MASTER

An accessibility based effect measurement tool to support mobility policies

an approach regarding attributes of accessibility measurements and mobility policies for different transport modes

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PREFACE

This report represents my graduation thesis regarding an accessibility based effect measurement tool to support mobility policies. The graduation thesis is the final exam of the master program Construction Management and Engineering (CME), provided by Eindhoven University of Technology. The graduation research is performed in cooperation with Royal HaskoningDHV.

After almost five months of hard work, a lot of meetings with my supervisors and hours of work as an intern at Royal HaskoningDHV, I am proud to present the official thesis to fulfill the requirements for the degree of Master of Science in Construction Management and Engineering, provided by Eindhoven University of Technology.

Five and a half years ago, I started the bachelor Built Environment at Eindhoven University of Technology. After finishing that bachelor, I continued with the master program Construction Management and Urban Development and now I am (almost) graduated in the field of Transport & Planning. Before getting into the content of the report, I would like to express my gratitude toward the people who have contributed to making this research possible.

I would like to thank Peter van der Waerden, Qi Han and Sander Hoen for their very personal support and time they have made to share their knowledge with me during the meetings and to provide feedback on my thesis. Their involvement during the graduation period made it a success. Moreover, I would also thank Royal HaskoningDHV for the opportunity to graduate at the company. The enthusiasm of the team encouraged me to make the best of the graduation research possible. Moreover, I would like to thank my fellow graduation mates for the nice time we had during our study period. Finally, I would like to thank my family and friends for their understanding and support during my entire study.

SUMMARY

In order to accurately identify the accessibility of areas and improve the accessibility of these places as well as the accessibility of the cities as a whole, there is an urgent need to further understand the changing land use structure and transport conditions. Therefore, there is a need for more insight into the effects of mobility policies for different transport modes. More knowledge on this topic is required in order to plan effective interventions and policy changes. Accessibility concepts are increasingly acknowledged as fundamental to understand the effects of measures in cities and regions. In line with this, accessibility instruments have been recognized as valuable support tools for land-use and transport planning. Most practitioners are convinced of the usefulness of accessibility instruments in planning practice, because they generate new and relevant insights for planners. Accessibility measures are in cases like Buitenring Parkstad and Wageningen related to the ‘’Ladder van Verdaas’’ to improve the accessibility. Moreover the ‘’Ladder van Verdaas’’ is a widely used method to identify solutions to accessibility problems. In line with the problem definition the following research question is defined:

‘’What are relevant attributes regarding accessibility measurements and mobility policies for different transport modes, and what is the applicability of these attributes per step of the ‘’Ladder van Verdaas’’?

Therefore the objective is to develop a tool including relevant attributes with realistic scores for included attributes for each step of the ‘’Ladder van Verdaas’’. The research methods that are applied to identify accessibility effects are documentary analysis and expert judgement. This resulted in an overview of attributes that are most important per transport mode and per step of the ‘’Ladder van Verdaas’’. On top of that, two pilots are executed to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool. The research method to visualize the effects is a geographical information system (GIS).

Accessibility is a term which is interpreted, defined and operationalized in different ways in the literature. Land-use and transport are two of the target components, which define requirements of accessibility. The other two components are the temporal and individual component. Ideally, all four components would be included in a definition of accessibility. However it is troublesome and too complex to include all four components equivalent. Therefore, this research focusses mainly on the transport component and to a lesser extent on land-use.

The ‘’Ladder van Verdaas’’ is a conceptual framework, which is suitable for examining possible solutions to an accessibility problem. The main scope of the ‘’Ladder van Verdaas’’ is to see if the construction of new infrastructure can be avoided as much as possible with other solutions (e.g. spatial planning, pricing policy or mobility management). Examples of applications of the ‘’Ladder van Verdaas’’ are the cases Buitenring Parkstad and Wageningen.

According to Bakker & Zwaneveld (2009), Decisio & Transaction Management Centre (2012), and Vervoort, Van der Ham, & Van Breemen (2015), attributes of the different transport modes are divided into direct effects, indirect effects, external effects, and distributional effects. On the basis of documentary analysis and expert judgement these effects are related to the ''Ladder van Verdaas''. The researches show relationships between effects that are implemented, and this forms, on the basis of these researches, an overview of the effects that are important per transport mode and at each step of the ''Ladder van Verdaas''. Travel time and travel costs are, for example, direct effects that are applicable for each transport mode and each step of the ''Ladder van Verdaas''. Regarding the other effects, the integration tool provides an overview of the effects that are applicable per transport mode and at each step of the ''Ladder van Verdaas''.

Accessibility effects are visualized regarding two pilots. These two pilots are (1) a new bike connection between Mook and Cuijk and (2) a capacity extension of the A67 between Venlo and Eindhoven. Visualized are the effects before modification/construction, the effects after modification/construction, and the effects of the integration of both situations.

The new bicycle connection brings Mook and Cuijk figuratively closer to each other. Therefore residents of both municipalities can more easily use each other's facilities. By comparing the situation before and after construction of the bike connection, the travel costs and health effects per trip are lower from Mook to Cuijk, because the distance is decreased and therefore the travel costs and health effects (in eurocent per kilometer) per trip also decrease. Regarding traffic safety, it is important at how many points of intersection road users can come into conflict. On the basis of this statement, traffic safety is, in the case of the bike connection between Mook and Cuijk, visualized by the number of potential conflict points. Therefore, because of the construction of the new bike connection, the accessible area is bigger with the same number of conflict points in the new situation. There are also measures visualized related to step 2 (''Fietsplan'') and step 3 (prioritization of bicycle) of the ''Ladder van Verdaas''. For example, based on travel time, the new bike connection enhances the accessibility from Mook to Cuijk, and ''Fietsplan'' enhances the accessibility in all directions. However, to a lesser extent from Mook to Cuijk, because of the barrier of the Maas. By relating the effects to the costs, it can be concluded which project is most cost-effective. Therefore, the integration tool is a valuable method to provide advanced insights into the effects of accessibility measurements and mobility policies for different transport modes.

The distance between Venlo and Eindhoven is equal in the situation before and after the modification of the A67. However, the travel time will be shorter, especially during rush hours. This brings Venlo and Eindhoven, by looking at travel time, figuratively closer to each other. Regarding the illustrations, there can be concluded that municipalities which are located closer to the highway A67, the effects are bigger. Regarding other effects (like travel costs); a recommendation is to apply traffic model calculations to provide more insight into the effects of the capacity extension of the A67 between Venlo and Eindhoven.

SAMENVATTING

Om de bereikbaarheid van gebieden nauwkeurig te identificeren en te verbeteren is er dringend behoefte aan meer inzicht in de effecten van mobiliteitsbeleid voor verschillende vervoerswijzen. Meer kennis over dit onderwerp is nodig om effectieve interventies en beleidsveranderingen uit te voeren. Bereikbaarheidsconcepten worden steeds meer erkend om de effecten van maatregelen in beeld te brengen. Daarom zijn bereikbaarheidsinstrumenten erkend als waardevolle ondersteuning voor ruimtelijke ordening en transport. De meeste deskundigen zijn overtuigd van het nut van de bereikbaarheidsinstrumenten in de praktijk, omdat ze nieuwe en relevante inzichten voor planners genereren. Bereikbaarheidsmaatregelen om de bereikbaarheid te verbeteren zijn in casussen als Buitenring Parkstad en Wageningen gerelateerd aan de ''Ladder van Verdaas''. Bovendien is de ''Ladder van Verdaas'' een veel gebruikte methode om oplossingen voor bereikbaarheidsproblemen te identificeren. In overeenstemming met de probleemstelling is de volgende onderzoeksvraag gedefinieerd:

''Wat zijn relevante parameters met betrekking tot bereikbaarheidsmaatregelen en mobiliteitsbeleid voor verschillende vervoerswijzen, en wat is de toepasbaarheid van deze parameters per stap van de ''Ladder van Verdaas'''?

Daarom is het doel om een tool te ontwikkelen, inclusief relevante parameters en realistische score per parameter voor elke trap van de ''Ladder van Verdaas''. De onderzoeksmethoden die worden toegepast om de bereikbaarheidseffecten te identificeren zijn 'documentary analysis' en 'expert judgement'. Dit resulteert in een overzicht van de parameters die per vervoermiddel en per stap van de ''Ladder van Verdaas'' van invloed zijn. Bovendien zijn twee pilots uitgevoerd om de werking van de tool te illustreren, en om te bekijken of de tool voldoet aan de verwachtingen en aanbevelingen te geven. De onderzoeksmethode om de effecten te visualiseren is een geografisch informatie systeem.

Bereikbaarheid is een term die in de literatuur op verschillende manieren wordt geïnterpreteerd, gedefinieerd en geoperationaliseerd. Ruimtelijke ordening en transport zijn twee van de componenten, waarop eisen van bereikbaarheid zijn te definiëren. De andere twee componenten zijn de tijdelijke en individuele component. Idealiter zouden alle vier de componenten worden opgenomen in de definitie van bereikbaarheid. Het is echter lastig en te complex om op alle vier de componenten te focussen. Afhankelijk van het gekozen perspectief ligt de focus altijd op één of twee componenten. Daarom wordt in dit onderzoek voornamelijk de focus gelegd op de component met betrekking tot transport.

De ''Ladder van Verdaas'' is een conceptueel kader, dat geschikt is voor het onderzoeken van mogelijke oplossingen voor een bereikbaarheidsprobleem. Het bestaat uit zeven stappen die zijn gerelateerd aan bereikbaarheidsmaatregelen met betrekking tot bijvoorbeeld ruimtelijke ordening, prijsbeleid, mobiliteitsmanagement, en als laatste stap het aanleggen van nieuwe infrastructuur. Voorbeelden van toepassingen zijn Buitenring Parkstad en Wageningen.

Volgens Bakker & Zwaneveld (2009), Decisio & Transaction Management Centre (2012) en Vervoort, Van der Ham, & Van Breemen (2015) zijn de parameters van de verschillende vervoerswijzen onderverdeeld in directe effecten, indirecte effecten, externe effecten en verdelingseffecten. Op basis van 'documentary analysis' en 'expert judgement' zijn de effecten gerelateerd aan de ''Ladder van Verdaas''. Deze onderzoeken vertonen verbanden tussen de effecten die zijn onderzocht, en op basis van deze onderzoeken, is een overzicht ontwikkeld van de effecten die van belang zijn per vervoerwijze en per stap van de ''Ladder van Verdaas''. Reistijd en reiskosten zijn bijvoorbeeld directe effecten die van toepassing zijn voor elke vervoerswijze en elke stap van de ''Ladder van Verdaas''. Met betrekking tot de andere parameters, geeft de geïntegreerde tool een overzicht van de parameters die van toepassing zijn per vervoerswijze en bij elke stap van de ''Ladder van Verdaas''.

Bereikbaarheidseffecten zijn inzichtelijk gemaakt met behulp van twee quick scans. Deze twee quick scans zijn: (1) een nieuwe fiets verbinding tussen Mook en Cuijk en (2) een capaciteitsverruiming van de A67 tussen Venlo en Eindhoven. Met behulp van kaarten zijn de effecten geïllustreerd alvorens de maatregel is toegepast, de effecten na het toepassen van de maatregel en de effecten van de integratie van beide situaties.

De nieuwe fietsverbinding brengt Mook en Cuijk figuurlijk dichter bij elkaar. Daarom kunnen inwoners van beide plaatsen makkelijker gebruik maken van elkaars faciliteiten. De illustraties maken ook zichtbaar dat de reiskosten en gezondheidseffecten, in de situatie na aanleg van de fietsverbinding, per reis lager zijn tussen Mook en Cuijk, omdat de afstand wordt verkleind en daarmee nemen de reiskosten en gezondheidseffecten per reis af. De verkeersveiligheid is in beeld gebracht op basis van het aantal potentiële conflictpunten vanuit Mook, omdat bij verkeersveiligheid het aantal conflictpunten voornamelijk van belang zijn. Door de aanleg van de fietsverbinding is het te bereiken gebied met hetzelfde aantal conflictpunten groter in de nieuwe situatie. Aan de hand van de ''Ladder van Verdaas'' zijn ook maatregelen toegepast die zijn gerelateerd aan stap 2 (''Fietsplan'') en stap 3 (prioriteren van fietsers) van de ''Ladder van Verdaas''. Bij het vergelijken van de effecten op basis van reiskosten van ''Fietsplan'' en de aanleg van de fietsverbinding, kan worden geconcludeerd dat de nieuwe fietsverbinding de bereikbaarheid verbetert tussen Mook en Cuijk. Door de maatregel ''Fietsplan'' wordt het bereikbare gebied met dezelfde reiskosten groter. Dit laatste geldt in mindere mate tussen Mook en Cuijk, vanwege de ligging van de Maas. Met behulp van de kosten die aan de projecten kunnen worden gerelateerd, kan gekeken worden welk project het meest kosteneffectief is. Hiervoor vormt de geïntegreerde tool een waardevolle methodiek om geavanceerde inzichten te verwerven.

De afstand tussen Venlo en Eindhoven is gelijk in de situatie voor en na de capaciteitsverruiming van de A67. De reistijd zal echter afnemen, en dit brengt bijvoorbeeld Venlo en Eindhoven, gezien de reistijd, figuurlijk dichter bij elkaar. De effecten voor inwoners van gemeenten die relatief veraf zijn gelegen van de A67 zijn de effecten kleiner. Met betrekking tot andere effecten (bijvoorbeeld reiskosten en accijnzen), is er de aanbeveling om berekeningen van een verkeersmodel toe te passen om meer inzicht te verwerven in de effecten van de capaciteitsverruiming.

ABSTRACT

Earlier research mentioned that there is a need for more insight into the effects of mobility policies for different transport modes. More knowledge on this topic is required in order to plan effective interventions and policy changes. Accessibility concepts are increasingly acknowledged as fundamental to understand the effects of measures. In cases like Buitenring Parkstad and Wageningen, accessibility measures are related to the ''Ladder van Verdaas''. The ''Ladder van Verdaas'' is a conceptual framework, which is suitable for examining possible solutions to an accessibility problem. The main scope is to see if the construction of new infrastructure can be avoided as much as possible with other solutions. Therefore, the objective is to develop an integration tool including relevant attributes with realistic scores for included attributes for each step of the ''Ladder van Verdaas''. The research methods that are applied to identify relevant attributes are documentary analysis and expert judgement.

On top of that, by using geographical information systems, two pilots are executed to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool. A pilot regarding the construction of the bike connection between Mook and Cuijk present, based on the relevant attributes, the differences between the situation before and after the construction of the bike connection. Moreover, the illustrations are compared regarding the effects of measures related to different steps of the ''Ladder van Verdaas''. For example, the new bike connection (step 7) enhances the accessibility from Mook to Cuijk, and a measure related to step 2 of the ´´Ladder van Verdaas´´ enhances the accessibility in all directions. However, to a lesser extent from Mook to Cuijk, because of the barrier of the Maas. The pilot regarding the capacity extension between Venlo and Eindhoven represent the attribute travel time to visualize the effects of the capacity extension. Regarding the illustration of other effects, a recommendation is to apply traffic model calculations. Herewith, the integration tool is a valuable method to provide advanced insights into the effects of accessibility measurements and mobility policies for different transport modes.

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1. INTRODUCTION

1.1. Problem definition

Because of the continuing urbanization of the world's population and the economic growth of cities, spatial urban areas expand and new communities, jobs, and services are decentralized (Cui et al., 2016). Though, existing transport networks have not developed at the same speed as urban growth, and this has generated, for example, isolated areas which are more difficult to reach by the (existing) transport systems (Cui et al., 2016). In order to accurately identify the accessibility of areas and improve the accessibility of these places as well as the accessibility of the cities as a whole, there is an urgent need to further understand the changing land use structure and transport conditions (e.g. Gwilliam, 2013). Therefore, information regarding effects of measurements (or policies) is needed to understand what attributes are needed to provide more insight into the effects of transport policies in different transport modes. The same is valid for tools that support this information generation and visualization.

Accessibility is a key concept in land use and transport policies, and infrastructure-based measures are an important type of accessibility measures (Liao & Van Wee, 2016). Recently, there has been a significant increase in the attention paid in both policy documents and academic literature to the robustness of the transport system (Liao & Van Wee, 2016). However, there is not a mature body of literature on the infrastructure-based accessibility measures expressing this concept. Moreover, accessibility is often a misunderstood, poorly defined and poorly measured construct (Geurs & Van Wee, 2004). Actually, finding an operational and theoretically sound concept of accessibility is quite difficult and complex. Therefore, land-use and infrastructure policy plans are often evaluated with accessibility measures which are easy to interpret for policy makers and researchers, such as travel speed or congestion levels on the road network, but this have strong methodological disadvantages (Geurs & Van Wee, 2004).

The ''Ladder van Verdaas'' is a widely used method to identify solutions to accessibility (mobility) problems (Modijefsky & Vervoort, 2010). The scope is to determine if goals of infrastructure can be achieved by less drastic measures, such as measures regarding pricing policy and mobility management, before considering more drastic measures (such as the construction of new infrastructure). Several criteria can be derived to evaluate the usefulness and limitations of accessibility measures for different study purposes, although there is no best approach for accessibility because different situations and purposes demand different approaches (Handy & Niemeier, 1997). Such criteria, for example, are described by Black & Conroy (1977), Jones (1981) and Handy & Niemeier (1997).

According to Geurs & Van Wee (2004), an accessibility measure should ideally take into account all components (land-use, transportation, temporal and individual component) and elements within these components. Therefore, an accessibility measure should firstly be sensitive to changes in the transport system. This means the ease for an individual to cover the distance between an origin and a destination with a specific transport mode or combination of modes, including the amount of time, costs, and effort. Secondly, an accessibility measure should be sensitive to changes in the land-use system, i.e. the amount, spatial distribution and quality of supplied opportunities, and the spatial distribution of the demand for those opportunities, and the confrontation between demand and supply. However, land-use changes not only have a direct impact on accessibility but also an indirect impact through the transport system. For example, more urbanization in a densely populated area might increase congestion levels, and therefore influence the ease of travelling. Thirdly, a measure should be sensitive to temporary constraints of opportunities. Finally, a measure should take into account individual abilities, opportunities, and needs.

These criteria should not be regarded as absolute but more in the line of what accessibility studies pursue. Applying the full set of criteria would imply a level of complexity and detail that probably can never be achieved in practice (Geurs & Van Wee, 2004). This is because different situations and study purposes demand different approaches in practical applications. However, it is important that the implications of violating one or more theoretical criteria should be recognized and described. According to Geurs & Van Wee (2004), four basic perspectives on measuring accessibility can be identified.

- **Infrastructure-based measures**
  These measures are analyzing the (simulated or observed) performance or the service level of transport infrastructure, such as average travel speed and level of congestion on the road network. Infrastructure-based measures are typically used in transportation planning.

- **Location-based measures**
  These measures analyze the accessibility of locations. Location-based measures describe the level of accessibility to spatially distributed activities. These measures are typically used in urban planning and geographical studies.

- **Person-based measures**
  This measure type is founded by Hägerstrand (1970). According to his space-time geography, many types of measures are analyzing accessibility at individual level. This means the time budgets for flexible activities, the location and duration of mandatory activities, and travel speed allowed by the transport system.

- **Utility-based measures**
  These measures analyze the (economic) benefits that people derive from access to spatially distributed activities. This measure type has its origin in economic studies.

In short, the existing transport networks have been developed less detailed than urban growth (Cui et al., 2016). Thereby, there are many categories of measures taken (infrastructure-based measures, location-based measures, person-based measures, and utility-based measures), but in order to accurately identify the accessibility of areas and improve the accessibility of these places as well as the accessibility of the cities as a whole, there is an urgent need to further understand transport conditions (e.g. Gwilliam, 2013). Therefore, it is needed to understand which attributes are needed to provide more insight into the effects of transport policy in different transport modes and which tools can be used to describe and visualize these effects. Accessibility concepts are increasingly acknowledged as fundamental to understand cities and regions (Silva, Bertolini, Brömmelstroet, Milakis, & Papa, 2017). The municipality of Wageningen and Wageningen University, for example, launched studies and initiatives of possible measures to improve accessibility related to the ''Ladder van Verdaas'' (Royal HaskoningDHV, 2014). At this case, variants are created on the basis of the ''Ladder van Verdaas'', and regarding these variants a traffic-related impact assessment is developed (table 1.1). As illustrated in table 1.1, the effect accessibility is by expert judgement only scored as + or ++, but accessibility effects can be described/visualized more precisely, and therefore, regarding to the scope of the project, a much more advanced choice can be made. As a result, in this research, an integration tool including relevant attributes with realistic scores for included attributes for each step of the ''Ladder van Verdaas'' will be developed. This provides a structured view on which effects are applicable for each transport mode and each step of the ''Ladder van Verdaas''.

Table 1.1: Overview traffic-related impact assessment Wageningen (Royal HaskoningDHV, 2014)

	Ref.	Variant A1	Variant A2	Variant B1	Variant B2
Traffic flow	0	+	+	+	+
Accessibility Wag UR	0	+	+	++	++
Robustness	0	+	+	++	++
Ease of crossing/ bicycle safety					
- N781	0	++	++	+	+
- Nijenoord Allee	0	++	++	+	++

1.2. Research questions and objective

Earlier research mentioned that there is a need for more insight into the effects of mobility policies for different transport modes (Cui et al., 2016). More knowledge on this topic is required in order to plan effective interventions and policy changes. Therefore the scientific relevance of the thesis is to structure relevant attributes (in an integration tool), including valuation regarding these effects.

Accessibility concepts are increasingly acknowledged as fundamental to understand cities and regions (Silva, Bertolini, Brömmelstroet, Milakis, & Papa, 2017). In line with this, accessibility instruments have been recognized as valuable support tools for land-use and transport planning. Silva et al. (2017) concluded that most practitioners are convinced of the usefulness of accessibility instruments in planning practice, because they generate new and relevant insights for planners. Therefore social relevance is to represent the effects in a fundamental way to provide insight into the effects of accessibility measures. The ''Ladder van Verdaas'' is a conceptual framework, which is suitable for examining possible solutions to an accessibility problem. The main scope is to see if the construction of new infrastructure can be avoided as much as possible with other solutions.

As mentioned in the previous section, there are multiple aspects which influence users to use a certain transport mode. In line with the problem definition the following research question is defined:

''What are relevant attributes regarding accessibility measurements and mobility policies for different transport modes, and what is the applicability of these attributes per step of the ''Ladder van Verdaas''?

In order to be able to answer the question stated above, the following sub-questions are composed:

- *''What is the definition and operationalization of accessibility?''*
- *''What is the composition and applicability of the ''Ladder van Verdaas'' in the context of effect studies?''*
- *''What are relevant attributes for each transport mode and for each step of the ''Ladder van Verdaas'', and what is a realistic score per attribute?''*
- *''By illustrating the working of the tool on the basis of 2 pilots, does the tool meets the expectations and what are recommendations regarding the applicability of the tool?''*

The objective is to develop a tool including relevant attributes with realistic scores for included attributes for each step of the ''Ladder van Verdaas''. This tool will be created on the basis of documentary analysis. In addition, realistic assumptions regarding unavailable information will be generated by consulting professionals in the field of traffic research. It is assumed that they have actual knowledge regarding these topics. This will result in an overview of attributes that are most important per transport mode and per step of the ''Ladder van Verdaas''. After creating the integration tool, two pilots will be executed, by using a geographical information system (GIS), to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool.

1.3. Research design

As mentioned before, the ''Ladder van Verdaas'' is a widely used method to identify solutions to accessibility (mobility) problems (Modijefsky & Vervoort, 2010). There are many possible measures to improve accessibility related to the ''Ladder van Verdaas''. By documentary analysis and expert judgement, relevant attributes will be processed in a structured system with realistic scoring per attribute for each step of the ''Ladder van Verdaas''. Thereby the ''Ladder van Verdaas'' determines the choice of the attributes (figure 1.1). The aspects as a result of the documentary analysis concerning travel time, together with other influencing aspects (e.g. social aspects, environmental aspects) are used to design an integration tool. This will result in an overview of attributes that are most important per transport mode and per step of the ''Ladder van Verdaas''.

Accessibility concepts are increasingly acknowledged as fundamental to understand cities and urban regions (Silva et al., 2017). Therefore, accessibility instruments have been recognized as valuable support tools for land-use and transport planning. By using geographical information systems (GIS), pilots will be executed illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool.

Figure 1.1: Research design

In short, the research can be illustrated as in figure 1.1. Firstly, there are accessibility measures and these measures can be related to the different steps of the ''Ladder van Verdaas''. Therefore it is important to investigate the composition and applicability of the ''Ladder van Verdaas''. On the basis of documentary analysis, an integration tool will be created, including which attributes are applicable per transport mode and each step of the ''Ladder van Verdaas''. The working of the tool will be illustrated on the basis of two pilots, by using geographical information systems.

1.4. Reading guide

Chapter 1 presents the introduction, including problem definition, research questions and objective, research design, and finally the report structure.

Chapter 2 of this report consists of a literature review answering the first and second sub-question defined in the previous section. A clear overview of existing literature, previous outcomes of researches, and relevant topics which are already covered in current literature is provided. The different sections of this chapter are the introduction, transport policies for different transport modes, measuring accessibility, and the ''Ladder van Verdaas''.

Chapter 3 describes the adopted research methodology. The first section regarding the introduction briefly discusses the research questions and the strengths and weaknesses of the chosen approach, including a plan to address them. The second section regarding the research approach is about the research methods used in this study. The third section about documentary analysis is about what sources and attributes are investigated, and in the fourth section these attributes are extensively described. The fifth section presents the integration tool, including the attributes that are applicable per transport mode and each step of the ''Ladder van Verdaas''. The integration tool forms a strong basis for future research and provides the most important attributes concerning the different transport modes at the different steps of the ''Ladder van Verdaas''.

After describing the methodology, the working of the integration tool will be illustrated on the basis of two pilots. Therefore chapter 4 outlines the application of the two pilots. Firstly, the bike connection between Mook and Cuijk will be evaluated by using the integration tool. Secondly, the capacity extension of A67 between Venlo and Eindhoven will be evaluated. Based on these pilots, expectations and recommendations will be provided regarding the tool.

The last chapter, chapter 5, is regarding the conclusion, including the general conclusions and the general discussion and recommendations.

2. LITERATURE REVIEW

2.1. Introduction

The length of the motorway network increased from around 300 km to 1500 km in the period between 1960 and 1975 (V&W & VRO, 1977). Moreover, personal mobility maintained its growth in the Netherlands in the period after 1975 (Heeres, Tillema, and Arts, 2012). Therefore Dutch personal mobility doubled in the period between 1970 and 2000, and transport mode car accounted for 70% of the kilometers traveled. For the period from now until 2040, a continuation of the mobility growth is expected. Though, the growth will be weaker due to demographic developments (CPB, MNP & RPB, 2006). Realization of new road infrastructure was, and is still needed to accommodate this continuous mobility growth. However, the increasing public awareness of growth and environmental issues since the early 1970s (Club of Rome, 1972) created public attention to the (negative) effects of increasing car traffic, which used to be only positively valued. Public opposition against infrastructure projects increased enormously, due to the attention paid to the effects of both traffic (e.g. safety and pollution aspects) and physical infrastructure (e.g. effects on soil, nature, landscape, and heritage).

In the 1970s, the mobility growth started to cause considerable delays, together with the economic and financial impacts of the oil crisis (Heeres, Tillema, and Arts, 2012). Because of new circumstances and the growth of road infrastructure, the infrastructure planning system required adaptation (Van der Heijden, 1996; Struiksma & Tillema, 2009). Comparable to developments observed in the environmental policy sector, there are two developments in the infrastructure planning system; internal and external integration (De Roo, 2003).

Internal integration of the traffic and transport sector has been applied after the declining public support regarding line-oriented road infrastructure planning (Heeres, Tillema, & Arts, 2012). This was the case because accommodating for the increasing personal mobility needs in the Netherlands could not be achieved only by the realization of additional road infrastructure. Internal integration is a process of integration of several components within the transport and traffic policy sector (De Roo, 2003). For example, the aims to improve the attractiveness of public transport (V&W & VROM, 1988). According to De Roo (2003), external integration is a process of integration with other policy sectors. In road infrastructure planning this would imply an integration of infrastructure policy and planning with related policy sectors like air quality.

The internal integration trend has developed further. For example, the network approach considers the coherence of the road network (V&W, 2004). In line with this, the aim of the Department of Public Works & Water Management (Rijkswaterstaat) is to position users of the road infrastructure network central to its operations (Rijkswaterstaat, 2004). The main ambition of the operations is to improve the traffic flows on the road infrastructure network, as experienced by the users. Therefore it is important to manage and consider the main road infrastructure network and underlying roads (including railways and waterways) as one coherent transport system. This public-oriented strategy is a process of internal integration. It requires close cooperation with managers of other transport networks (Van den Brink, 2009).

In the policy ''Mobility Approach'' (V&W, 2008), the network approach was further developed by optimizing connections and opportunities such as the establishment of parallel lanes on highways. The policy aims at achieving a robust mobility system of high quality. Some members of parliament insisted through a manifest (Verdaas, Slob, Hofstra, & Mastwijk, 2005) for a further extension by going through seven steps in decision making on infrastructure. This extension is named the ''Ladder van Verdaas''.

The ''Ladder van Verdaas'' is a widely used method to identify solutions to accessibility (mobility) problems (Modijefsky & Vervoort, 2010). It's scope is to determine if goals of infrastructure can be achieved by less drastic measures, such as measures regarding pricing policy and mobility management, before considering more drastic measures (such as the construction of new infrastructure). Construction of new infrastructure should only be considered when policies regarding travel behavior, or better utilization of existing infrastructure (with minor modifications) are not the appropriate solution.

The next section is about transport policies for different transport modes (public transport, car, and bike). The section about accessibility measurement starts with an exploration of the concept of accessibility. Accessibility is multi-interpretable, which requires a substantiated definition and operationalization. Accessibility is analyzed in response to the various components and accessibility measures, as proposed by Geurs & Van Wee (2004). After conceptualizing accessibility, the focus shifts to travel behavior aspects and mechanisms (section 2.3.2.). Section 2.3.3 provides an overview of the various ways in which accessibility has been measured, on the basis of Curtis & Scheurer (2007). The last section of this paragraph (section 2.3.4.) is about accessibility evaluation. Section 2.4 presents the setup of ''Ladder van Verdaas''. Finally, paragraph 2.6 is regarding the conclusion.

2.2. Transport policies for different transport modes

This paragraph evaluates several transport policies for different transport modes, respectively for transport modes public transport, car, and bike. The last paragraph of this section is about spatial mobility policy, because spatial planning has always played an important role in transportation policy.

2.2.1. Public transport

The description of public transport starts with a view on railways. The following issues are of importance when considering public transport in this study: capacity extension, safety, accessibility, participation, and the impact of more public transport.

Railway *capacity extension* has a positive effect on mobility and accessibility, but at relatively high costs (CPB &PBL, 2016). Therefore, capacity extension is usually socially unprofitable. Passenger transport by trains has a lower impact than passenger transport by cars, both for the environment and traffic safety. It depends on the number of new passengers who previously traveled by car, by bike and/or did not travel whether an extension of the rail network is beneficial for the environment and traffic safety. In many cases, the balance will have a negative impact on the environment (CPB & PBL, 2016).

Measures to further improve *traffic safety* of public transport provide little safety gains compared to the costs associated with this. Investments in safer crossings that simultaneously provide travel time gains are sometimes socially profitable. Examples of measures that can cost-effectively improve accessibility are selective, mostly smaller projects to better use the existing railway infrastructure, to improve pre- and post-transport (to achieve a relatively high profit), and the replacement of single tracks with a low occupancy by a bus.

To improve *accessibility*, investing in local public transport (bus, tram, metro) is more cost-effective than expanding railway infrastructure. Particularly selective, small-scale projects can increase accessibility cost-effectively. The effects on traffic safety and the environment depend on the situation. A lower frequency of bus or tram outside rush hour, on routes with low capacity utilization, is expected to be beneficial to the prosperity. This is because it reduces costs while not substantially decreasing accessibility by public transport. Public transport in cities can be more efficient in places with fewer stops and a less dense network.

Many policy documents and programs have an important role in public transport in ensuring that everyone can *participate* in society. Groups that, more than others, are considered to rely on public transport are elderly, disabled, students, households with low income, and people without a driver’s license. However, research shows that most benefits from the public offering reach the higher income groups. This is especially the case for the train. Moreover, disabled and elderly seem not to be depending on public transport above average. Except 'older elderly' who are no longer able to travel by car or (electric) bike. There are effective ways to promote mobility of these groups by investing in public transport. Applying grants can play a useful role, such as a monthly credit on a transport card.

In practice, *the impact of more public transport* seem to be limited to solve congestion, because of the low trade-off between public transport and car transport. The provision of local public transport can lead to a decrease in congestion, but this effect is strongest in the cities themselves. Investments in public transport especially lead to new displacements and less use of the bike. Car use, however, barely decreases. Therefore, there is an increase of negative effects on quality of life (emissions, noise disturbance, and traffic safety). Although at public transport there is, per kilometer traveled, less environmental damage and less accidents happen than in car. In many cases, investments in public transport have a limited negative impact on the environment. Measures that combine an improvement in urban transport by discouraging car can turn out a quite positive balance for the environment. It varies per situation to what extent such measures make a positive contribution to social prosperity.

2.2.2. The car

The description of transport mode car starts with a view on the impact of capacity extension. Looking at the car, most important issues are capacity extension, new road infrastructure, pricing policy, and accessibility.

Travel times will be shorter and the travel time reliability will increase by *capacity extension* of the main road network (CPB & PBL, 2016). The effects of the construction or widening of roads are lower in the long term than in the short term. This is because a capacity extension also attracts new traffic. Moreover, in general, capacity extension leads to an increase in emissions and noise. However, these effects are relatively small compared to the travel time gains. The effects on traffic safety can be either positive or negative.

The total costs of many *new road infrastructure* projects are relatively high, often due to the high integration costs. Carrying out new projects will only lead to prosperity gains if the congestion increases substantially (CPB & PBL, 2016). It also applies to some of the projects considered in Multi-annual program Infrastructure, Space, and Transport (Meerjarenprogramma Infrastructuur, Ruimte en Transport, abbreviated: MIRT). Additional social cost-benefit analysis (SCBAs) of these projects can help by prioritization and selection of the projects.

Regarding *pricing policy*, higher fuel taxes lead to less car use, a decrease in accessibility (because driving is expensive), less congestion, fewer emissions and noise, and fewer casualties. An increase of fuel taxes also has a negative impact on the purchasing power and the economy, and provides probably more tax revenue for the government. For the effects on traffic safety, emissions and noise it matters where someone is driving, with which fuel is used, what type of vehicle is used and what age of the vehicle is. The fuel taxes for road users are averaged over all fuels, model cars and places where driving around is in balance with the social cost of emissions, noise and road safety (in monetary terms). In other words, the polluter pays. Therefore an overall substantial increase or decrease in taxes is not obvious.

There are other measures possible to improve *accessibility* on the main road network. These measures are under the name of ‘’use (better) information and innovation’’. Examples include the intelligent management and design of road infrastructure, encouraging changes in behavior among road users, but also to facilitate intelligent transportation and information systems. An important part of these measures is found under the Better Utilization Program of the Ministry of Infrastructure and Environment. In this program, innovative solutions are searched for, to reduce travel time for the main traffic bottlenecks during rush hours. Several measures in this program seem to lead to less congestion.

Some measures improve accessibility at relatively low cost, such as adjustment of traffic lights. For many measures, however, information about the costs is insufficiently accessible (CPB & PBL, 2016). Therefore there is need for a better understanding of the relationship between the cost of these measures, applicability in different situations and the impact on accessibility. When information about this is more accessible, prosperity enhancing measures can also be applied to other locations.

2.2.3. The bike

Cycling is good for the environment, health and accessibility (CPB & PBL, 2016). Thereby the health benefits are bigger than the decrease of traffic safety. A switch from car or public transport to bicycle produces social benefits. Therefore both can be meaningful for national government and for local authorities to promote cycling measures.

Tax incentives for bicycle can promote to switch from car or public transport to bicycle (the so-called modal split) at commuting (CPB & PBL, 2016). Moreover, users show high appreciation for fast cycle routes. By creating certain fast cycle routes, a connection is made between urban areas by means of a high comfort bicycle facility. Although there is a growing attention for cycling, there still exists a 'knowledge gap' when considering the effectiveness of new or improved bicycle infrastructure (Van Overdijk, 2016).

To stimulate the use of public transport it is also important to improve pre- and post-transport. Therefore for example bicycle facilities are important at a train station, because 40 percent of the pre-transport and about 15 percent of the post-transport of rail travel takes place by bike.

2.2.4. Spatial mobility policy

Transportation and mobility issues have always played an important role in spatial planning in the Netherlands (Snellen, 2002). Vice versa, spatial issues have continuously played a role in transportation policy. Accessibility is both dependent on the spread of activities, as well as the available transport system (Geurs & Van Wee, 2004). Therefore transportation policies and the spatial structure are important for a well-functioning transport system (CPB & PBL, 2016). Long distances between home and work require longer trips, longer travel times, and lead to more traffic on the road. Concentration of housing, facilities and/or jobs nearby nodes (public transport and/or roads), provides easier access to realistic networks. A well-functioning planning policy ensures optimal locations offered for various activities, such as residence and work. The impact on mobility and accessibility is one of the factors that should play a role in planning decisions.

Various instruments (like spatial planning) and measures can be deployed to create strategies. These instruments can increase the concentration of activities, the accessibility of destinations, and reduce car use. For example, concentration leads to an increase in public transport and bike use, which in turn leads to less environmental damage. An increase in bike use is generally detrimental to road safety, but the health effects are positive and outweigh the disadvantages for traffic safety (CPB & PBL, 2016). Land development along highways leads to more car use, whereby congestion and environmental damage increase.

A more effective and efficient coordination between infrastructure and urbanization can be achieved by combining the financing of infrastructure and space (CPB & PBL, 2016). This could include adjusting the Multiannual program Infrastructure and Transport (MIT), so that funds can be more easily used for spatial solutions to mobility problems. It would also create better decision/responsibility concerning spatial and mobility policy, for example at the regional level, or at a private party. With spatial choices it is important to take sufficiently into account the implications for the mobility, accessibility and transport infrastructure.

2.3. Measuring accessibility

2.3.1. Definition of accessibility

This section starts with an exploration of the concept of accessibility. Accessibility is multi-interpretable, which requires a substantiated definition and operationalization. The meaning of accessibility is very widely; it contains time accessibility, spatial accessibility, and even involves psychology and sociology. Much of the literature has provided different definitions and calculation methods from a different perspective. As proposed by Geurs & Van Wee (2004), accessibility is analyzed in response to the various components and accessibility measures. After conceptualizing accessibility, the focus shifts to travel behavior aspects and mechanisms.

Accessibility is a term which is interpreted, defined and operationalized in different ways in literature. Hansen (1959) describes accessibility as ''the potential of opportunities for interaction'', Dalvi and Martin (1976) mention accessibility ''the ease with which any land-use activity can be reached from a location using a particular transport system''. More recently the impact of accessibility on society is highlighted, by looking at the opportunities for participation in activities of individuals. The more sites can be reached within acceptable time and costs, the higher the potential for interaction (more time and or money available, whereby making more possible), and the number of activities which are open to participate on (Geurs & Van Wee, 2004; Handy & Niemeier, 1997). However accessibility is highly dependent on the spatial distribution of activities. After all, in general, locations where little or no activities occur are less attractive. In addition, the attractiveness of a location also depends on the size, quality and type of operations that can be deployed there. Most activities are clustered in urban networks, such as the Arnhem Nijmegen City Region. These areas want to reach many individuals at the same time, so the transport system should be used. Thus, accessibility is both dependent on the spread of activities (spatial planning), as well as the available transport system (mobility). This emphasizes the bond between both sectors.

