssum	**Kleikoelen**	225	145	69,6	48%	75	52%
Beekdaelen	**Klein-Doenrade**	160	115	77,05	67%	38	33%

Voerendaal	**Klimmen**	1740	980	656,6	67%	323	33%
Brunssum	**Klingbemden**	560	330	217,8	66%	112	34%
Brunssum	**Klingelsberg**	580	380	243,2	64%	137	36%
Landgraaf	**Klinkerkwartier**	935	595	345,1	58%	250	42%
Brunssum	**Koutenveld**	290	100	50	50%	50	50%
Brunssum	**Kruisberg**	1100	770	515,9	67%	254	33%
Voerendaal	**Kunderberg**	15	5	3,35	67%	2	33%
Voerendaal	**Kunrade**	3315	2010	1346,7	67%	663	33%
Brunssum	**Langenberg**	1360	945	661,5	70%	284	30%
Landgraaf	**Lauradorp**	3045	1950	1189,5	61%	761	39%
Landgraaf	**Leenhof**	705	480	307,2	64%	173	36%
Brunssum	**Lemmender**	1065	600	252	42%	348	58%
Landgraaf	**Lichtenberg**	1670	1075	623,5	58%	452	42%
Heerlen	**Lindeveld**	800	530	360,4	68%	170	32%
Heerlen	**Maria Gewanden**	3490	2310	1293,6	56%	1016	44%
Heerlen	**Mariarade-Noord**	1785	1080	658,8	61%	421	39%
Heerlen	**Mariarade-Zuid**	1575	1075	677,25	63%	398	37%
Heerlen	**Meezenbroek**	2935	1850	943,5	51%	907	49%
Beekdaelen	**Merkelbeek-Douvergenhout**	1610	1050	703,5	67%	347	33%
Brunssum	**Merkelbeekerdal**	105	70	39,9	57%	30	43%
Landgraaf	**Mijnbuurt**	1970	1280	806,4	63%	474	37%
Voerendaal	**Mingersborg**	30	15	10,05	67%	5	33%
Heerlen	**Molenbergpark**	1275	695	423,95	61%	271	39%
Simpelveld	**Molsberg-Rodeput**	975	625	431,25	69%	194	31%
Heerlen	**Musschemig**	940	675	438,75	65%	236	35%
Beekdaelen	**Nagelbeek-Hegge**	995	635	406,4	64%	229	36%
Landgraaf	**Namiddagsche Driessen**	1155	825	569,25	69%	256	31%
Heerlen	**Nieuw Lotbroek-Noord**	1720	1055	654,1	62%	401	38%
Heerlen	**Nieuw Lotbroek-Zuid**	2620	1730	986,1	57%	744	43%
Heerlen	**Nieuw-Einde**	1405	975	546	56%	429	44%
Landgraaf	**Nieuwenhagerheide**	3130	1900	1102	58%	798	42%
Kerkrade	**Nulland**	2895	1795	1023,2	57%	772	43%
Beekdaelen	**Nuth**	4560	2685	1664,7	62%	1020	38%
Brunssum	**Oeloven**	925	515	339,9	66%	175	34%
Beekdaelen	**Oensel**	125	85	60,35	71%	25	29%
Beekdaelen	**Oirsbeek**	3580	2135	1451,8	68%	683	32%
Landgraaf	**Op de Kamp**	830	455	236,6	52%	218	48%
Heerlen	**Op de Nobel**	1085	680	414,8	61%	265	39%
Brunssum	**Op de Vaard**	485	260	161,2	62%	99	38%
Brunssum	**Op de Vos**	1455	840	512,4	61%	328	39%
Brunssum	**Op den Haan**	760	475	299,25	63%	176	37%
Brunssum	**Op gen Hoes**	240	180	138,6	77%	41	23%
Brunssum	**Ora et Labora**	5	5	2,9	58%	2	42%
Landgraaf	**Oud Nieuwenhagen**	3395	2165	1320,7	61%	844	39%
Heerlen	**Palemig**	640	435	274,05	63%	161	37%
Landgraaf	**Parkheide**	1865	1320	963,6	73%	356	27%
Heerlen	**Passart**	2070	1270	609,6	48%	660	52%
Simpelveld	**Prickart-Broek**	260	175	127,75	73%	47	27%
Heerlen	**Pronsebroek**	665	390	237,9	61%	152	39%
Beekdaelen	**Puth**	2010	1245	859,05	69%	386	31%
Voerendaal	**Ransdaal**	905	520	353,6	68%	166	32%

Voerendaal	**Retersbeek**	105	60	40,2	67%	20	33%
Landgraaf	**Rimburg**	660	410	262,4	64%	148	36%
Brunssum	**Rode Beek**	55	35	20,3	58%	15	42%
Kerkrade	**Rolduckerveld**	2375	1455	771,15	53%	684	47%
Brunssum	**Rozengaard**	1285	800	432	54%	368	46%
Brunssum	**Rumpener Beemden**	895	400	216	54%	184	46%
Landgraaf	**Schaesberg Centrum**	2955	1770	1079,7	61%	690	39%
Heerlen	**Schaesbergerveld**	2505	1755	1070,6	61%	684	39%
Heerlen	**Schandelen**	1620	1035	569,25	55%	466	45%
Heerlen	**Schelsberg**	265	140	86,8	62%	53	38%
Heerlen	**Schiffelerveld**	150	90	48,6	54%	41	46%
Beekdaelen	**Schimmert**	2270	1345	954,95	71%	390	29%
Beekdaelen	**Schinnen**	1540	870	539,4	62%	331	38%
Beekdaelen	**Schinveld**	4565	2850	1795,5	63%	1055	37%
Brunssum	**Schuttersveld**	990	570	302,1	53%	268	47%
Simpelveld	**Simpelveld**	2370	1295	815,85	63%	479	37%
Kerkrade	**Spekholzerheide**	3215	1950	1131	58%	819	42%
Beekdaelen	**Sweikhuizen**	580	330	227,7	69%	102	31%
Beekdaelen	**Swier**	315	210	155,4	74%	55	26%
Heerlen	**'t Loon**	735	360	205,2	57%	155	43%
Heerlen	**Ten Esschen**	155	110	64,9	59%	45	41%
Voerendaal	**Termaar**	730	435	274,05	63%	161	37%
Heerlen	**Terschuren**	490	275	129,25	47%	146	53%
Beekdaelen	**Tervoorst en omgeving**	825	485	320,1	66%	165	34%
Kerkrade	**Terwinselen**	3870	2320	1508	65%	812	35%
Heerlen	**Terworm**	25	15	9,6	64%	5	36%
Beekdaelen	**Thull**	140	80	53,6	67%	26	33%
Brunssum	**Treebeek-Noord**	1505	1020	734,4	72%	286	28%
Brunssum	**Treebeek-Zuid**	1695	1060	593,6	56%	466	44%
Voerendaal	**Ubachsberg**	1440	810	534,6	66%	275	34%
Heerlen	**Uterweg**	1665	1150	667	58%	483	42%
Beekdaelen	**Vaesrade**	990	640	454,4	71%	186	29%
Heerlen	**Versiliënbosch**	640	375	150	40%	225	60%
Kerkrade	**Verspreide huizen Dentgenbach**	20	10	5,9	59%	4	41%
Voerendaal	**Verspreide huizen Voerendaal**	355	220	158,4	72%	62	28%
Brunssum	**Vijverpark**	160	70	43,4	62%	27	38%
Kerkrade	**Vink**	2575	1680	1125,6	67%	554	33%
Voerendaal	**Voerendaal**	3120	1795	1184,7	66%	610	34%
Brunssum	**Vondelstraat**	220	160	116,8	73%	43	27%
Heerlen	**Vrieheide**	1480	1055	611,9	58%	443	42%
Landgraaf	**Waubach**	2940	1555	855,25	55%	700	45%
Kerkrade	**Waubacherveld**	1025	590	354	60%	236	40%
Heerlen	**Weggebekker**	395	265	100,7	38%	164	62%
Heerlen	**Welten-Dorp**	3570	1880	1203,2	64%	677	36%
Voerendaal	**Weustenrade**	225	160	116,8	73%	43	27%
Beekdaelen	**Wijnandsrade**	1325	755	483,2	64%	272	36%
Voerendaal	**Winthagen**	85	50	33,5	67%	17	33%
Heerlen	**Zeswegen**	2325	1655	893,7	54%	761	46%
Heerlen	**Ziekenhuis**	210	90	0	0%	0	0%

F

Potential Mobility Index

Buurt	PMI_CAR	PMI_PT	PMI_CYCL	PMI_WALK	PMI_AVG
Aalbeek	33,1	10,7	14,8	4,3	15,7
Aarveld	25,6	7,6	13,8	4,1	12,8
Abdissenbosch	29,4	7,4	14,0	4,1	13,7
Achter de Haesen	24,4	8,7	13,4	4,0	12,6
Achter de Put	23,7	8,1	13,0	4,0	12,2
Achter den Winkel	24,7	7,2	13,2	4,0	12,3
Amstenrade	26,2	7,6	13,2	4,0	12,8
Amstenraderveld	21,9	6,7	12,9	3,8	11,3
Arensgenhout	36,5	10,6	14,8	4,3	16,6
Baneheide	36,5	9,0	13,4	4,1	15,8
Beersdal	25,6	7,4	14,2	4,0	12,8
Beitel	32,4	7,4	13,0	4,0	14,2
Bekkerveld	24,1	7,9	13,4	4,1	12,4
Benzenrade	29,9	7,9	14,0	4,1	14,0
Bexdelle	26,4	7,5	14,1	4,0	13,0
Bingelrade	27,9	7,6	13,8	3,9	13,3
Bleijerheide	34,8	10,0	13,5	4,0	15,6
Bocholtz	36,5	9,5	14,0	4,1	16,0
Bocholtzerheide	32,9	8,6	12,8	3,8	14,6
Bouwberg	27,8	6,5	13,3	3,9	12,9
Brandenberg	24,2	5,2	14,1	4,1	11,9
Brunssumer Heide	17,8	6,1	13,0	3,9	10,2
Brunssumerheide (1)	22,1	5,3	12,7	3,7	11,0
Buitengebied	23,3	5,7	11,7	3,4	11,0
Buitengebied Brunssumerhei	19,2	5,3	13,0	3,8	10,3
Burettestraat en omgeving	23,3	7,9	13,9	4,1	12,3
Caumerveld	24,6	7,7	13,6	4,1	12,5
Centrum	24,9	8,8	14,2	4,1	13,0
Chevremont	31,1	10,5	13,9	4,1	14,9
Colmont	29,1	7,4	13,1	4,1	13,4
Craubeek	32,0	8,9	14,8	4,2	15,0
De Dem en omgeving	26,5	7,8	14,4	4,1	13,2
De Dormig	24,9	8,4	13,2	4,1	12,7
De Eggen	26,9	8,4	14,2	4,1	13,4
De Heide	20,8	7,1	14,2	4,0	11,5
De Hemelder	25,9	7,3	13,8	4,0	12,7
De Kattekoelen	23,8	7,3	14,0	3,9	12,2
De Kling	27,9	8,0	14,2	4,1	13,5
De Koumen	26,0	7,7	14,2	4,0	13,0
De Streek	27,3	7,8	14,0	4,0	13,3
De Streep	24,7	8,1	13,0	4,0	12,5
De Struiken	23,9	7,3	13,5	3,9	12,1
Douve Weien	25,8	7,8	13,6	4,1	12,8
Douvenberg	22,8	7,2	13,5	3,9	11,8
Dr. Nolensplein en omgeving	25,6	7,8	13,8	4,1	12,8
Dr. Schaepmanplein en omge	25,7	7,5	13,5	4,1	12,7
Egstraat en omgeving	25,4	7,9	13,6	4,1	12,7
Eikenderveld	25,3	8,3	14,2	4,1	13,0
Eiske	24,3	7,8	13,2	4,0	12,3