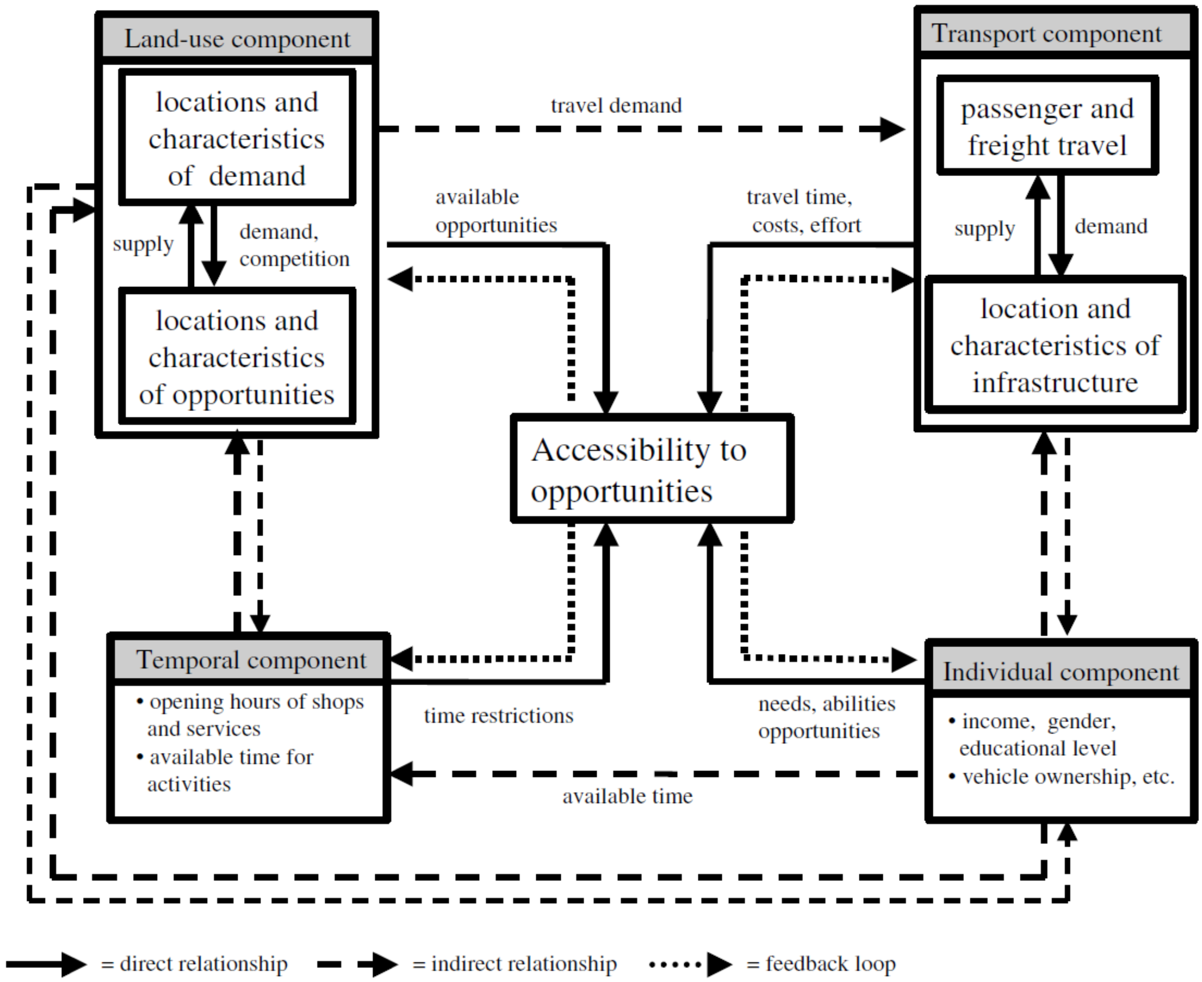

Figure 2.1: Relationships between components of accessibility (Geurs & Van Wee, 2004)

Figure 2.1 illustrates the relationships between components of accessibility. Spatial planning (land-use) and transport system (transport) are two of the target components, which define requirements of accessibility. The other two components are the temporal and individual component (Geurs & Van Wee, 2004).

- Land-use component: spatial component consisting of the number, quality and spatial distribution of activities at each destination, as well as the demand for these activities at the source location.

- Transport component: mobility component, expressed in the effort (disutility) it takes for individuals to bridge the distance between origin and destination using a particular mode of transport. They include the time (travel, waiting, and parking), costs (fixed and variable), and effort (reliability, comfort, accident risk).

- Temporal component: time constraints both have the number of available activities at a particular time and the available time individuals have to participate in an activity.

- Individual component: personal component, including personal needs (depending on age, income, education, family situation), options (depending on physical condition, available modalities) and opportunities (depending on income, travel budget, education level, etc.) of individuals. These personal characteristics affect access to both the transport and the spatial distribution of activities.

The components are, as can be interpreted logically from the description, also connected to each other. The land-use component (spread of operations) is for example a major part of influence on transport component (demand for movements). In addition, this component also provides temporal restrictions, and it also influences personal characteristics (individual component). The individual component affects all other components. The individual component determines the time available (temporal component), the procedures that a person can and wants to use (transport component) and also the activities that can be achieved within personal limitations (land-use component). Geurs and Van Wee (2004) further distinguish a number of feedback loops. For example, an increasing number of activities may lead to an increase of the individual possibilities, for example, one gets a better job thus reducing personal (financial) limitations.

Ideally, all four components, as a result of the above relations, would be included in a definition of accessibility. However, Geurs & Van Wee (2004) describe that it is troublesome and too complex to include all four components equivalent. Depending on the selected perspective, the focus is always on one or two components above the other components. Therefore, there are developed four appointed accessibility measures which represent more or less all components (Geurs & Van Wee, 2004). More or less is in this an important nuance. The infrastructure-based accessibility measure, for example, does not take into account the spatial distribution of activities and therefore has no land-use component. Besides that, the temporal component is not explicitly included in the person-based accessibility measure. Only implicitly this component comes back, for example, because accessibility is measured both inside and outside rush hour. The individual component will be included in the person-based and utility-based accessibility measure, while in the other two accessibility measures this component is less prominent.

2.3.2. Travel behavior aspects and mechanisms

Urban form, socio-demographic factors, and psycho-social factors can play a part in influencing individuals' travel behavior. Research regarding the influence of urban form shows that higher density land use with mixed zoning and greater access to sustainable transport modes is more likely to promote sustainable travel behavior than low density, single use, land zoning (Curtis and Perkins, 2006).

In addition, various socio-demographic factors also appear to play a part in determining people's travel behavior. For example, research shows that aspects such as household composition, gender, age, income, and car ownership all influence the choice of travel mode and duration and length of the journey. Gender and household composition appear to be less important in influencing travel behavior, but the other factors are significant.

A variety of psycho-social factors also influence travel behavior, including travel choice. The destination influences the choice of transport mode and trip distance (Tillema and Jorritsma, 2016). For example if a residential location is well served by public transport, but the work location is not, public transport is not a good option for commuting trips. Availability of parking lots, parking fees and costs of public transport are other important aspects. This partly determines the attractiveness of (the use of) certain different transport modes. Psycho-social variables such as the perception of masculinity, power, and safety are significant determinants of travel behavior (Cullinane, 2002; Hiscock et al., 2002). So, there is a perception that a car can increase social standing in society and protect from the more 'undesirable' or 'eccentric' users of public transport (Curtis and Perkins, 2006).

To conclude on the relative influence of urban form variables, socio-demographic and psycho-social factors, is difficult. There is considerable variability in choice of variables measured in influencing travel behavior, as is there variability in the way in which survey samples control for these variables (Curtis and Perkins, 2006).

2.3.3. Accessibility measurement

The purpose of this part of the paragraph is to provide an overview of the various ways in which accessibility has been measured. Appendix A shows a seven-fold classification, according to Curtis and Scheurer (2007). The seven categories are: Spatial separation measures, contour measures, gravity measures, competition measures, time-space measures, utility measures, and network measures.

- **Spatial separation measures**
  According to Geurs & Van Eck (2001), the spatial separation model identified by Bhat et al. (2000) can be categorized as an infrastructure-based measure. Physical distance between infrastructure elements is only used as input, and therefore this model is suitable for the analysis of nodes and network structures (Curtis and Scheurer, 2007). Behavioral aspects of travel choices are, however, not taken into account.

- **Contour measures**
  The element of travel time is prominently used in the composition of the indicator, and defines thresholds of maximum desirable travel times for different types of activities (Curtis and Scheurer, 2007). Herewith catchment areas of jobs, visitors, customers, employees, and other travelers are mapped out as contours for each node under consideration.

- **Gravity measures**
  The gravity model treats every transport user within the study area equally and disregards variations in individual preferences in relation to the desirability of activities (Baradaran and Ramjerdi, 2001).

- **Competition measures**
  Competition measures incorporate capacity constraints of activities and users into accessibility measure (Curtis and Scheurer, 2007). These measures are relevant to station areas, because station areas also accommodate activity centers.

- **Time-space measures**
  Time-space measures are about travel opportunities within pre-defined time constraints and focus specifically on space-time paths, or the time budgets, of transport users (Curtis and Scheurer, 2007).

- **Utility measures**
  Utility measures are regarding societal or individual benefits of accessibility. In order to look at accessibility from different perspectives and get a weighed overall picture, the utility approach is the best way to measure accessibility (Groot et al., 2011).

- **Network measures**
  Porta et al. (2006) take the investigation of accessibility to the level of analyzing entire movement within networks. The primal approach and the dual approach are the two approaches, which are based on the identification of nodes and edges as the twin components of any network.

Bertolini et al. (2005) recommend the use of a contour measure based on travel time and/or a travel cost measure that takes into account the effects from measures, socio-demographic factors and travel purposes (for example road pricing). The limitations of sharply defined isochrones for mapping individual travel decisions are in real life much more spatially and temporarily fluid (Curtis & Scheurer, 2007). They suggest the consideration of a gravity-based measure that can show a more gradual decline of attraction utility with increasing travel time and cost (Curtis & Scheurer, 2007). As explained in the first section of this paragraph, Geurs & Van Wee (2004), described several perspectives on accessibility into common measurements or, failing that, the application of several accessibility measures in the same context. The authors acknowledge, however, that 'applying the full set of criteria would imply a level of complexity and detail that can probably never be achieved in practice'. In a discussion on feedback effects between different components of accessibility (land use, transportation, temporal, individual), it is pointed out that land use densification may result in greater traffic congestion and thus an increase in 'the disutility for an individual to cover the distance between an origin and a destination using a specific transport mode' (Curtis & Scheurer, 2007).

2.3.4. Accessibility evaluation

Accessibility impacts of transport and land use changes, for example, those due to policies, are often evaluated by using accessibility measures. Herewith policy makers and researchers can easily operationalize and interpret the impact, but this does generally not satisfy theoretical criteria (Geurs & Van Wee, 2004).

According to the Netherlands Commission for Environmental Assessment (2011), in the exploration phase it is sufficient if the information provides general insight into the effects of and differences between the alternatives. The level of detail of the effect determination should be consistent with that decision. In the broad exploration it is better to use expert judgement, rules of thumb and simple models where possible. Use detailed calculation if needed to achieve sufficiently substantiated conclusions and choices between alternatives (Netherlands Commission for Environmental Assessment, 2011). It is important to manage the associated risks of uncertainties which are inherent effect determinations and to explore the possibilities (Draaijers et al., 2013). This can be realized by setting measures that are used when the actual effects were more negative than the predicted effects.

Several methods have been developed to evaluate transportation plans (Pyrialakou, Gkritza, & Fricker, 2014). For example, Golub and Martens (2014) proposed an accessibility-based approach to evaluate transportation projects. Specifically, the authors focused on the differences in access to employment opportunities between automobile and public transportation users and accounted for low-income and minority populations. In another study with similar goals, Manaugh and El-Geneidy (2012) suggested a methodology to evaluate the equity impacts of proposed projects in Montreal, considering both accessibility and mobility changes that the projects will bring, as well as the projects' effects on spatial mismatch. Specifically, the authors evaluated scenarios before and after the implementation of the projects that involved changes in accessibility to suitable employment opportunities that socially disadvantaged populations have, changes in travel time to employment centers by transit, and changes in time savings.

2.4. Ladder van Verdaas

Before making adjustments to the infrastructure, there is much to be gained by measures to ensure that there are fewer traffic movements (Van den Berg et al., 2016). Spatial planning plans aimed at creating shorter distances between home, work, and services. People change their behavior with price incentives: pricing of parking and temporary provision of rewards for good behavior such as avoiding rush hour and cycling. In addition, this involves the largest employers take responsibility by starting with an active program for mobility, with the aim to reduce traffic pressure. Also, it is known that this is an effective means (Van den Berg et al., 2016).

There are several options to solve accessibility problems (Netherlands Commission for Environmental Assessment, 2011). Options may be new infrastructure, but also otherwise, modification or better utilization of existing infrastructure, or other or additional public transport. Therefore the ''Ladder van Verdaas'' offers a conceptual framework, which is suitable for examining possible solutions to an accessibility problem (CROW-KpVV, 2016). This ladder has seven steps. All the steps can, whether or not in combination, contribute to solving the problem.

The main scope of the ''Ladder van Verdaas'' is to see if the construction of new infrastructure can be avoided as much as possible with other solutions.

Therefore the ''Ladder van Verdaas'' has seven steps, of which the last one, the seventh is about new infrastructure. The attention to steps 1 to 5 is often insufficient. Therefore policy makers and administrators have to pay more attention to these steps. The options of the ''Ladder van Verdaas'' are created by ambition and behavior. Citizens, businesses, and drivers will have to adapt to the ambition. For example, if motorists for every one in seven trips do not use their cars, there is no need for new roads.

Prior to invest in a large-scale project (like Buitenring Parkstad) it is desirable to first determine whether problems can be resolved in a different and/or less drastic way (Modijefsky & Vervoort, 2010). Therefore, the ''Ladder Verdaas'' is applied in the case of Buitenring Parkstad. Buitenring Parkstad is a project which is a combination of the last three steps of the ''Ladder van Verdaas''. The route of Buitenring Parkstad partly runs on existing roads where measures are taken to utilize it better and to expand capacity. In addition, new infrastructure will also be realized. Because the ''Ladder van Verdaas'' is applied, the combination of better utilization, extension and construction of new infrastructure appears to be the most appropriate approach to address the problems outlined. Besides that, the ''Ladder van Verdaas'' is used in Wageningen to solve accessibility problems by evaluating all steps of the ''Ladder van Verdaas'' (Royal HaskoningDHV, 2014; Van den Berg et al., 2016). The ''Ladder van Verdaas'' is used in Wageningen as a guide for measures to be taken and regarding phasing. As a result, a lower financial investing is required and greater efficiency is achieved (Van den Berg et al., 2016).

Different interventions are available to reduce negative effects on the traffic flow, safety, and environment. These available interventions are categorized in seven steps, inspired by the ''Ladder van Verdaas'' (Verdaas, 2005). The ''Ladder van Verdaas'' is an accepted method to systematically pass through possible interventions in a mobility question (Ammerlaan, 2012). The methodology aims at weighing solutions and avoiding constructing new or extending existing infrastructure as much as possible by applying alternative solutions. An overview of the seven different (alternative) steps is shown in figure 2.2.

As illustrated in figure 2.2, the first step of the ''Ladder van Verdaas'' is about spatial planning. The second step is regarding pricing policy, and the third step is about mobility management. The fourth step is about optimization of public (and active) transport. Next steps are regarding better utilization and modification of existing infrastructure. The seventh step is regarding the construction of new infrastructure. Next sections describe all steps.

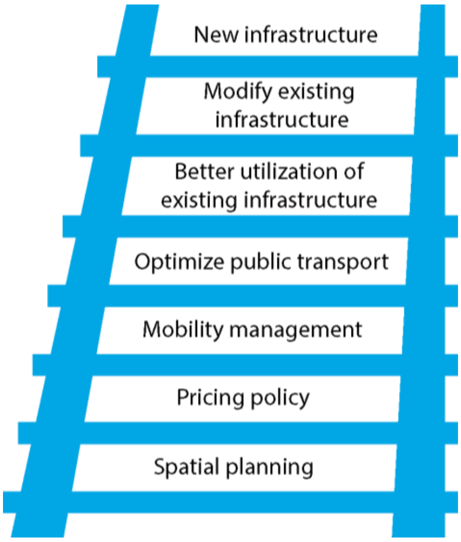

Figure 2.2: Ladder van Verdaas (based on Verdaas et al., 2005)

1. Spatial planning

Spatial planning can structure the demand for mobility (Netherlands Commission for Environmental Assessment, 2011). Siting, scale, and density of buildings, restructuring and function mix affect the movement of people and goods. In practice, it seems that there is room to arrange e.g. housing, recreational facilities, and business parks differently. The essence of spatial planning measures is that the search locations for spatial programs are seen as much as possible from the accessibility of an area (Modijefsky & Vervoort, 2010). Integrated area development can contribute to the maintainability of the mobility and mobility problems in an area. Measures in spatial planning offer opportunities especially to avoid areas in future accessibility and livability (Modijefsky & Vervoort, 2010). Possible measures regarding spatial planning are:

- Minimizing distances between activities (living – working – facilities)
- Direct connections between important nodes: living – working – facilities (e.g. public transport and bicycle facilities)
- Promote ‘living near the work location’

2. Pricing policy

Pricing policy measures influence the behavior of road users (Netherlands Commission for Environmental Assessment, 2011). Even without national policy, there are local and regional measures possible. For example toll and variable parking rates. Several studies show that differentiated pricing policy (in place, time, and vehicle category) has positive effects on accessibility (Netherlands Commission for Environmental Assessment, 2011). Other examples of possible measures are:

- Introducing paid parking
- Reward employees to avoid the rush hour
- Promote cycling through fees for bicycles and e-bikes

3. Mobility management

Mobility management can reduce car use and includes a range of measures aimed at influencing modality and timing of movements. Studies show that mobility management can often reduce, but not solve accessibility and quality of life issues. Mobility management measures often have a different impact on different types of travelers (commuting, business, school traffic, leisure traffic, etc.). However, studies on the effects of mobility management measures mainly relate to commuting and do not always relate to the effects of other types of travelers (Aalbers, 2011). Examples of mobility management measures are:

- Promotion and facilitation of home- and teleworking
- Avoid rush hours through flexible working hours and distribution of lecture times
- Stimulating and facilitating other forms of sustainable transport for staff and students

4. Optimize public (and active) transport

Optimization of public transport and bike infrastructure can contribute significantly to improve accessibility (Netherlands Commission for Environmental Assessment, 2011). Therefore a well-structured public transport network is important. At city and regional level cycling competes with other transport modes (Netherlands Commission for Environmental Assessment, 2011). Possible measures for optimizing public and active transport are:

- Easily accessible bus stops, including important facilities
- Transferia (Park & Ride)
- Realization of Bike Share Points
- Improvement of existing and new bicycle routes

5. Better utilization of existing infrastructure

In the case of better utilization of existing infrastructure, the scope is to increase the capacity and quality without (much) new asphalt (Modijefsky & Vervoort, 2010). Better use of the existing road network provides capacity gains without having to take drastic physical measures. Examples are speed reduction and extending the use of the number of lanes.

6. Modification of existing infrastructure

Modify existing infrastructure means that the capacity of existing roads increased substantially. Such measures contribute to the achievement of objectives regarding the promotion of a traffic flow and reduction of traffic diversion. Widening existing roads, as well as a better use of existing infrastructure, in theory, can result in undesired effects on quality of life, because more traffic will utilize the connection.

7. New infrastructure

The construction of new infrastructure may be an appropriate solution to accessibility problems, but will also lead to problems regarding the quality of life and safety. Additional road capacity can improve the flow of traffic or create a new faster, safer route. Depending on the location of the new infrastructure, this may result in a better quality of life in areas that are relieved by the new infrastructure. On the other hand, it is the most drastic measure of the ‘’Ladder van Verdaas’’.

2.5. Conclusions

As stated in chapter 1, there is a need for more insight into the effects of mobility policies for different transport modes. If the scope of measures is related to accessibility, there is a possibility to compare the effects of the measures on accessibility.

Accessibility is a term which is interpreted, defined and operationalized in different ways in literature. Land-use and transport are two of the target components, which define requirements of accessibility. The other two components are the temporal and individual component. Ideally, all four components would be included in a definition of accessibility. However it is troublesome and too complex to include all four components equivalent. Therefore, this research focusses mainly on the transport component and to a lesser extent on land-use. Factors that can play a part in influencing travel behavior are regarding urban form, socio-demographic factors, and psycho-social factors.

There are various ways in which accessibility has been measured. Appendix A shows a seven-fold classification: Spatial separation measures, contour measures, gravity measures, competition measures, time-space measures, utility measures, and network measures. Accessibility impacts of transport and land use changes, for example, those due to policies, are often evaluated by using accessibility measures. Herewith policy makers and researchers can easily operationalize and interpret the impact, but this does generally not satisfy theoretical criteria.

Several methods have been developed to evaluate transportation plans. An example is a methodology to evaluate the equity impacts of proposed projects in Montreal, considering both accessibility and mobility changes that the projects will bring, as well as the projects' effects on spatial mismatch. Specifically, scenarios are evaluated before and after the implementation of the projects that involved changes in accessibility to suitable employment opportunities that socially disadvantaged populations have, changes in travel time to employment centers by transit, and changes in time savings.

The ''Ladder van Verdaas'' is a conceptual framework, which is suitable for examining possible solutions to an accessibility problem. The main scope is to see if the construction of new infrastructure can be avoided as much as possible with other solutions. Examples of applications of the ''Ladder van Verdaas'' are in the case of Buitenring Parkstad and Wageningen. Because of the application of the ''Ladder van Verdaas'' at Buitenring Parkstad, the combination of exploitation, extension and construction of new infrastructure appears to be the most appropriate approach to address the problems outlined. Besides that, the ''Ladder van Verdaas'' is used in Wageningen to solve accessibility problems by evaluating all steps of the ''Ladder van Verdaas''. It is used as a guide for measures to be taken and regarding phasing. As a result, a lower financial investing is required and greater efficiency is achieved. Therefore, in the next chapter, relevant attributes will be structured on the basis of the ''Ladder van Verdaas'', including interpretation per attribute.

3. METHODOLOGY

3.1. Introduction

This chapter regarding methodology starts by discussing the research questions and objective briefly. Section 3.1.2 sets out the conceptual framework. Finally, the last section is a summary of the research methods and the underpinning approach.

3.1.1. Research questions and objective

Earlier research mentioned that there is a need for more insight into the effects of mobility policies for different transport modes (Cui et al., 2016). More knowledge on this topic is required in order to plan effective interventions and policy changes. There are multiple aspects which influence users to use a certain transport mode. In line with the problem definition the following research question is defined as: ‘’What are relevant attributes regarding accessibility measurements and mobility policies for different transport modes, and what is the applicability of these attributes per step of the ‘’Ladder van Verdaas’’?

The objective is to create a tool including relevant attributes for all types of projects and to process them in a structured system with realistic scoring per attribute for each step of the ‘’Ladder van Verdaas’’. This tool will be created on the basis of documentary analysis. In addition, realistic assumptions regarding unavailable information will be generated by consulting professionals in the field of traffic research. It is assumed that they have actual knowledge regarding these topics. This will result in an overview of attributes that are most important per transport mode and per step of the ‘’Ladder van Verdaas’’. After creating the integration tool, two pilots will be executed, by using a geographical information system (GIS), to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool.

3.1.2. Conceptual framework

As described before, the objective is to create a tool including relevant attributes for different types of projects and to process them in a structured system with realistic score per attribute for each step of the ‘’Ladder van Verdaas’’. This provides insights into which attributes are applicable at a traffic research, and also the relationships of the effects that are applicable at the different transport modes and steps of the ‘’Ladder van Verdaas’’.

The ‘’Ladder van Verdaas’’ is extensively described in section 2.5. In short, the ‘’Ladder van Verdaas’’ is a conceptual framework that can be used in examining possible solutions to a traffic problem (CROW-KpVV, 2016). The main purpose of the ‘’Ladder van Verdaas’’ is to see if the construction of new infrastructure can be avoided as much as possible with other solutions. Herewith the effect can be measured.

The ''Ladder van Verdaas'' consists of seven different (alternative) solutions:

- Spatial planning;
- Pricing policy;
- Mobility management;
- Optimize public (and active) transport;
- Better utilization of existing infrastructure;
- Modify existing infrastructure;
- New infrastructure

The ''Ladder van Verdaas'' is an approach that is widely used to identify solutions to mobility problems (Modijefsky & Vervoort, 2010). Therefore attributes will be investigated on the basis of this conceptual framework. This make it an experimental method, because the ''Ladder van Verdaas'' is not 'tried and tested' to provide insights into effectiveness of mobility policies.

Weakness of the conceptual framework is that not all transport modes are taken into account, e.g. transport modes like mopeds or walking. Moreover the transport modes train, bus, tram and metro are combined into public transport. Another weakness is that attributes which are of importance could vary per project. For example, regarding step one and three, the measures can be related to a wide variety of projects. Therefore, it is important to formulate a clear goal of the projects. To illustrate the working of the integration tool and to provide recommendations regarding the tool, two pilots will be executed.

3.1.3. Summary

In short, a structured system of relevant attributes will be created for different transport modes and for each step of the ''Ladder van Verdaas''. This tool will be created on the basis of documentary analysis. In addition, realistic assumptions regarding unavailable information will be generated by consulting professionals in the field of traffic research (expert judgement). On top of that, by using geographical information systems, pilots will be executed to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool.

3.2. Approach

This section describes in detail how the study is conducted, including conceptual and operational definitions of the components used in the study. Figure 3.1 illustrates the research approach. The research methods that are applied to identify relevant attributes are documentary analysis and expert judgement. The research method to visualize the effects is a geographical information system (GIS). These research methods will be extensively described in this paragraph.

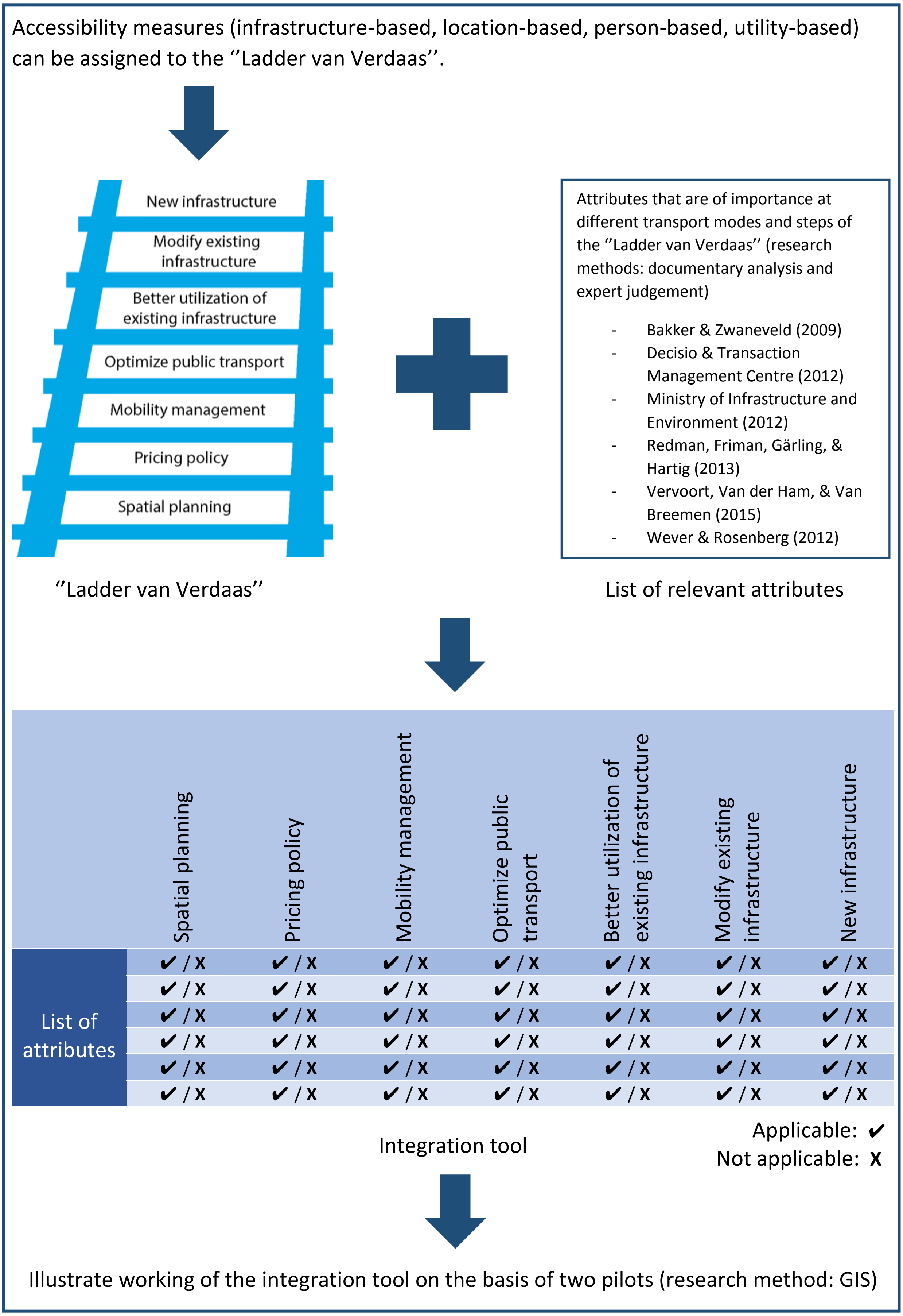

Figure 3.1: Research approach

Documentary analysis

By creating the integration tool, based on the ''Ladder van Verdaas'', the applicable research method is documentary analysis. Documentary analysis involves obtaining data from existing documents such as secondary data, empirical data generated by others (Verschuren & Doorewaard, 2015), and literature. The choice for documentary analysis is related to the fact that different researchers have identified which attributes are applicable at different transport modes, and therefore there is no need to carry out an own survey. In addition to the evaluations there are also scientific papers and dissertations, and there is travel behavior of passengers that affects the use of transport modes. Together these documents form the documentary analysis.

Expert judgement

According to Wilson (2017), expert judgement plays an important role in forecasting and elsewhere, as it can be used to quantify models when no data are available and to improve predictions from models when combined with data. Therefore, in addition to the documentary analysis, realistic assumptions regarding unavailable information will be generated, by consulting a professional in the field of traffic research. Expert judgement is obviously prone to bias; the limitations can be summarized as subjective, risky and prone to error, the reasoning is known only to the owner of the estimate, and the estimate depends on the level of experience (Rush & Roy, 2001). To be successful, according to Rush & Roy (2001), the expert needs to have many years of experience. Therefore, the information that is unavailable in the documents of the documentary analysis will be estimated on the basis of the knowledge and experience of an expert with at least 10 years of experience.

Geographical information systems

According to Longley, Goodchild, Maguire, & Rhind (2011) a geographical information system (GIS) is defined as a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world. GIS is fundamentally about solving real-world problems and any manual or computer based set of procedures can be used to store and manipulate geographically referenced data. Therefore the two base components in GIS software are maps (visual representation) and data-views (consists of a number of records of a similar type).

There is a huge range of applications of GIS and they include topographic base mapping, socio-economic and environmental modeling, global and interplanetary modeling, and education. Applications generally set out to fulfill the five M’s of GIS: Mapping, measurement, monitoring, modeling, and management.

Assessing accessibility to individual activities in metropolitan areas has been a long-standing interest in transportation geography (Chen et al., 2014; Karou and Hull, 2014; Le Vine et al., 2013; Lin et al., 2014; Martínez and Viegas, 2013). Transportation equity affects people’s economic and social opportunities (Handy and Niemeier, 1997; Litman, 2002; Niemeier, 1997). Therefore, improving transport accessibility is increasingly used to cope with social inequality, particularly for socially disadvantaged groups (Sanchez et al., 2003).

To calculate the accessibility value of public transport and its differences in a particular area to surrounding regions, the paper of Yan-yan, Pan-yi, Jian-hui, Guo-chen, Xin, & Yi (2016) raised a new concept; Area Public Transit Accessibility (APTA). This concept is based on passenger travel behavior, travel psychology hypothesis and the service range of transit network and road network. By using the software package ArcGIS, Yan-yan et al. (2016) applied this method to evaluate the accessibility values of every traffic zone in Beijing Chaoyang district. The results showed that the APTA can provide a clear description of the accessibility value level in a particular area to surrounding regions, which provides quantitative information for location analysis and public transit network optimization.

3.3. Data collection

This section and appendix B explain how data is gathered, generated and analyzed. The data is gathered by documentary analysis. The following documents represent relevant attributes and these documents are extensively described in appendix B:

- Bakker & Zwaneveld (2009);
- Decisio & Transaction Management Centre (2012);
- Ministry of Infrastructure and Environment (2012);
- Redman, Friman, Gärling, & Hartig (2013);
- Vervoort, Van der Ham, & Van Breemen (2015);
- Wever and Rosenberg (2012).

There are many factors that affect the demand for a movement. Moreover, at transport mode public transport other factors play a role than, for example, at transport mode car. According to Bakker & Zwaneveld (2009), Decisio & Transaction Management Centre (2012), and Vervoort, Van der Ham, & Van Breemen (2015), effects are divided in direct effects, indirect effects, external effects, and distributional effects. Therefore these types of effects are discussed respectively in section 3.3.1., 3.3.2., 3.3.3., and 3.3.4.

3.3.1. Direct effects

Direct effects are the effects for the owner/operator and users of the project. In this research, the relevant attributes for users are of importance. Several direct effects are discussed in detail in the next sections.

Travel time, waiting time, and frequency

Accessibility benefits are often the primary goal of a public transport project (Bakker & Zwaneveld, 2009). This provides existing and new public transport travelers faster, more frequent and/or more reliable trips. These benefits can be converted into indicators in euro per hour. How this should be done and what indicators can be used is described in the Overview Effects Infrastructure (OEI) guideline. The time valuation (in euro per hour) differs thereby for instance per trip purpose. For example, a business traveler would often spend more money for a shorter journey than someone who is going shopping or going to work.

Travel time of public transport consists of several components (Bakker & Zwaneveld, 2009). A public transport journey can often only be made a few times per hour. This depends on the frequency with which a transport service is provided. So a public transport traveler starts with waiting for the next opportunity for departure. Before there can be traveled by public transport, one usually must first go to the public transport stop; before transport time. After a wait at the public transport stop there follows boarding and the actual start of the trip. After one or more changes (including, once again, waiting time) travelers arrive at the final stop. Following is the onward transport time to the destination; post-transport time. To determine the travel time gains, these parts of the journey should be merged and expressed in monetary terms. Although there is a possible debate on the indicators to be used, the key figures illustrated in table 3.1 are applied in social cost-benefits analysis.
The effect on the travel times may be determined on the basis of the change in the anticipated travel time and the number of movements (trips) for each origin-destination pair. The travel time changes are expressed in monetary terms, by using the occupancy rates per vehicle and journey time valuations per traveler and motive.

The differences in travel times, divided by passenger and freight transport, are provided by the Province of Limburg. Based on the regional traffic model the data is divided by motifs.
Prices are in euros per person (price level 2015), market prices including VAT and other direct taxes. The data in table 3.1 is analyzed in the edition ''the social value of shorter and more reliable travel times'' (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2013).

Table 3.1: Travel time valuations per motive, price level 2015 (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2013)

Motive	**Travel time valuation (€/hour)**
Home-to-work	€ 9.95
Business	€ 28.23
Other	€ 8.07

However, travel time valuations per transport mode can be even more important. Though, there is considerable uncertainty regarding travel time valuation of cyclists (Decisio & Transaction Management Centre, 2012). The extreme values hold a bandwidth of the travel time valuation between 6.65 (travel time valuation of bus, tram, metro travelers), and 14.03 euro per hour (rounded 2.1 times higher). For the other modalities an organisation regarding economic expertise (Steunpunt Economische Expertise, abbreviated: SEE) provides indicators. The average travel time valuation for each mode is shown in table 3.2. However, travel time can also be valued in time (minutes) without the valuation in euros.

Table 3.2: Travel time valuations per transport mode (Decisio & Transaction Management Centre, 2012; KiM, 2013)

	Bike	Car	Freight traffic	Bus	Train
Travel time valuation (€/hour)	6.65 - 14.03	10.70	45.38	6.65	7.60

Reliability

Congestion and travel time also affect the reliability of the traffic network. As the capacity is lower, there is a bigger chance of delays along the way. A chance of congestion means that it has to be taken into account, but not that there is always congestion. The default code from the Overview Effects Infrastructure (OEI) guideline and its additions is an additional effect of 25 percent on the travel time benefits. This leads to an additional network effect of 1 to 8 cents per kilometer short distance car movement. Network effects are indirect effects and are described in section 3.4.2.

Reliability of a trip increases by a decrease in congestion. In accordance with the opinion of the Central Planning Bureau (CPB), the effects on travel time reliability are caused by 25 percent of travel time benefits resulting from reduced congestion (vehicle loss hours).

For cyclists there can be assumed that a shorter travel leads to a higher reliability (less traffic lights, intersections, etc.). For public transport the rate should not be applied, because public transportation is based on a proprietary system (rail, bus lanes, coordinated traffic lights, etc.), and timetable.

Table 3.3: Reliability per transport mode (Decisio & Transaction Management Centre, 2012)

	Bike	Car	Public transport
% of travel time benefits	25%	25%	PM

Travel costs

The amounts travelers and government spend in a year on different transport modes may be related to the performance of these modes of transport in that year (Bakker & Zwaneveld, 2012). This creates an overview, as illustrated in table 3.4, of the average expenditure (paid) per passenger kilometer in the Netherlands. Included are costs of vehicle purchase, vehicle use, vehicle exploitation and investments in and maintenance of infrastructure.

Table 3.4: Average expenditure in the Netherlands in eurocent per passenger kilometer (price level 2007)

Average expenditure	Travelers	Government
Car	22	4
Train	8	16
Bus, tram and metro	11	32

Parts of the expenditure of travelers are revenue for the government (taxes, especially in the car). Furthermore, it is only in terms of actual expenditure. Unpaid costs are excluded such as environment, traffic safety, congestion and loss of income on a different allocation of resources. The average total travel costs valuation for transport modes is shown in table 3.5.

Table 3.5: Total travel costs per transport mode in eurocent per kilometer (Decisio & Transaction Management Centre, 2012)

	Bike	Bus	Train
Travel costs (eurocent/km)	7	11	8

Cost of a ride change due to a change of kilometers with existing travelers. The difference in vehicle kilometers is multiplied by the variable cost for rides. Travel expenses have been updated to price level 2015.

Table 3.6: Variable expenses for cars and freight traffic, in eurocent per kilometer, price level 2015 (Vervoort, Van der Ham, & Van Breemen, 2015)

	Variable expenses
Car	8.52
Freight traffic	13.10

Comfort

During the trip also changes in the comfort directly affect the prosperity of travelers. This is for instance a more comfortable vehicle: a train instead of a bus, or better chairs. A project can also make sure that the traveler can sit more frequent. In short, these are all things that are relevant for people and therefore should be included in a cost-benefit analysis. The monetization of the comfort effects, like travel time gains, is theoretically possible. However, there are few indicators available for both the Netherlands and worldwide. Unfortunately, in practice mostly is decided that comfort effects cannot be expressed in money, so comfort effects are often described qualitatively.

Effects during construction period

Construction of new infrastructure is possibly disturbing for existing users or local residents. Travel time delays that occur due to this, for example, would be reflected in the cost-benefit balance. In addition, congestion could be reduced because motorists choose the train: a lot of suggested positive prosperity effect of public transport.

Option value and non-utility value

The option value (Geurs, 2006) of public transport is the amount of money people have, in the case of unforeseen circumstances, nonetheless to be able to use public transportation. So the option value its origin is in the value that individuals assign to reduce uncertainty. Risk-averse individuals will spend money to reduce this uncertainty. The possibility to use public transport in case of emergency thus has a value, the option value. Unforeseen

circumstances can actually relate to occasional use (in case the car is not available), but also to a future situation in which a person is highly dependent on the public transport for many journeys. The option value is already reflected in the higher ticket price that an operator requires an operator to occasional travelers. The benefits of these ‘higher willingness to pay by occasional travelers’ can thus already be reflected in operating income. Only the option value which comes on top of those already internalized value, is an additional wealth effect.
The non-utility value (DfT, 2007) is the value an individual attaches importance that others use or can use public transport.

3.3.2. Indirect effects

Indirect effects are effects that occur in other markets due to the passing of the direct effects (Vervoort, Van der Ham, & Van Breemen, 2015). One could think of the labor market; commuters can start looking further afield a better paying job as a result of travel time. Indirect effects are approximated on the basis of indicators.
0 to 30 percent of the transport benefit is a reasonable estimate for the size of the additional indirect effects of public transport projects. In social cost-benefit analysis of road infrastructure a rate of 10 percent is applied (Vervoort, van der Ham, &, van Breemen, 2015).

Besides direct transport benefits it can be expected that when traveling is in a generic sense 'cheap', it affects the rest of the economy. The economy can therefore grow faster, which increases more prosperity to the direct benefit of the 'cheaper' travels. This idea, expressed by many people, is also supported by economic research. Economists therefore use the name 'indirect economic effects'. These effects arise because the transportation benefits affect the economy. Moreover these effects only make an additional contribution to the prosperity and existence of market imperfections, such as economies of scale. Therefore many indirect economic effects only distribute wealth.

Elhorst et al. (2004) provides a broad overview of indirect economic effects. However in the literature there is no consensus about the underlying mechanisms and extent of (additional) indirect economic effects. A quote from the handbook for cost-benefit analysis for public transport projects in the United States: "While users of this guidebook may wish for a recipe or formula to calculate larger (indirect) economic benefits to overall economy, there simply are no reliable relationships or methods for calculating them that can be applied to local transit projects" (TRB, 2002). Jumping to conclusions about potential effects and how big they are is therefore not appropriate. Therefore the 'general feeling' of the 'not-knowing' is too overwhelming (Hof et al., 2006). However the subject is too important to put it aside as too complicated. Therefore 'wider economic benefits and impact on GDP' were investigated in 2005, commissioned by the UK Department for Transport (DfT, 2005). This research focused on agglomeration effects. In the context of public transport projects, this is also a frequently mentioned reason for additional prosperity benefits. According to DfT (2005) other sources of indirect economic effects are budgetary or labor market effects and a better functioning of not-perfect functioning markets. These three effects will be explained in the next sections.