Emma	25,3	7,4	14,0	4,0	12,7
Erenstein	29,6	10,5	13,6	4,1	14,4
Exdel	23,8	6,4	12,9	4,0	11,8
Eygelshoven-Kom	29,0	8,7	14,5	4,1	14,1
Fromberg	31,2	8,8	14,1	4,1	14,5
Giezenveld	25,0	7,8	13,8	4,1	12,7
Gracht	33,3	8,5	13,1	4,0	14,8
Grasbroek	24,5	8,8	14,3	4,1	12,9
Gravenrode	24,4	6,8	12,8	4,0	12,0
Groenstraat	29,8	7,9	14,2	4,1	14,0
Groot Rennemig	25,9	7,1	14,2	4,1	12,8
Groot-Doenrade	32,7	9,7	14,8	4,2	15,3
Haanrade	29,6	9,1	14,4	4,2	14,3
Haansberg	25,8	7,8	13,8	4,1	12,9
Haasdal	36,1	9,5	14,8	3,9	16,1
Heerlen-Centrum	22,1	9,3	14,3	4,2	12,5
Heerlerbaan-Oost	28,5	8,3	14,0	4,2	13,7
Heerlerbaan-West	25,5	8,0	13,3	4,2	12,7
Heerlerheide Kom	24,7	7,3	14,2	4,1	12,6
Heilust	31,0	8,2	13,6	4,2	14,3
Heistraat	26,1	7,5	13,1	4,0	12,7
Heksenberg	23,6	7,9	13,8	4,0	12,3
Hellebeuk	31,3	8,8	14,1	4,1	14,6
Hendrik en omgeving	24,2	5,3	12,6	3,9	11,5
Het Heufken	27,2	7,9	14,3	4,1	13,4
Hoefveld	26,8	7,8	13,4	4,1	13,0
Hoensbroek-Centrum	26,4	8,1	14,6	4,1	13,3
Hofpoel	26,3	8,7	14,5	4,1	13,4
Holz	32,8	9,4	14,0	4,1	15,1
Hommert (gedeeltelijk)	27,4	7,9	14,0	4,1	13,3
Hopel	27,9	9,2	14,3	4,1	13,9
Hoppersgraaf	24,3	9,3	14,2	4,1	13,0
Houserveld	27,7	7,6	13,6	3,9	13,2
Huls	29,7	9,2	12,9	4,2	14,0
Hulsberg	25,9	8,0	13,9	4,0	12,9
Hulsveld	31,6	9,5	13,4	4,2	14,7
Husken	26,4	7,1	14,2	4,0	12,9
Imstenrade	22,2	7,2	12,7	4,0	11,5
In de Cramer	25,2	7,6	13,9	4,1	12,7
Industrieterrein De Horsel	34,5	9,3	14,5	4,1	15,6
Jabeek	31,1	7,8	14,1	3,9	14,2
Kaalheide	30,6	8,3	13,4	4,1	14,1
Kakert	22,3	6,5	12,9	3,9	11,4
Kerkeveld	24,7	8,6	14,2	4,0	12,9
Kerkrade-Centrum	31,3	10,4	13,4	4,0	14,8
Kleikoelen	27,0	7,2	14,3	4,0	13,1
Klein-Doenrade	27,0	8,2	12,8	3,7	12,9
Klimmen	31,9	9,7	14,3	4,2	15,1
Klingbemden	28,0	8,0	14,3	4,1	13,6
Klingelsberg	26,4	7,2	14,1	4,0	12,9

Klinkerkwartier	24,6	8,3	13,5	4,0	12,6
Koutenveld	25,2	8,1	14,1	4,0	12,8
Kruisberg	25,6	7,6	13,6	4,0	12,7
Kunderberg	29,0	7,1	13,6	4,0	13,5
Kunrade	27,3	7,8	14,3	4,0	13,4
Langenberg	23,8	7,6	13,7	4,0	12,3
Lauradorp	27,9	7,6	13,8	4,1	13,4
Leenhof	24,9	8,0	13,5	4,0	12,6
Lemmender	27,6	7,9	14,1	4,0	13,4
Lichtenberg	24,1	7,9	13,2	4,1	12,3
Lindeveld	25,6	8,0	13,7	4,1	12,8
Maria Gewanden	29,8	8,6	14,4	4,2	14,2
Mariarade-Noord	28,9	8,8	14,5	4,2	14,1
Mariarade-Zuid	27,6	7,9	14,3	4,1	13,5
Meezenbroek	24,0	7,3	14,1	4,0	12,4
Merkelbeek-Douvergenhout	25,2	6,4	13,2	3,9	12,2
Merkelbeekerdal	26,4	7,1	14,1	4,0	12,9
Mijnbuurt	26,6	8,0	13,3	4,0	13,0
Mingersborg	29,8	8,5	13,0	4,1	13,8
Molenbergpark	23,0	7,7	12,7	4,1	11,9
Molsberg-Rodeput	33,4	7,8	13,8	4,1	14,8
Musschemig	24,8	8,8	14,2	4,1	13,0
Nagelbeek-Hegge	36,1	9,5	14,4	4,1	16,0
Namiddagsche Driessen	27,6	7,5	14,2	4,2	13,4
Nieuw Lotbroek-Noord	27,2	7,6	14,8	4,1	13,4
Nieuw Lotbroek-Zuid	27,3	7,7	14,6	4,1	13,4
Nieuw-Einde	24,3	7,1	14,3	4,1	12,4
Nieuwenhagerheide	27,0	7,0	13,6	4,1	12,9
Nulland	31,8	9,9	13,4	4,0	14,8
Nuth	32,2	8,7	14,9	4,1	15,0
Oeloven	27,2	8,7	14,3	4,1	13,6
Oensel	36,8	10,4	15,1	4,0	16,6
Oirsbeek	28,5	8,4	14,6	4,1	13,9
Op de Kamp	26,4	7,9	13,5	4,2	13,0
Op de Nobel	23,6	8,7	13,8	4,2	12,6
Op de Vaard	25,7	8,3	13,9	4,1	13,0
Op de Vos	26,4	7,0	14,0	4,0	12,8
Op den Haan	26,4	8,2	13,8	4,1	13,1
Op gen Hoes	27,4	8,5	14,5	4,0	13,6
Ora et Labora	27,8	5,5	13,1	3,8	12,6
Oud Nieuwenhagen	28,1	7,9	13,9	4,2	13,5
Palemig	24,6	6,9	14,0	4,0	12,4
Parkheide	27,4	7,6	13,4	4,1	13,1
Passart	26,4	7,4	14,7	4,1	13,2
Prickart-Broek	31,0	8,3	12,6	3,7	13,9
Pronsebroek	23,8	7,7	13,7	4,0	12,3
Puth	34,3	9,3	14,5	4,1	15,5
Ransdaal	29,4	10,6	14,0	4,1	14,5
Retersbeek	29,8	7,0	14,6	4,1	13,8
Rimburg	26,4	7,2	14,7	4,2	13,1

Rode Beek	27,2	7,8	13,8	4,0	13,2
Rolduckerveld	27,1	8,6	13,3	4,0	13,3
Rozengaard	27,3	8,4	14,5	4,1	13,6
Rumpener Beemden	25,8	8,1	14,2	4,0	13,1
Schaesberg Centrum	24,4	7,7	13,0	4,0	12,3
Schaesbergerveld	24,6	8,0	13,9	4,1	12,7
Schandelen	23,5	8,4	14,0	4,1	12,5
Schelsberg	21,1	7,3	13,4	4,0	11,4
Schiffelerveld	23,9	7,0	13,5	4,1	12,1
Schimmert	34,2	9,8	15,0	4,2	15,8
Schinnen	32,3	8,6	15,1	4,2	15,1
Schinveld	32,3	9,3	14,9	4,2	15,2
Schuttersveld	25,8	7,7	14,0	4,1	12,9
Simpelveld	31,3	9,4	13,4	4,1	14,6
Spekholzerheide	27,4	7,9	12,7	4,0	13,0
Sweikhuizen	37,3	9,3	14,7	4,0	16,3
Swier	27,9	6,9	14,2	3,9	13,2
't Loon	25,3	9,1	14,2	4,2	13,2
Ten Esschen	25,9	0,2	14,2	2,8	10,8
Termaar	32,0	10,9	14,2	4,2	15,3
Terschuren	28,9	7,3	13,9	4,0	13,5
Tervoorst en omgeving	30,5	8,5	14,8	4,2	14,5
Terwinselen	30,7	8,1	13,8	4,1	14,2
Terworm	22,3	6,4	12,7	3,8	11,3
Thull	25,6	7,0	13,9	4,1	12,6
Treebeek-Noord	26,7	7,8	14,4	4,1	13,3
Treebeek-Zuid	26,5	7,4	14,4	4,1	13,1
Ubachsberg	30,0	7,7	13,4	4,2	13,8
Uterweg	24,2	7,4	13,9	4,0	12,4
Vaesrade	26,8	7,5	13,4	4,0	12,9
Versiliënbosch	24,9	8,6	14,1	4,1	12,9
Verspreide huizen	29,7	8,3	14,2	4,4	14,2
Verspreide huizen Dentgenba	28,6	7,3	12,6	3,7	13,0
Verspreide huizen Voerendaa	24,9	7,4	12,5	4,0	12,2
Vijverpark	24,4	8,3	14,5	4,1	12,8
Vink	28,9	9,0	14,0	4,1	14,0
Voerendaal	26,3	8,9	14,7	4,0	13,5
Vondelstraat	24,7	7,7	13,9	4,1	12,6
Vrieheide	23,4	7,2	13,3	3,9	12,0
Waubach	22,6	7,9	14,1	4,2	12,2
Waubacherveld	25,6	9,0	13,8	4,2	13,2
Weggebekker	24,1	6,2	13,2	3,8	11,8
Welten-Dorp	26,4	8,7	13,9	4,1	13,3
Weustenrade	28,1	7,2	14,2	4,0	13,4
Wijnandsrade	30,8	7,9	14,8	4,1	14,4
Winthagen	28,8	7,0	13,9	4,0	13,4
Zeswegen	24,0	8,1	13,6	4,0	12,4
Ziekenhuis	27,8	8,0	13,9	4,0	13,4