The main conclusion from the OEI guideline (Eijgenraam, Koopmans, Tang, & Venster, 2000) is that indirect effects can only be additional if there is market failure or international redistribution. Therefore these types of effects and the following markets need attention:
- Effects on product markets;
- Effects on labor market;
- Effects on housing and land market;
- Effects of excise duties and subsidies;
- Health effects (of cycling);
- Network effects;
- Knowledge and innovation spillover effects;
- International effects.

The capital market is supposed to work perfectly and will therefore not be further discussed. In this section the types of market failures are explained and how these lead to additional indirect effects. Moreover, the OEI guideline only defines when and how additional indirect effects occur, but does not provide instructions for calculation. This section is, in particular, about the conditions whereby additional indirect effects occur.

Product market
Many effects on the transport market reach end users via the product market. As long as all markets work well, these are redistributive effects. There are a number of reasons why product markets do not work well and they should be included as additional indirect effect in social cost-benefit analysis.

1) Product specific taxes and subsidies lead to distortion of the market, if they are not provided to correct externalities. If there is a market (which is affected by the project) distortionary taxes and subsidies are present. Therefore the effects of a change in tax revenue and expenditure must be included as an indirect effect.

2) Market power and economies of scale: If there are effects on the transport market these are passed on to other markets. A reduction of the transportation costs will lead to a reduction in the prices of products in the supermarket. If the market operates according to the principles of full competition, all transportation benefits are eventually passed on to consumers. The impact on the transport market will fully benefit the consumer (the direct effect is equal to the indirect effect, which is therefore not additional, but only one shift). However, if there is market power (such as a monopoly, think of the NS and Schiphol, or monopolistic competition), there may be economies of scale. Though, these are additional.

If there is market power, profit can be made by manufacturers. The market does not work perfectly. A reduction in transport costs leads to an adjustment of supply from the producer: he will want to maximize his profits. This also leads to a reduction in the price to the consumer, as more producers will want to put off now increased margins by product (until a new equilibrium). The effect on the product market is larger than the transport (both producers and consumers have a surplus). Thus, there is an additional indirect effect. However, the wealth effect on the product market (through the transport) is less than if there had been full competition. Because the producer does not calculate the entire cost, the product demand (and also transport demand) will rise less rapidly than if it was fully passed.

3) Product differentiation: more different products can reach the market through lower transportation costs. A wider range of products creates a positive additional effect.

4) Agglomeration and cluster effects: Most agglomeration and cluster effects are not additional. Companies want lower transaction costs, so this is a direct accessibility effect. Costs related to labor (scope of the labor market) are discussed in the next section. Only if clusters lead to unpaid exchange of knowledge and innovation, there is an additional effect.

Labor market
A first effect of infrastructure investments on the labor market is the reduction in commuting costs. The benefits of lower commuting costs and their impact on location choice are primarily direct effects. These are, after all, just travel time benefits of commuting. However, labor market effects through taxes and social prosperity payments also have to be taken into account (these are additional effects). Commuting charges increase the cost of labor, and if the cost decreases, the demand for labor increases. In many cases, this means redistribution, but if there is a "mismatch" between demand and supply in a region, then better accessibility could lead to additional employment. The increase in employment that is associated with this (as a rule of thumb) is halfway filled with former social prosperity payment recipients. Because a social prosperity payment is on average half of the salary, the additional benefit is 25% of wages of the new jobs.

Causes for disturbances on the labor market are social prosperity payments, limited wage flexibility (e.g. CAO), and labor mobility. These factors may cause long-term discrepancies between supply and demand. Reduced labor mobility is particularly addressed for primary and secondary skilled personnel, for higher skilled workers the labor market works well. There are no anticipated additional indirect effects. If the domestic sector wages (CAO) is above the regional equilibrium wage, there is a labor surplus. The labor supply exceeds demand and involuntary unemployment. The demand for labor in the region increases by better infrastructure; this will lead to additional employment. All the characteristics of the regional labor result in regional equilibrium wage. For example, a region with many low-skilled workers has a relatively low wage equilibrium and thus unemployment. Indeed, domestic sector wages (CAO) leads to higher labor costs than employers are willing to pay.

If there is an excess demand (CAO is below the regional equilibrium wage), an increase in demand does not lead to a reduction in unemployment. However, the less extensive production companies disappear. So the additional productivity is the prosperity gain.

Through secondary terms of employment, excess demand does not happen often. This increases the wages, which brings the market back into balance. Prosperity gains in the labor market will thus, in practice, in particular prevent a reduction in unemployment and its paired reduction of benefits. Other effects are mainly shifts of transport benefits to wages.

Point infrastructure has a more predictable effect on the regional job market than line infrastructure. Expanding point infrastructure in a region leads to more demand in that region. Extension of line infrastructure can lead to an increase or decrease in the demand for labor in both regions.

Agglomeration benefits occur because companies and persons like to settle near each other. This fact leads to higher productivity, and thus higher wages. Therefore applies: the larger the agglomeration, the greater the benefits, and the higher the productivity. The size of the agglomeration depends thereby on the (generalized) travel to important economic activities. If a project reduces the generalized travel costs, the agglomeration will get bigger. And that delivers a positive additional indirect economic impact.

Land market and housing market

Without market imperfections and without foreign effects, there is no additional infrastructure or prosperity effect on the land market. Better accessibility leads to higher land prices; however the land market has three basic imperfections.

1) Quantity restrictions in land use planning. From the viewpoint of unpriced external effects (loss of landscape and nature), spatial planning is desired and leads to higher land prices.

2) Subsidies for land development and use (industrial subsidies, rent subsidies, and mortgage interest). If projects lead to an increase in subsidies by the construction and maintenance of industrial and residential locations, there are additional prosperity losses.

3) External effects of land use for others. Infrastructure leads to a change in location preferences. The new residents or businesses thereby do not take into account effects of their decisions on others; for example, to get a nice view depriving nuisance or pollution of a company. These effects should be included in a social cost-benefit analysis to the extent they are additional (and not just a shift).

Because industrial areas (subsidies) and tenement (no flexible pricing, such as apartments and subsidized) lead to greater market distortions, this land market securities attention are of interest for a social cost-benefit analysis. Moreover, the subsidies on the land market (especially in industrial areas) can solve bottlenecks in other markets. Besides the negative wealth effect of subsidies, positive wealth effects on other markets can arise. At the time of the OEI guideline, there was limited empirical evidence for positive or negative effects.

Subsidies and excise duties

The national government, provinces and municipalities invest in infrastructure, subsidize public transport, purchase transport for groups, and impose taxes on car ownership and use.

Less car use leads to lower tax revenues due to excise duties. However, motorists save fuel taxes. Both effects have to be included (or not netted). Effects on tax revenue, however, are often not included in cost-benefit analysis, the excise duties indeed are saved (implicit in the calculations) by motorists. There are specific amounts of excise duty per passenger kilometer that can be used in a social cost-benefit analysis. It is about an average of approximately 4 euro cents per vehicle kilometer avoided.

Table 3.7: Excise duties for cars and freight traffic, in eurocent per kilometer, price level 2015 (Ecorys, 2007)

	Excise duties
Car	4.34
Freight traffic	14.94

Cost of a ride change due to a change of kilometers with existing travelers. The same applies to the tax revenue for the government. The difference in vehicle kilometers is multiplied by excise duties. Thereby excise duties have been updated to price level 2015.

Health effects (of cycling)

An average home-work trip by bike is 4.3 kilometers in the Netherlands (CBS, 2016). Assuming 46 weeks on average four days a week, cycling to work produces 23 cents (€ 364 / (4.3 kilometers * 2 * 46 weeks * 4 days)) for every cycled kilometer. To convert this effect to the average bike kilometer this amount will be multiplied by the proportion of commuting cyclists overall. In total 20 percent of the number of bicycle kilometers by day are related to commuting. Therefore the labor productivity benefits are about 4.6 cents per bicycle kilometer.

Table 3.8: Increase labor productivity of cyclists (Decisio & Transaction Management Centre, 2012)

	Increase labor productivity
Bike	4.6 eurocent per kilometer

In addition to increasing labor productivity of cyclists, is also increasing the number of healthy life years and life expectancy of cyclists. RIVM has calculated that the burden of disease due to inactivity in the Netherlands is about 270 thousand DALYs. DALY stands for "disability adjusted life years" and is a measure of the overall burden caused by diseases. It measures the number of people who die prematurely due to illness and the number of years that people live with disabilities due to illness. RIVM has assessed that if inhabitants of the Netherlands would cycle more frequently (one day per week extra) and longer (cycling 30 minutes extra per day), the disease burden decreases by 1.3 percent, or 3510 DALYs after one year.

With the premise of RIVM (cycling an extra day a week and 30 minutes on each of those days) the following calculation can be made: If we assume that the average citizen of the Netherlands cycles 2.2 days per week (20 to 30 minutes per day), this means the starting point of extra cycling of the RIVM is about 1.1 to 1.6 hours per week. This is 15 to 22.5 kilometers per citizen of the Netherlands extra per week at an average of 14.2 kilometer per hour. If all 16 million citizens of the Netherlands cover this extra distance, 52 weeks per year, this leads to a reduction of 3510 DALYs. With a score of 70 thousand euros per DALY, a score of 2.1 eurocent per kilometer to health benefits can be assumed.

Table 3.9: Health effects of cycling (Decisio & Transaction Management Centre, 2012)

	Health effects of cycling
Bike	1.7-2.5 eurocent per kilometer

Network effects

The shift from labor, business and population has a feedback effect on the mobility. If all the indirect effects are included, the network effect should also be mapped. However, this effect is expected to be quite limited. There are few methods to properly map the indirect network effects.

Knowledge and innovation spillover effects

Clusters can lead to more sharing of knowledge through lower transport costs within a sector, diversification of sectors and proximity of suitable staff. These points are logical reasons for the emergence of agglomerations, but are related to the passing of direct transport effects and a well-functioning labor market for highly qualified personnel.

An exception occurs when knowledge is exchanged without being paid for it. Proximity reduces costs, allowing this to happen more frequently. In that case, there is an additional prosperity effect. If it can be made plausible that it plays a significant role, this should be included in a social cost-benefit analysis.

International effects

Lower transport costs affect the imports and exports of goods and services and thus attract and drain securities and the Dutch consumer surplus. This has an effect on public finances and the labor market (macro-economic feedback). In a tight labor market the increased demand for goods and services will lead to higher wages and displacement of low productive labor. This indirectly leads to more imports and less exports of goods, leading to a neutralization of the positive indirect effect on the labor market. Tax and benefits changes too, and this alter market imperfections.

3.3.3. External effects

Movement of people and goods are based on individual decisions, but always have side effects that are experienced by others than the individual decision maker (CPB and PBL, 2016). This is because if someone undertakes a journey, it will be busier on the road or in the train, which leads to additional travel time (traffic jams), accidents or inconvenience to others (standing in the train). Besides that, travelling is usually associated with environmental pollution (CO_2, nitrogen oxides, sulfur dioxide and particulates, and noise disturbance) and fatalities. The disadvantages suffered by other passengers or the environment are not included in individual decision to make a trip. So travel has, in addition to positive external effects, also negative external effects that affect others prosperity negatively.

When individual decision makers take into account the negative external effects of their behavior, the sum of individual decisions leads to overconsumption of mobility and an excess of damage. If mobility users would consider external damage in their decision to make a journey, there would be a better balance between the advantages and disadvantages of mobility. The government can ensure that the external damage is indeed included in individual decisions with regulation and taxation. This may for example include taxes (emissions, environment), a mandatory liability insurance (safety, damage) and ramp metering or congestion charging (congestion).

External effects are reflected on goods with no markets and therefore there are no market prices. This concerns, for example, emissions, noise, traffic safety, barrier, and intersection of the landscape. In the cost-benefit analysis four external effects are quantified four external effects: traffic safety, noise and air quality, and greenhouse gas emissions.

Air quality and greenhouse gas emissions

Effects on greenhouse gas emissions are quantified. Hereby is assumed that there is a direct relationship between the size and spread of traffic and nuisance caused by traffic. Specifically, the benefits are provided by the use of the previously available indices per vehicle kilometer, whereby, if possible distinction is made to the location (inside or outside the built-up area).

Table 3.10: Valuations of greenhouse gas emissions, in euro per hour, price level 2015 (CE Delft, 2014)

	Greenhouse gas emissions	Climate costs
Inside built-up area	Passenger transport weighted average	€ 11.53/1.000 travel km
	Freight transport weighted average	€ 8.80/1.000 tons-km
Outside built-up area	Passenger transport weighted average	€ 11.53/1.000 travel km
	Freight transport weighted average	€ 8.80/1.000 tons-km

Table 3.11: Valuations of air quality, in euro per hour, price level 2015 (CE Delft, 2014)

	Air quality	Climate costs
Inside built-up area	Passenger transport weighted average	€ 5.85/1.000 travel km
	Freight transport weighted average	€ 14.40/1.000 tons-km
Outside built-up area	Passenger transport weighted average	€ 0.53/1.000 travel km
	Freight transport weighted average	€ 7.10/1.000 tons-km

Noise

Effects of noise are calculated based on the number of noise-affected homes in the alternatives. The following table shows the number of houses again by class noise level (dB).

Table 3.12: Valuation noise disturbance, in eurocent per dB, price level 2015 (CPB, 2004)

	Valuation in eurocent per dB
48 – 53 dB	14 eurocent/dB
53 – 58 dB	83 eurocent/dB
58 – 63 dB	152 eurocent/dB
63 – 68 dB	206 eurocent/dB
68 – 73 dB	366 eurocent/dB
> 73 dB	504 eurocent/dB

Traffic safety

The aspect safety is divided into traffic safety, social safety and impact on external safety. Traffic safety is monetized based on indicators from the document "Safety in social cost-benefit analysis’’ of Rijkswaterstaat and Ecorys (2012). The social cost-benefit analysis is based on the valuation of first-aid wounded, which is based on the reported rate of accidents.

Table 3.13: Valuation traffic safety (in million euros, price level 2015)

	Valuation in million euro per accident
Fatality	€ 3.234.294 million per accident
First-aid wounded	€ 11.989 million per accident
Only material damage	€ 4.670 million per accident

However, when constructing a new road the number of accidents is unknown. Therefore the key figures for car, bus, and bike (in eurocent per km) are calculated by SWOV and Ecorys (2008).

Table 3.14: Costs of traffic safety (SWOV & Ecorys, 2008)

	Inside built-up area	Outside built-up area
Car (eurocent/vehicle km)	6.3	2.5
Bus (eurocent/travel km)	5.4	2.1
Bike (eurocent/km)	6.2	2.5

External safety

External safety concerns the risk of accidents involving hazardous substances that affects residents or surrounding areas. The consequences of accidents involving hazardous substances depend on the location of the accident; in a densely built-up area this will be much larger than in a vacant area. Such effects can only be understood on the basis of a specific analysis of the change of the alternative in individual risk and group risk. According to the EIA plan, it is sufficient to qualitatively describe possible external safety effects.

Social safety

There are no rules of thumb developed to monetize social safety effects (Ministry of Infrastructure and Environment (2012). If these effects occur, it is sufficient to describe these effects qualitatively.

Effects on soil, water, nature, and landscape and heritage

In addition to these user-related aspects this section will provide information regarding other relevant effects of the EIA plan. These aspects can be limited to those aspects which the alternatives are distinctive from the base case. In addition, the description may be qualitative, unless there are large-scale effects. If an effect is substantial must be determined case by case, possibly in consultation with the client. In any case, of each project it must be defined if it is located in a Natura 2000 site, whether there is any external force to a nearby Natura 2000 site and whether there are any nitrogen problems in the context of PAS (nitrogen deposition). The issues can be classified into major groups:

- Soil
- Groundwater and surface water
- Nature
- Landscape and cultural heritage

Only in exceptional cases, monetization of these effects is desired (Ministry of Infrastructure and Environment, 2012). If that is the case, one can use the OEI guideline.

3.3.4. Distributional effects

The deployment of infrastructure to promote regional economy, for example in terms of productivity or employment, is difficult to justify. Such effects of new infrastructure are often small and uncertain. And if they already occur, they usually occur at the expense of other regions (redistribution effect). This redistribution effect generally means a shift from one peripheral region to another, and not, for example from Randstad to a peripheral region.

According to Bakker & Zwaneveld, table 3.15 provides an overview of relevant distributional effects. These distributional effects are: availability and the use of public transport by social target groups (social function), increase GDP, income and spending effects (income redistribution), and, in general, pros and cons per ethnic group, region and users versus non-users. These examples include not all possible distributional effects; but these effects often play a role in public transport projects.

Table 3.15: Distributional effects of public transport (Bakker & Zwaneveld, 2009)

Availability and the use of public transport by social target groups (social function)	- relationship with non-utility value
Increase GDP	- due to agglomeration benefits - due to increased employment - due to longer working hours - due to accepting more productive jobs
Income and spending effects (income redistribution)	
General: pros and cons per ethnic group, region and users versus non-users	

3.3.5. Summary

Table 3.16 provides an overview of the interpretation of the effects described in sections 3.3.1., 3.3.2., 3.3.3, and 3.3.4. The interpretation is based on the documents. If available, there is presented a valuation in euros or the measure unit appointed to the effects. Otherwise the attribute is described according to the description in the documents.

Table 3.16: Interpretation (description/valuation/measure unit) of attributes (part 1/2)

	Attributes	Interpretation (description/valuation/measure unit)
Direct effects	**Travel time**	Euros per hour (per transport mode): Train: €7,60/h; Bus: €6,65/h; Freight traffic: €45,38/h; Car: €10,70/h; Bicycle: €6,65/h - €14,03/h; Euros per hour (per motive): Home-to-work: €9,95/h; Business: €28,23/h; Other: €8,07/h
	Waiting time	Public transport: Weighting factor: 1.50 (related to travel time: 1.00)
	Frequency	Public transport: Weighting factor: 0.77 (related to travel time: 1.00)
	Information provision	How much information is provided about routes and interchanges
	Vehicle condition	The physical and mechanical condition of vehicles, including frequency of breakdowns
	Reliability (of travel time)	Bus, car and bicycle: 25% of travel time benefits
	Travel costs	Train: 8,00 eurocent/km; Bus, tram and metro: 11,00 eurocent/km; Car: 22,00 eurocent/km; Bicycle: 7,00 eurocent/km
	Comfort	Public transport: Weighting factor: 0.96 (related to travel time: 1.00)
	Effects during construction period	Disturbing of existing users or local residents (valuation in hours)
	Option value and non-utility value	The possibility to use public transport in case of emergency

Table 3.16: Interpretation (description/valuation/measure unit) of attributes (part 2/2)

	Attributes	Interpretation (description/valuation/measure unit)
Indirect effects	**Effects on product market**	Productivity
	Effects on labor market	Number of jobs. Increase labor productivity: Bicycle: 4.6 eurocent/km
	Effects on housing and land market	Hectare
	Health effects (of cycling)	Bicycle: 1.7-2.5 eurocent/km
	Subsidies	Bus: 29 eurocent/km; Car: 0 eurocent/km; Bicycle: 0 eurocent/km
	Excise duties	Bus: 0 eurocent/km; Freight traffic: 14.94 eurocent/km; Car: 4.34 eurocent/km; Bicycle: 0 eurocent/km
	Network effects	The feedback effect on the mobility of the shift from labor, business and population
	Knowledge and innovation spillover effects	Sharing of knowledge (higher by lower transport costs)
	International effects	Impact on the imports and exports of goods and services
External effects	**Greenhouse gas emissions (global emissions)**	Inside built-up area: Passenger transport: €11.53/1000 travel km; Freight transport: €8.80/1000 tons-km; Outside built-up area: Passenger transport: €11.53/1000 travel km; Freight transport: €8.80/1000 tons-km
	Air quality (local emissions)	Inside built-up area: Passenger transport: €5.85/1000 travel km; Freight transport: €14.40/1000 tons-km; Outside built-up area: Passenger transport: €0.53/1000 travel km; Freight transport: €7.10/1000 tons-km
	Noise	48-53 dB: 14 eurocent/dB/house; 53-58 dB: 83 eurocent/dB/house; 58-63 dB: 152 eurocent/dB/house; 63-68 dB: 206 eurocent/dB/house; 68-73 dB: 366 eurocent/dB/house; >73 dB: 504 eurocent/dB/house
	Traffic safety	Inside built-up area: Bus: 5.4 eurocent/travel km; Car: 6.3 eurocent/vehicle km; Bicycle: 6.2 eurocent/km; Outside built-up area: Bus: 2.1 eurocent/travel km; Car: 2.5 eurocent/vehicle km; Bicycle: 2.5 eurocent/km
	External safety	Change in situation in the increase/decrease of the effect on objects
	Social safety	Change in social safety
	Effects on soil	Number of cubic meters (amount of earthmoving)
	Effects on groundwater and surface water	Areas (impact water management)
	Effects on nature	Number of hectares or length of intersection Bird and Habitat areas, EHS, etc.
	Effects on landscape and heritage	Number of affected objects
Distributional effects	**Availability and use of PT by social target groups**	This effect is regarding the social function: the availability and the use of public transport by social target groups
	Increase GDP	Direct transport benefits can lead to increased employment and thus a higher GDP
	Income and spending effects	Income distribution and spending effects
	General: pros and cons per ethnic group. region. and users versus non-users	Generally formulated distributional effects, e.g. pros and cons per region

3.4. Integration tool

Previous section described the attributes according to the documents presented in both section 3.3 and appendix B. This section provides an overview of the effects that are applicable per transport mode and at each step of the ''Ladder van Verdaas''.

3.4.1. Direct effects

According to Ministry of Infrastructure and Environment attributes like travel time, travel costs and reliability (of travel time) are applicable for all transport modes at all steps of the ''Ladder van Verdaas''. However travel time and reliability (of travel time) are indirect effects of measures of the second step named pricing policy. Waiting time and frequency are applicable for public transport at step 4 'optimize public and active transport', step 5 'better utilization of existing infrastructure', step 6 'modify existing infrastructure', and step 7 'new infrastructure'.

Information provision and vehicle condition are applicable for projects at transport mode public transport at step 4 'optimize public and active transport', step 5 'better utilization of existing infrastructure', step 6 'modify existing infrastructure', and step 7 'new infrastructure'. At these 4 steps information provision is also applicable for transport mode car. Vehicle condition is applicable for both transport mode car and transport mode bicycle at step 4, 5, 6, and 7.

According to Wever & Rosenberg (2012), comfort elements are only applicable for public transport. This is because comfort elements involve, for example, waiting time for ticket sales, stairs, availability toilet, availability luggage racks, views, etc. These aspects are also part of the image of public transport. Despite that image, comfort is only one of many factors that mean something for the public transport. However, profit can be reached at this point (KiM, 2009). There are no good indicators available to measure prosperity effects of improving comfort in the broadest sense of the word. However, it is possible to derive indicators on the basis of conducting a Stated Preference (SP) survey of travelers using the 'willingness-to-pay method'.

Effects during construction period are only applicable at steps relating to construction of infrastructure. This is only the case for step 6 'modify existing infrastructure' and step 7 'new infrastructure'. The option value (Geurs, 2006) of public transport is the amount of money people have, in the case of unforeseen circumstances, nonetheless to be able to use public transportation. Therefore this effect is only applicable at transport mode ''Public transport''.

3.4.2. Indirect effects

According to Ministry of Infrastructure and Environment (2012), indirect effects are on product markets, labor market, housing and land market. Furthermore, knowledge and spillover effects and international (land border transcending) effects are indirect effects related to traffic projects. All these effects can be of importance on all transport modes and at all steps of the ''Ladder van Verdaas''. Health effects of cycling are related to transport mode bicycle and are also applicable at all steps of the ''Ladder van Verdaas''.

Subsidies are mainly related to transport mode public transport. However at step 2 'pricing policy' and step 3 'mobility management' subsidies can also be applicable at transport mode car and bicycle, because for example subsidies related to electric cars or ''Fietsplan''. Excise duties are related to transport mode car and are applicable at all steps of the ''Ladder van Verdaas'' (Decisio & Transaction Management Centre, 2012; Ministry of Infrastructure and Environment, 2012; Vervoort, Van der Ham, & Van Breemen, 2015; Wever & Rosenberg, 2012.

3.4.3. External effects

According to Bakker & Zwaneveld (2009), Ministry of Infrastructure and Environment (2012), and Vervoort, Van der Ham, & Van Breemen (2015), external effects are air quality, greenhouse gas emissions, and noise (disturbance), which are applicable for transport modes public transport and car at all steps of the ''Ladder van Verdaas''. Traffic safety is applicable for all transport modes at all steps of the ''Ladder van Verdaas''. According to Ministry of Infrastructure and Environment (2012), social safety is applicable for transport mode public transport, and external safety is applicable for transport modes car and bicycle.

Effects on soil, groundwater and surface water, nature, and landscape and heritage are applicable at all transport modes at step one, six, and seven of the ''Ladder van Verdaas''. This is because at these steps the measures are related to new asphalt and this may have impact on soil, nature, etc.

3.4.4. Distributional effects

Availability and the use of public transport by social target groups (social function) is related to all steps of the ''Ladder van Verdaas'' for transport mode public transport (Bakker & Zwaneveld, 2009). On the basis of expert judgement, distributional effects like the increase of GDP, income and spending effects, etc. can be applicable at transport modes public transport, car and bike and at all steps of the ''Ladder van Verdaas''.

3.4.5. Summary

Bakker & Zwaneveld (2009); Decisio & Transaction Management Centre (2012); Ministry of Infrastructure and Environment (2012); Redman, Friman, Gärling, & Hartig (2013); Vervoort, Van der Ham, & Van Breemen (2015); and Wever and Rosenberg (2012) together provide an overview of effects that are of importance for different transport modes. The applicability of attributes that cannot be justified on the basis of documentary analysis is justified on the basis of expert judgement (S. Hoen, personal communication, October 28, 2016). As a result, the applicability of the effects related to step 4, 5, 6 and 7 of the ''Ladder van Verdaas'' is mainly justified by documentary analysis, and the effects related to step 1, 2 and 3 of the ''Ladder van Verdaas'' are justified by expert judgement. This is because regarding step 1, 2 and 3 the documents did not present if the attributes were applicable or not.

Table 3.17 and 3.18 illustrate which attributes are applicable per transport mode and at each step of the ''Ladder van Verdaas''. Moreover the cells are colored related to the used sources (documents/expert judgement). Together the effects implemented in these researches show relationships, and this provides, on the basis of these researches, an overview of the effects that are important per transport mode and each step of the ''Ladder van Verdaas''. Travel time and travel costs are, for example, direct effects that are applicable for each transport mode and each step of the ''Ladder van Verdaas''. The applicability of direct, indirect, external, and distributional effects is respectively described in section 3.4.1., 3.4.2., 3.4.3., and 3.4.4.

Table 3.17: Applicability of attributes in step 1 to 4 of the ''Ladder van Verdaas''

	Attributes	1. Spatial planning			2. Pricing policy			3. Mobility management			4. Optimize public and active transport		
		PT	Car	Bike	PT	Car	Bike	PT	Car	Bike	PT	Car	Bike
Direct effects	Travel time	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Waiting time	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗
	Frequency	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗
	Information provision	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✗
	Vehicle condition	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓
	Reliability (of travel time)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Travel costs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Comfort	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗
	Effects during construction period	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Option value and non-utility value	✓	✗	✗	✓	✗	✗	✓	✗	✗	✓	✗	✗
Indirect effects	Effects on product market	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Effects on labor market	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Effects on housing and land market	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Health effects (of cycling)	✗	✗	✓	✗	✗	✓	✗	✗	✓	✗	✗	✓
	Subsidies	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✗	✗
	Excise duties	✗	✓	✗	✗	✓	✗	✗	✓	✗	✗	✓	✗
	Network effects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Knowledge and innovation spillover effects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	International effects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
External effects	Air quality (local emissions)	✓	✓	✗	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Greenhouse gas emissions (global emissions)	✓	✓	✗	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Noise	✓	✓	✗	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Traffic safety	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	External safety	✗	✓	✓	✗	✓	✓	✗	✓	✓	✗	✓	✓
	Social safety	✓	✗	✗	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Effects on soil	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Effects on groundwater and surface water	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Effects on nature	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Effects on landscape and heritage	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
Distributional effects	Availability and use of PT by social target groups	✓	✗	✗	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Increase GDP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Income and spending effects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	General: pros and cons per ethnic group, region, and users versus non-users	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Legend

✓ Applicable
✗ Not applicable

(Dark blue) Based on documentary analysis (Bakker & Zwaneveld, 2009; Ministry of Infrastructure and Environment, 2012; Redman, Friman, Gärling, & Hartig, 2013)
(Light blue) Based on documentary analysis (Decisio & Transaction Management Centre, 2012; Ministry of Infrastructure and Environment, 2012)
(Medium blue) Based on documentary analysis (Ministry of Infrastructure and Environment, 2012; Vervoort, Van der Ham, & Van Breemen, 2015; Wever & Rosenberg, 2012)
(Light green) Based on expert judgement

Table 3.18: Applicability of attributes in step 5 to 7 of the "Ladder van Verdaas"

	Attributes	5. Better utilization of existing infrastructure			6. Modify existing infrastructure			7. New infrastructure		
		PT	Car	Bike	PT	Car	Bike	PT	Car	Bike
Direct effects	Travel time	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Waiting time	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Frequency	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Information provision	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Vehicle condition	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Reliability (of travel time)	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Travel costs	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Comfort	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Effects during construction period	✗	✗	✗	✓	✓	✓	✓	✓	✓
	Option value and non-utility value	✓	✗	✗	✓	✗	✗	✓	✗	✗
Indirect effects	Effects on product market	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Effects on labor market	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Effects on housing and land market	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Health effects (of cycling)	✗	✗	✓	✗	✗	✓	✗	✗	✓
	Subsidies	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Excise duties	✗	✓	✗	✗	✓	✗	✗	✓	✗
	Network effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Knowledge and innovation spillover effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
	International effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
External effects	Air quality (local emissions)	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Greenhouse gas emissions (global emissions)	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Noise	✓	✓	✗	✓	✓	✗	✓	✓	✗
	Traffic safety	✓	✓	✓	✓	✓	✓	✓	✓	✓
	External safety	✗	✓	✓	✗	✓	✓	✗	✓	✓
	Social safety	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Effects on soil	✗	✗	✗	✓	✓	✓	✓	✓	✓
	Effects on groundwater and surface water	✗	✗	✗	✓	✓	✓	✓	✓	✓
	Effects on nature	✗	✗	✗	✓	✓	✓	✓	✓	✓
	Effects on landscape and heritage	✗	✗	✗	✓	✓	✓	✓	✓	✓
Distributional effects	Availability and use of PT by social target groups	✓	✗	✗	✓	✗	✗	✓	✗	✗
	Increase GDP	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Income and spending effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
	General: pros and cons per ethnic group, region, and users versus non-users	✓	✓	✓	✓	✓	✓	✓	✓	✓

Legend

✓ Applicable
✗ Not applicable

(dark blue) Based on documentary analysis (Bakker & Zwaneveld, 2009; Ministry of Infrastructure and Environment, 2012; Redman, Friman, Gärling, & Hartig, 2013)
(light blue) Based on documentary analysis (Decisio & Transaction Management Centre, 2012; Ministry of Infrastructure and Environment, 2012)
(medium blue) Based on documentary analysis (Ministry of Infrastructure and Environment, 2012; Vervoort, Van der Ham, & Van Breemen, 2015; Wever & Rosenberg, 2012)
(light green) Based on expert judgement

3.5. Conclusions

According to Bakker & Zwaneveld (2009), Decisio & Transaction Management Centre (2012), and Vervoort, Van der Ham, & Van Breemen (2015), attributes of the different transport modes are divided into direct effects, indirect effects, external effects, and distributional effects. On the basis of documentary analysis and expert judgement these attributes are related to the ‘’Ladder van Verdaas’’. The applicability of the effects related to step 4, 5, 6 and 7 of the ‘’Ladder van Verdaas’’ are mainly justified by documentary analysis and the effects related to step 1, 2 and 3 of the ‘’Ladder van Verdaas’’ are justified by expert judgement. This is because regarding step 1, 2 and 3 the documents did not represent if the attributes were applicable or not. Step 1 and 3 of the ‘’Ladder van Verdaas’’ can be related to a wide variety of projects. Therefore, it should be noted that at some projects related to step 1 and 3 of the ‘’Ladder van Verdaas’’ an attribute can be applicable, while according to the integration tool the attribute it is not applicable. As a result, follow-up research is needed to provide more insight into which additional attributes are applicable at these steps of the ‘’Ladder van Verdaas’’.

Table 3.16 provides an overview of the interpretation related to the effects described in section 3.3. The interpretation is based on the documents. If available, there is presented a valuation in euros or the measure unit appointed to the effects. Otherwise the attribute is described according to the description in the documents. Regarding the interpretation of the attributes that are not valued by the researchers of the documents, there is follow-up research needed to provide more insight into the effectiveness of these attributes.

The integration tool provides an overview of relevant attributes that are implemented in different researches. Together these researches show relationships between attributes that are implemented, and this forms, on the basis of these researches, an overview of the attributes that are important per transport mode and at each step of the ‘’Ladder van Verdaas’’ (table 3.17 and 3.18).

For example, travel time and travel costs are direct effects that are applicable for each transport mode and each step of the ‘’Ladder van Verdaas’’. Another example is the attribute frequency. This attribute is only applicable for transport mode public transport on step 3 to 7 of the ‘’Ladder van Verdaas’’. The attribute health effects is only applicable for transport mode bike and can be applicable at all steps of the ‘’Ladder van Verdaas’’. Effects on soil, water, nature, landscape and heritage are applicable for all transport modes at step 1, 6 and 7 of the ‘’Ladder van Verdaas’’. Regarding the relevant attributes, table 3.17 and 3.18 provide an overview of the effects that are applicable per transport mode and at each step of the ‘’Ladder van Verdaas’’.

In chapter 4, two pilots will be executed to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool.

4. APPLICATION

4.1. Introduction

RMO Noord-Limburg (Regional Mobility Organisation North-Limburg) acts as a platform where seven municipalities of North-Limburg cooperate in the fields of traffic and transport. RMO North-Limburg consists of the municipalities: Mook en Middelaar, Gennep, Bergen, Venray, Venlo, Horst aan de Maas and Peel en Maas (figure 4.1). To utilize the power of the region it is necessary to ensure good accessibility by improving and maintaining all infrastructure networks by road, rail, water and air at a high level (RMO North-Limburg, 2013). Any disruption of this network has an adverse effect on achieving the ambitions and put the position of North-Limburg under pressure.

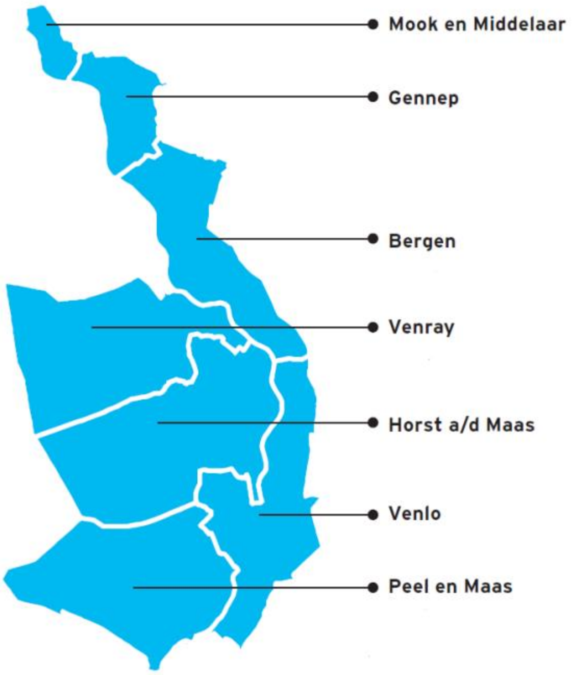

Figure 4.1: Municipalities of RMO North-Limburg (based on RMO Venray-Venlo, 2011)

The region North-Limburg itself takes high responsibility for its infrastructure. It has the ambition to realize infrastructure projects to reach the desired level of accessibility and maintain the infrastructure. Besides about fifty large and small projects which are initiated by the region itself, there are some projects that transcend the borders of North-Limburg.

The municipalities of North-Limburg have jointly drawn up a strategic regional vision. This regional vision articulates the aspirations and desires of the region. The region will create a distinctive profile that matches the character of the area. In the regional vision, four supporting functions are distinguished: housing, healthcare, leisure and tourism, and agriculture. The aim is to strengthen these functions and thereby to bring about a qualitative leap for the region. To achieve this, three programs are devised. These strengthen the east-west connections and expand existing networks (especially for bicycle and pedestrian), improve the spatial quality of the built environment and the landscape, and finally also exploit the qualities of the Maas (and mitigating the risks).

The limited number of connections across the river Maas can lead to relatively high travel times (dependent on the route), especially for slow traffic. That is the reason for RMO North-Limburg to strengthen the east-west connections (on both sides of the river), and expanding existing networks of slow traffic.

The projects in North-Limburg, as listed by RMO Venray-Venlo (2011), can be assigned to various steps of the ''Ladder van Verdaas''. There is assumed that these projects are indicated by continuing the ''Ladder van Verdaas''. So at first spatial planning measures, then pricing policy measures, mobility management measures etcetera were not sufficiently to achieve the goal of the project. In this research, the ''Ladder van Verdaas'' is used as instrument to identify solutions to accessibility problems, but not as a tool in the decision-making process.

Most of the projects belong to the *seventh step* of the ''Ladder of Verdaas''. Projects on this step of the ''Ladder van Verdaas'' are mainly similar projects concerning bicycle connections, such as bicycle connections across the river Maas. Moreover, according to the integration tool the effects are according to documentary analysis regarding the last steps of the ''Ladder van Verdaas''. The project concerning the construction of the bicycle connection Mook-Cuijk is part of the fast cycle route Cuijk-Mook-Nijmegen, and therefore seems interesting for a relatively large part of the population of North-Limburg. To execute a pilot on a lower step of the ''Ladder van Verdaas'', a pilot will be executed regarding capacity extension of the A67 between Venlo and Eindhoven. This project is applicable on the *sixth step* of the ''Ladder van Verdaas''.

By executing the pilots, it is important to provide insight into the effects and calculations that are related to the objective of the projects. The objective of the pilot regarding the bike connection is to stimulate the use of the bicycle, by constructing the fast cycle route Cuijk-Mook-Nijmegen. Therefore, the most important attributes related to this project are travel time, travel cost, health effects and traffic safety. The objective of the pilot regarding the capacity extension of the A67 is to reduce travel times. Therefore maps regarding travel times are generated to illustrate the impact. For example, effects on air quality, noise, soil, nature, water, etc. are not related to the objective, and therefore these effects are not visualized.

4.2. Bike connection Mook - Cuijk

4.2.1. Introduction

As described in paragraph 2.4, the main scope of the ''Ladder van Verdaas'' is to see if the construction of new infrastructure can be avoided as much as possible with other solutions. Therefore, in line with the ''Ladder van Verdaas'', three measures on different steps of the ''Ladder van Verdaas'' are visualized in this paragraph. An example of a measure related to step two 'pricing policy' is ''Fietsplan''. By using ''Fietsplan'', it is for workers possible to buy a bicycle including substantial tax benefit. A measure related to step three 'mobility management' is the prioritization of bicycle routes. The project of RMO North-Limburg regarding the new bike connection between Mook and Cuijk is related to the step seven of the ''Ladder van Verdaas''.

According to the Province of Gelderland (2016), the bicycle bridge across the river Maas between the villages Mook and Cuijk (marked in blue in figure 4.2) is the most important part of the fast bicycle route Cuijk-Mook-Nijmegen. Herewith the Province of Gelderland will encourage the bicycle use. In the planning around the bridge the extension of railway infrastructure will be taken into account. In addition, both dykes and N271 will be crossed in different levels. On the side of Cuijk the bicycle bridge connects to the Lange Linden; on the side of Mook the bicycle bridge connect via a bicycle tunnel to the Middelweg. The new road sections are marked in blue in figure 4.2.

Figure 4.2: Map of the environment of Mook and Cuijk, including new road sections (marked in blue).

To provide insight into the effects of a measure of **step two** of the ''Ladder van Verdaas'', the impact of ''Fietsplan'' is illustrated. Indeed, the government provides companies the opportunity to offer a bicycle to their employees to encourage commuting by bicycle. However, the advantage of a new bike from the ''Fietsplan'' depends on a person's income. The average benefit is 42% of the purchase price (Nationale Fiets Projecten, 2016). As a result, there are only effects related to the attribute travel costs. This is because ''Fietsplan'' does not affect the travel time of transport mode bicycle.

A project related to **step three** of the ''Ladder van Verdaas'' concerns the prioritization of bicycle routes. By giving priority to transport mode bicycle at intersections, the delay at junctions can be decreased, and this encourages the use of transport mode bicycle. Therefore, the effects on travel time by conventional bike, pedelec, and speed pedelec are illustrated. There can be assumed that the effects related to travel costs by bicycle are very small.