G

Shortfall for each neighbourhood

Municipality	Neighbourhood	PT TT30	PT TT30 TC3	CAR TT30	CAR TT30 TC3	CYCLE TT30
Beekdaelen	Aalbeek	0,488	0,652	0,000	0,750	0,239
Beekdaelen	Amstenrade	0,473	0,473	0,000	0,302	0,000
Beekdaelen	Arensgenhout	0,800	0,800	0,000	0,851	0,490
Beekdaelen	Bingelrade	0,904	0,904	0,000	0,580	0,232
Beekdaelen	Groot-Doenrade	0,834	0,834	0,000	0,756	0,289
Beekdaelen	Haasdal	0,936	0,936	0,000	0,931	0,724
Beekdaelen	Hommert (gedeeltelijk)	0,531	0,531	0,000	0,350	0,000
Beekdaelen	Hulsberg	0,341	0,623	0,000	0,763	0,278
Beekdaelen	Industrieterrein De Horsel	0,593	0,593	0,000	0,571	0,085
Beekdaelen	Jabeek	0,754	0,754	0,000	0,769	0,424
Beekdaelen	Klein-Doenrade	0,631	0,631	0,000	0,649	0,132
Beekdaelen	Merkelbeek-Douvergenhout	0,767	0,767	0,000	0,450	0,070
Beekdaelen	Nagelbeek-Hegge	0,434	0,727	0,000	0,645	0,336
Beekdaelen	Nuth	0,386	0,386	0,000	0,510	0,000
Beekdaelen	Oensel	0,920	0,920	0,000	0,931	0,700
Beekdaelen	Oirsbeek	0,645	0,645	0,000	0,426	0,062
Beekdaelen	Puth	0,878	0,878	0,000	0,699	0,414
Beekdaelen	Schimmert	0,868	0,868	0,000	0,780	0,535
Beekdaelen	Schinnen	0,880	0,880	0,000	0,543	0,118
Beekdaelen	Schinveld	0,744	0,744	0,000	0,727	0,283
Beekdaelen	Sweikhuizen	0,988	0,988	0,000	0,894	0,516
Beekdaelen	Swier	0,937	0,937	0,000	0,430	0,000
Beekdaelen	Tervoorst en omgeving	0,910	0,910	0,000	0,716	0,215
Beekdaelen	Thull	0,793	0,793	0,000	0,466	0,042
Beekdaelen	Vaesrade	0,738	0,738	0,000	0,395	0,000
Beekdaelen	Wijnandsrade	0,632	0,632	0,000	0,551	0,000
Beekdaelen	Average	0,723	0,752	0,000	0,632	0,238
Brunssum	Achter de Put	0,224	0,224	0,000	0,329	0,000
Brunssum	Amstenraderveld	0,651	0,651	0,000	0,366	0,000
Brunssum	Bexdelle	0,467	0,467	0,000	0,415	0,000
Brunssum	Bouwberg	0,834	0,834	0,000	0,644	0,253
Brunssum	Brandenberg	0,927	0,927	0,000	0,515	0,000
Brunssum	Brunssumer Heide	0,768	0,768	0,000	0,549	0,000
Brunssum	Buitengebied	0,514	0,514	0,000	0,422	0,000
Brunssum	Centrum	0,204	0,204	0,000	0,530	0,000
Brunssum	De Eggen	0,429	0,429	0,000	0,540	0,000
Brunssum	De Heide	0,719	0,719	0,000	0,561	0,000
Brunssum	De Hemelder	0,449	0,449	0,000	0,250	0,000
Brunssum	De Kattekoelen	0,784	0,784	0,000	0,720	0,099
Brunssum	De Kling	0,553	0,553	0,000	0,508	0,000
Brunssum	De Streek	0,486	0,486	0,000	0,431	0,000
Brunssum	De Struiken	0,459	0,459	0,000	0,281	0,000
Brunssum	Douvenberg	0,522	0,522	0,000	0,273	0,000
Brunssum	Emma	0,336	0,336	0,000	0,188	0,000