The project regarding the new bike connection between Mook and Cuijk is related to the **seventh step** of the ''Ladder van Verdaas''. Accessibility maps of measures are created according to other steps of the ''Ladder van Verdaas'' to provide insight into the impact of measures that are related to the objective of encouraging the use of bicycle on other steps of the ''Ladder van Verdaas''. Regarding the new bike connection, effects are visualized related to travel time and travel costs. Moreover, to illustrate indirect and external effects of the new bike connection between Mook and Cuijk, there are illustrations created regarding health effects and traffic safety before and after the construction of the bike connection.

4.2.2. Dataset

To provide insight into the impact of the new bicycle connection, a network is created as network dataset in a geodatabase using open data (NDW). Roads which are not suitable for cycling (e.g. motorway A67, A73, and N271) are not part of the bicycle network. Therefore a field is added to the attribute table. In this table road sections that are prohibited for cycling are scored as 1 and then the roads with a score of 1 are removed from the shapefile. Fields like Lengthkm, Time15_3, Time16_1, Time17_4, Time19, etc. will be added to produce accessibility maps after creating the new network dataset. Travel speeds of 15.3 km/h, 17.4 km/h, and 24.5 km/h are applied to provide a representation for respectively conventional bicycle, pedelec (pedaling supported up to 25 km/h), and speed pedelec (pedaling supported up to 45 km/h). Free flow travel speeds of these bicycle types are respectively 16.1 km/h, 19.0 km/h, and 24.9 km/h (table 4.1). Therefore a delay at junctions is implemented. Delays are implemented at junctions to provide a more realistic view of travel times. A 5 seconds (0.08 minutes) delay at every junction is assumed, because the delay at junctions is mainly 0-15 seconds in the environment of Mook and Cuijk (Fietstelweek, 2015). By applying a delay of 5 seconds, the accessibility of travel speeds of 15.3 km/h, 17.4 km/h, and 24.5 km/h is similar to the accessibility of free flow travel speeds in combination with a delay of 5 seconds.

Table 4.1: Mean speed per trip in km/h for different bicycle types (Schleinitz et al., 2015)

	Bicycle	***Pedelec***	***Speed pedelec***
Speed	*15.3*	*17.4*	*24.5*
Speed free flow	*16.1*	*19.0*	*24.9*

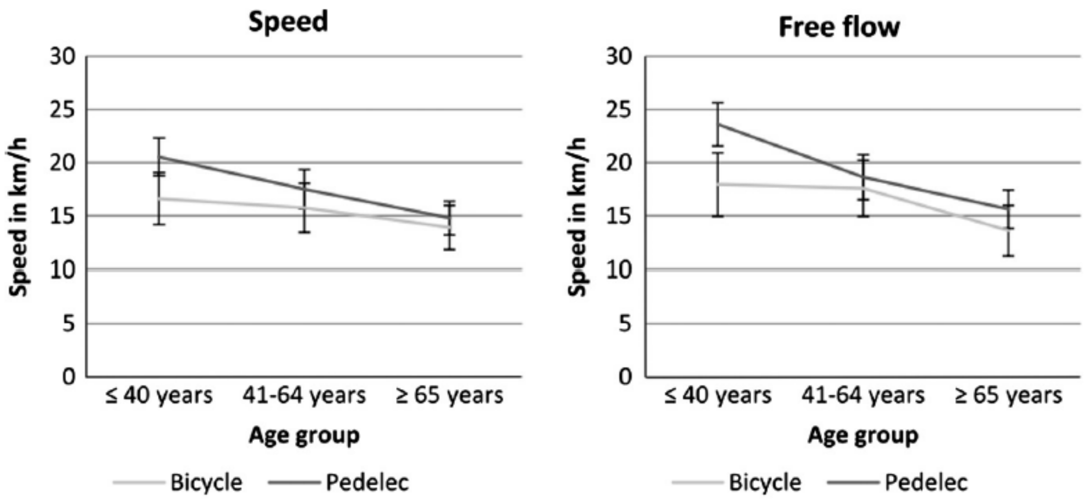

Figure 4.3: Travel speed and free flow travel speed by bicycle of different age groups (Schleinitz et al., 2015)

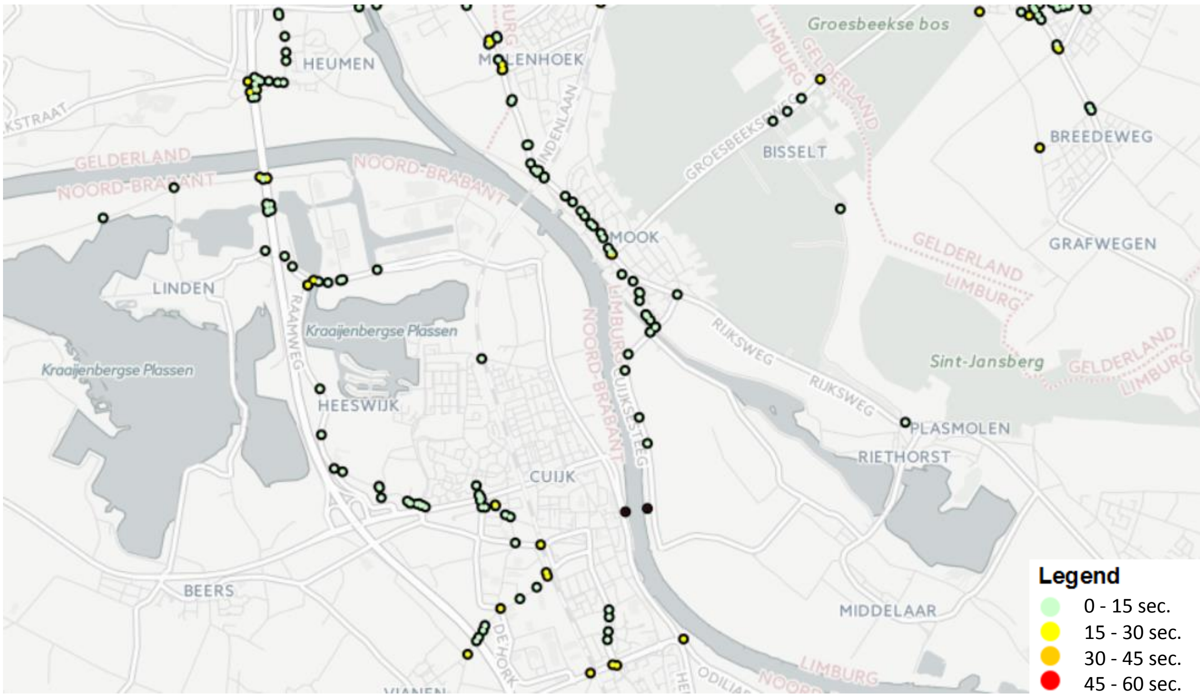

Figure 4.4: Delay at junctions (Fietstelweek, 2015)

The speed of cyclists moving through traffic varies considerably (CROW, 2010). The speed depends on personal characteristics, bicycle characteristics (such as the type of bike), and environmental characteristics, including the traffic environment and traffic intensity.

Because cycling promotes health positively, cyclists deliver higher productivity. The social effects of increased labor productivity are on average around 0.05 euros per kilometer, both in urban and very light urban environment, and both inside and outside built-up areas.

In addition to increasing labor productivity of cyclists, cycling is also increasing the number of healthy life years and life expectancy of cyclists. According to the RIVM (2010), the burden of disease due to inactivity is about 270 thousand DALYs in the Netherlands. DALY stands for "disability adjusted life years" and is a measure of the overall burden caused by diseases. It measures the number of people who die prematurely due to illness and the number of years that people live with disabilities due to illness. RIVM has assessed that if inhabitants of the Netherlands would cycle more frequently (one day per week extra) and longer (cycling 30 minutes extra per day), the disease burden decreases by 1.3 percent, or 3510 DALYs after one year.

With the premise of RIVM (cycling an extra day a week and 30 minutes on each of those days), the following calculation can be made: If we assume that the average citizen of the Netherlands cycles 2.2 days per week (20 to 30 minutes per day), this means the starting point of extra cycling of the RIVM is about 1.1 to 1.6 hours per week. This is 15 to 22.5 kilometers per citizen of the Netherlands extra per week at an average of 14.2 kilometer per hour. If all 16 million citizens of the Netherlands extra cover this distance, 52 weeks per year, leads to a reduction of 3510 DALYs. With a score of 70.000 euros per DALY, a score of 2.1 eurocent per kilometer to health benefits is assumed.

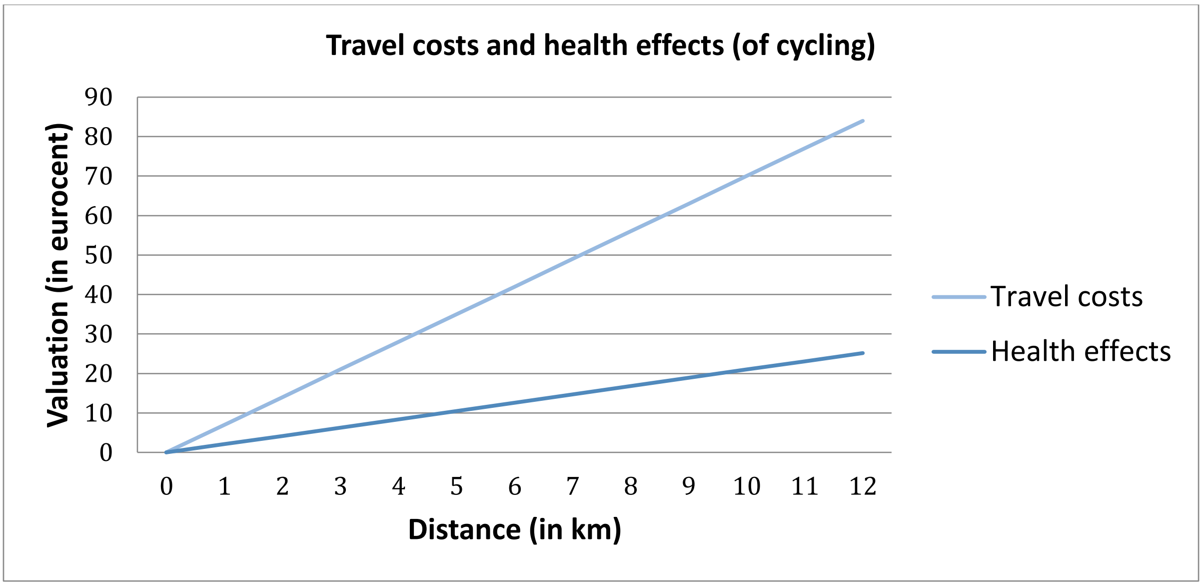

Figure 4.5: Valuation of travel costs and health effects (of cycling)

Field ''Lengthkm'' is measured by calculate geometry in ArcMap 10.4.1 (figure 4.6). To create a new network dataset some steps have to be continued. In the step to specify the attributes, these are calculated as in table 4.2.

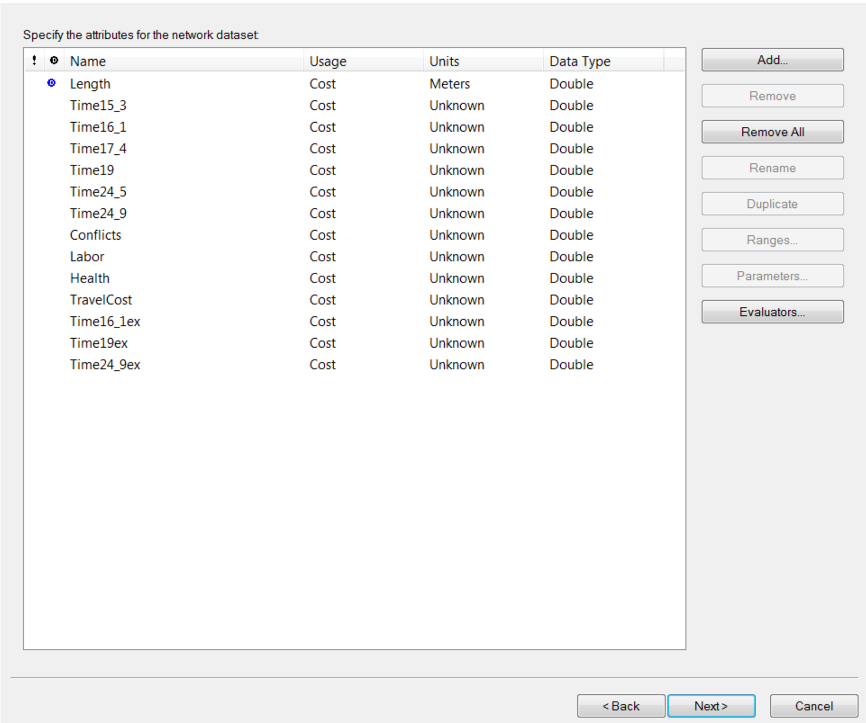

Figure 4.6: Fields in the new Network Dataset in ArcMap 10.4.1.

Table 4.2: Specification of attributes in the Network Dataset

Name	Type	Formula	Delay
Lengthkm (km)	Double	Calculate geometry (km)	
Time15_3 (15.3 km/h)	Double	[Lengthkm] /15.3*60	
Time16_1 (16.1 km/h)	Double	[Lengthkm] /16.1*60	Junction (0.08 min.)
Time17_4 (17.4 km/h)	Double	[Lengthkm] /17.4*60	
Time19 (19.0 km/h)	Double	[Lengthkm] /19.0*60	Junction (0.08 min.)
Time24_5 (24.5 km/h)	Double	[Lengthkm] /24.5*60	
Time24_9 (24.9 km/h)	Double	[Lengthkm] /24.9*60	Junction (0.08 min.)
Travel costs	Double	[Lengthkm] *7.00 [Lengthkm] *4.06 (''Fietsplan'')	
Health effects	Double	[Lengthkm] *2.10	
Conflicts	Double	1 (one conflict per road section)	

Key figures of traffic safety regarding transport mode car, bus, and bike (in eurocent per km) are calculated by SWOV and Ecorys (2008). However, regarding traffic safety, it is important how many points of intersection road users can come into conflict (SWOV, 2014). Therefore the fewer potential conflict points, the safer (SWOV, 2014). On the basis of this statement, traffic safety is visualized by the number of potential conflict points. However, there are also other aspects that of importance to traffic safety. Moreover the safety or risk of an intersection is usually expressed as the number of accidents per number of vehicles passed (intensity). Valuation of travel costs and health effects are respectively 7.00 and 2.10 eurocents per km.

Because the travel costs of transport mode bicycle are mainly related to the purchase price, it is assumed that travel costs of participants of ''Fietsplan'' decreases by 42%. Therefore the travel costs per kilometer are (100-42) % of 7.00 eurocent, which is equal to 4.06 eurocent.

A restriction at road sections that are, for example, longer than 2 km can also be created. It can be assumed that the speed on these roads is a few km/hour higher than on roads shorter than 2 km (figure 4.7). Another recommendation is regarding height differences. This is because travel speeds by transport mode bicycle are dependent on height differences. According to figure 4.8, this is especially the case for the region northeast of Mook (Groesbeek-Nijmegen).

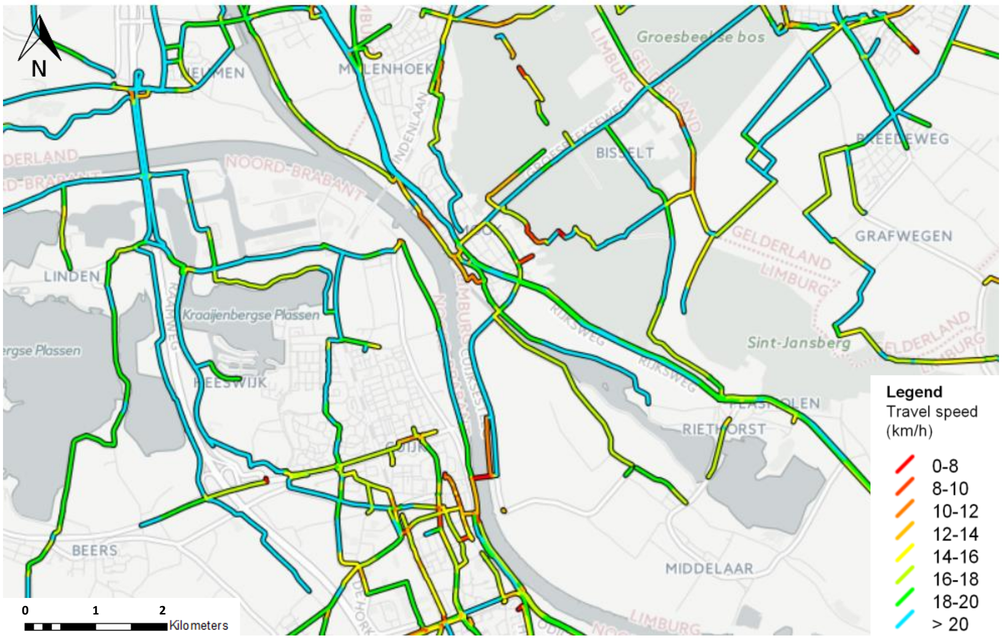

Figure 4.7: Travel speed (km/h) at road sections (Fietstelweek, 2015)

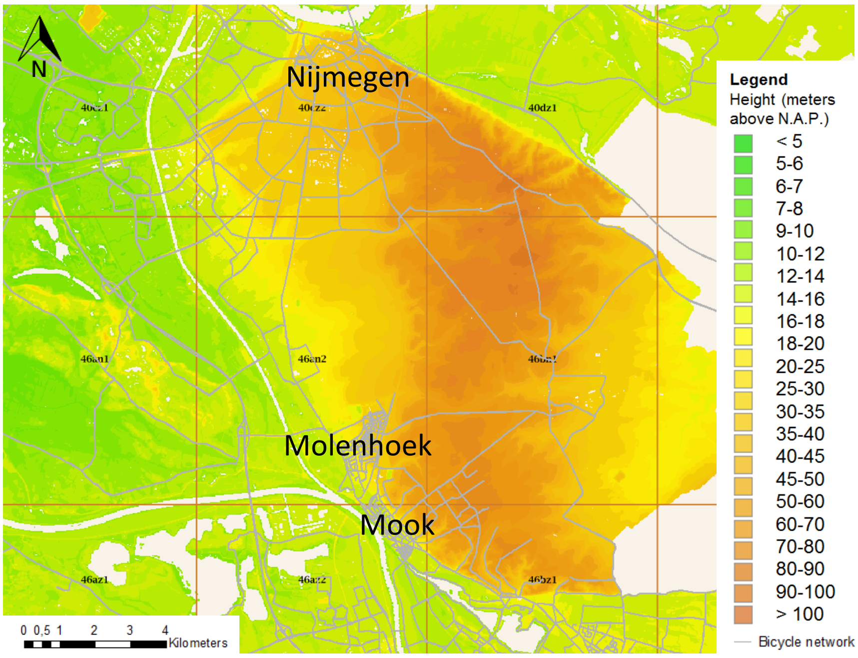

Figure 4.8: Height map (Actueel Hoogtebestand Nederland, 2015)

4.2.3. Analysis

After creating the network dataset, the effects of the different measures can be analyzed on the basis of the different attributes. Appendix C shows the various maps regarding the accessibility effects. These effects are visualized by maps of the situation before the measure, the situation after the measure, and the integration of both situations. Figure 4.9 shows, for example, the accessibility maps in all situations of the new bike connection between Mook and Cuijk at a travel time of 24.5 km/h.

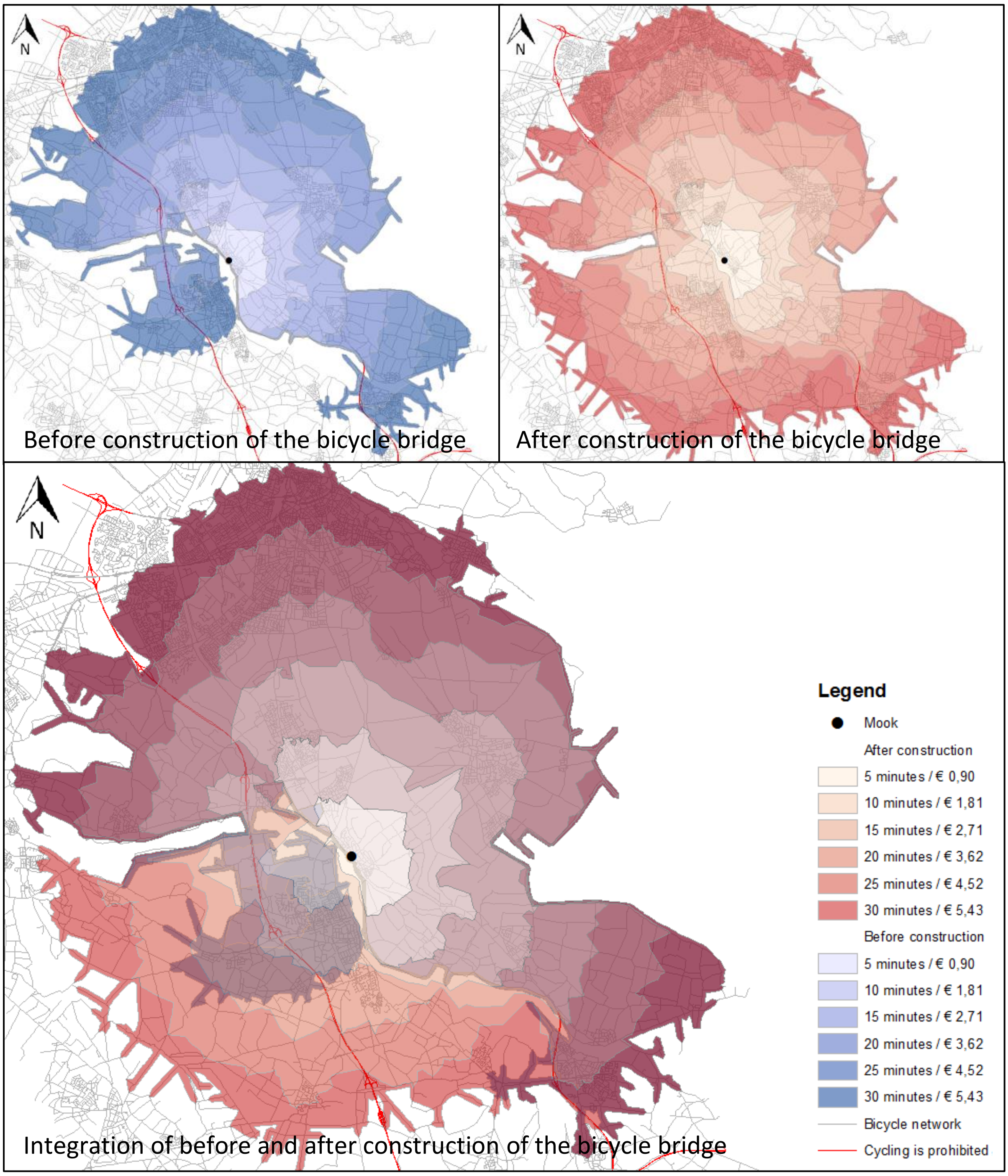

Figure 4.9: Accessibility maps from Mook, on the basis of an average travel speed of 24.5 km per hour related to a speed pedelec (situation before construction, after construction and integration of both situations)

In this section the maps presented in appendix C will be described. Firstly, figure **C.1** in appendix C presents the location of Mook, the surrounding municipalities, and the municipality borders of the Maas. Secondly, figures **C.2, C.3 and C.4** present the maps regarding the effects of ''Fietsplan'' (travel costs) related to step 2 'pricing policy' of the ''Ladder van Verdaas. Conclusion of these maps is that participants of ''Fietsplan'' can access a bigger area with the same amount of travel costs. As a result, the effectiveness of this measure can maps can be compared with the effectiveness of the new bike connection between Mook and Cuijk. Thirdly, figures **C.5-C.13** illustrate the maps regarding the effects on travel time for conventional bike, pedelec and S-pedelec of the priority measure related to step 3 'mobility management' of the ''Ladder van Verdaas''. The maps present the situation before the measure, the situation after the measure, and the integration of the effects of both measures of the travel speed related to conventional bike, pedelec, and speed pedelec. In short, the accessible area (at the same travel time and/or cost) is bigger after the measure. Thus, the accessible area increases by prioritizing transport mode bicycle compared to the measures of the ''Fietsplan''. This measure can also be related to the effectiveness of the new bike connection. Therefore, finally, figures **C.14-C.40** present the effectiveness of the new bike connection between Mook and Cuijk. The effectiveness is visualized respectively based on travel time, travel costs, health effects and traffic safety.

Figure C.14-C.31 in appendix C present accessibility maps based on travel speeds related to conventional bike, pedelec, and speed pedelec. These maps are based on travel time in minutes, and valued in euros. Indeed, according to Decisio & Transaction Management Centre (2012), the valuation of travel time for transport mode bicycle is € 10.85 per hour. Therefore the value per 5 minutes is € 0.90. When looking at the travel times, the time to travel from Mook to Cuijk is considerably shorter. So if inhabitants of Mook visit facilities in Cuijk by transport mode bicycle, the travel time will be reduced by 15 minutes. Travel costs and health effects per trip are after construction lower for the existing cyclists from Mook to Cuijk, because the distance is decreased and therefore the travel costs and health effects (in eurocent per kilometer) also decrease. However, it is not investigated, but it can be assumed that because of the shorter distance between Mook and Cuijk, the use of the bicycle will be encouraged between these two places. Therefore the total health effects can increase.

Regarding traffic safety, the accessible area is bigger in the new situation than in the current situation. This is because in the new situation the number of conflicts is reduced by travelling from Mook to the other side of the Maas, due to the construction of the bicycle connection.

In accordance with the opinion of the Central Planning Bureau (CPB), the effects on travel time reliability are caused by 25 percent of travel time benefits resulting from reduced congestion (vehicle loss hours). For cyclists there can be assumed that a shorter travel leads to a higher reliability (less traffic lights, intersections, etc.).

4.3. Capacity extension A67 Venlo - Eindhoven

4.3.1. Introduction

A good road network in North-Limburg is indispensable for the connections of the main ports and the processing of European transport flows (RMO North-Limburg, 2013). Businesses in the Netherlands benefit from the optimization of international connections from Limburg. This also contributes to the European corridors. In addition, a lot of value is added to the flow of goods in the Venlo region. This allows that the A67 has to process a lot of freight traffic. Therefore the region aims to expand the capacity of the A67 between Eindhoven and Venlo from two to three lanes.

Figure 4.10: Location of North-Limburg and A67 (RMO North-Limburg, 2013)

The A67 is the main connection axis which connects the ports of Rotterdam and Antwerp to the hinterland, especially the Ruhr region and Eastern Europe. Within the Netherlands, the A67 provides a connection between Eindhoven Brainport and Greenport Venlo.

Motorway A67 is located in the Netherlands from Eersel (in the southwest of the Netherlands), via Eindhoven to Venlo. In Venlo near the German border, the highway turns into the E34 (in the direction of Duisburg). It is a motorway with 2x2 lanes and an emergency lane. The A67 Venlo - Eindhoven is 75 kilometers long and is characterized by a high share of freight traffic and a narrow profile. This causes problems like accidents, trucks on the narrow lane and traffic flow problems at the connections.

4.3.2. Dataset

In Eindhoven, between the junctions De Hogt and Leenderheide, the A67 merges with the A2 and therefore the road is 2x3 lanes, located parallel to the N2 (also 2x2 lanes). In the area between Eindhoven and Venlo, the emergency lane is narrow on some road sections and there are breakdown bays. Within the region there are worries about the functioning of the A67. In some locations congestion regularly occurs and it is expected that this will increase in the short and medium term. The A67 is perceived as relatively unsafe. This is particularly the case for road sections that are poorly lighted and for road sections with narrow lanes. Between junction Leenderheide and Someren there is a ban on overtaking for trucks in both directions during the day (6-19 hours). The maximum speed is 120 or 130 km/h (figure 4.11 and 4.12).

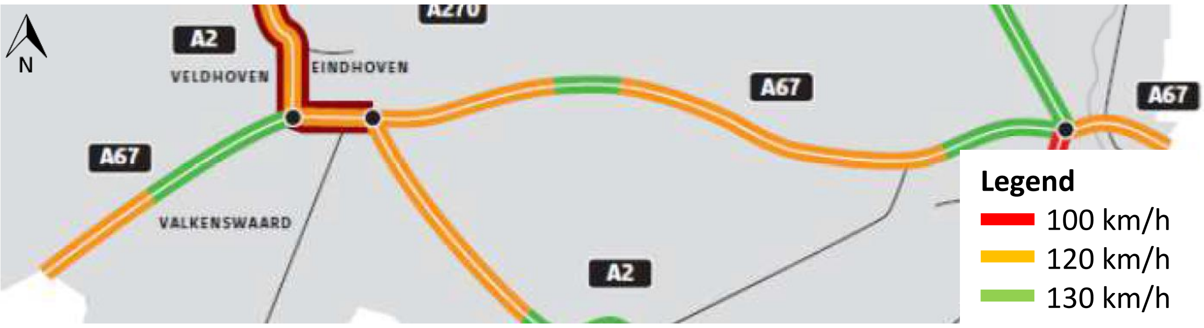

Figure 4.11: Maximum speed 6:00-19:00 (Beter Bereikbaar Zuidoost-Brabant, 2016)

Figure 4.12: Maximum speed 19:00-6:00 (Beter Bereikbaar Zuidoost-Brabant, 2016)

Compared to the maximum speed, the travel speed is considerably lower during rush hours. Table 4.3 illustrates the average travel speeds in the morning peak in 2015 on road sections of the A67 that will be extended. Based on expert judgement (Ministry of Infrastructure and Environment, 2016) the travel speeds in the new situation are on average 112 km/h.

Table 4.3: Travel speeds during the morning peak (on average in 2015)

Road number	Road section	Travel speed
A67L	Geldrop (34) - Leenderheide (junction)	86
A67L	Someren (35) - Geldrop (34)	65
A67L	Asten (36) - Someren (35)	79
A67R	Leenderheide (junction) - Geldrop (34)	103
A67R	Geldrop (34) - Someren (35)	105
A67R	Someren (35) - Asten (36)	100

4.3.3. Analysis

On the basis of the travel speeds presented in table 4.3, accessibility maps are created to visualize the impact of capacity extension for the inhabitants of the municipalities of North-Limburg (appendix D, figure D.1-D.14). The travel time is classified in minutes. However, the valuation of travel time is € 10.70 per hour, so the valuation per 5 minutes is equal to € 0.89. For the inhabitants of the municipality of Mook en Middelaar and Gennep, there are no effects on the basis of travel time (appendix D, figure D.1-D.4), because they do not use the A67. However, by comparing the maps of the other municipalities the effects are visible. This is because these municipalities are located closer to the highway A67 than the municipalities Mook en Middelaar and Gennep. In the most favorable case, the travel time gain is one minute on a total travel time of 10 minutes (decrease of 10%). According to the model, this is the case during the morning rush. Figure 4.13 presents the difference between the situation before modification (marked in purple) and after modification (marked in red). The effects for the inhabitants of the municipality Bergen are also smaller than the effects for the inhabitants of Horst, Peel en Maas, Venlo and Venray.

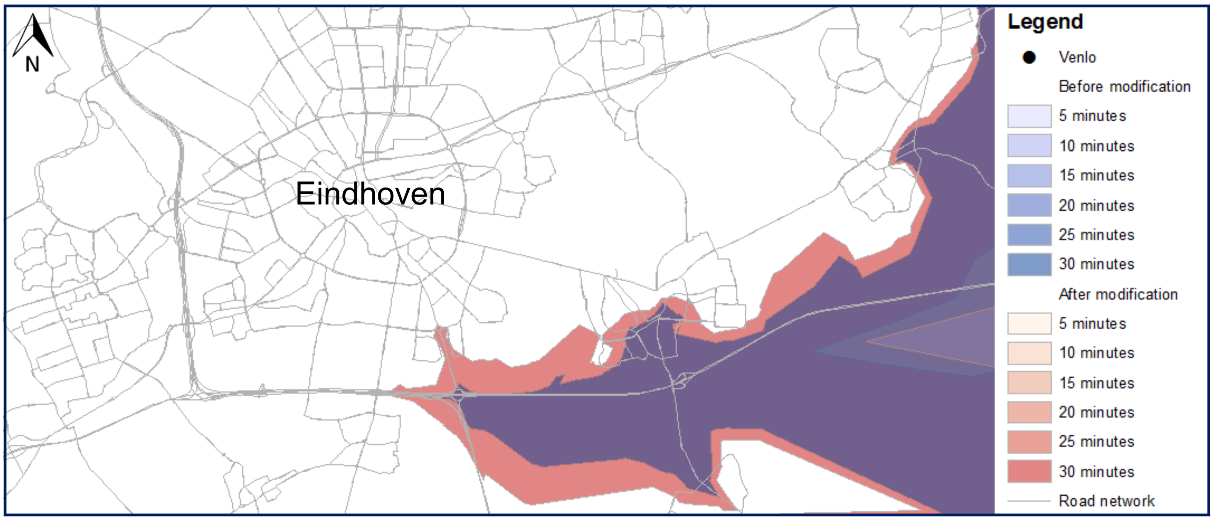

Figure 4.13: Accessibility map on the basis of travel time (travel time from Venlo)

Travel costs and excise duties are dependent on distance; the valuation of these attributes is dependent on the number of kilometers. In the pilot of Venlo – Eindhoven the number of kilometers between, for example Venlo and Eindhoven, do no not change. Therefore the maps regarding travel costs and excise duties represent no changes between before and after modification. However, the travel costs can be lower if there is less congestion. Moreover the routes, according to the traffic model will change, and this affects the travel distance. Therefore, a recommendation is to apply traffic model calculations regarding this project to provide more insight into the effects of the capacity extension.

4.4. Conclusions

4.4.1. Bike connection Mook - Cuijk

Accessibility effects are visualized regarding the situation before the measure, the situation after the measure, and the integration of both measures.

The new bicycle connection brings Mook and Cuijk figuratively closer to each other. Therefore residents of both municipalities can more easily use each other's facilities. Travel costs and health effects per trip are after construction lower for the existing cyclists from Mook to Cuijk, because the distance is decreased and therefore the travel costs and health effects (in eurocent per kilometer) also decrease. However, it is not investigated, but it can be assumed that because of the shorter distance between Mook and Cuijk, the use of the bicycle will be encouraged between these two places. Therefore the total health effects can increase. To calculate the total health effects, there is more information needed, for example on the basis of a prediction tool, regarding the number of cyclists before and after the construction.

Regarding traffic safety, the numbers of potential conflict points are visualized in the situation before and after the construction of the bike connection. However, there are also other aspects that are of importance to traffic safety. Moreover the safety or risk of an intersection is usually expressed as the number of accidents per number of vehicles passed (intensity). However, the numbers of accidents are not known in the pilot of the bike connection. Therefore, regarding traffic safety the numbers of points of conflicts are visualized in the situation before and after the construction. As a result, the accessible area is bigger (at the same risk) in the new situation than in the current situation. This is because in the new situation the number of conflicts is reduced by travelling from Mook to the other side of the Maas, due to the construction of the bicycle connection.

By comparing the impact of the measures related to step 2 and 7 of the ''Ladder van Verdaas'', regarding travel costs there can be concluded that these measures have a different impact on travel costs (figure 4.14). The new bike connection enhances the accessibility from Mook to Cuijk, and ''Fietsplan'' enhances the accessibility in all directions. However, to a lesser extent from Mook to Cuijk, because of the barrier of the Maas. Therefore, the travel costs from Mook to Cuijk are similar to travel costs from Mook to the center of Nijmegen. Due to the new bike connection the barrier of the Maas between Mook and Cuijk will disappear, and therefore the impact of the new bike connection is related to users of the bicycle connection between Mook and Cuijk. An important point to note is that the impact of ''Fietsplan'' is only related to participants of ''Fietsplan''.

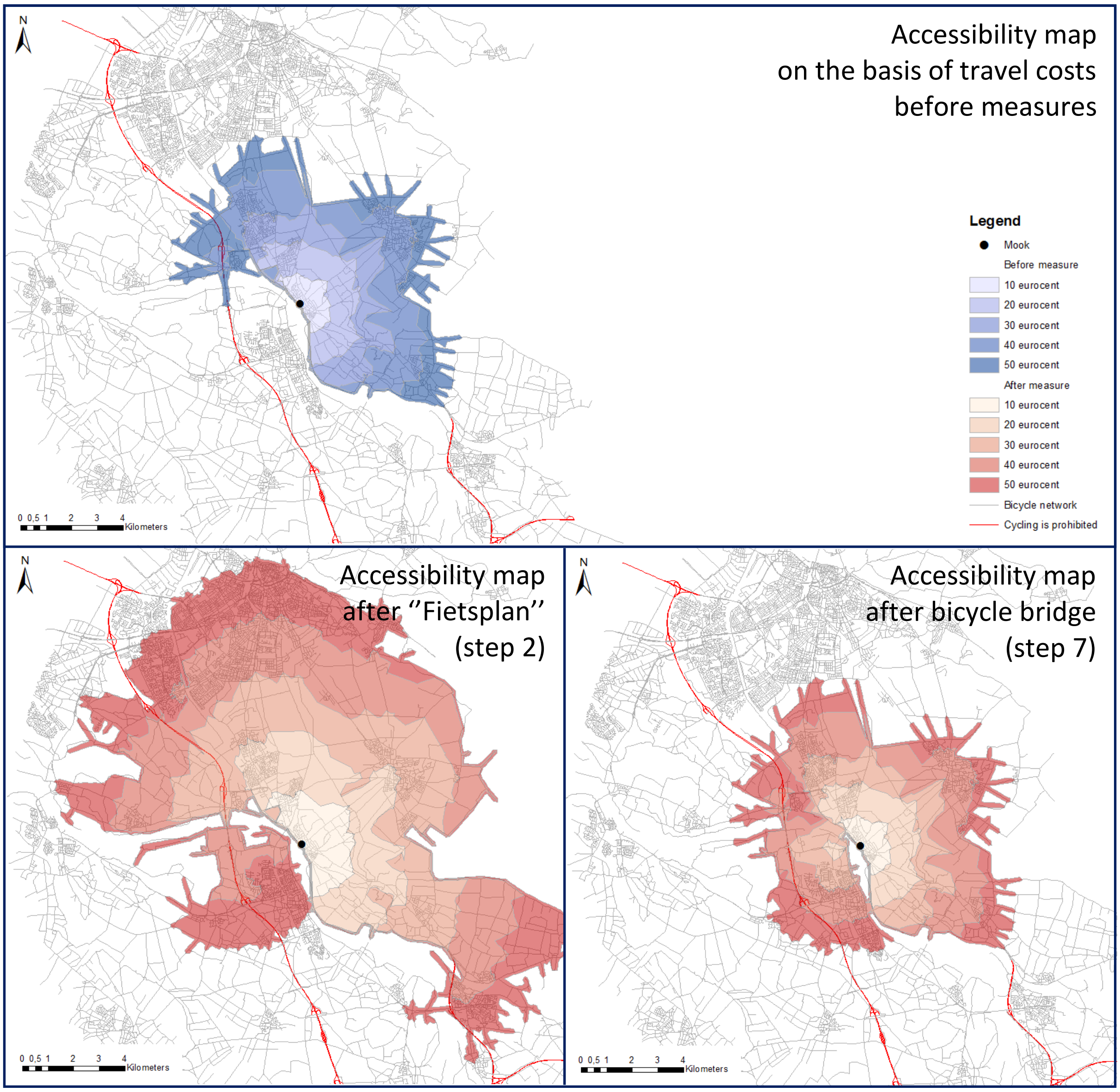

Figure 4.14: Accessibility maps on the basis of travel costs (before and after measures)

In short, based on the illustrations, the conclusion is that effects on the basis of travel costs regarding the measure related to step two of the ''Ladder van Verdaas'' enhances the accessibility in all directions. However, to a lesser extent from Mook to Cuijk, because of the barrier of the Maas. And the new bike connection enhances only the accessibility from Mook to Cuijk, and therefore this effect is only applicable for bicyclists between Mook and Cuijk. The impact of the measure related to step two (''Fietsplan'') is only applicable for participants of ''Fietsplan''.

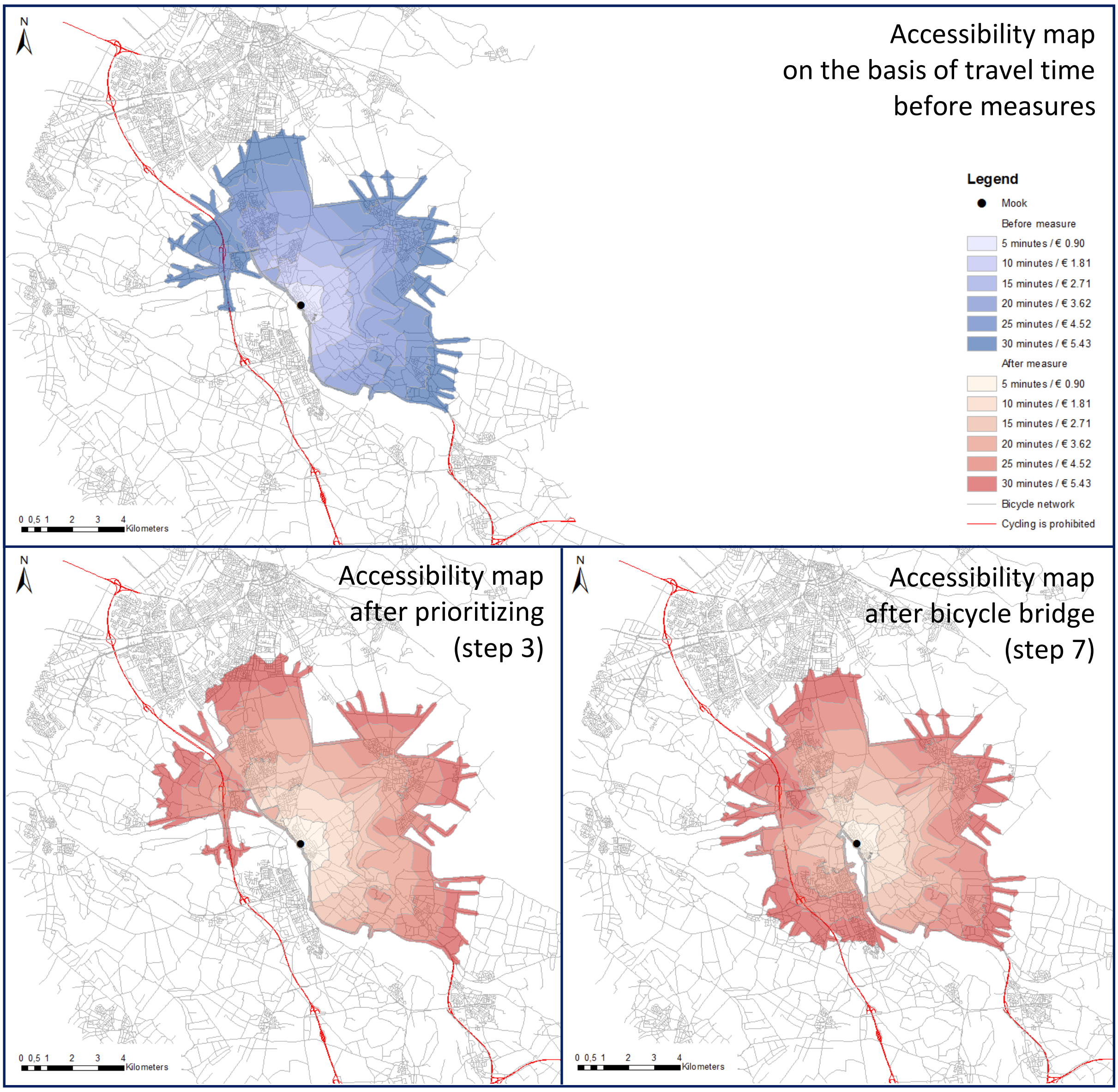

Figure 4.15: Accessibility maps on the basis of travel time (before and after measures)

By comparing the impact of the measures related to step three and seven of the ''Ladder van Verdaas'', regarding travel times it can be concluded that these measures have a different impact on travel time (figure 4.15). By applying the measure related to step 3 of the ''Ladder van Verdaas'' the delay at junctions decreases. Therefore, the accessible area increases within the same travel time for all cyclists. In the case of the new bike connection, the travel time only decreases for cyclists between Mook and Cuijk. Therefore, by executing this pilot, the recommendation is to formulate a clear objective and to apply the most cost-effective measure related to the objective. If the goal is to encourage bicycle use, relating to the ''Ladder van Verdaas'', less drastic measures can be more cost-effective than the construction of the bike connection between Mook and Cuijk.

In all accessibility maps the effects are visualized from the center of Mook. This point is representative for the inhabitants of the Mook, located in North-Limburg. However, another location (e.g. shopping location, school) can be interesting too. Therefore, by developing this tool and using the software package ArcGIS, the effects from another location can be easily duplicated and analyzed.

According to Decisio & Transaction Management Centre (2013), the new bicycle connection brings Mook and Cuijk figuratively closer to each other. Therefore residents of both municipalities can more easily use each other's facilities. This has spatial-economic consequences that will be reflected in, for example, the land value (effects on land market) and the support base for services. These effects are partly double counting with the travel time benefits of the cyclists. After all, just because the travel time decreases, there are spatial economic effects. For this reason and because of the uncertainty of the extent of the effect, Decisio & Transaction Management Centre (2013) suffice with the conclusion that the improved infrastructure is expected to entail positive spatial economic effects.

4.4.2. Capacity extension A67 Venlo - Eindhoven

In the pilot regarding the capacity extension of the A67 between Venlo and Eindhoven, attributes are also visualized regarding the situation before the measure, the situation after the measure, and the integration of both measures.

Regarding the pilot of the capacity extension of the A67 between Venlo and Eindhoven, the distance between Venlo and Eindhoven is equal in the situation before and after the modification of the A67. However the travel time will be shorter, especially during rush hour. This brings Venlo and Eindhoven, by looking at travel time, figuratively closer to each other. However, for the inhabitants of some municipalities (Mook en Middelaar and Gennep), there are no effects on the basis of travel time (appendix D, figure D.1-D.4), because there are no changes between before and after modification (they do not use the A67). For municipalities that are located closer to the highway A67 than the municipalities Mook en Middelaar and Gennep, there are changes visible between the situation before and after modification. The accessibility effects for the inhabitants of the municipality Bergen are also smaller than the effects for the inhabitants of Horst, Peel en Maas, Venlo and Venray.

Regarding the illustration of the effects, the maps on the basis of zone level create a distorted view, because the colors of the zone only change if a zone belongs to another category (0-15 minutes, 15-30 minutes, etc.). Therefore the recommendation is to zoom in on the area of, for example, Eindhoven. This will provide more insight into the changes as a result of the capacity extension of the A67 between Venlo and Eindhoven.

Travel costs and excise duties are dependent on distance; the valuation of these attributes is dependent on the number of kilometers. In the pilot of Venlo – Eindhoven the number of kilometers between, for example Venlo and Eindhoven, do no not change. Therefore the maps regarding travel costs and excise duties represent no changes between before and after modification. However, the travel costs can be lower if there is less congestion. Moreover the routes, according to the traffic model will change, and this affects the travel distance. Therefore, a recommendation is to apply traffic model calculations regarding this project to provide more insight into the effects of the capacity extension.

Regarding this pilot, the travel time gain is in the most favorable case one minute on a total travel time of 10 minutes (decrease of 10%). According to the model, this is the case during the morning rush. A recommendation is to look at measures at other steps of the ''Ladder van Verdaas''. These measures can also be less drastic and therefore maybe more cost-effective. On the other hand, if measures on steps one to six are not sufficient, the option of new infrastructure has to be evaluated too, because this measure could have much more impact, but is also related to higher costs. Therefore, the cost-effectiveness has to be evaluated.

5. CONCLUSION

5.1. General conclusions

The objective of this research, as stated earlier in chapter 1, was to develop a tool including relevant attributes with realistic scores for included attributes for each step of the ''Ladder van Verdaas''. This tool is created on the basis of documentary analysis and expert judgement. On top of that, by using geographical information systems, pilots are executed to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool. Therefore the main research question was as follows:

''What are relevant attributes regarding accessibility measurements and mobility policies for different transport modes, and what is the applicability of these attributes per step of the ''Ladder van Verdaas''?

In order to be able to answer the main research question, several sub-questions can be answered now:

- *''What is the definition and operationalization of accessibility?''*

In order to provide an answer to this sub-question, the results of the literature review have been presented in chapter 2. As described in this chapter, accessibility is a term which is interpreted, defined and operationalized in different ways in literature. Land-use and transport are two of the target components, which define requirements of accessibility. The other two components are the temporal and individual component. Ideally, all four components would be included in a definition of accessibility. However it is troublesome and too complex to include all four components equivalent. Therefore, this research focusses mainly on the transport component and to a lesser extent on land-use. Factors that can play a part in influencing travel behavior are regarding urban form, socio-demographic factors, and psycho-social factors.

There are various ways in which accessibility has been measured. Appendix A shows a seven-fold classification: Spatial separation measures, contour measures, gravity measures, competition measures, time-space measures, utility measures, and network measures. Accessibility impacts of transport and land use changes, for example, those due to policies, are often evaluated by using accessibility measures. Herewith policy makers and researchers can easily operationalize and interpret the impact, but this does generally not satisfy theoretical criteria.

Several methods have been developed to evaluate transportation plans. An example is a methodology to evaluate the equity impacts of proposed projects in Montreal, considering both accessibility and mobility changes that the projects will bring, as well as the projects' effects on spatial mismatch. Specifically, scenarios are evaluated before and after the implementation of the projects that involved changes in accessibility to suitable employment opportunities that socially disadvantaged populations have, changes in travel time to employment centers by transit, and changes in time savings.

- *''What is the composition and applicability of the ''Ladder van Verdaas'' in the context of effect studies?''*

The ''Ladder van Verdaas'' is a conceptual framework, which is suitable for examining possible solutions to an accessibility problem. The main scope is to see if the construction of new infrastructure can be avoided as much as possible with other solutions. The composition of the ''Ladder van Verdaas'' is as follows:

- Spatial planning;
- Pricing policy;
- Mobility management;
- Optimize public (and active) transport;
- Better utilization of existing infrastructure;
- Modify existing infrastructure;
- New infrastructure.

Examples of applications of the ''Ladder van Verdaas'' are in the case of Buitenring Parkstad and Wageningen. Because of the application of the ''Ladder van Verdaas'' at Buitenring Parkstad, the combination of exploitation, extension and construction of new infrastructure appeared to be the most appropriate approach to address the problems outlined. Besides that, the ''Ladder van Verdaas'' is used in Wageningen to solve accessibility problems by evaluating all steps of the ''Ladder van Verdaas''. The ''Ladder van Verdaas'' is used in Wageningen as a guide for measures to be taken and regarding phasing. As a result, a lower financial investing is required and greater efficiency is achieved. However, in the case of Wageningen, accessibility (in general) is only scored as --, -, + or ++, and this can be described/visualized per attribute related to accessibility, and therefore, related to the scope of the project, a much more advanced choice can be made. Therefore, in this research, relevant attributes are structured on the basis of the ''Ladder van Verdaas'', including interpretation (definition/valuation/measure unit) per attribute.

- *''What are relevant attributes for each transport mode and for each stage of the ''Ladder van Verdaas'', and what is a realistic score per attribute?''*

Bakker & Zwaneveld (2009), Decisio & Transaction Management Centre (2012), Ministry of Infrastructure and Environment (2012), Redman, Friman, Gärling, & Hartig (2013), Vervoort, Van der Ham, & Van Breemen (2015), and Wever & Rosenberg (2012) provide relevant attributes regarding different transport modes. According to these documents, relevant attributes of the different transport modes are divided into direct effects, indirect effects, external effects, and distributional effects (table 5.1).

Table 5.1: Relevant attributes, as a result of the documentary analysis

Direct effects	Indirect effects	External effects	Distributional effects
Travel time	Effects on product market	Air quality	Availability and use of PT by social groups
Waiting time	Effects on labor market	Greenhouse gas emissions	Increase GDP
Frequency	Effects on housing and land market	Noise	Income and spending effects
Information provision	Health effects	Traffic safety	General: pros and cons per ethnic group, region, and users versus non-users
Vehicle condition	Subsidies	External safety	
Reliability (of travel time)	Excise duties	Social safety	
Travel costs	Network effects	Effects on soil	
Comfort	Knowledge and innovation spillover	Effects on ground and surface water	
Effects during construction period	International effects	Effects on nature	
Option value and non-utility value		Effects on landscape and heritage	

Legend

- Applicable for transport modes public transport, car and bike
- Applicable for transport modes public transport and car
- Applicable for transport modes car and bike
- Only applicable for transport mode public transport
- Only applicable for transport mode car
- Only applicable for transport mode bike

On the basis of documentary analysis and expert judgement, the attributes presented in table 5.1 are related to the ''Ladder van Verdaas''. The applicability of the attributes related to step 4, 5, 6 and 7 of the ''Ladder van Verdaas'' is mainly justified by documentary analysis, and the attributes related to step 1, 2 and 3 of the ''Ladder van Verdaas'' are justified by expert judgement. This is because regarding step 1, 2 and 3 the documents did not represent if the attributes were applicable or not. As described before, step 1 and 3 of the ''Ladder van Verdaas'' can be related to a wide variety of projects. Therefore, it should be noted that at some projects related to step 1, 2 and 3 of the ''Ladder van Verdaas'' an attribute can be applicable, while according to the integration tool the attribute it is not applicable. As a result, follow-up research is needed to provide more insight into which additional attributes are applicable at these steps of the ''Ladder van Verdaas''.

Table 3.16 provides an overview of the interpretation (description/valuation/measure unit) related to the attributes described in section 3.3. The interpretation is based on the documents. If available there is presented a valuation in euros or the measure unit appointed to the attributes. Otherwise the attribute is described according to the description in the documents. Regarding the interpretation of the attributes that are not valued by the researchers of the documents, there is follow-up research needed to provide more insight into the effectiveness of these attributes.

The integration tool (table 3.17 and 3.18) provides an overview of relevant attributes that are implemented in different researches. Together these researches show relationships between attributes that are implemented, and this forms, on the basis of these researches, an overview of the attributes that are important per transport mode and at each step of the ''Ladder van Verdaas''.

For example, travel time and travel costs are direct effects that are applicable for each transport mode and each step of the ''Ladder van Verdaas''. Another example is the attribute frequency. This attribute is only applicable for transport mode public transport on step 3 to 7 of the ''Ladder van Verdaas''. The attribute health effects is only applicable for transport mode bike and can be applicable at all steps of the ''Ladder van Verdaas''. Effects on soil, water, nature, landscape and heritage are applicable for all transport modes at step 1, 6 and 7 of the ''Ladder van Verdaas''. Regarding the relevant attributes, table 3.17 and 3.18 provide an overview of the effects that are applicable per transport mode and at each step of the ''Ladder van Verdaas''. In chapter 4, two pilots are executed to illustrate the working of the tool and see if the tool meets the expectations and to provide recommendations regarding the applicability of the tool.

- *''By illustrating the working of the tool on the basis of 2 pilots, does the tool meets the expectations and what are recommendations regarding the applicability of the tool?''*

In both pilots, accessibility effects are visualized regarding the situation before the measure, the situation after the measure, and the integration of both measures to provide insight into the differences between the situation before and after the measure. According to the illustrations, the new bicycle connection brings Mook and Cuijk figuratively closer to each other. Therefore residents of both municipalities can more easily use each other's facilities.

By comparing the impact of the measures related to step 2 and 7 of the ''Ladder van Verdaas'', regarding travel costs there can be concluded that these measures have a different impact on travel costs. The new bike connection enhances the accessibility from Mook to Cuijk, and ''Fietsplan'' enhances the accessibility in all directions. However, to a lesser extent from Mook to Cuijk, because of the barrier of the Maas. Therefore, the travel costs from Mook to Cuijk are similar to travel costs from Mook to the center of Nijmegen. Due to the new bike connection the barrier of the Maas between Mook and Cuijk will disappear, and therefore the impact of the new bike connection is related to users of the bicycle connection between Mook and Cuijk. An important point to note is that the impact of ''Fietsplan'' is only related to participants of ''Fietsplan''.

By comparing the impact of the measures related to step three and seven of the ''Ladder van Verdaas'', regarding travel times it can be concluded that these measures have a different impact on travel time. By applying the measure related to step 3 of the ''Ladder van Verdaas'' the delay at junctions decreases. Therefore, within the same travel time, the accessible area increases for all cyclists. In the case of the new bike connection, the travel time only decreases for cyclists between Mook and Cuijk. Therefore, by executing this pilot, the recommendation is to formulate a clear objective and to apply the most cost-effective measure related to the objective. If the goal is to encourage bicycle use, relating to the ''Ladder van Verdaas'', less drastic measures can be more cost-effective than the construction of the bike connection between Mook and Cuijk.

Travel costs and health effects per trip (in eurocent per kilometer) are lower after construction for the existing cyclists between Mook and Cuijk, because the distance is decreased and therefore the travel costs and health effects also decrease. However, it is not investigated, but it can be assumed that because of the shorter distance between Mook and Cuijk, the use of the bicycle will be encouraged between these two places. Therefore the total health effects can increase. To calculate the total health effects, there is more information needed, for example on the basis of a prediction tool, regarding the number of cyclists before and after the construction.

Regarding traffic safety, the numbers of potential conflict points are visualized in the situation before and after the construction of the bike connection. However, there are also other aspects that are of importance to traffic safety. Moreover the safety or risk of an intersection is usually expressed as the number of accidents per number of vehicles passed (intensity). However, the numbers of accidents are not known in the pilot of the bike connection. Therefore, regarding traffic safety the numbers of conflict points are visualized in the situation before and after the construction. As a result, the accessible area is bigger in the new situation than in the current situation. This is because in the new situation the number of conflicts is reduced by travelling from Mook to the other side of the Maas, due to the construction of the bicycle connection.

Regarding the pilot of the capacity extension of the A67 between Venlo and Eindhoven, the distance between Venlo and Eindhoven is equal in the situation before and after the modification of the A67. However the travel time will be shorter, especially during rush hour. This brings Venlo and Eindhoven, by looking at travel time, figuratively closer to each other. However, for the inhabitants of some municipalities (Mook en Middelaar and Gennep), there are no effects on the basis of travel time (appendix D, figure D.1-D.4), because there are no changes between before and after modification (because they do not use the A67 between Venlo and Eindhoven). For municipalities that are located closer to the highway A67 than the municipalities Mook en Middelaar and Gennep, there are changes visible between the situation before and after modification. The accessibility effects for the inhabitants of the municipality Bergen are also smaller than the effects for the inhabitants of Horst, Peel en Maas, Venlo and Venray.

Travel costs and excise duties are dependent on distance; the valuation of these attributes is dependent on the number of kilometers. In the pilot of Venlo – Eindhoven the number of kilometers between, for example Venlo and Eindhoven, do no not change. Therefore the maps regarding travel costs and excise duties represent no changes between before and after modification. However, the travel costs can be lower if there is less congestion. Moreover the routes, according to the traffic model will change, and this affects the travel distance. Therefore, a recommendation is to apply traffic model calculations regarding this project to provide more insight into the effects of the capacity extension.

By having provided an answer on all sub-questions, an answer is given to the main question of this research.

5.2. General discussion and recommendations

Geurs & Van Wee (2004), build a strong case for the incorporation of several perspectives on accessibility into common measurements or, failing that, the application of several accessibility measures in the same context. However, ‘applying the full set of criteria would imply a level of complexity and detail that can probably never be achieved in practice’.

The integration tool provides an overview of relevant attributes that are implemented in different researches. The authors of these researches are: Bakker & Zwaneveld (2009), Decisio & Transaction Management Centre (2012), Ministry of Infrastructure and Environment (2012), Redman, Friman, Gärling, & Hartig (2013), Vervoort, Van der Ham, & Van Breemen (2015), and Wever & Rosenberg (2012). Together these researches show relationships between relevant attributes, and this provides an overview of the effects that are important per transport mode and at each step of the ‘’Ladder van Verdaas’’.

The applicability of the attributes related to step 4, 5, 6 and 7 of the ‘’Ladder van Verdaas’’ are mainly justified by documentary analysis and the attributes related to step 1, 2 and 3 of the ‘’Ladder van Verdaas’’ are justified by expert judgement. This is because regarding step 1, 2 and 3 the documents did not present if the attributes were applicable or not. As described before, step 1 and 3 of the ‘’Ladder van Verdaas’’ can be related to a wide variety of projects. Therefore the applicability of some effects can be doubtful regarding some projects, and therefore there is needed more information regarding some relevant attributes. Moreover some effects can be applicable or just not applicable in a certain project, or the effects can be zero. As a result, follow-up research is needed to provide more insight into which (additional) effects are applicable at these steps of the ‘’Ladder van Verdaas’’.

The integration tool offers more opportunities and can be valuable regarding insights into effects of mobility policies. However, the application of a simpler method is less time consuming as, for example, the application in Wageningen. Of interest is to determine a clear goal and then act accordingly. When the goal is accessibility in general, the most important effects can be applied. However, as stated before, the application of this tool is more labor-intensive than the application in Wageningen, but provides more advanced insights into attributes related to accessibility. Thereby, the ‘’Ladder van Verdaas’’ offers a method to determine the effects, and therefore a less drastic measure can be implemented. Herewith, the costs can be reduced, which is also socially relevant.

Effects that are presented by Bakker & Zwaneveld (2012) and Redman, Friman, Gärling, & Hartig (2013) are applicable at transport mode public transport, and based on expert judgement these effects can also of importance at other transport modes. The effects of Decisio and Transaction Management Centre (2012) and Vervoort, Van der Ham, & Van Breemen (2015) are based on social cost-benefit analyses. Social cost-benefit analyses (SCBAs) are used to assess the impacts of road investment projects in many countries (Saelensminde, 2004). However, such analyses are not used to assess the impacts of measures designed to improve the safety and/or mobility of pedestrians and cyclists. The reason for this might be that important impacts such as traffic safety and health effects are very difficult to make an adequate monetary valuation thereof and therefore the results of such SCBAs will be uncertain (Saelensminde, 2004).

It will be essential to perform new valuation studies to improve valuations of for example traffic safety. In the pilot of the bike connection between Mook and Cuijk, traffic safety is based on the number of conflict points. This provides a simplified view of traffic safety, but there are numerous other elements that affect traffic safety. The relationship between statistical risk reflected in traffic safety statistics and the more subjectively felt traffic safety is one topic that should be investigated in such valuation studies. More information on the relationship between physical activity and the incidence and costs will probably be available in the near future. This will make it possible to include more reliable estimates.

It is not known whether substituting walking or cycling for car and public transport use will result in more or fewer people injured in traffic accidents. This issue is complicated by the fact that accidents involving single cyclists are underreported in accident statistics. Obtaining more accurate information on the number of accidents involving cyclists should therefore have high priority in order to correctly estimate the costs of more bicycle use in the future.

According to Saelensminde (2004), there is limited information on both current and projected future numbers of pedestrians and cyclists. Related to this issue, there is a need for more research about risk and traffic safety related to cycling on dedicated tracks versus cycling on bicycle lanes on roads and how different designs of cycle routes influence the intensity of bicycle use.

The pilot regarding the bike connection between Mook and Cuijk provides insights into the impact of the construction of this bike connection regarding the travel time per conventional bike, pedelec, and speed pedelec, travel costs, traffic safety, and health effects. The pilot regarding the capacity extension of the A67 between junction Leenderheide and Asten provides insights for stakeholders into the effects related to travel time and travel costs.

By comparing the impact of the measures of step 3 and 7 of the ‘’Ladder van Verdaas’’, regarding travel times there can be concluded that these measures have a different impact on travel time. The travel time related to the measure of step 3 of the ‘’Ladder van Verdaas’’ is, by applying the measure, shorter to the same destination in all directions. In the case of the new bike connection, the travel time is only shorter for cyclists between Mook and Cuijk. Therefore, by executing this pilot, the recommendation is to formulate a clear objective and to apply the most cost-effective measure related to the objective. If the goal is to encourage bicycle use, relating to the ‘’Ladder van Verdaas’’, less drastic measures can be more cost-effective than the construction of the bike connection between Mook and Cuijk.

According to Schleinitz et al. (2015), travel speeds of 15.3 km/h, 17.4 km/h, and 24.5 km/h and free flow travel speeds of 16.1 km/h, 19.0 km/h, and 24.9 km/h are applied to provide a representation for respectively conventional bicycle, pedelec (pedaling supported up to 25 km/h), and speed pedelec (pedaling supported up to 45 km/h). However, the speed of cyclists moving through traffic varies considerably (CROW, 2010). The speed depends on personal characteristics, bicycle characteristics (such as the type of bike) and environmental characteristics, including the traffic environment and traffic intensity.

Regarding the travel time maps of the pilot of the bike connection between Mook and Cuijk, there can also be created a restriction at road sections that are, for example, shorter than 2 km. This is because there can be assumed that the speed on these roads is a few km/hour lower than on roads longer than 2 km. Another recommendation is regarding heights. This is because travel speeds by transport mode bicycle are also dependent on height. For example this is the case for the region northeast of Mook (Groesbeek-Nijmegen).

Regarding the pilot of the capacity extension, the travel time gain is in the most favorable case one minute, on a total travel time of 10 minutes (decrease of 10%). According to the model, this is the case during the morning rush. A recommendation is to look at measures at other steps of the ''Ladder van Verdaas''. These measures can also be less drastic and therefore maybe more cost-effective. On the other hand, if measures on steps one to six are not sufficient, the option of new infrastructure has to be evaluated too, because this measure could have much more impact, but is also related to higher costs. Therefore, the cost-effectiveness has to be evaluated.

Travel costs and excise duties are dependent on distance; the valuation of these attributes is dependent on the number of kilometers. In the pilot of Venlo – Eindhoven the number of kilometers between, for example Venlo and Eindhoven, do no not change. Therefore the maps regarding travel costs and excise duties represent no changes between before and after modification. However, the travel costs can be lower if there is less congestion. Moreover the routes, according to the traffic model will change, and this affects the travel distance. Therefore, a recommendation is to apply traffic model calculations regarding this project to provide more insight into the effects of the capacity extension.

REFERENCES

Aalbers, C. (2011). *Mobiliteitsmanagement en verkeersmanagement in MIRT-verkenningen.* (Master's thesis). Delft University of Technology, Delft, the Netherlands. Retrieved from http://repository.tudelft.nl/islandora/object/uuid:b9ff450f-3c35-49e1-a1ff-b783396b86f5?collection=education

Ammerlaan, D. (2012, September 28). *Effectiveness agricultural vehicle interventions on rural distributor roads.* (Master's thesis). Delft University of Technology, Delft, the Netherlands. Retrieved from http://repository.tudelft.nl/islandora/object/uuid%3A12d477df-17bd-4b56-9881-d62eae68bd38?collection=education

Bakker, P., & Zwaneveld, P. (2009, January). *Het belang van openbaar vervoer: De maatschappelijke effecten op een rij.* The Hague, the Netherlands: CPB and KiM. Retrieved from https://www.cpb.nl/sites/default/files/publicaties/download/het-belang-van-openbaar-vervoer-de-maatschappelijke-effecten-op-een-rij.pdf

Baradaran, S., Ramjerdi, F. (2001). Performance of accessibility measures in Europe. *Journal of Transportation and Statistics, 4,* 31-48.

Bertolini, L., Le Clercq, F., Kapoen, L. (2005). Sustainable Accessibility: A Conceptual Framework to Integrate Transport and Land Use Plan-Making: Two Test Applications in the Netherlands and a Reflection on the Way Forward. *Transport Policy, 12,* 207-220.

Beter Bereikbaar Zuidoost-Brabant (2016). *Basisgegevens A67: Verkeer-ongevallen-overige gegevens.* Eindhoven, the Netherlands. Retrieved from www.sre.nl/projecten/brabant-in-car-iii/basisgegevens-a67

Bhat, C., Handy, S., Kockelman, K., Mahmassani, H., Chen, Q., Weston, L. (2000, May). *Development of an Urban Accessibility Index: Literature Review.* Austin, TX: University of Texas (Center for Transportation Research). Retrieved from https://ctr.utexas.edu/wp-content/uploads/pubs/4938_1.pdf

Black, J., & Conroy, M. (1977). Accessibility measures and the social evaluation of urban structure. *Environment and Planning, A* 9*,* 1013-1031.

CE Delft (2014*). Luchtkwaliteit en verkeer.* Delft, the Netherlands. Retrieved from http://www.ce.nl/art/uploads/file/Presentaties/2014/20140208_Luchtkwaliteit-en-verkeer_HvE.pdf

Chen, S., Claramunt, C., Ray, C. (2014). A spatio-temporal modelling approach for the study of the connectivity and accessibility of the Guangzhou metropolitan network. *Journal of Transport Geography,* 36, 12-23.

CPB (2004). *Economische toets op de Nota Mobiliteit.* The Hague, the Netherlands. Retrieved from https://www.cpb.nl/sites/default/files/publicaties/download/economische-toets-op-de-nota-mobiliteit.pdf

Club of Rome (1972). *The limits to growth: a report for the Club of Rome's project on the predicament of mankind.* New York, NY. Retrieved from http://collections. dartmouth.edu/published-derivatives/meadows/pdf/meadows_ltg-001.pdf

CPB, MNP & RPB (2006). *Welvaart en leefomgeving.* The Hague, the Netherlands. Retrieved from http://www.welvaartenleefomgeving.nl/pdf_files/ WLO_achtergronddocument.pdf

CPB & PBL (2016). *Kansrijk mobiliteitsbeleid.* The Hague, the Netherlands. Retrieved from http://www.pbl.nl/sites/default/files/cms/publicaties/ PBL&CPB_2016_Kansrijk_Mobiliteitsbeleid_2337.pdf

CROW (2010, June 14). *Basisinformatie - Karakteristieken van voertuigen en mensen.* Ede, the Netherlands. Retrieved from http://www.crow.nl/publicaties/karakteristieken-van-voertuigen-en-mensen

CROW-KpVV (2016). *De Ladder van Verdaas.* Utrecht, the Netherlands. Retrieved from http://www.wikken-wegen.nl/start-wikken-en-wegen/stap-1/stap-5/voorbeelden-van-invalshoeken/de-ladder-van-verdaas/

Cui, J., Liu, F., Janssens, D., An, S., Wets, G., & Cools, M. (2016). Detecting urban road network accessibility problems using taxi GPS data. *Journal of Transport Geography, 51,* 147–157

Cullinane, S. (2002). The relationship between car ownership and public transport provision: a case study of Hong Kong. *Transport Policy, 9*(1), 29-39.

Curtis, C., & Perkins, T. (2006). *Travel behaviour: A review of recent literature.* Bentley, Australia: Curtin University. Retrieved from http://urbanet.curtin.edu.au/local/pdf/ARC_TOD_Working_Paper_3.pdf

Curtis, C., & Scheurer, J. (2007, March). *Working Paper No 4: Accessibility measures: Overview and practical applications.* Bentley, Australia: Curtin University. Retrieved from http://urbanet.curtin.edu.au/local/pdf/ARC_TOD_Working_Paper_4.pdf

Dalvi, M.Q., Martin, K.M., 1976. The measurement of accessibility: some preliminary results. *Transportation, 5,* 17–42.

De Roo, G. (2003). *Environmental planning in the Netherlands: too good to be true.* Aldershot, United Kingdom: Avebury.

Decisio & Transaction Management Centre (2012, June 28). *Maatschappelijke kosten en baten van de fiets: Quick scan.* Amsterdam, the Netherlands. Retrieved from http://www.decisio.nl/wp-content/uploads/2014/11/MKBA-Fiets.pdf

Decisio & Transaction Management Centre (2013, January 17). *MKBA Snelfietsroute Cuijk – Nijmegen.* Amsterdam, the Netherlands. Retrieved from http://decisio.nl/projecten-mobiliteit-infrastructuur/2014/mkba-snelfietsroute-cuijk-mook-nijmegen/

DfT (2005). *Transport, wider economic benefits and impacts on GDP.* London, United Kingdom: UK Department for Transport.

DfT (2007). *Transport Analysis Guidance (TAG) Unit 3.6.1: The Option Values Sub-Objective.* London, United Kingdom: UK Department for Transport.

Draaijers, G., Annema, J.A., Korver, W., Otte, H., de Vos, P., & Van Rhijn, M. (2013). *Kan effectbepaling niet eenvoudiger? Toepassen vuistregels en expert judgement in m.e.r.* Deventer, the Netherlands: Goudappel Coffeng.

Ecorys (2007, October 31). *Effecten aanvullende varianten eindbeeld kilometerprijs.* Rotterdam, the Netherlands. Retrieved from http://parlis.nl/pdf/bijlagen/BLG14213.pdf

Eijgenraam, C.J.J., Koopmans, C.C., Tang, P.J.G. & Verster, A.C.P. (2000). *Evaluatie van Infrastructuurprojecten: Leidraad voor Kosten-batenanalyse.* The Hague/Rotterdam, the Netherlands: CPB and NEI.

Elhorst, J.P., Heyma, A., Koopmans, C.C. & Oosterhaven, J. (2004). *Indirecte Effecten Infrastructuurprojecten: Aanvulling op de Leidraad OEI.* Groningen/Amsterdam, the Netherlands: Rijksuniversiteit Groningen and SEO.

Fietstelweek (2015). *Resultaten 2015.* Utrecht, the Netherlands. Retrieved from http://fietstelweek.nl/resultaten-2015/

Geurs, K.T. (2006). *De optiewaarde van het spoor: De waardering van de aanwezigheid en het gebruik van regionale spoorlijnen.* Bilthoven, the Netherlands: Milieu en Natuur Planbureau.

Geurs, K.T., & Van Eck, R. (2001, June). *Accessibility measures: review and applications. Evaluation of accessibility impacts of land-use transport scenarios, and related social and economic impacts.* Bilthoven, the Netherlands: RIVM.

Geurs, K.T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography, 12,* 127–140

Golub, A., & Martens, K. (2014). Using principles of justice to assess the modal equity of regional transportation plans. *Journal of Transport Geography, 41,* 10–20.

Groot, W., Warffemius, P., Koopmans, C., & Annema, J. A. (2011). *Gegeneraliseerde reiskosten als maat voor bereikbaarheid.* Antwerpen, Belgium.

Gwilliam, K. (2013). Cities on the move: ten years after. *Research in Transportation Economics, 40,* 3–18.

Handy, S. L., & Niemeier, D. A. (1997). Measuring accessibility: an exploration of issues and alternatives. *Environment and Planning, A* 29*,* 1175–1194.

Hansen, W.G. (1959). How accessibility shapes land use. *Journal of American Institute of Planners, 25*(1), 73–76.

Heeres, N., Tillema, T., & Arts, J. (2012). Integration in Dutch planning of motorways: From ‘‘line’’ towards ‘‘area-oriented’’ approaches*. Transport Policy, 24,* 148–158.

Hiscock, R., Macintyre, S., Kearns, A., & Ellaway, A. (2002). Means of transport and ontological security: Do cars provide psycho-social benefits to their users? *Transportation Research Part D: Transport and Environment, 7*(2), 119-135.

Hof, B., Koopmans, C. &. Teulings, C. (2006). *Een nieuwe fundament: Borging van publieke belangen op de woningmarkt.* Amsterdam, the Netherlands: SEO.

Jones, S.R. (1981*). Accessibility measures: a literature review.* Wokingham, United Kingdom: Transport and Road Research Laboratory.

Karou, S., Hull, A. (2014). Accessibility modelling: predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK. *Journal of Transport Geography, 35*, 1–11.

Kennisinstituut voor Mobiliteitsbeleid (KiM) (2013). *De maatschappelijke waarde van kortere en betrouwbaardere reistijden.* The Hague, the Netherlands. Retrieved from https://www.kimnet.nl/publicaties/rapporten/2013/11/18/de-maatschappelijke-waarde-van-kortere-en-betrouwbaardere-reistijden

Le Vine, S., Lee-Gosselin, M., Sivakumar, A., Polak, J. (2013). A new concept of accessibility to personal activities: development of theory and application to an empirical study of mobility resource holdings. *Journal of Transport Geography, 31,* 1–10.

Liao, F. & Van Wee, B. (2016, May 17). Accessibility measures for robustness of the transport system*. Transportation, 43,* 1–21

Lin, T., Xia, J., Robinson, T.P., Goulias, K.G., Church, R.L., Olaru, D., Tapin, J., & Han, R. (2014). Spatial analysis of access to and accessibility surrounding train stations: a case study of accessibility for the elderly in Perth, Western Australia. *Journal of Transport Geography, 39,* 111–120.

Litman, T. (2002). Evaluating transportation equity. *World Transport Policy & Practice, 8,* 50–65.

Longley, P.A., Goodchild, M.F., Maguire, D.J., & Rhind, D.W. (2011). *Geographic information systems & science.* Hoboken, NJ: Aptara.

Manaugh, K., El-Geneidy, A. (2012). *Who benefits from new transportation infrastructure? Using accessibility measures to evaluate social equity in transit provision.* Montreal, Canada.

Martínez, L.M., Viegas, J.M. (2013). A new approach to modelling distance-decay functions for accessibility assessment in transport studies. *Journal of Transport Geography, 26,* 87–96.

Ministry of Infrastructure and Environment (2012, September). *KBA bij MIRT-verkenningen: Kader voor het invullen van de OEI-formats.* The Hague, the Netherlands. Retrieved from https://www.rwseconomie.nl/documenten/rapporten/2016/augustus/augustus/kader-kba-bij-mirt-verkenningen

Ministry of Infrastructure and Environment (2016, June 9). *De nieuwe hoofdwegennet indicator.* The Hague, the Netherlands. Retrieved from https://www.rijksoverheid.nl/.../De+nieuwe+hoofdwegennet+indicator_eindrapport.pdf

Modijefsky, M., & Vervoort, K. (2010, June). *Buitenring Parkstad Limburg: Toetsing op doelbereik & MKBA. Rotterdam.* Rotterdam, the Netherlands: Ecorys. Retrieved from www.mkba-informatie.nl/index.php/download_file/force/132/315/

Nationale Fiets Projecten (2016). *Fietsplan en belastingdienst.* Heerenveen, the Netherlands. Retrieved from http://www.nationalefietsprojecten.nl/pageid=975/fietsplan_en_de_belastingdienst.html

Netherlands Commission for Environmental Assessment (2011). *Toepassing 'Elverding' in plan-m.e.r.* Utrecht, the Netherlands. Retrieved from http://api.commissiemer.nl/docs/mer/diversen/factsheet_21.pdf

Niemeier, D. A. (1997). Accessibility: an evaluation using consumer welfare. *Transportation, 24,* 377–396.

Province of Gelderland (2016). *Over de snelfietsroute Cuijk-Mook-Nijmegen.* Arnhem, the Netherlands. Retrieved from http://www.snelfietsroutecuijknijmegen.nl/

Pyrialakou, V.D., Gkritza, K., & Fricker, J.D. (2014). Accessibility, mobility, and realized travel behavior: Assessing transport disadvantage from a policy perspective. *Journal of Transport Geography, 51,* 252–269.

Redman, L., Friman, M., Gärling, T., & Hartig, T. (2013). Quality attributes of public transport that attract car users: A research review. *Transport Policy, 25,* 119–127.

Rijkswaterstaat (2004). *Ondernemingsplan: een nieuw perspectief voor Rijkswaterstaat* (Business plan Directorate-General of Public Works and Water Management). The Hague, the Netherlands.

Rijkswaterstaat (2010, Augustus 16). *Zinvolle effectbepaling (ZEB) verkeer: Eindrapport i.o.v. projectdirectie sneller en beter.* The Hague, the Netherlands.

Rijkswaterstaat & Ecorys (2012, February 1). *Veiligheid in maatschappelijke kosten-baten analyse.* Delft, the Netherlands.

RIVM (2010). *Exchanging car trips by cycling in the Netherlands.* Bilthoven, the Netherlands.

RMO North-Limburg (2013). *De infra-ambitie van Noord-Limburg.* Venlo, the Netherlands. Retrieved from http://www.rmonoordlimburg.nl/documenten/Infra-ambitie_Noord-Limburg.pdf

RMO Venray-Venlo (2011*). Regionale mobiliteitsvisie.* Venlo, the Netherlands. Retrieved from http://www.rmonoordlimburg.nl/media/pdf/RMO001_%20rapportage.pdf

Royal HaskoningDHV (2014, October 27). *Varianten bereikbaarheid Wageningen.* Amersfoort, the Netherlands: Provincie Gelderland. Retrieved from https://www.gelderland.nl/bestanden/Documenten/Gelderland/05Verkeer-en-vervoer/N-wegen/N781/160812_Samenvatting_Verkeersstudie_Wageningen_definitief.pdf

Rush, C., & Roy, R. (2001, December 1). *Expert judgement in cost estimating: Modelling the reasoning process.* Bedford, United Kingdom. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.18.2813&rep=rep1&type=pdf

Saelensminde, K. (2004). Cost–benefit analyses of walking and cycling track networks taking into account insecurity, health effects and external costs of motorized traffic. *Transportation Research, Part A* 38*,* 593–606.

Sanchez, T.W., Stolz, R., Ma, J.S. (2003). *Moving to equity: Addressing inequitable effects of transportation policies on minorities.* Cambridge, MA: Harvard University and Center for Community Change Report.

Schleinitz, K., Petzoldt, T., Franke-Bartholdt, L., Krems, J., & Gehlert, T. (2015). The German naturalistic cycling study: Comparing cycling speed of riders of different e-bikes and conventional bicycles. *Safety Science, 92,* 290-297.

Silva, C., Bertolini, L., Brömmelstroet, M. te, Milakis, D., & Papa, E. (2017). Accessibility instruments in planning practice: Bridging the implementation gap. *Transport Policy, 53,* 135–145.