Brunssum	**Haansberg**	0,231	0,231	0,000	0,240	0,000
Brunssum	**Hendrik en omgeving**	0,945	0,945	0,000	0,545	0,000
Brunssum	**Het Heufken**	0,484	0,484	0,000	0,381	0,000
Brunssum	**Hofpoel**	0,331	0,331	0,000	0,560	0,000
Brunssum	**Houserveld**	0,736	0,736	0,000	0,587	0,050
Brunssum	**Kerkeveld**	0,314	0,314	0,000	0,526	0,000
Brunssum	**Kleikoelen**	0,629	0,629	0,000	0,447	0,000
Brunssum	**Klingbemden**	0,560	0,560	0,000	0,524	0,000
Brunssum	**Klingelsberg**	0,492	0,492	0,000	0,348	0,000
Brunssum	**Koutenveld**	0,480	0,480	0,000	0,509	0,000
Brunssum	**Kruisberg**	0,327	0,327	0,000	0,371	0,000
Brunssum	**Langenberg**	0,218	0,218	0,000	0,140	0,000
Brunssum	**Lemmender**	0,493	0,493	0,000	0,429	0,000
Brunssum	**Merkelbeekerdal**	0,785	0,785	0,000	0,552	0,021
Brunssum	**Oeloven**	0,433	0,555	0,000	0,611	0,000
Brunssum	**Op de Vaard**	0,351	0,351	0,000	0,406	0,000
Brunssum	**Op de Vos**	0,446	0,446	0,000	0,289	0,000
Brunssum	**Op den Haan**	0,456	0,456	0,000	0,508	0,000
Brunssum	**Op gen Hoes**	0,555	0,555	0,000	0,576	0,002
Brunssum	**Ora et Labora**	0,849	0,849	0,000	0,643	0,132
Brunssum	**Rode Beek**	0,728	0,728	0,000	0,622	0,104
Brunssum	**Rozengaard**	0,562	0,562	0,000	0,555	0,000
Brunssum	**Rumpener Beemden**	0,233	0,233	0,000	0,270	0,000
Brunssum	**Schuttersveld**	0,474	0,474	0,000	0,420	0,000
Brunssum	**Treebeek-Noord**	0,322	0,322	0,000	0,215	0,000
Brunssum	**Treebeek-Zuid**	0,343	0,343	0,000	0,223	0,000
Brunssum	**Vijverpark**	0,294	0,294	0,000	0,406	0,000
Brunssum	**Vondelstraat**	0,112	0,112	0,000	0,130	0,000
Brunssum	**Average**	0,500	0,503	0,000	0,435	0,015
Heerlen	**Aarveld**	0,056	0,056	0,000	0,000	0,000
Heerlen	**Beersdal**	0,041	0,041	0,000	0,005	0,000
Heerlen	**Beitel**	0,165	0,165	0,000	0,122	0,000
Heerlen	**Bekkerveld**	0,006	0,006	0,000	0,000	0,000
Heerlen	**Benzenrade**	0,213	0,213	0,000	0,000	0,000
Heerlen	**Burettestraat en omgeving**	0,003	0,003	0,000	0,000	0,000
Heerlen	**Caumerveld**	0,009	0,009	0,000	0,000	0,000
Heerlen	**De Dem en omgeving**	0,148	0,148	0,000	0,140	0,000
Heerlen	**De Koumen**	0,078	0,078	0,000	0,008	0,000
Heerlen	**Douve Weien**	0,004	0,004	0,000	0,000	0,000
Heerlen	**Dr. Nolensplein en omgeving**	0,000	0,000	0,000	0,000	0,000
Heerlen	**Dr. Schaepmanplein en omgeving**	0,001	0,001	0,000	0,000	0,000
Heerlen	**Egstraat en omgeving**	0,003	0,003	0,000	0,004	0,000
Heerlen	**Eikenderveld**	0,000	0,000	0,000	0,000	0,000
Heerlen	**Giezenveld**	0,000	0,000	0,000	0,000	0,000
Heerlen	**Grasbroek**	0,000	0,000	0,000	0,000	0,000
Heerlen	**Groot Rennemig**	0,101	0,101	0,000	0,023	0,000
Heerlen	**Heerlen-Centrum**	0,000	0,000	0,000	0,000	0,000
Heerlen	**Heerlerbaan-Oost**	0,005	0,005	0,000	0,000	0,000

Heerlen	Heerlerbaan-West	0,012	0,012	0,000	0,000	0,000
Heerlen	Heerlerheide Kom	0,092	0,092	0,000	0,043	0,000
Heerlen	Heksenberg	0,036	0,036	0,000	0,004	0,000
Heerlen	Hoensbroek-Centrum	0,110	0,110	0,000	0,111	0,000
Heerlen	Hoppersgraaf	0,000	0,000	0,000	0,000	0,000
Heerlen	Husken	0,070	0,070	0,000	0,000	0,000
Heerlen	Imstenrade	0,000	0,000	0,000	0,023	0,000
Heerlen	In de Cramer	0,035	0,035	0,000	0,002	0,000
Heerlen	Lindeveld	0,028	0,034	0,000	0,000	0,000
Heerlen	Maria Gewanden	0,266	0,266	0,000	0,301	0,000
Heerlen	Mariarade-Noord	0,163	0,163	0,000	0,178	0,000
Heerlen	Mariarade-Zuid	0,250	0,250	0,000	0,169	0,000
Heerlen	Meezenbroek	0,047	0,047	0,000	0,000	0,000
Heerlen	Molenbergpark	0,001	0,001	0,000	0,000	0,000
Heerlen	Musschemig	0,000	0,000	0,000	0,000	0,000
Heerlen	Nieuw Lotbroek-Noord	0,195	0,195	0,000	0,095	0,000
Heerlen	Nieuw Lotbroek-Zuid	0,111	0,111	0,000	0,059	0,000
Heerlen	Nieuw-Einde	0,306	0,306	0,000	0,091	0,000
Heerlen	Op de Nobel	0,000	0,000	0,000	0,000	0,000
Heerlen	Palemig	0,108	0,108	0,000	0,000	0,000
Heerlen	Passart	0,139	0,139	0,000	0,089	0,000
Heerlen	Pronsebroek	0,022	0,022	0,000	0,027	0,000
Heerlen	Schaesbergerveld	0,001	0,001	0,000	0,000	0,000
Heerlen	Schandelen	0,000	0,000	0,000	0,000	0,000
Heerlen	Schelsberg	0,088	0,088	0,000	0,004	0,000
Heerlen	Schiffelerveld	0,000	0,000	0,000	0,000	0,000
Heerlen	't Loon	0,000	0,000	0,000	0,000	0,000
Heerlen	Ten Esschen	0,284	0,284	0,000	0,001	0,000
Heerlen	Terschuren	0,634	0,634	0,000	0,407	0,000
Heerlen	Terworm	0,000	0,000	0,000	0,004	0,000
Heerlen	Uterweg	0,162	0,162	0,000	0,020	0,000
Heerlen	Versiliënbosch	0,010	0,010	0,000	0,042	0,000
Heerlen	Vrieheide	0,245	0,245	0,000	0,059	0,000
Heerlen	Weggebekker	0,667	0,667	0,000	0,200	0,000
Heerlen	Welten-Dorp	0,005	0,008	0,000	0,000	0,000
Heerlen	Zeswegen	0,000	0,000	0,000	0,009	0,000
Heerlen	Ziekenhuis	0,102	0,102	0,000	0,000	0,000
Heerlen	Average	0,090	0,090	0,000	0,040	0,000
Kerkrade	Bleijerheide	0,732	0,732	0,000	0,523	0,073
Kerkrade	Chevremont	0,142	0,266	0,000	0,289	0,000
Kerkrade	Erenstein	0,079	0,133	0,000	0,194	0,000
Kerkrade	Eygelshoven-Kom	0,437	0,437	0,000	0,436	0,000
Kerkrade	Gracht	0,039	0,039	0,000	0,089	0,000
Kerkrade	Haanrade	0,738	0,738	0,000	0,436	0,011
Kerkrade	Heilust	0,120	0,120	0,000	0,063	0,000
Kerkrade	Holz	0,512	0,512	0,000	0,491	0,079
Kerkrade	Hopel	0,046	0,046	0,000	0,214	0,000
Kerkrade	Kaalheide	0,212	0,212	0,000	0,124	0,000
Kerkrade	Kerkrade-Centrum	0,185	0,185	0,000	0,277	0,000
Kerkrade	Nulland	0,744	0,744	0,000	0,494	0,057

Kerkrade	Rolduckerveld	0,515	0,515	0,000	0,437	0,051
Kerkrade	Spekholzerheide	0,335	0,335	0,000	0,067	0,000
Kerkrade	Terwinselen	0,006	0,006	0,000	0,019	0,000
Kerkrade	Verspreide huizen Dentgenbach	0,683	0,683	0,000	0,312	0,000
Kerkrade	Vink	0,410	0,410	0,000	0,390	0,000
Kerkrade	Waubacherveld	0,045	0,045	0,000	0,367	0,000
Kerkrade	Average	0,332	0,342	0,000	0,290	0,015
Landgraaf	Abdissenbosch	0,672	0,672	0,000	0,683	0,000
Landgraaf	Achter de Haesen	0,000	0,000	0,000	0,000	0,000
Landgraaf	Achter den Winkel	0,166	0,166	0,000	0,000	0,000
Landgraaf	Brunssumerheide (1)	0,825	0,825	0,000	0,478	0,000
Landgraaf	Buitengebied Brunssumerheide (2)	0,746	0,746	0,000	0,280	0,000
Landgraaf	De Dormig	0,019	0,026	0,000	0,006	0,000
Landgraaf	De Streep	0,013	0,013	0,000	0,000	0,000
Landgraaf	Eiske	0,064	0,064	0,000	0,000	0,000
Landgraaf	Exdel	0,617	0,617	0,000	0,249	0,000
Landgraaf	Gravenrode	0,673	0,673	0,000	0,190	0,000
Landgraaf	Groenstraat	0,514	0,514	0,000	0,574	0,000
Landgraaf	Heistraat	0,025	0,025	0,000	0,002	0,000
Landgraaf	Hoefveld	0,313	0,313	0,000	0,193	0,000
Landgraaf	Kakert	0,075	0,075	0,000	0,001	0,000
Landgraaf	Klinkerkwartier	0,019	0,019	0,000	0,003	0,000
Landgraaf	Lauradorp	0,685	0,685	0,000	0,407	0,000
Landgraaf	Leenhof	0,002	0,002	0,000	0,000	0,000
Landgraaf	Lichtenberg	0,019	0,019	0,000	0,053	0,000
Landgraaf	Mijnbuurt	0,018	0,018	0,000	0,000	0,000
Landgraaf	Namiddagsche Driessen	0,707	0,707	0,000	0,684	0,000
Landgraaf	Nieuwenhagerheide	0,433	0,433	0,000	0,260	0,000
Landgraaf	Op de Kamp	0,064	0,064	0,000	0,089	0,000
Landgraaf	Oud Nieuwenhagen	0,302	0,302	0,000	0,165	0,000
Landgraaf	Parkheide	0,421	0,421	0,000	0,575	0,000
Landgraaf	Rimburg	0,840	0,840	0,000	0,696	0,147
Landgraaf	Schaesberg Centrum	0,086	0,086	0,000	0,000	0,000
Landgraaf	Waubach	0,604	0,604	0,000	0,657	0,000
Landgraaf	Average	0,330	0,331	0,000	0,231	0,005
Simpelveld	Baneheide	0,716	0,716	0,000	0,676	0,270
Simpelveld	Bocholtz	0,963	0,963	0,000	0,685	0,363
Simpelveld	Bocholtzerheide	0,963	0,963	0,000	0,916	0,468
Simpelveld	Huls	0,123	0,123	0,000	0,311	0,000
Simpelveld	Hulsveld	0,123	0,123	0,000	0,323	0,000
Simpelveld	Molsberg-Rodeput	0,671	0,671	0,000	0,324	0,000
Simpelveld	Prickart-Broek	0,646	0,646	0,000	0,675	0,143
Simpelveld	Simpelveld	0,469	0,469	0,000	0,497	0,000
Simpelveld	Average	0,584	0,584	0,000	0,551	0,156
Voerendaal	Colmont	0,785	0,785	0,000	0,626	0,000
Voerendaal	Craubeek	0,356	0,356	0,000	0,645	0,000
Voerendaal	Fromberg	0,998	0,998	0,000	0,947	0,505
Voerendaal	Hellebeuk	0,784	0,784	0,000	0,798	0,366