Struiksma, R., & Tillema, T. (2009). *Planning van rijkswegen: van lijn- naar gebiedsopgave.* Groningen, the Netherlands. Retrieved from https://www.rug.nl/research/ursi/collaboration/duurzamewegen/planningvanrijkswegenvanlijnnaargebiedsopgave.pdf

SWOV (2014). *SWOV-Factsheet Kruispunttypen.* The Hague, the Netherlands. Retrieved from https://www.swov.nl/sites/default/files/publicaties/gearchiveerde-factsheet/nl/factsheet_kruispunttypen_gearchiveerd.pdf

SWOV & Ecorys (2008). *De invloed van mobiliteit op verkeersveiligheid.* The Hague, the Netherlands. Retrieved from www.swov.nl/en/file/15788/download?token=8zhpXUF3

Tillema, T., & Jorritsma, P. (2016, July). *Ruimtelijke kenmerken: Geografische bereikbaarheid en reisgedrag.* The Hague, the Netherlands: KiM. Retrieved from https://www.kimnet.nl/publicaties/rapporten/2016/08/11/ruimtelijke-kenmerken-geografische-bereikbaarheid-en-reisgedrag

TRB (2002). *Estimating the benefits and costs of public transit projects: A guidebook for practitioners.* Washington D.C.: National Academy Press.

V&W (2004). *Nota Mobiliteit: Naar een betrouwbare en voorspelbare bereikbaarheid.* The Hague, the Netherlands.

V&W (2008). *MobiliteitsAanpak: Vlot en veilig van deur tot deur.* The Hague, the Netherlands.

V&W & VRO (1977). *Structuurschema Verkeer en Vervoer.* The Hague, the Netherlands: Staatsuitgeverij.

V&W & VROM (1988). *Tweede Struktuurschema Verkeer en Vervoer: Beleidsvoornemen.* The Hague, the Netherlands.

Van den Berg, L., Busman, R., Dobbelsteijn, R., Hidding, M., Hoofwijk, H., Van Ingen, T., … Yntema, U. (2016, February). *Een draagvlakvariant voor doorstroming en bereikbaarheid voorgesteld door een coalitie van bewonersorganisaties en maatschappelijke groeperingen.* Wageningen, the Netherlands: Wageningen goed op weg. Retrieved from http://wageningengoedopweg.nl/wp-content/uploads/WGOW-Rapport_AVB29022016-def-los-LRV_web.pdf

Van den Brink, M.A. (2009*). Rijkswaterstaat on the horns of a dilemma.* (Doctoral dissertation, Rijksuniverstiteit Groningen, Groningen, the Netherlands). Retrieved from http://www.rug.nl/research/portal/publications/rijkswaterstaat-on-the-horns-of-a-dilemma(d438a444-ac5b-4a7b-9412-cefbf62967e2).html

Van Overdijk, R.P.J. (2016). *The influence of comfort aspects on route and mode choice decisions of cyclists in the Netherlands: An approach to improve bicycle transportation planning in practice.* (Master's thesis). Eindhoven University of Technology, Eindhoven, the Netherlands.

Verdaas, C., Slob, A., Hofstra, P., & Mastwijk, J. (2005). *MIT-manifest "Van roerei tot omelet".* The Hague, the Netherlands.

Verschuren, P., & Doorewaard, H. (2015, July). *Het ontwerpen van een onderzoek.* Amsterdam, the Netherlands: Boom Lemma uitgevers.

Vervoort, K., van der Ham, C., & van Breemen, R. (2015, December 16). *MKBA Randweg Nederweert.* Rotterdam, the Netherlands: Ecorys. Retrieved from http://www.limburg.nl/Beleid/Verkeer_en_Vervoer/Infraprojecten/N266_Nederweert_A2

Wever, E., & Rosenberg, F. (2012). *Omgevingskwaliteiten bij MIRT-projecten: Overzicht van methoden voor het meten en waarderen van welvaartseffecten in een MKBA.* Amsterdam, the Netherlands: Ministry of Infrastructure and Environment. Retrieved from http://www.mkba-informatie.nl/mkba-voor-gevorderden/richtlijnen/omgevingskwaliteiten-bij-mirt-projecten/

Wilson, K.J. (2017). An investigation of dependence in expert judgement studies with multiple experts. *International Journal of Forecasting, 33,* 325–336.

Yan-yan, C., Pan-yi, W., Jian-hui, L., Guo-chen, F., Xin, L. & Yi, G. (2016). An evaluating method of public transit accessibility for urban areas based on GIS. *Procedia Engineering, 137,* 132 – 140.

APPENDICES

Appendix A: Overview of accessibility measures

Table A.1: Overview of accessibility measures (Curtis & Scheurer, 2007)

	Methodological category	Approach/measure	Pros and cons
1) Spatial separation measures	Spatial separation model (Bhat et al., 2000) Infrastructure measures (Geurs & Van Eck, 2001) Travel-cost approach (Baradaran & Ramjerdi, 2001)	Measures travel impediment or resistance between origin and destination, or between nodes. Travel impediment measures can include: - Physical (Euclidean) - Distance - Network distance (by mode) - Travel time (by mode) - Travel time (by network status, congestion, free-flow etc.) - Travel cost (variable user cost or total social cost) - Service quality (e.g. public transport frequency)	Data is generally easily available from digital mapping material and other public sources. No consideration of land use patterns and spatial distribution of opportunities.
2) Contour measures	Contour measures (Geurs & Van Eck, 2001) Cumulative opportunity model (Bhat et al., 2000)	Defines catchment areas by drawing one or more travel time contours around a node, and measures the number of opportunities within each contour (jobs, employees, customers etc.).	Incorporates land use and attends to infrastructure constraints by using travel time as indicator for impediment. Definition of travel time contours may be arbitrary and does not differentiate between activities and travel purposes. Methodology cannot capture variation in accessibility between activities within the same contour.
3) Gravity measures	Gravity model (Bhat et al., 2000) Potential accessibility measure (Geurs & Van Eck, 2001)	Defines catchment areas by measuring travel impediment on a continuous scale.	More accurate representation of travel resistance than in contour measure, but tends to be less legible. Does not differentiate between travel purposes and individual drivers for travel.
4) Competition measures	Competition measures (van Wee, Hagoort, & Annema, 2001) Joseph & Bantock measure (Joseph & Bantock, 1982) Inverse balancing factor model (Geurs & Van Eck, 2001)	Incorporates capacity constraints of activities and users into accessibility measure. May make use of any of the preceding three models.	Provides a regional perspective on accessibility.
5) Time-space measures	Time-space measures (Bhat et al., 2000; Geurs & Van Eck, 2001) Person-based measures (Geurs & van Wee, 2004)	Measures travel opportunities within pre-defined time constraints.	Well-suited to examine trip chaining and spatial clustering of activities. Usually requires project-specific user surveys, limiting the geographical range and compatibility of data.
6) Utility measures	Utility measures (Bhat et al, 2000; Geurs & Van Eck, 2001) Utility-based surplus approach (Baradaran & Ramjerdi, 2001)	Measures individual or societal benefits of accessibility. Indicators can include: - Economic utility (to the individual, or to the community) - Social or environmental benefits (e.g. social inclusion, greenhouse effects) - Individual motivations of travel (by activity or travel purpose) - Option and non-user benefits of transport infrastructure	The empirical link between infrastructure provision and economic performance is tenuous and contested. The indicator can analyze existing motivations of travel, but cannot anticipate feedback effects between land use and travel patterns, or future behavior patterns of users.
7) Network measures	Multiple centrality assessment (Porta et al., 2006)	Measures centrality across entire movement networks. Networks can be represented by: - Primal approach (networks are understood as intersections connected by route segments) - Dual approach (networks are understood as route segments connected by intersections)	More intuitive, and allows for the incorporation of a travel impediment measure in the network analysis. Clearly captures the topological form of a network, and can be used to assess its spatial legibility.

Appendix B: Documentary analysis

Data is gathered by documentary analysis. The following documents represent relevant attributes and these documents are described in this appendix:

- Bakker & Zwaneveld (2009);
- Decisio & Transaction Management Centre (2012);
- Ministry of Infrastructure and Environment (2012);
- Redman, Friman, Gärling, & Hartig (2013);
- Vervoort, Van der Ham, & Van Breemen (2015);
- Wever & Rosenberg (2012).

Bakker & Zwaneveld (2009)
Table B.1 provide a compact overview of all possible prosperity effects of a public transport project. Some rare effects are not reflected in the tables. The tables were drawn up after examining several concrete cost-benefit analysis and several domestic and foreign guidelines. The various effects are discussed in more detail in section 3.3.

Table B.1: Attributes for public transport travelers (Bakker & Zwaneveld, 2009)

Attributes	Description
Accessibility benefits (travel time, waiting time, and reliability)	- commuting - business - social-recreational and other - school
Comfort (during travel time)	- per transport mode/facility (e.g. 'railbonus') - crowding in train/station - material - train stations
Effects during construction	
Option value and 'non-utility value'	
Agglomeration effects	- increase/decrease productivity
Budgetary impact higher/lower GDP	- due to higher > lower participation - due to longer > shorter working hours - due to more productive > less productive jobs
Other budgetary impacts	- excise duties/charges
Subsidies	
International effects	
Emissions, local	- of public transport, walking, mopeds/bikes, motors and cars
Emissions, global	- of public transport, walking, mopeds/bikes, motors and cars

Noise (disturbance)	- of public transport, walking, mopeds/bikes, motors and cars
Traffic safety	- of public transport, walking, mopeds/bikes, motors and cars
Effects on nature and recreation	
Availability and the use of public transport by social target groups (social function)	- relationship with non-utility value
Increase GDP	- due to agglomeration benefits - due to increased employment - due to longer working hours - due to accepting more productive jobs
Income and spending effects (income redistribution)	
General: pros and cons per ethnic group, region and users versus non-users	

Decisio & Transaction Management Centre (2012)
The Ministry of Infrastructure and Environment uses the OEI methodology (Overview Effects Infrastructure) to analyze the social costs and benefits of infrastructure and other measures. For the large MIRT projects the use of this method is mandatory. For bicycle infrastructure this method is hardly used until 2012, partly because the investment amounts are often relatively limited. However, a social cost-benefit analysis (SCBA) is also for smaller projects a useful way to structure objective decision information. Therefore, the Ministry of Infrastructure and Environment instructed Decisio & Transaction Management Centre to perform a quick scan of the possibilities of application of the OEI tools for bicycle measures.

Table B.2: Overview attributes (Decisio & Transaction Management Centre, 2012)

Attributes	Valuation
Travel time	Train: €7,60/h; Bus: €6,65/h; Car: €10,70/h; Bicycle: €6,65/h-€14,03/h
Reliability	Bus, car and bicycle: 25% of travel time benefits
Travel costs	Train: 8,00 eurocent/km; Bus: 11,00 eurocent/km; Car: 8,63 eurocent/km; Bicycle: 7,00 eurocent/km
Subsidies	Bus: 29 eurocent/km; Car: 0; Bicycle: 0
Excise duties	Bus: 0; Car: 3,2 eurocent/km; Bicycle: 0
Health effects (of cycling)	Bicycle: 2,1 eurocent/km
Effects on housing market and land market	
Effects on labor market (increase labor productivity)	Bicycle: 4,6 eurocent/km
Network effects	
Emissions (pollution)	

Noise	Inside built-up area: Bus and car: € 0,011/km; Outside built-up area: Bus and car: €0,001/km
Traffic safety	Inside built-up area: Bus: 5,4 eurocent/km; Car: 6,3 eurocent/km; Bicycle: 6,2 eurocent/km; Outside built-up area: Bus: 2,1 eurocent/km; Car: 2,5 eurocent/km; Bicycle: 2,5 eurocent/km
Effects on nature and ecology	Described qualitatively

Ministry of Infrastructure and Environment (2012)

Ministry of Infrastructure and Environment (2012) developed among others the format road projects (table B.3). This format focuses on the most common road projects in the MIRT and is suitable for the following types of projects:

- Better use of existing infrastructure
- Capacity extension of existing infrastructure
- Construction of new infrastructure

These types of projects are related to step five, six and seven of the ''Ladder van Verdaas''. Also for other road projects, for example in the case of a better integration of existing infrastructure, the increase of the spatial quality, or the increase of traffic safety, the format (or a large part of it) will be relevant (Ministry of Infrastructure and Environment, 2012). In such a case, it is recommended to align the format with the client.

Ministry of Infrastructure and Environment developed the basis format for public transport projects (table B.4). Besides the monetized impacts over the entire period, the physical project effects are also displayed.

Table B.3: Attributes of basis format road projects (Ministry of Infrastructure and Environment, 2012)

Attributes	Measure unit
Travel time	Hours
Reliability	Euro
Travel costs	Vehicle km
Excise duties	Euro
Effects during construction period	Hours
Traffic safety	Injury victims
External safety	Number of objects
Greenhouse gas emissions	Emissions
Air quality	Emissions
Noise	Number of noise nuisance (or houses) per decibel category

Effects on soil	Number of cubic meters (amount of earthmoving)
Effects on groundwater and surface water	Areas (impact water management)
Effects on nature	Number of hectares or length
Effects on landscape and heritage	Number of (impaired) objects

Table B.4: Attributes of basis format public transport projects (Ministry of Infrastructure and Environment, 2012)

Attributes	Measure unit
Travel time	Hours
Waiting time	Hours
Comfort	Occupancy rate
Reliability	% change
Travel costs	Euro
Effects during construction period	Hours
Traffic safety	Injury victims
Social safety	Change in social safety
Greenhouse gas emissions	Emissions
Air quality	Emissions
Noise	Number of noise nuisance (or houses) per decibel category
Effects on soil	Number of cubic meters (amount of earthmoving)
Effects on groundwater and surface water	Areas (impact water management)
Effects on nature	Number of hectares or length
Effects on landscape and heritage	Number of (impaired) objects

Table B.5: Attributes regarding indirect effects (Ministry of Infrastructure and Environment, 2012)

Attributes	Measure unit
Extra tax levies (excise duties)	Euro
Effects on product market	Productivity
Effects on labor market	Number of jobs
Knowledge and innovation spillover effects	Productivity
International effects	Number of jobs
Effects on housing market and land market	Hectare

Redman, Friman, Gärling, & Hartig (2013)

Public transport (PT) together with cycling and walking are generally agreed to be sustainable alternatives to private car use. The aim of the authors of this document is to contribute to a better understanding of the aspects regarding public transport quality. Toward achieving this aim, relevant research was sought to answer the question: What quality attributes of public transport services are attractive to users (table B.6)?

Table B.6: Attributes according to Redman, Friman, Gärling, & Hartig (2013)

Attributes	Definition
Travel time (speed)	The time spent travelling between specified points
Waiting time (ease of transfers / interchanges)	How simple transport connections are (time spent waiting)
Frequency	How often the service operates during a provided period
Travel cost (pricing)	The monetary cost of travel
Reliability	How closely the actual service matches the route timetable
Comfort	How comfortable the journey is regarding access to seat, noise levels, driver handling, air-conditioning
Safety	How safe from traffic accidents passengers feel during the journey as well as personal safety
Information provision	How much information is provided about routes and interchanges
Vehicle condition	The physical and mechanical condition of vehicles, including frequency of breakdowns

Vervoort, Van der Ham, & Van Breemen (2015)

Construction of large infrastructure has not only traffic effects and effects on the environment, but also makes heavy demands on the available public resources (Vervoort, Van der Ham, & Van Breemen, 2015). For better transparency and commercialization of policy information about the usefulness and necessity of infrastructure projects, the Ministry of Transport and the Ministry of Economic Affairs have initiated the so-called OEEI guide.

Central Planning Bureau (CPB) and Ecorys (formerly NEI) have prepared this guide in 1999, which is based on several sub-studies. OEEI (now renamed OEI) stands for Research (Economic) Effects of Infrastructure. This program is a methodological framework designed for social evaluations (social cost-benefit analysis) of major infrastructure projects. In recent years, the system for implementation of social cost-benefit analysis (SCBA) fleshed out in a number of additions. For all projects that have been or are intended to be included in the MIRT project book are required in SCBA (Vervoort, Van der Ham, & Van Breemen, 2015). This therefore applies to all government projects, but also for many regional projects a SCBA is increasingly prescribed to allow careful decision.

Since September 2012, there is the so-called SCBA at MIRT Explorations - Framework for completing OEI formats for government projects and large regional projects that need government funding (Ministry of Infrastructure and Environment, 2012). This framework provides guidelines for the implementation of SCBAs (Vervoort, Van der Ham, & Van Breemen, 2015).

The effects of the measure are the difference between the situation without the measure (reference or zero-variant) and the situation including the measure (project variant or project alternative) in a social cost-benefit analysis. The differences between the two situations are the project effects to be included in a SCBA (Vervoort, Van der Ham, & Van Breemen, 2015).

A SCBA is not a new impact study. In a SCBA, the effects of a project are ordered in a systematic manner in accordance with prescribed guidelines and subsequently measured in monetary terms (Vervoort, Van der Ham, & Van Breemen, 2015). The SCBA is therefore a "head" of the impact statement of a project. In the SCBA, the effects of an infrastructure project include accessibility, environment and economy together. By appreciating all effects on the same basis compared to each other, discussions can be conducted objectively on the importance of specific effects. Besides that, there arises a picture of the social and economic desirability of a project with the resultant total results of the SCBA.

A social cost-benefit analysis calculates the socio-economic return on investment in a similar way as happens in a financial analysis. However, a SCBA is not only the financial costs and benefits for those directly involved, but included all the possible effects of a measure for all parties. There is generally made a distinction between direct, indirect and external effects of a measure.

Table B.7: Attributes of social cost-benefit analysis (Vervoort, Van der Ham, & Van Breemen, 2015)

Attributes	Valuation
Travel time	Home-to-work: €9,95/h; Business: €28,23/h; Freight traffic: €45,38/h; Other: €8,07/h
Reliability	25% of travel time benefits
Travel costs	Car: 8,52 eurocent/km; Freight traffic: 13,10 eurocent/km
Excise duties	Car: 4,34 eurocent/km; Freight traffic: 14,94 eurocent/km
Effects on product market Effects on labor market Effects on housing and land market	Indirect effects are between 0 and 30 % of benefits for transport mode car. In the social cost-benefit analysis is applied a rate of 10%
Traffic safety	Fatality: € 3.234.294 per accident; First-aid wounded: € 11.989 per accident; Only material damage: € 4.670 per accident
Greenhouse gas emissions	Inside built-up area: Passenger transport: €11,53/1000 travel km; Freight transport: €8,8/1000 tons-km; Outside built-up area: Passenger transport: €11,53/1000 travel km; Freight transport: €8,8/1000 tons-km
Air quality	Inside built-up area: Passenger transport: €5,85/1000 travel km; Freight transport: €14,40/1000 tons-km; Outside built-up area:

Noise	Passenger transport: €0,53/1000 travel km; Freight transport: €7,10/1000 tons-km
	48-53 dB: 14 eurocent/dB; 53-58 dB: 83 eurocent/dB; 58-63 dB: 152 eurocent/dB; 63-68 dB: 206 eurocent/dB; 68-73 dB: 366 eurocent/dB; >73 dB: 504 eurocent/dB

Wever & Rosenberg (2012)

The environmental quality accessibility describes the change in generalized transport costs for all traffic participants (Wever & Rosenberg, 2012). Attributes that play a role are: Changes in travel expenses and travel time, frequency, number of transit or transshipment sites, service level, reliability and waiting or storage periods (Wever & Rosenberg, 2012). At passenger transport aspects like travel comfort are also important.

Prosperity effects are reflected in a change in travel time, costs, and comfort. Time can then be divided in approximate travel time and reliability. Costs can be split into travel costs and excise duties. The comfort benefits are only applicable to public transport projects.

Table B.8: Attributes according to Wever & Rosenberg (Wever & Rosenberg, 2012)

Attributes	**Method to determine prosperity effects**
Travel time	Travel time/vehicle x occupancy rate x price
Travel costs	Vehicle kilometers x price
Excise duties	Vehicle kilometers x price
Reliability	25% increase of travel time benefits, in the case of decrease in congestion
Comfort (only applicable for public transport)	Different increases related to the travel time valuation Vehicle kilometers x price
Greenhouse gas emissions	Vehicle kilometers x price
Air quality	Vehicle kilometers x price
Noise (disturbance)	Number of houses with noise disturbance x dB x price
Traffic safety	Vehicle kilometers x price
External safety	Group risk
Effects on nature	Number of hectares or length and expert judgement
Effects on soil	Number of cubic meters (amount of earthmoving)
Effects on water	Areas (impact water management)

Appendix C: Maps regarding bike connection Mook - Cuijk

Firstly, figure C.1 presents the location of Mook and surrounding municipalities. Important to note is that all figures are visualized in the same projection. Secondly, figures C.2, C.3 and C.4 present the maps regarding the effects of ‘’’Fietsplan’’ (travel costs) related to step 2 ‘pricing policy’ of the ‘’Ladder van Verdaas. Thirdly, figures C.5-C.13 illustrate the maps regarding the effects on travel time for conventional bike, pedelec and speed pedelec of the priority measure related to step 3 ‘mobility management’ of the ‘’Ladder van Verdaas’’. Finally, figures C.14-C.40 present the effectiveness of the new bike connection between Mook and Cuijk, related to step 7 ‘new infrastructure’ of the ‘’Ladder van Verdaas’’. The effectiveness is visualized respectively based on travel time, travel costs, health effects and traffic safety.

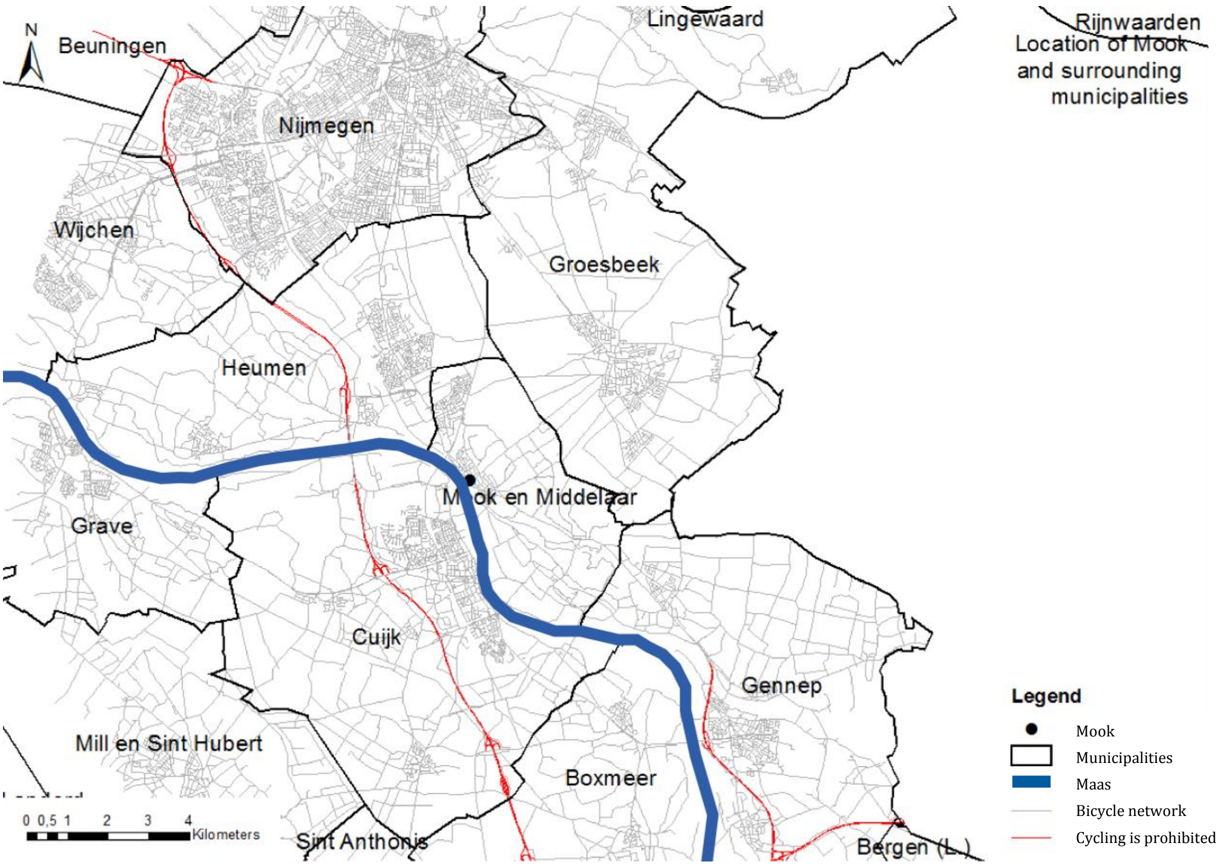

Figure C.1: Location of Mook and surrounding municipalities

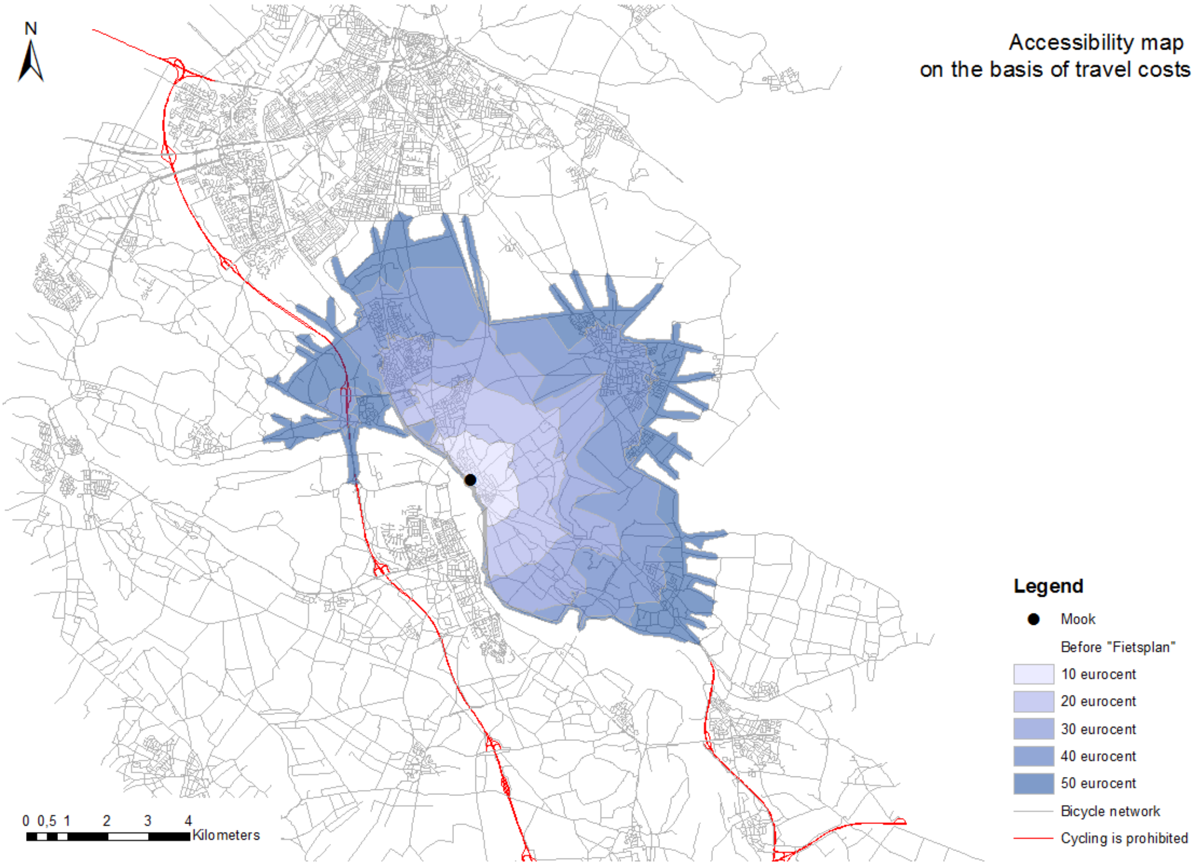

Figure C.2: Accessibility map on the basis of travel costs (before ''Fietsplan'', step 2)

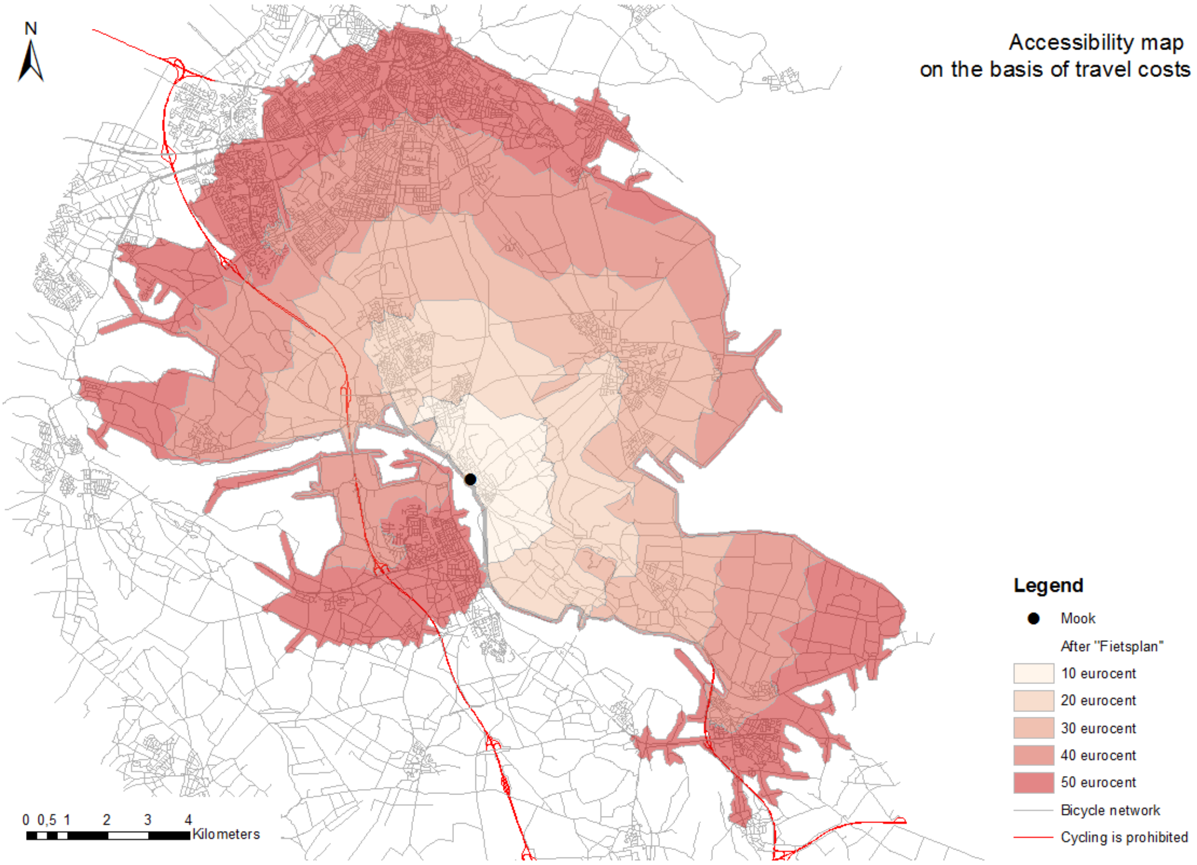

Figure C.3: Accessibility map on the basis of travel costs (after ''Fietsplan'', step 2)

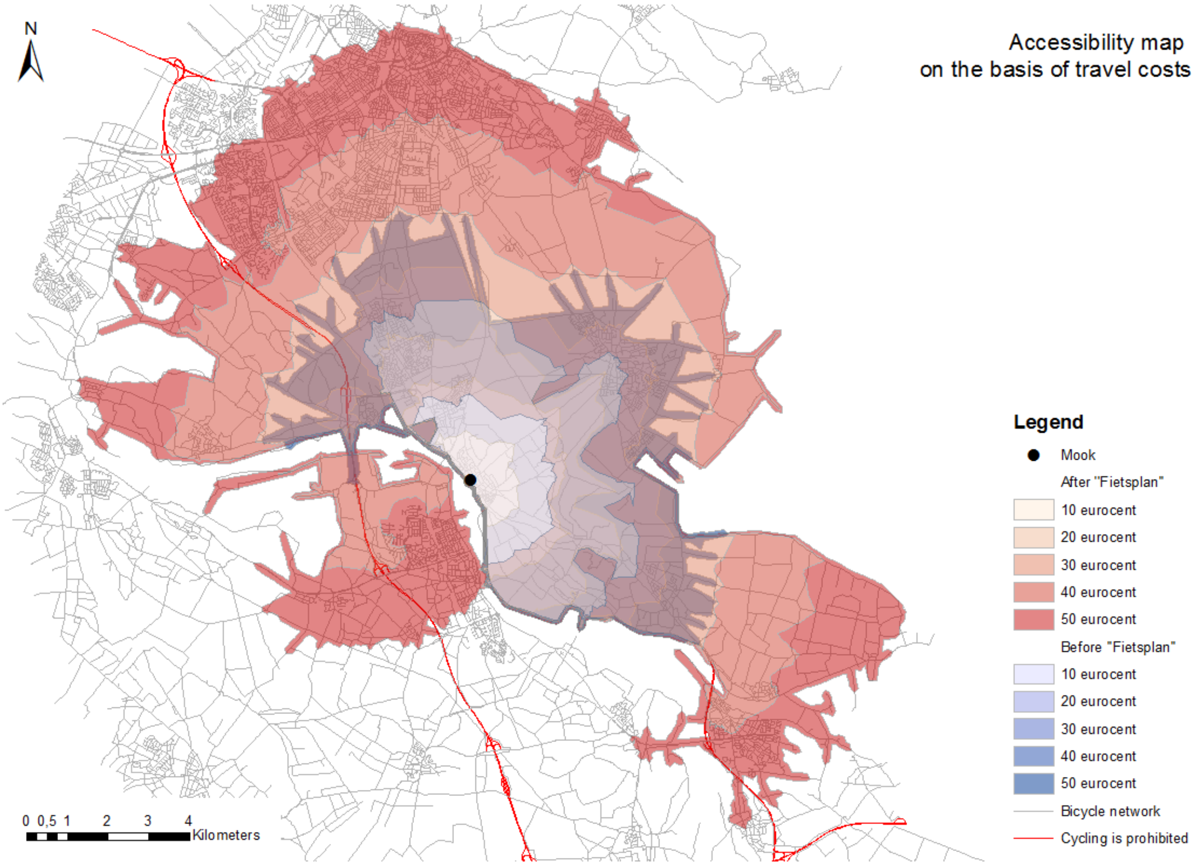

Figure C.4: Accessibility map on the basis of travel costs (before and after ''Fietsplan'', step 2)

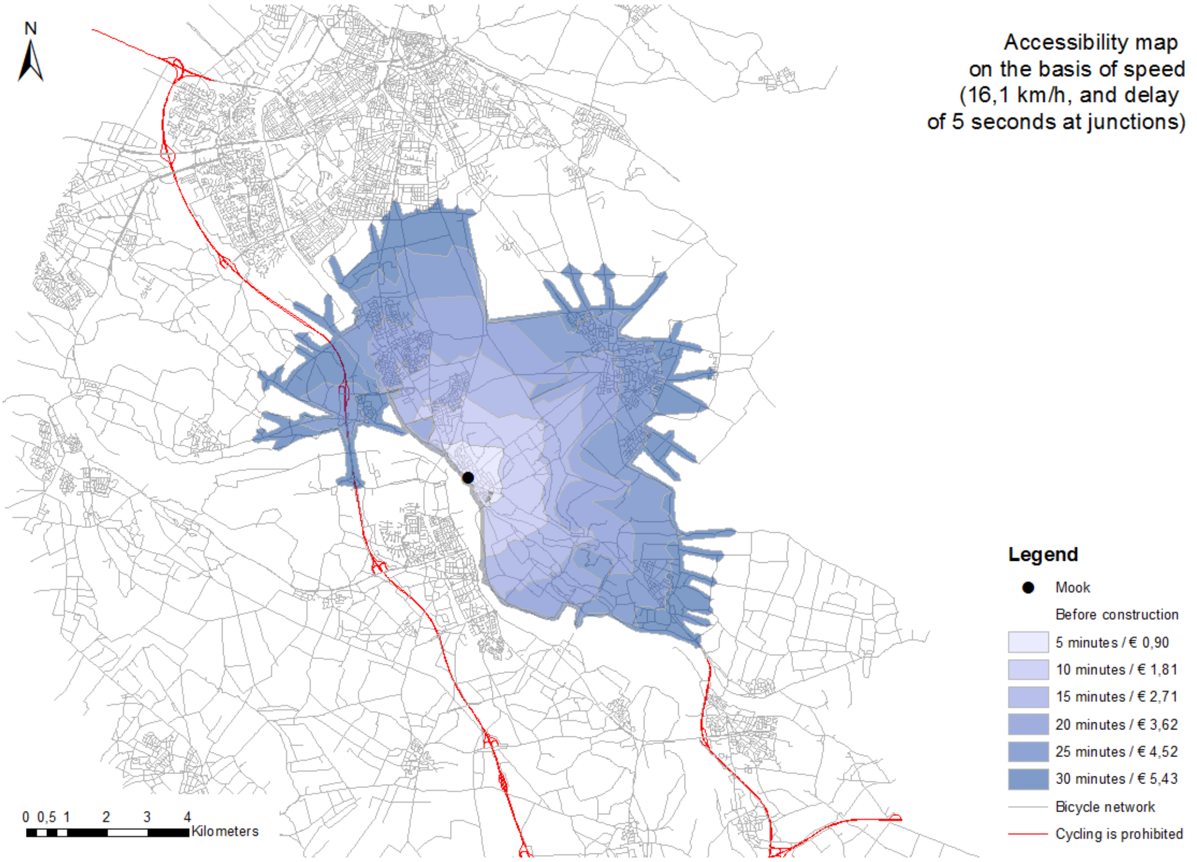

Figure C.5: Accessibility map on the basis of travel speed (before measure, step 3)

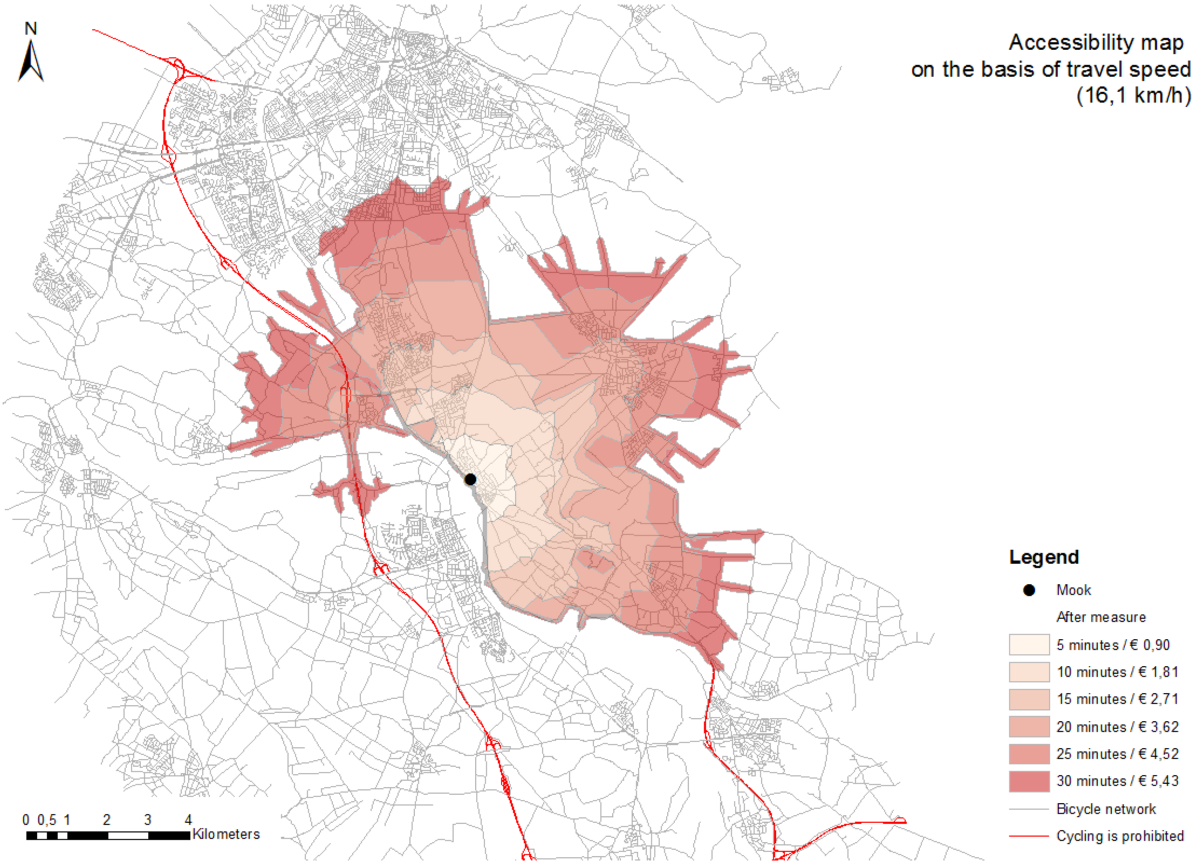

Figure C.6: Accessibility map on the basis of travel speed (after measure, step 3)

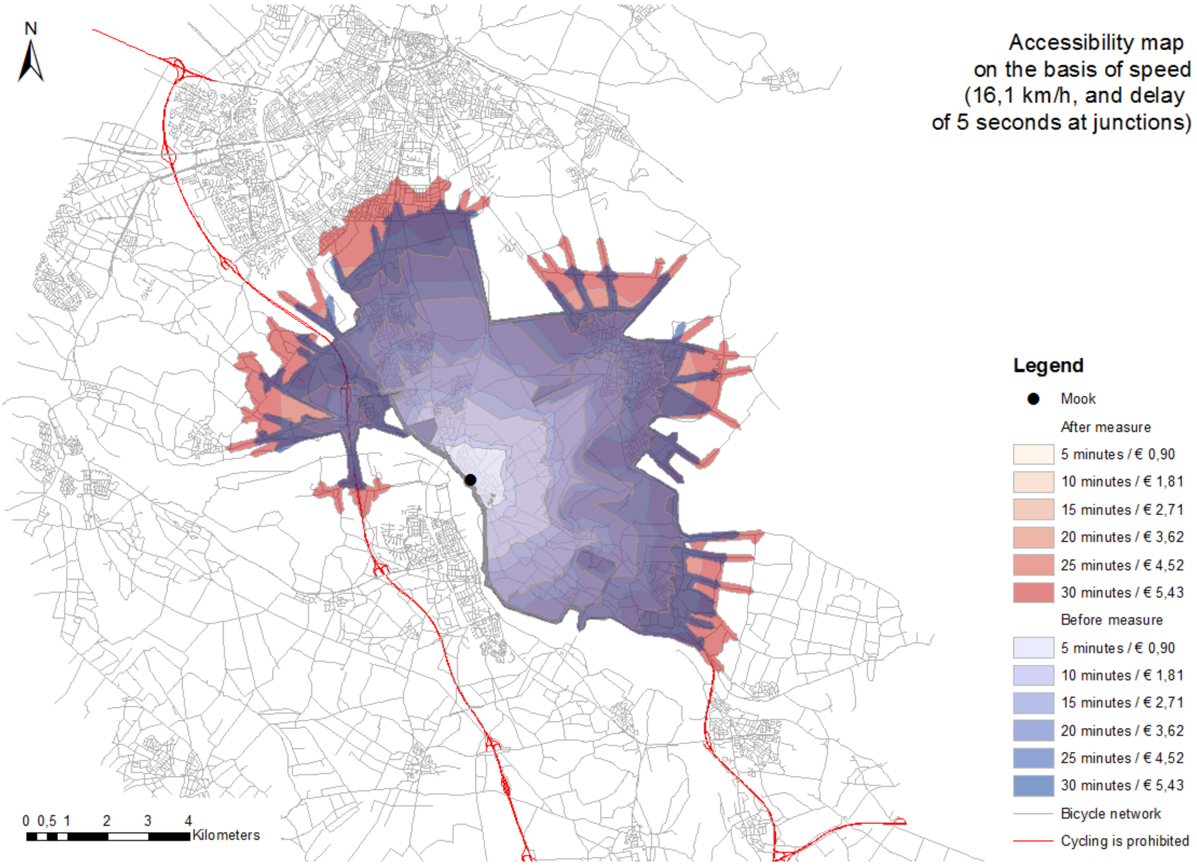

Figure C.7: Accessibility map on the basis of travel speed (before and after measure, step 3)

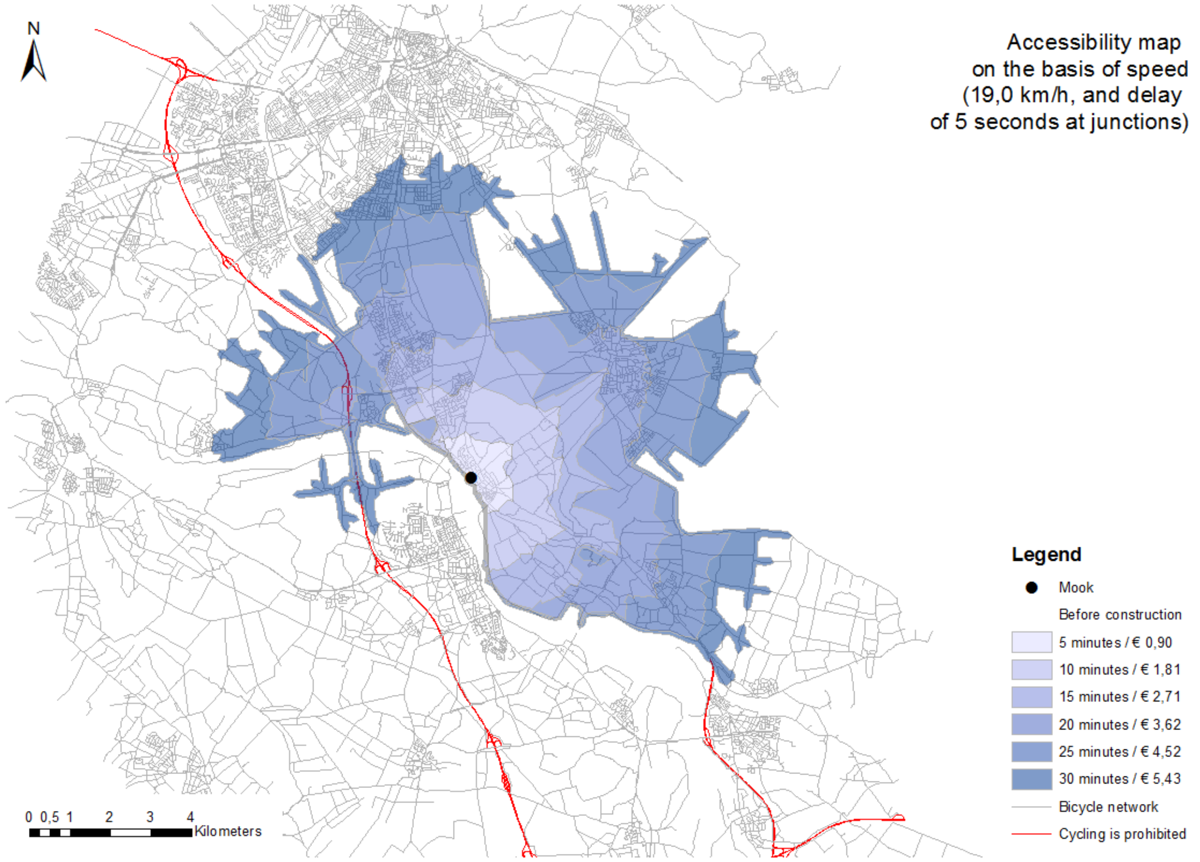

Figure C.8: Accessibility map on the basis of travel speed (before measure, step 3)

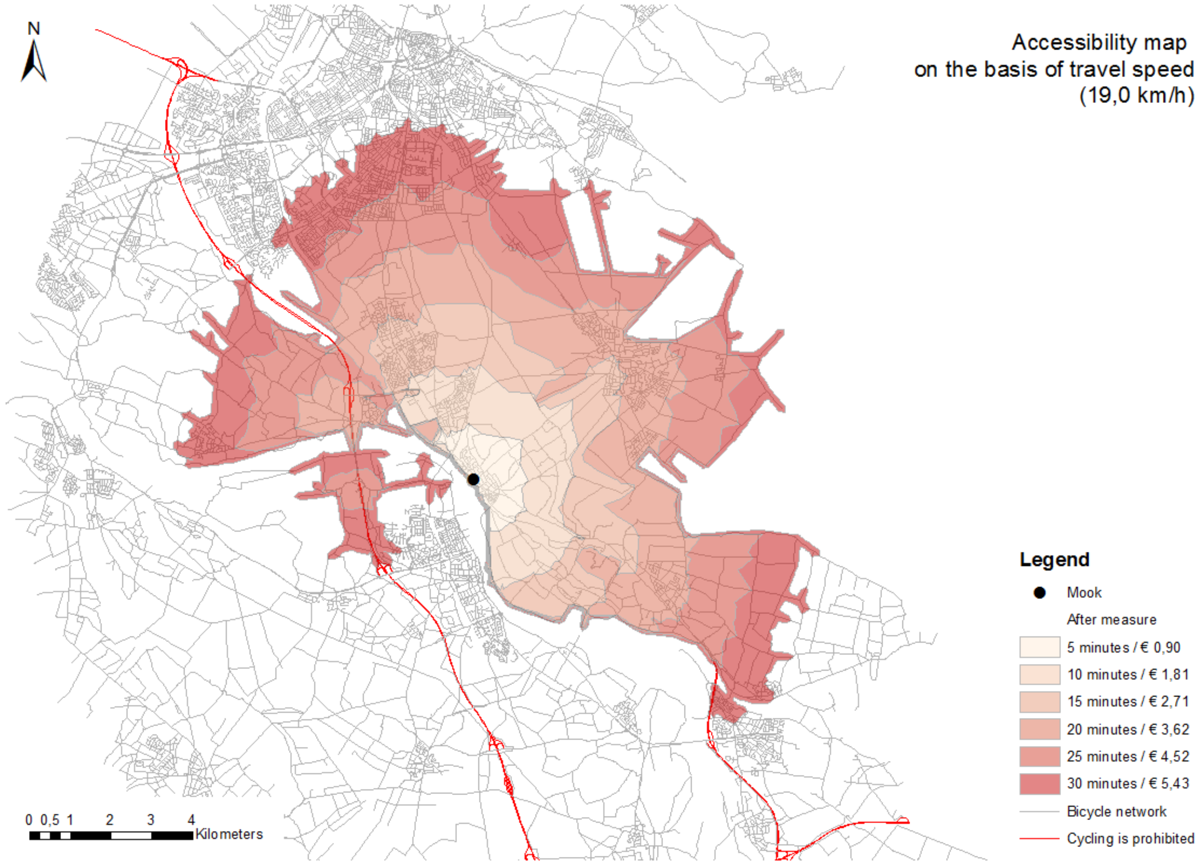

Figure C.9: Accessibility map on the basis of travel speed (after measure, step 3)

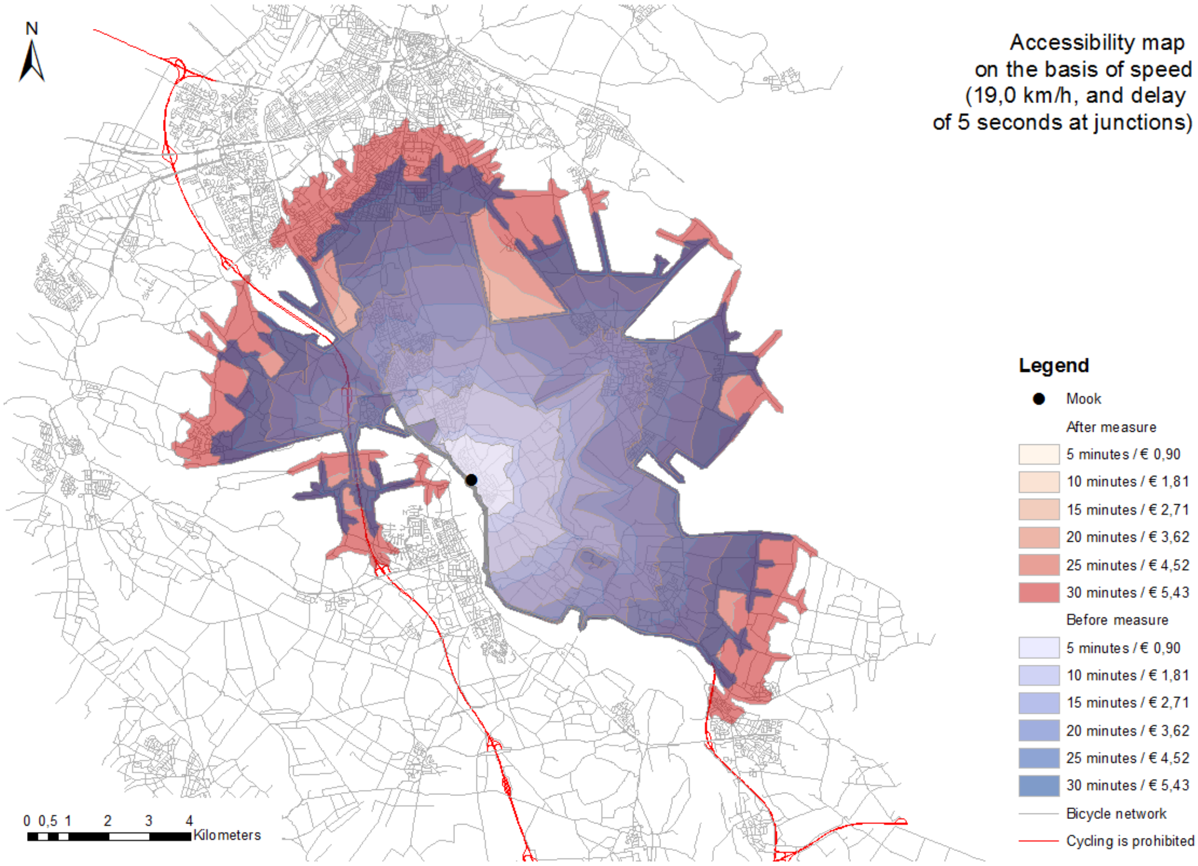

Figure C.10: Accessibility map on the basis of travel speed (before and after measure, step 3)

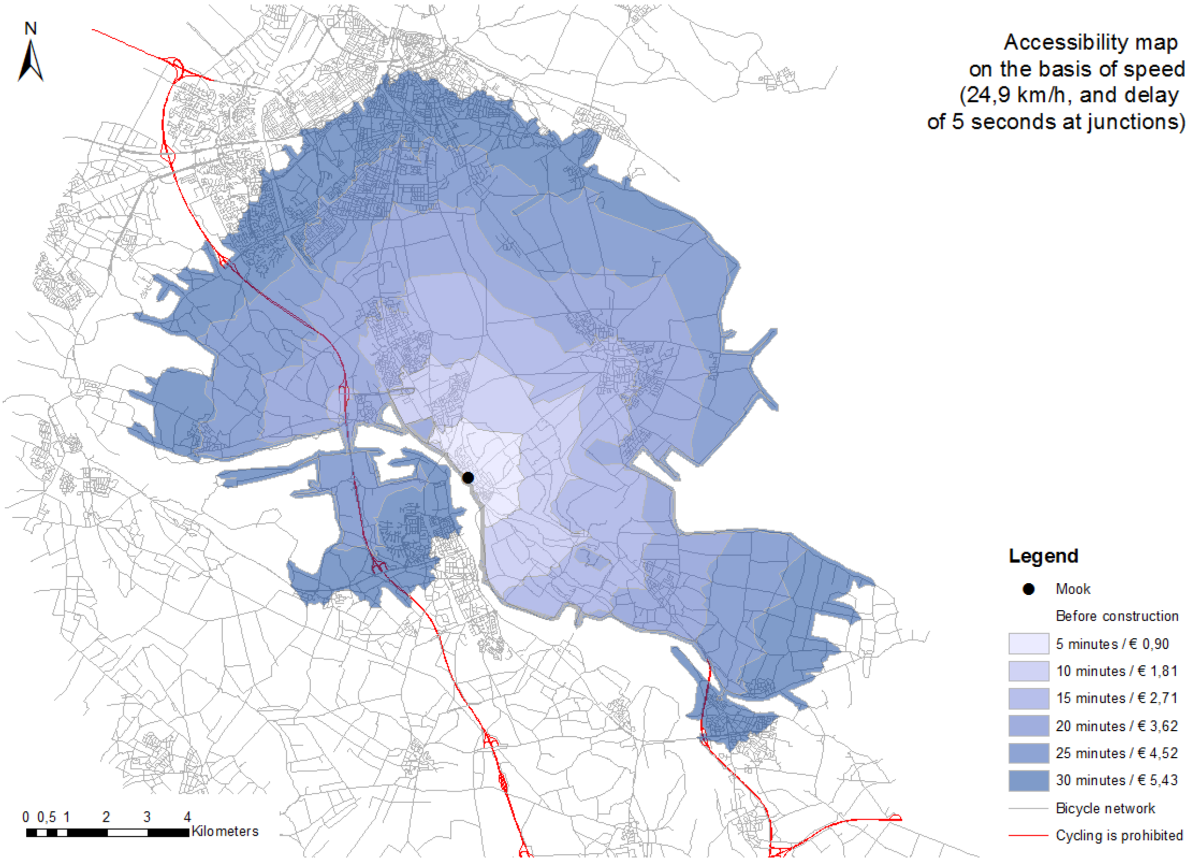

Figure C.11: Accessibility map on the basis of travel speed (before measure, step 3)

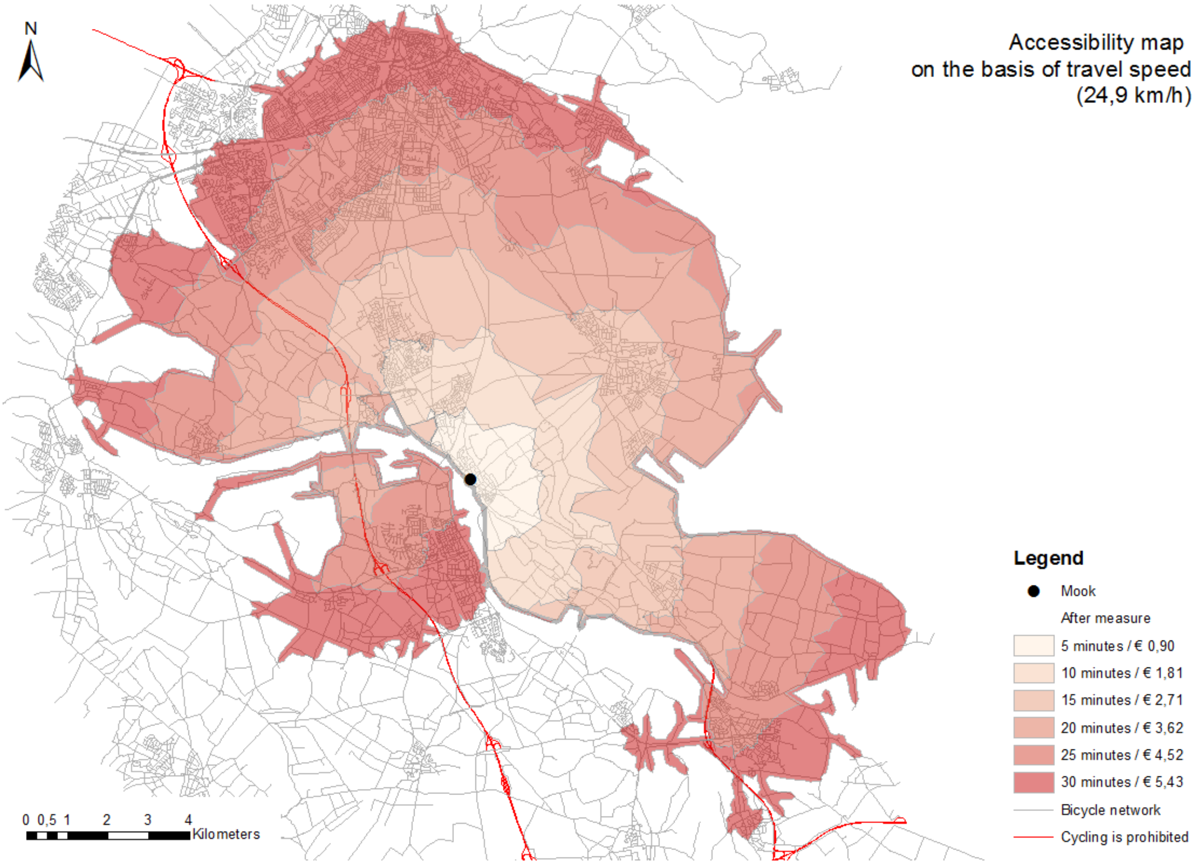

Figure C.12: Accessibility map on the basis of travel speed (after measure, step 3)

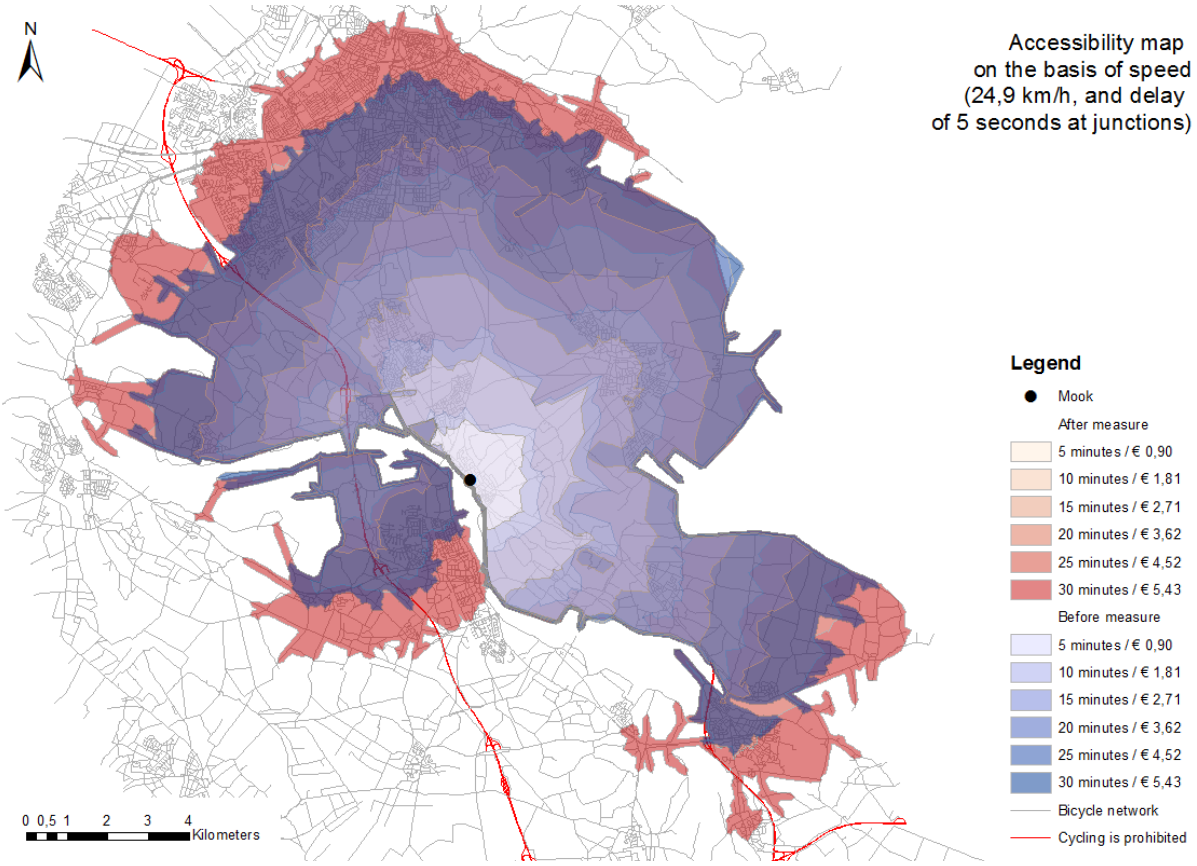

Figure C.13: Accessibility map on the basis of travel speed (before and after measure, step 3)

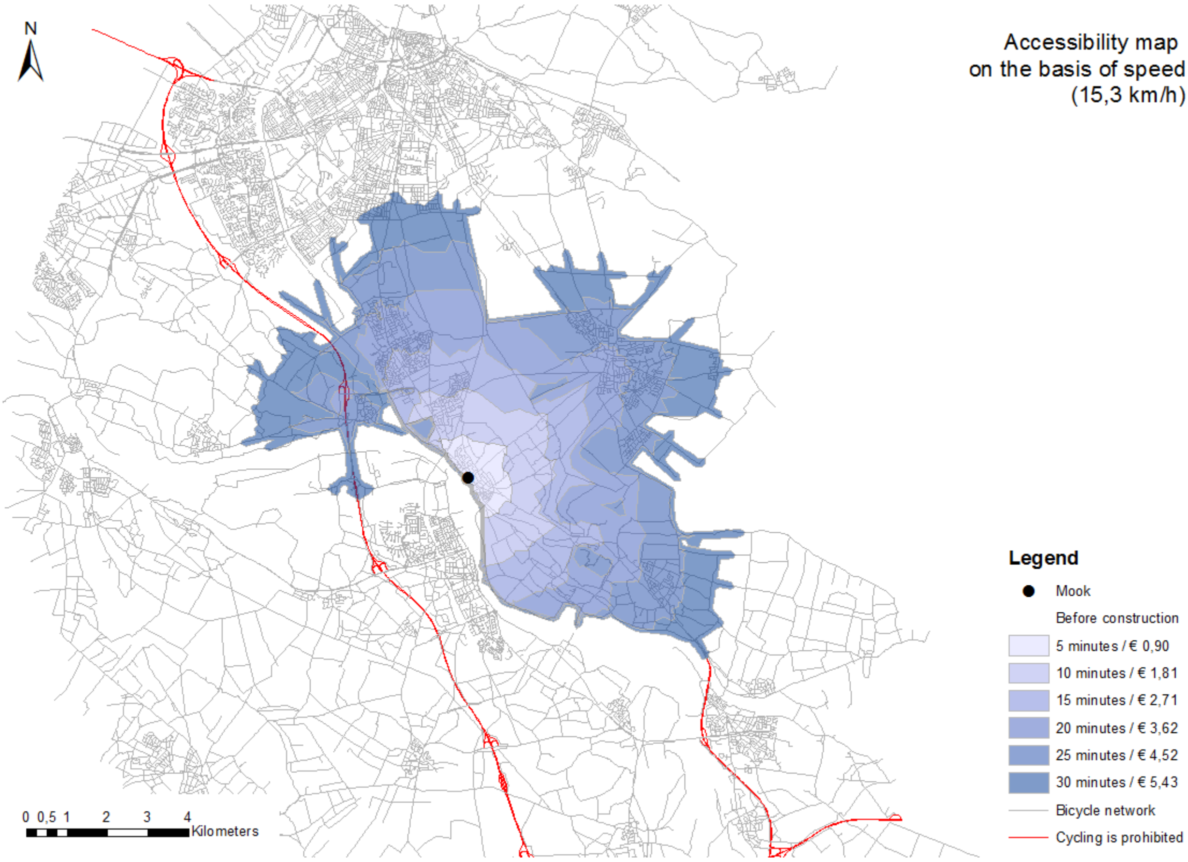

Figure C.14: Accessibility map on the basis of travel speed (before construction, step 7)

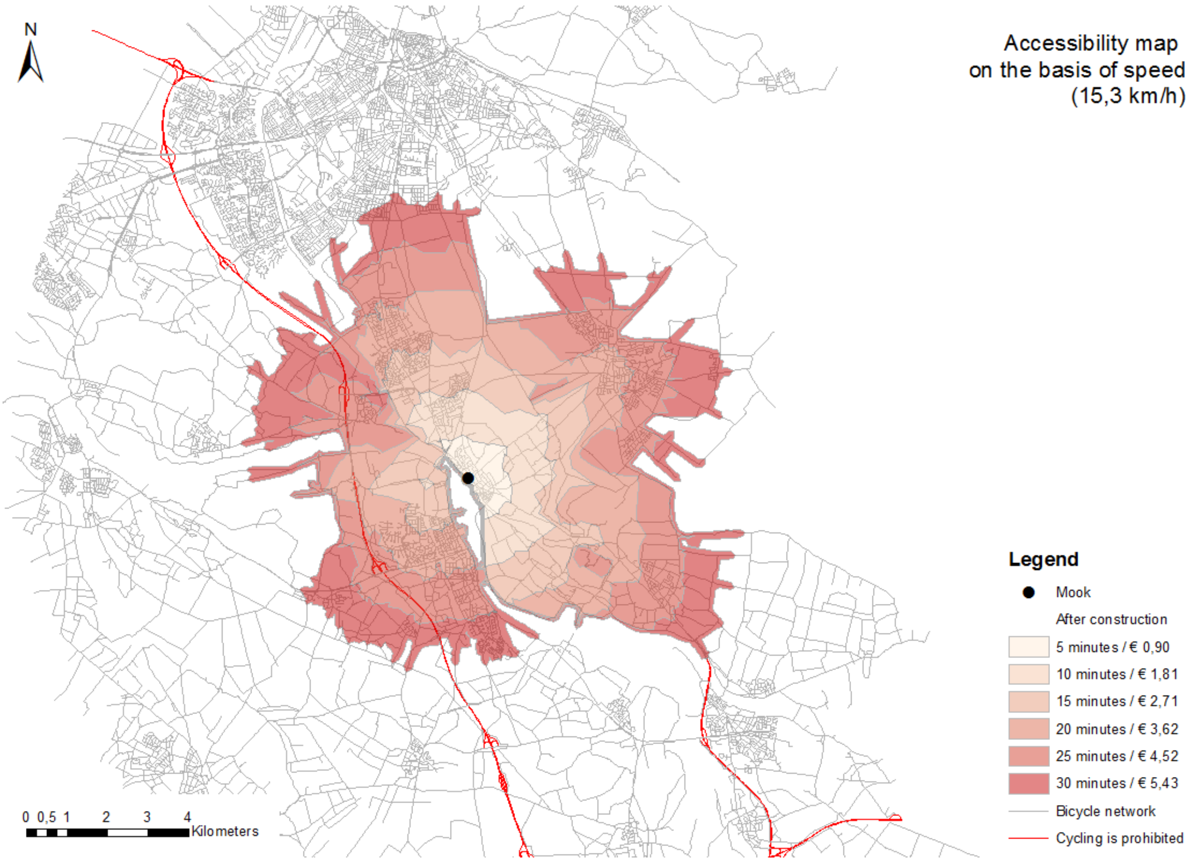

Figure C.15: Accessibility map on the basis of travel speed (after construction, step 7)

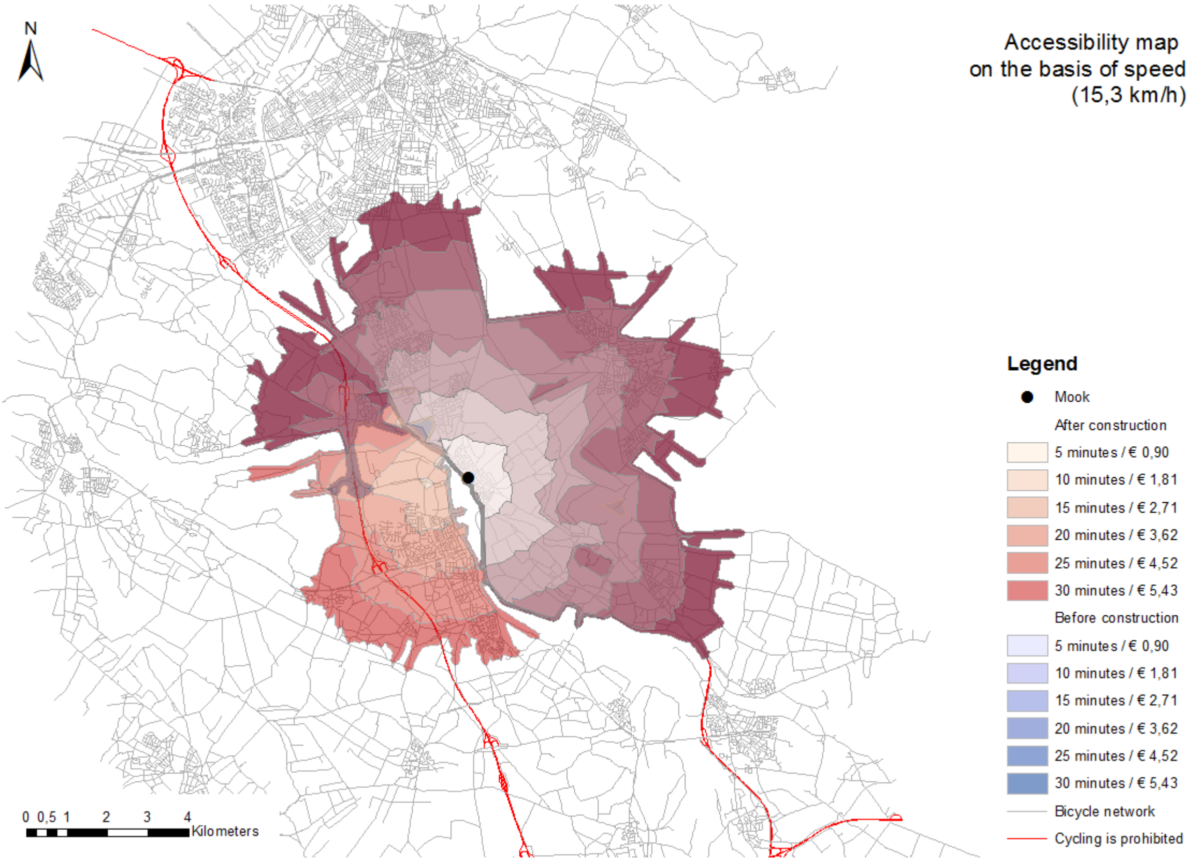

Figure C.16: Accessibility map on the basis of travel speed (before and after construction, step 7)

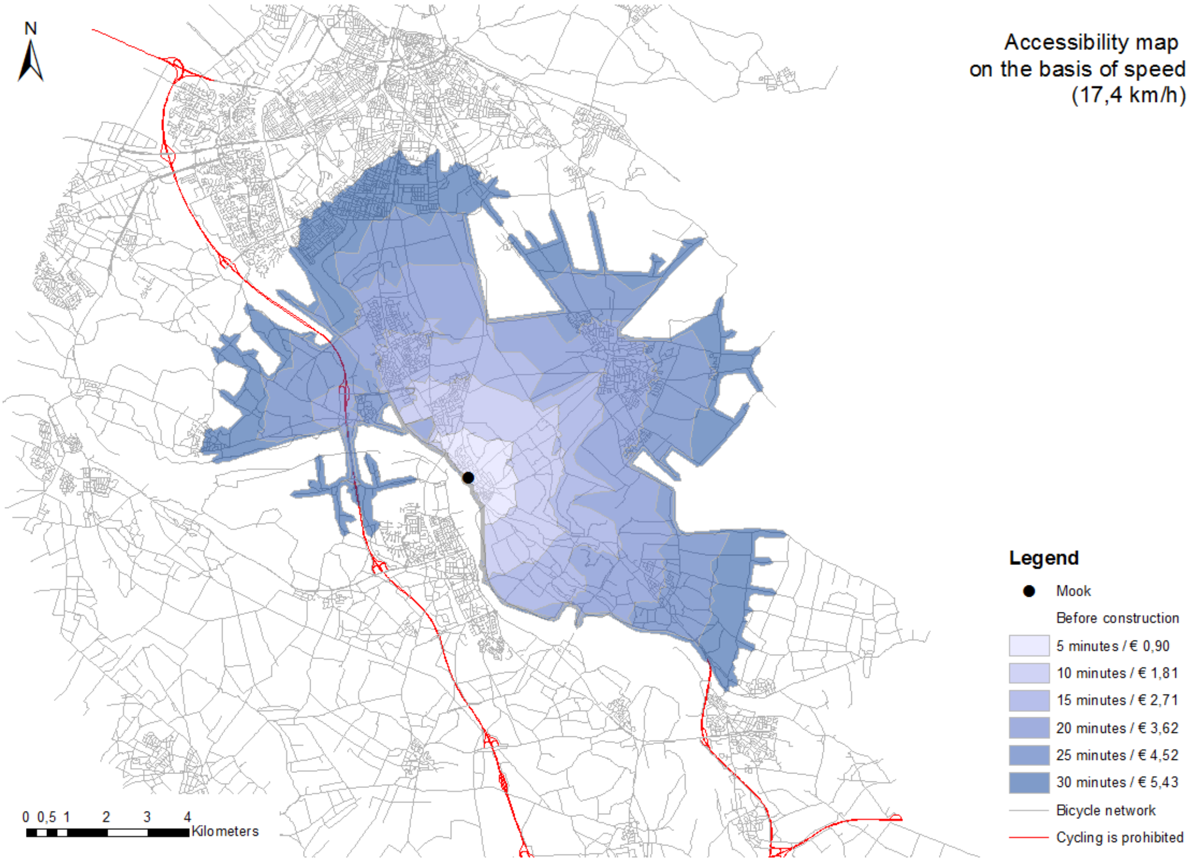

Figure C.17: Accessibility map on the basis of travel speed (before construction, step 7)

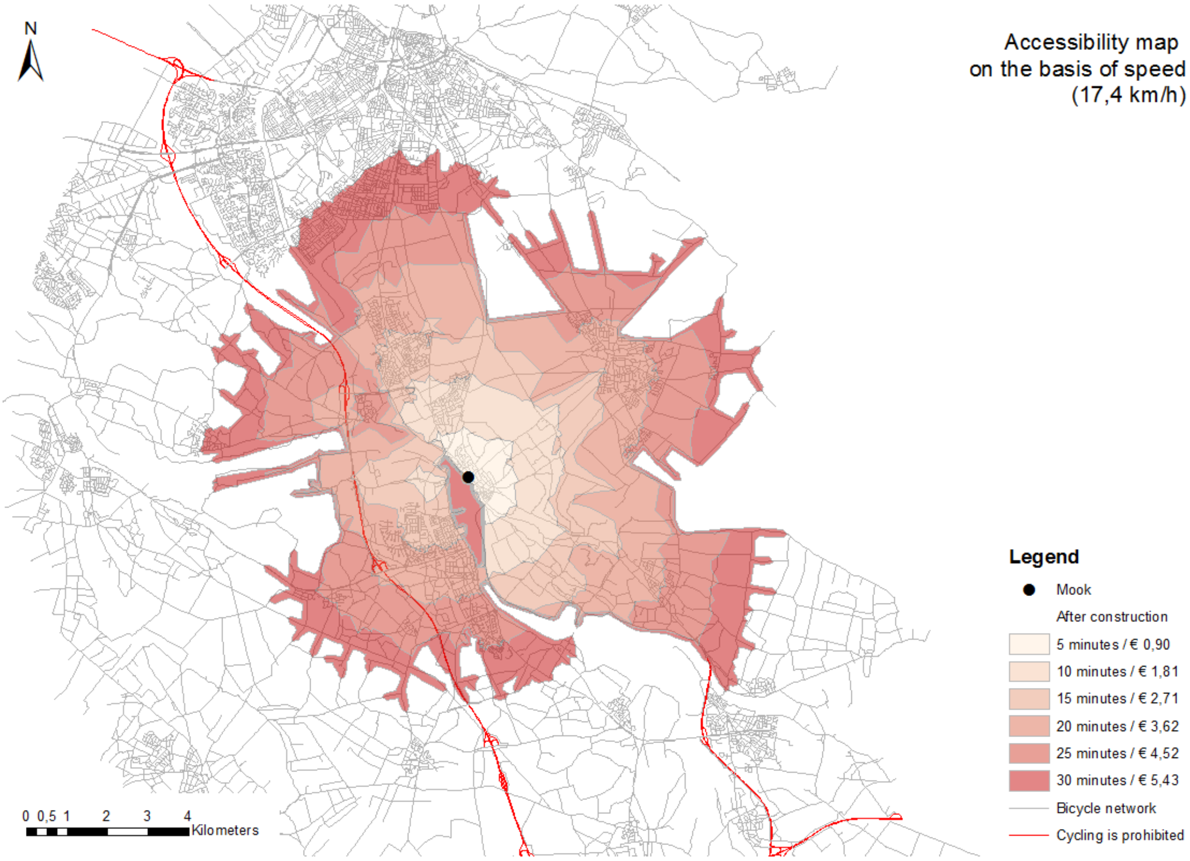

Figure C.18: Accessibility map on the basis of travel speed (after construction, step 7)

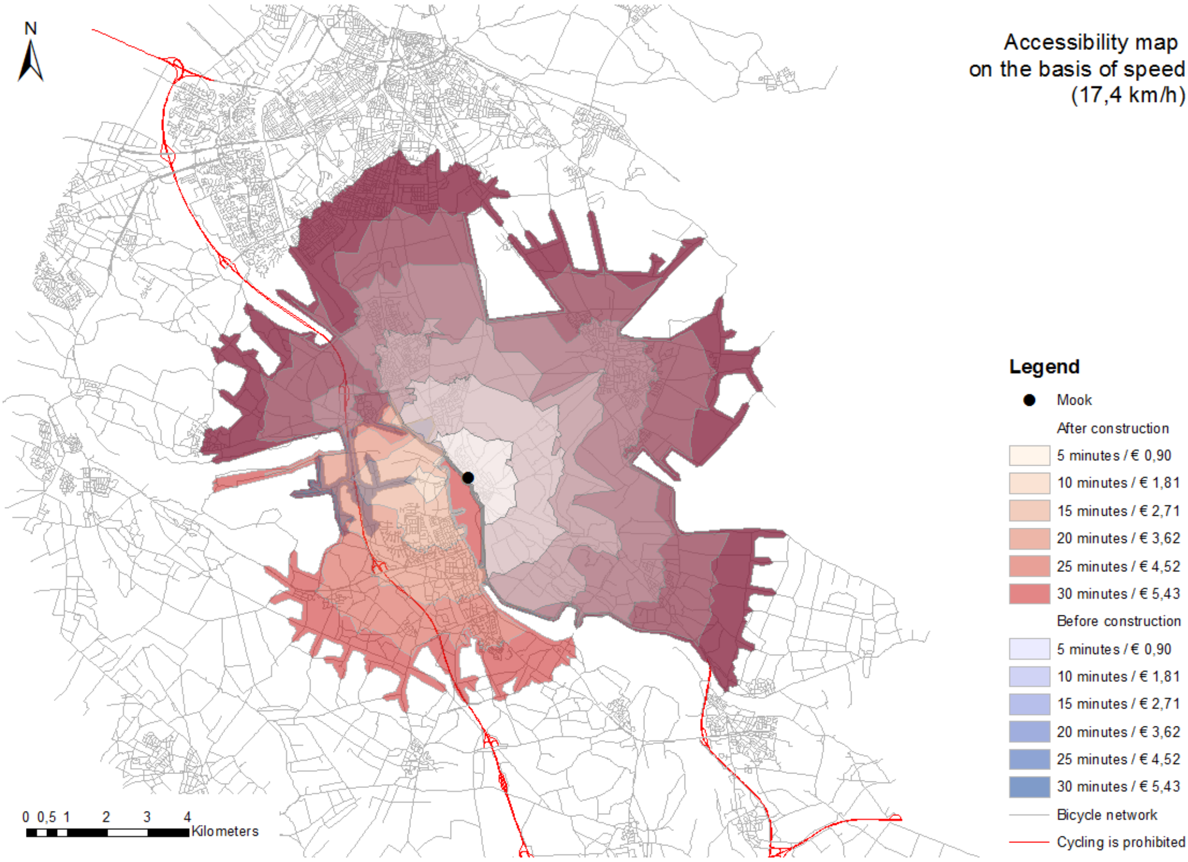

Figure C.19: Accessibility map on the basis of travel speed (before and after construction, step 7)