Voerendaal	**Klimmen**	0,314	0,316	0,000	0,810	0,001
Voerendaal	**Kunderberg**	0,364	0,364	0,000	0,044	0,000
Voerendaal	**Kunrade**	0,186	0,186	0,000	0,036	0,000
Voerendaal	**Mingersborg**	0,384	0,384	0,000	0,256	0,000
Voerendaal	**Ransdaal**	0,446	0,447	0,000	0,871	0,021
Voerendaal	**Retersbeek**	0,795	0,795	0,000	0,151	0,000
Voerendaal	**Termaar**	0,332	0,333	0,000	0,827	0,014
Voerendaal	**Ubachsberg**	0,384	0,384	0,000	0,212	0,000
Voerendaal	**Verspreide huizen Voerendaal**	0,457	0,457	0,000	0,403	0,000
Voerendaal	**Voerendaal**	0,194	0,203	0,000	0,148	0,000
Voerendaal	**Weustenrade**	0,506	0,506	0,000	0,127	0,000
Voerendaal	**Winthagen**	0,465	0,465	0,000	0,306	0,000
Voerendaal	**Average**	0,484	0,485	0,000	0,450	0,057

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Sensitivity analysis

	CAR		PT		CYCL		WALK	
	Avg. Job acc. (%)	Avg. Job acc. (#)	Avg. Job acc. (%)	Avg. Job acc. (#)	Avg. Job acc. (%)	Avg. Job acc. (#)	Avg. Job acc. (%)	Avg. Job acc. (#)
TT (15)	63%	64934	3%	3479	19%	19214	2%	1973
TT (30)	100%	102584	24%	24566	61%	63060	7%	7463
TT (45)	100%	102584	57%	58740	89%	91484	15%	15736
TT (60)	100%	102584	82%	84062	99%	101298	25%	25736
TT (90)	100%	102584	100%	102584	100%	102584	50%	51377
TC (2)	14%	14280	19%	19761	100%	102584	100%	102584
TC (3)	28%	28571	61%	62860	100%	102584	100%	102584
TC (4)	45%	46184	89%	90990	100%	102584	100%	102584
TC (5)	60%	61952	98%	100944	100%	102584	100%	102584
TC (6)	72%	74016	100%	102584	100%	102584	100%	102584
TC (12)	100%	102584	100%	102584	100%	102584	100%	102584
TT (15) + TC (2)	14%	14280	3%	3472	19%	19214	2%	1973
TT (15) + TC (3)	28%	28569	3%	3479	19%	19214	2%	1973
TT (15) + TC (4)	44%	45042	3%	3479	19%	19214	2%	1973
TT (15) + TC (5)	55%	56355	3%	3479	19%	19214	2%	1973
TT (30) + TC (2)	14%	14280	16%	16373	61%	63060	7%	7463
TT (30) + TC (3)	28%	28571	24%	24316	61%	63060	7%	7463
TT (30) + TC (4)	45%	46184	24%	24566	61%	63060	7%	7463
TT (30) + TC (5)	60%	61952	24%	24566	61%	63060	7%	7463
TT (45) + TC (2)	14%	14280	19%	19533	89%	91484	15%	15736
TT (45) + TC (3)	28%	28571	51%	52332	89%	91484	15%	15736
TT (45) + TC (4)	45%	46184	57%	58534	89%	91484	15%	15736
TT (45) + TC (5)	60%	61952	57%	58739	89%	91484	15%	15736
TT (60) + TC (2)	14%	14280	19%	19734	99%	101298	25%	25736
TT (60) + TC (3)	28%	28571	60%	61186	99%	101298	25%	25736
TT (60) + TC (4)	45%	46184	79%	81026	99%	101298	25%	25736
TT (60) + TC (5)	60%	61952	82%	83966	99%	101298	25%	25736

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