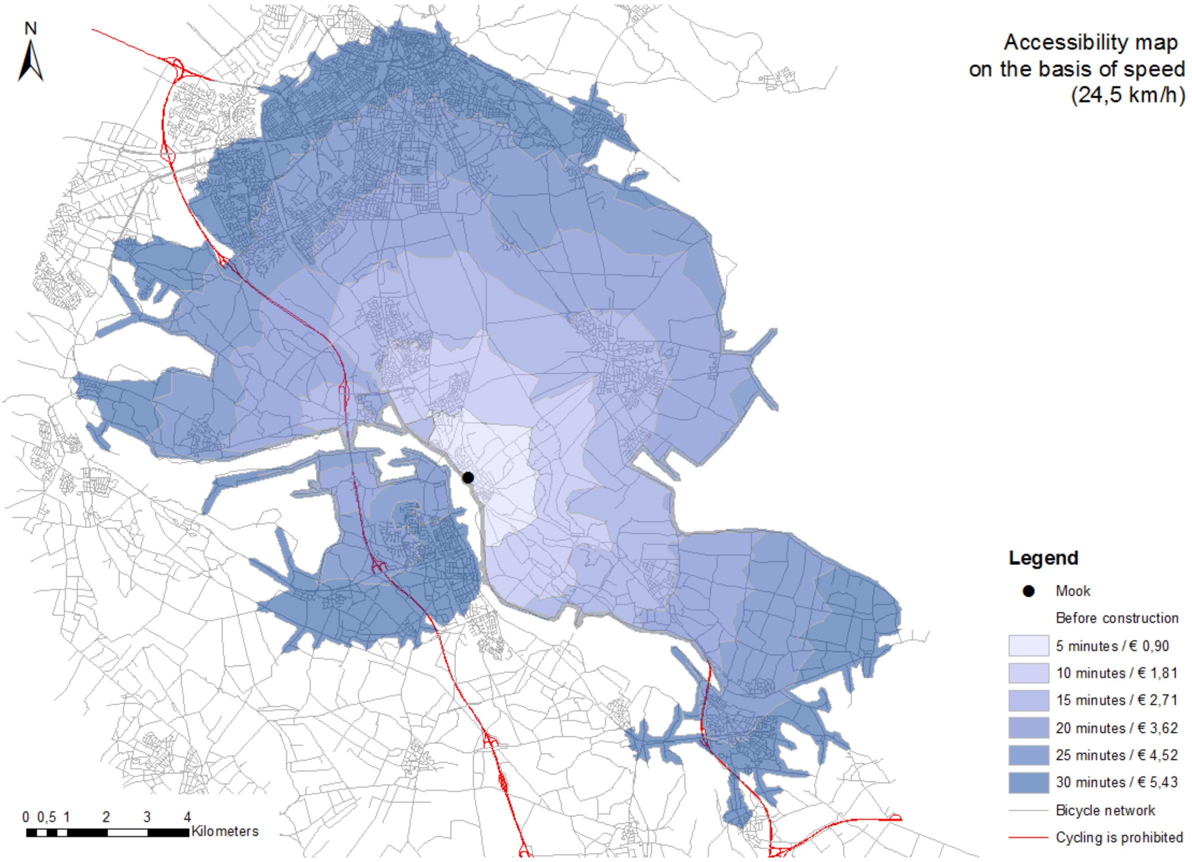

Figure C.20: Accessibility map on the basis of travel speed (before construction, step 7)

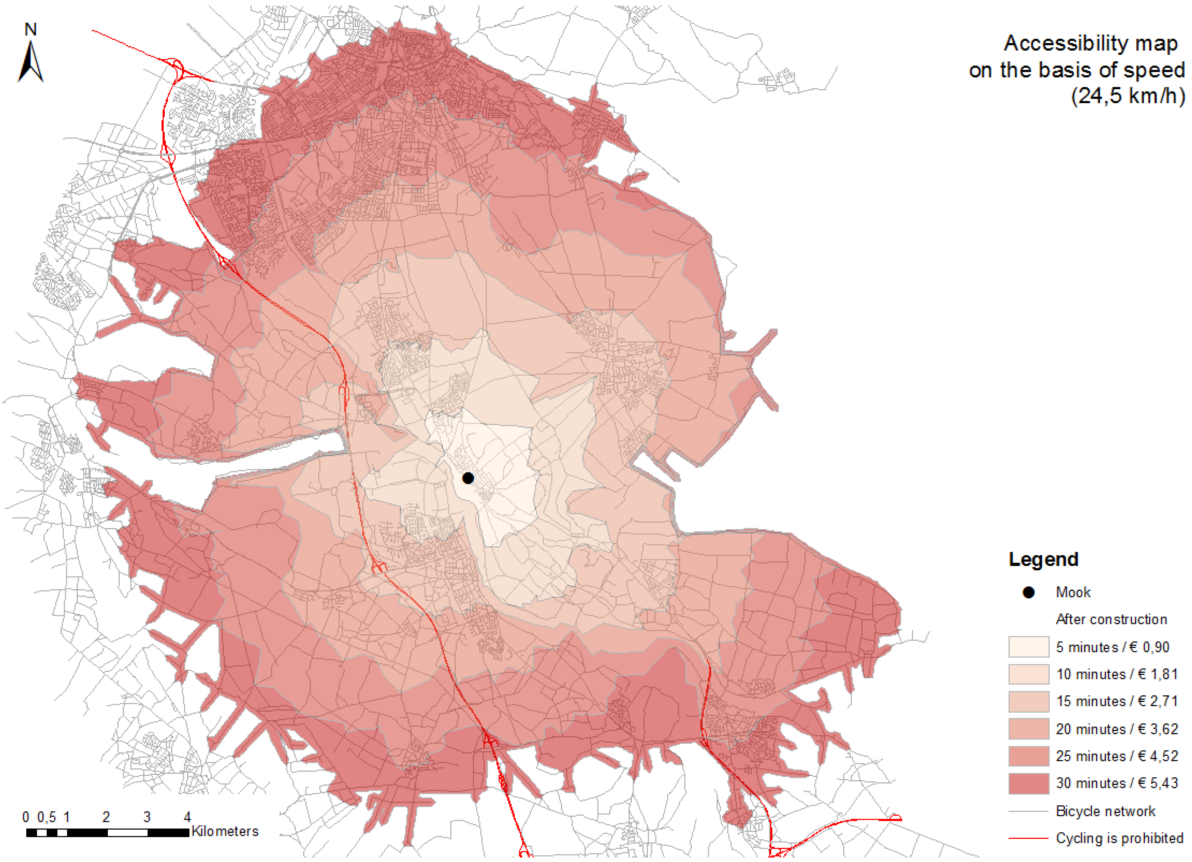

Figure C.21: Accessibility map on the basis of travel speed (after construction, step 7)

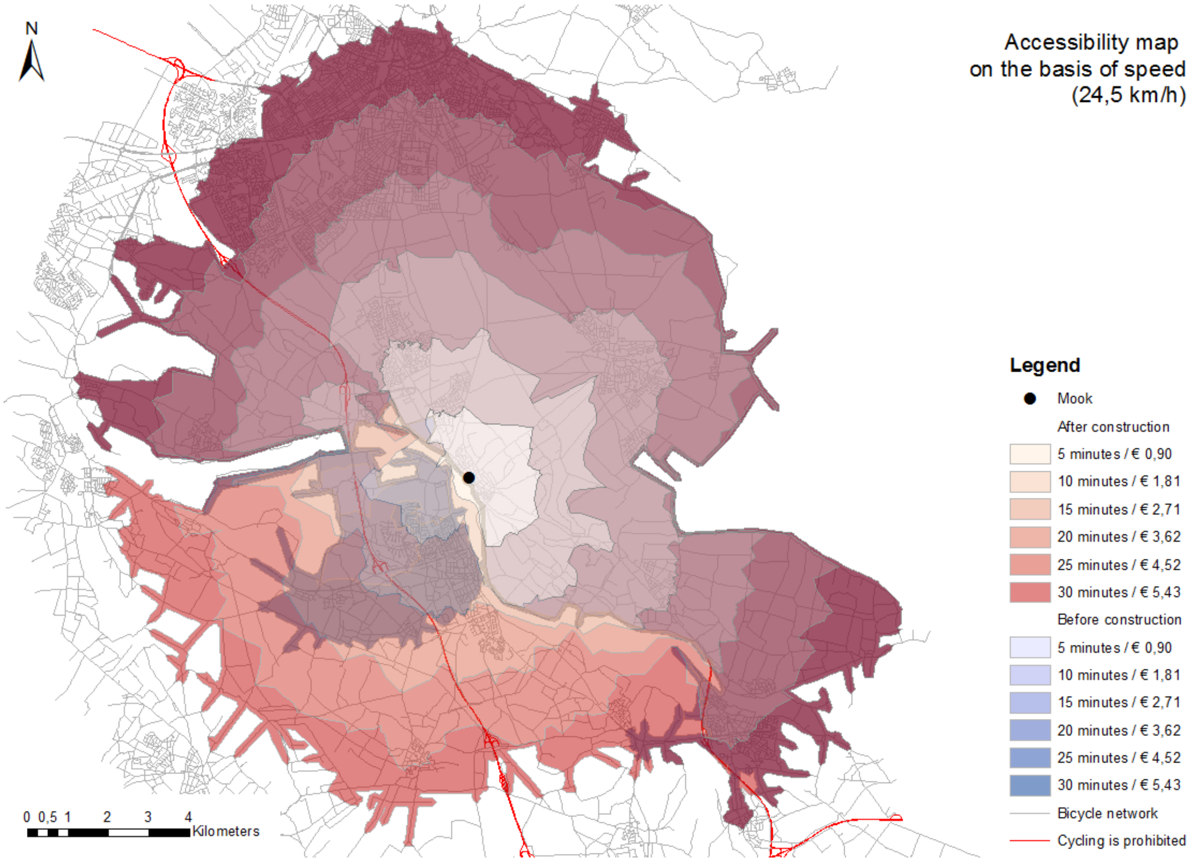

Figure C.22: Accessibility map on the basis of travel speed (before and after construction, step 7)

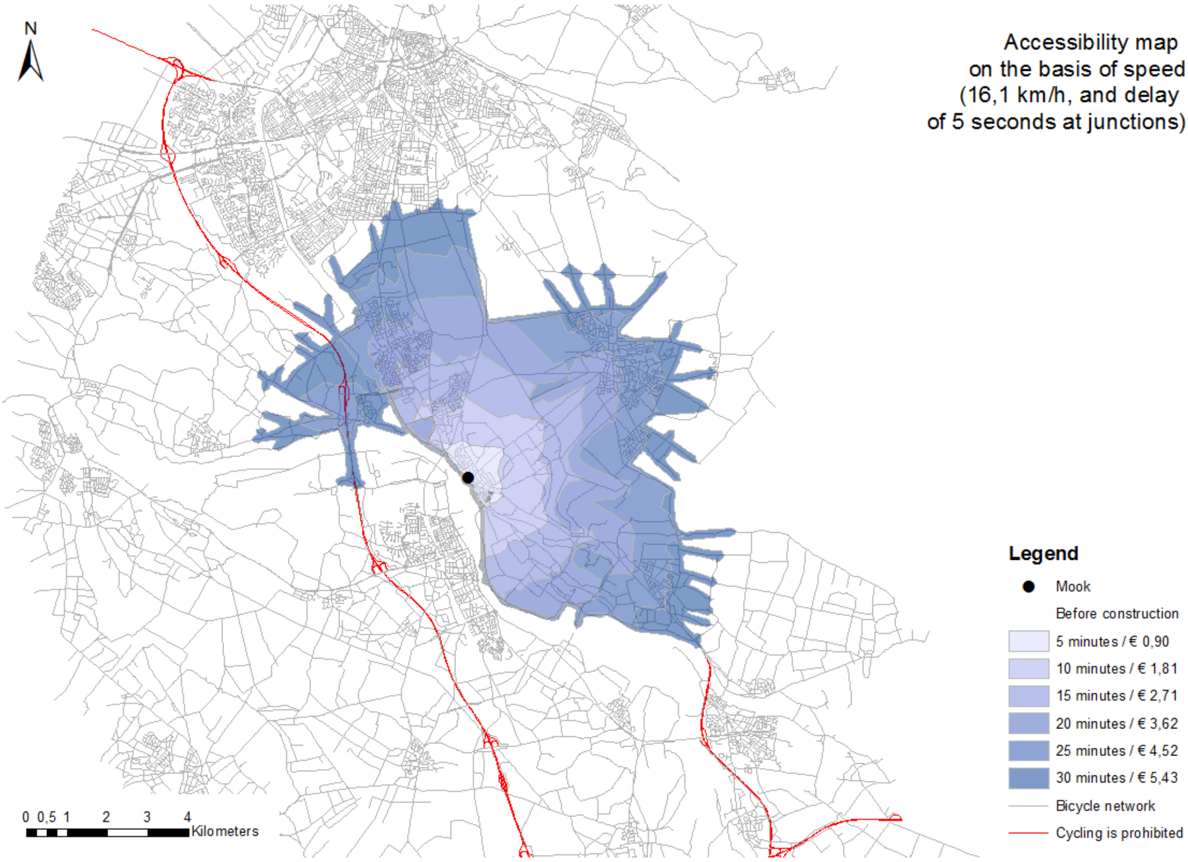

Figure C.23: Accessibility map on the basis of travel speed (before construction, step 7)

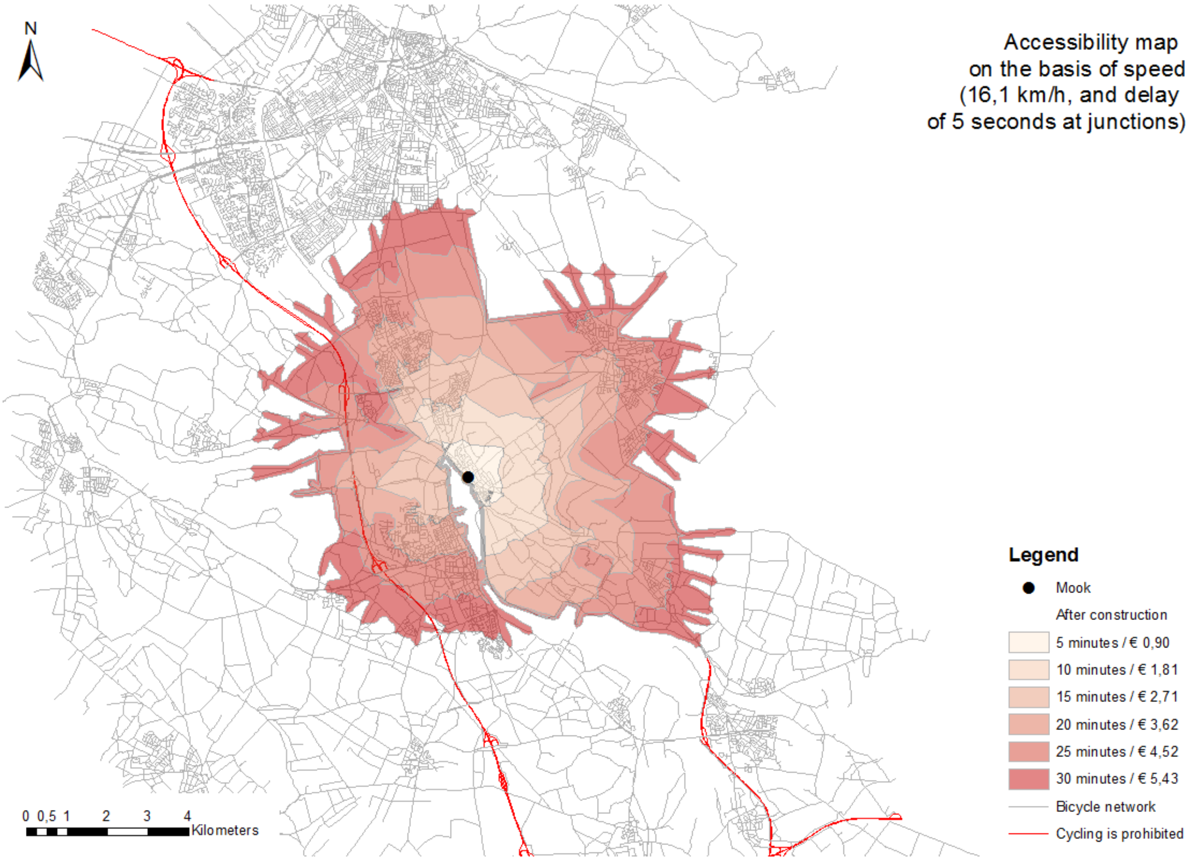

Figure C.24: Accessibility map on the basis of travel speed (after construction, step 7)

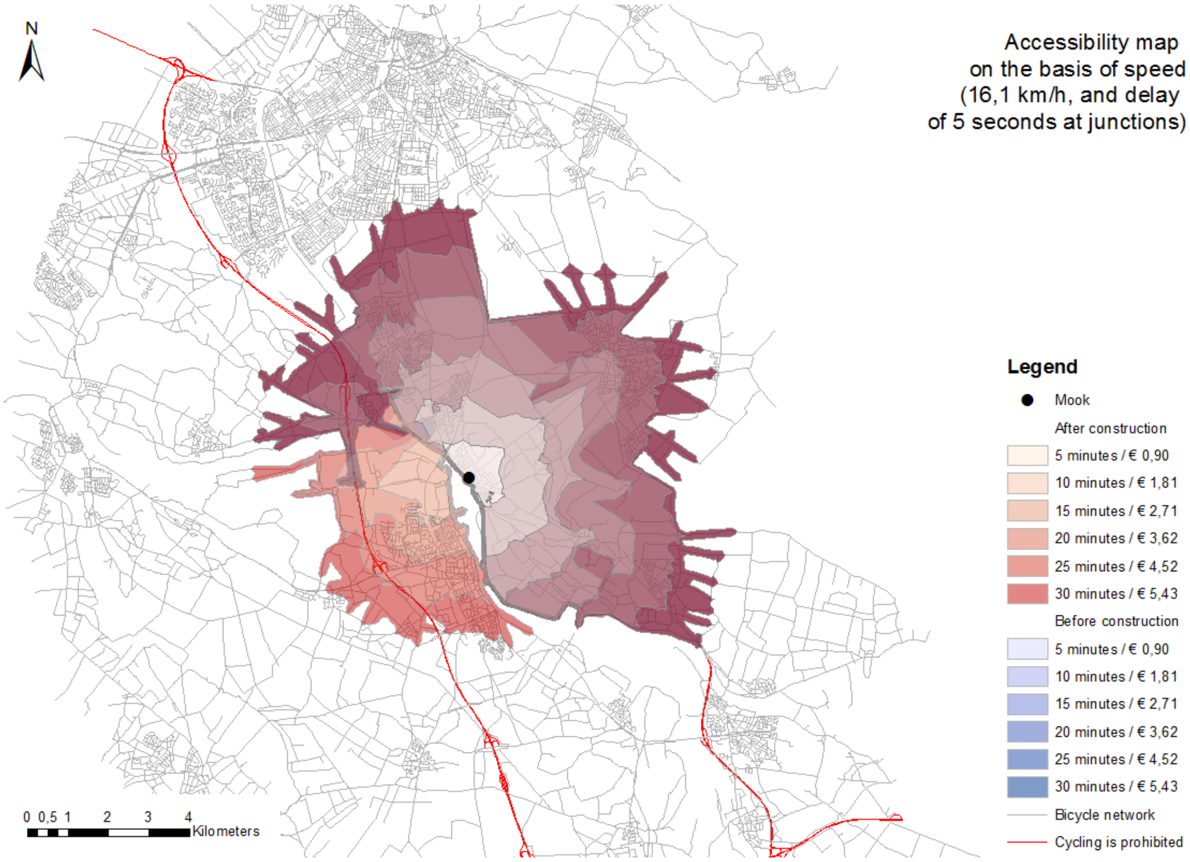

Figure C.25: Accessibility map on the basis of travel speed (before and after construction, step 7)

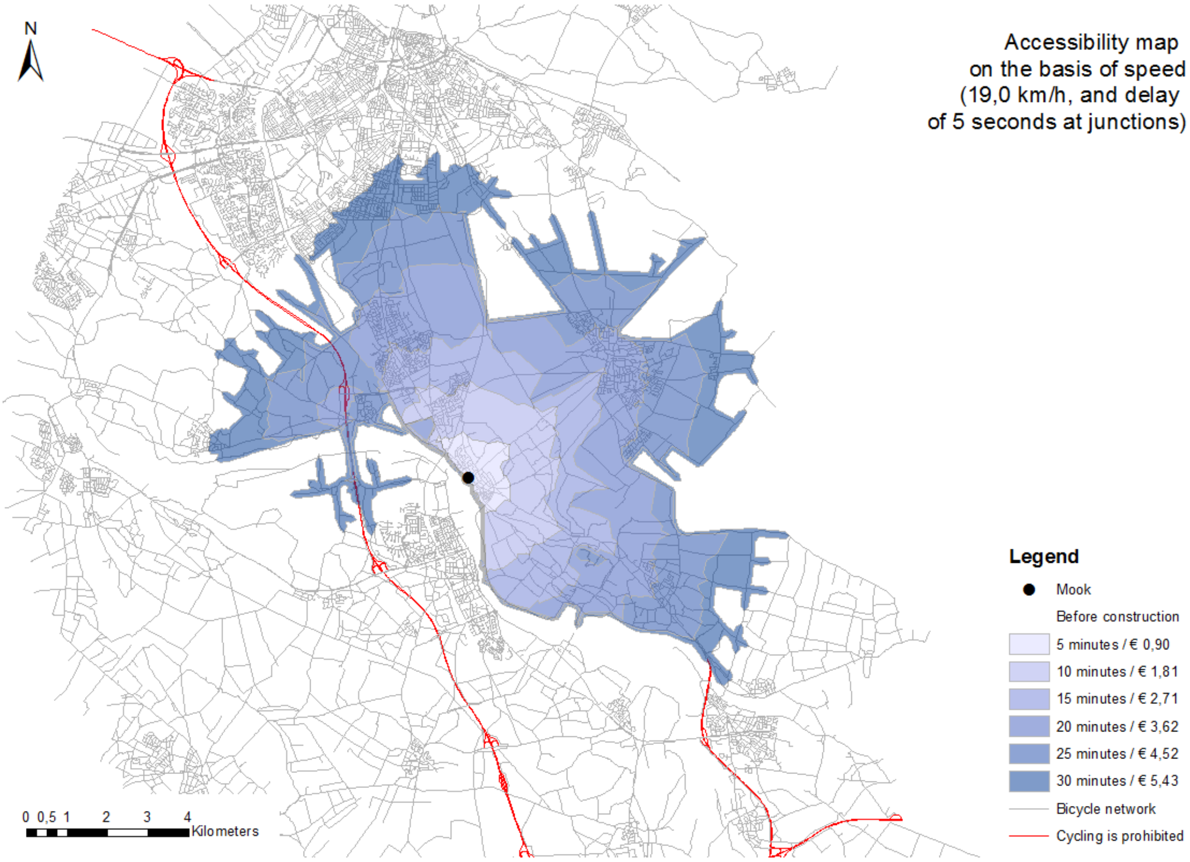

Figure C.26: Accessibility map on the basis of travel speed (before construction, step 7)

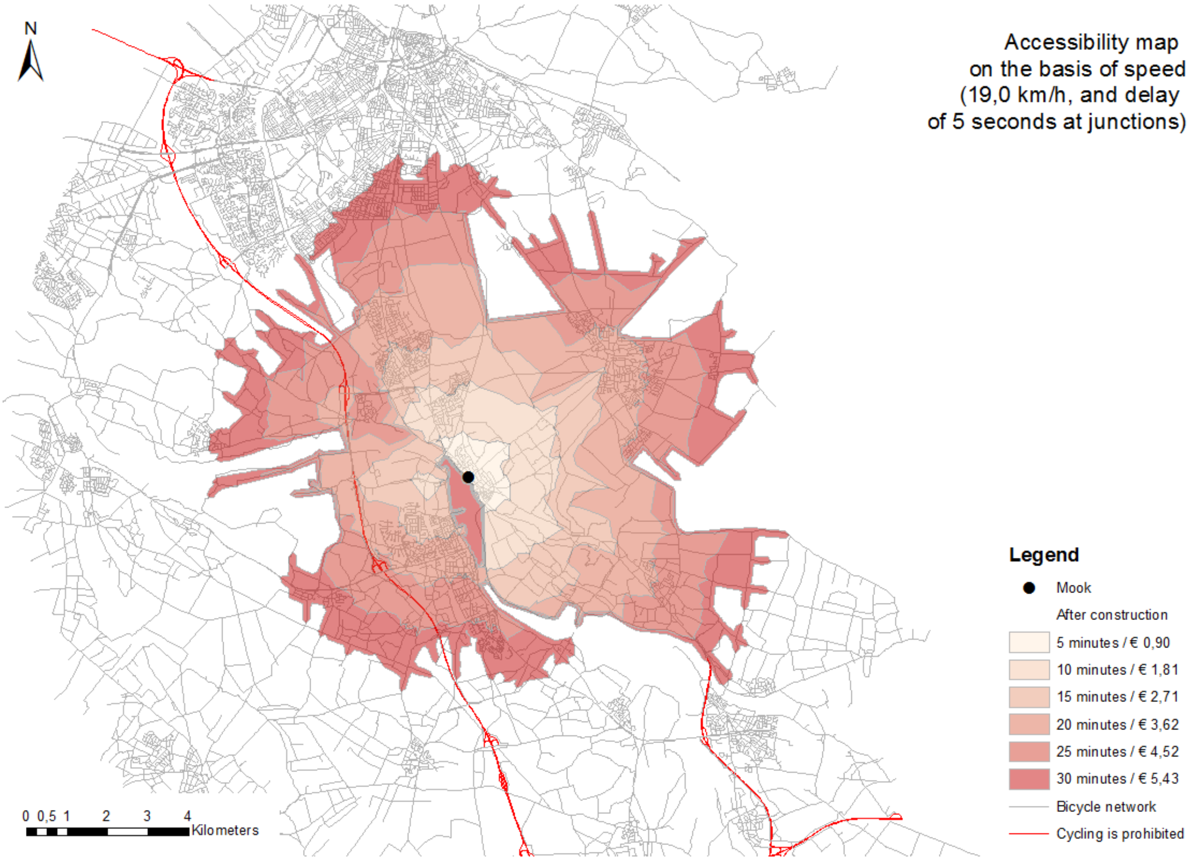

Figure C.27: Accessibility map on the basis of travel speed (after construction, step 7)

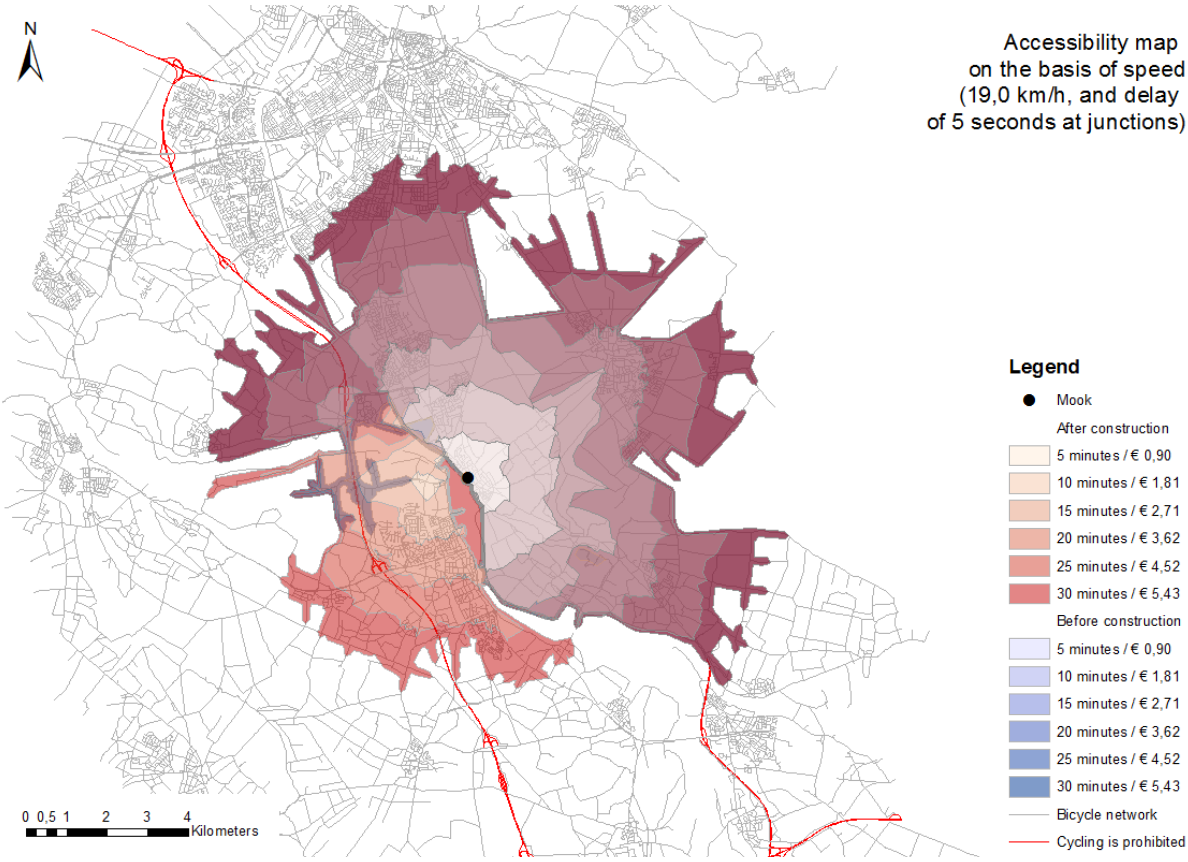

Figure C.28: Accessibility map on the basis of travel speed (before and after construction, step 7)

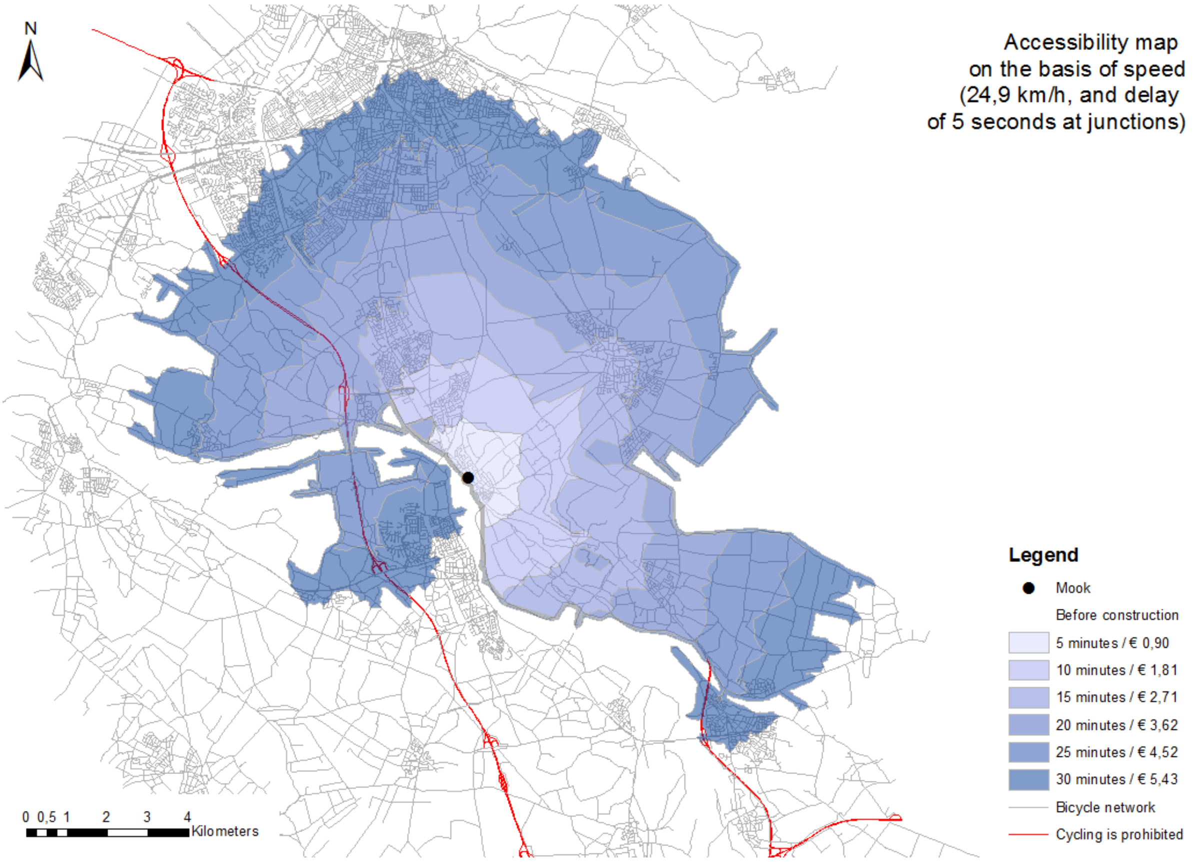

Figure C.29: Accessibility map on the basis of travel speed (before construction, step 7)

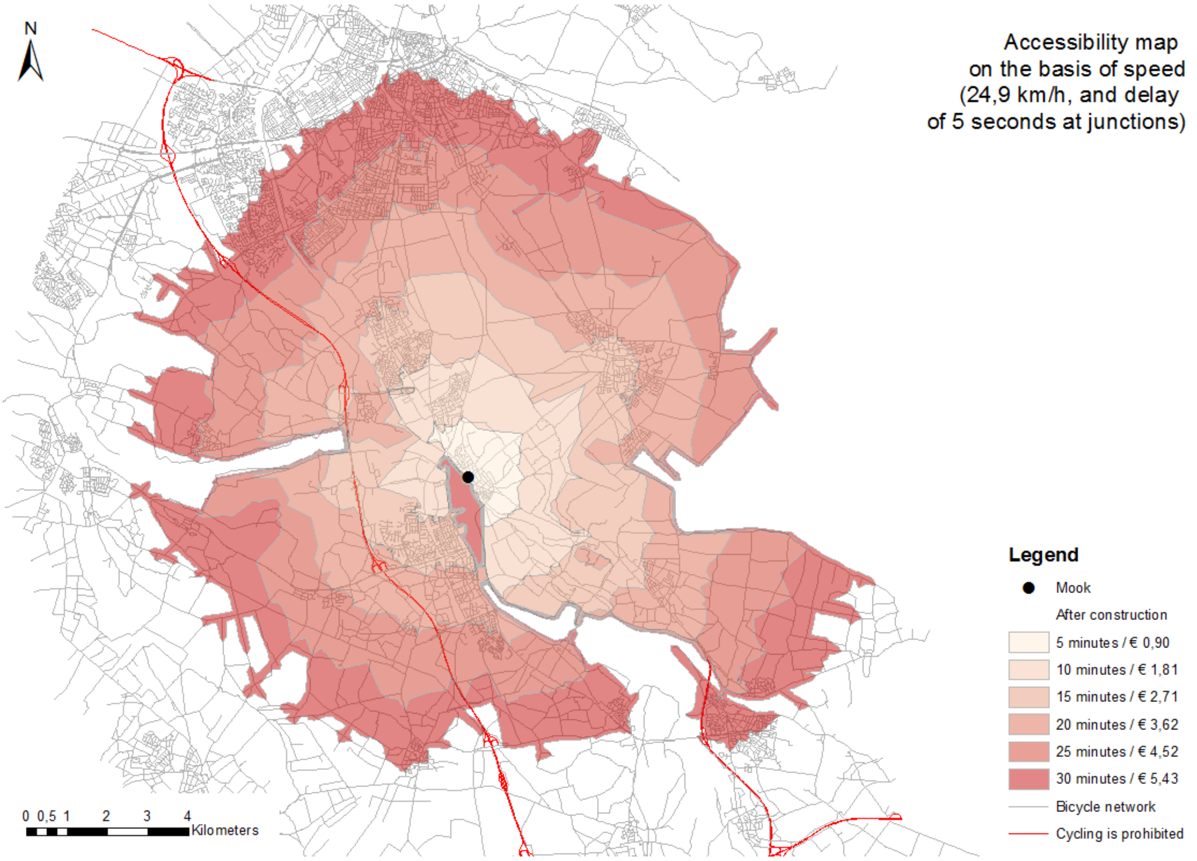

Figure C.30: Accessibility map on the basis of travel speed (after construction, step 7)

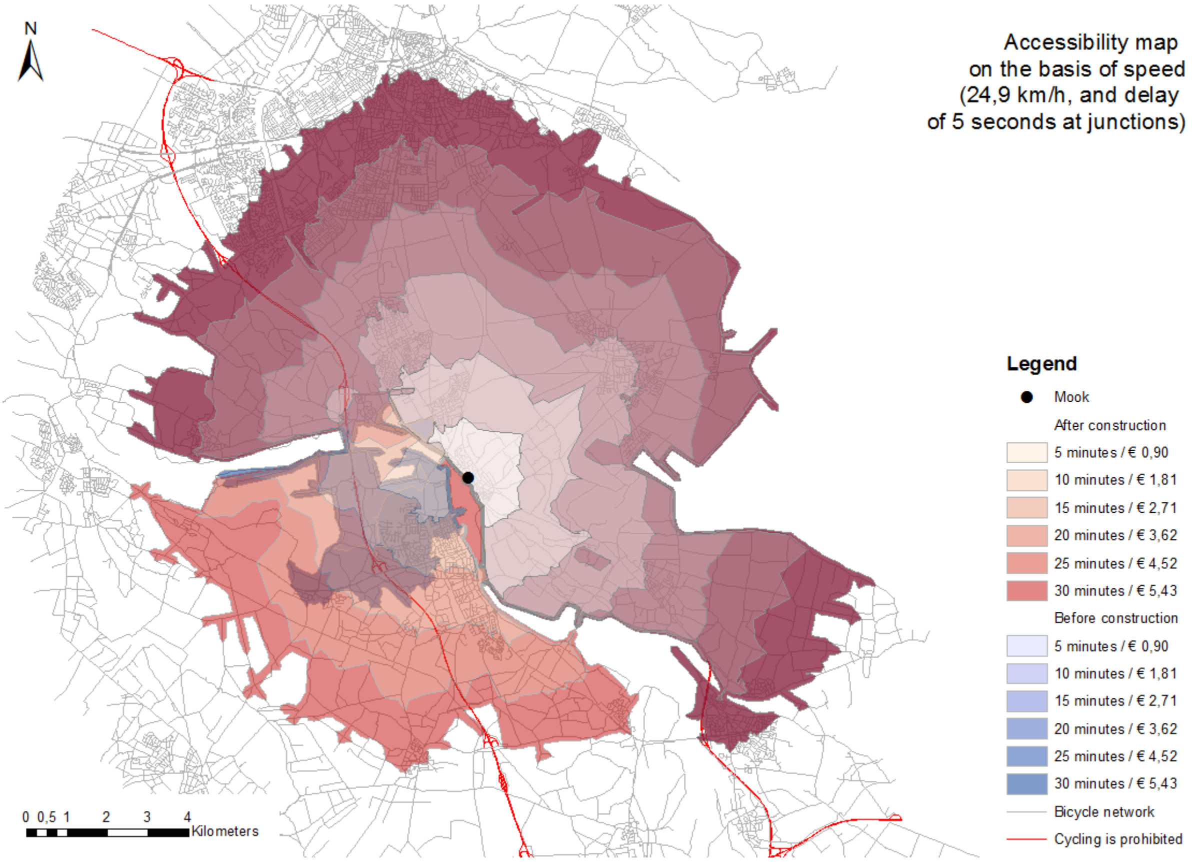

Figure C.31: Accessibility map on the basis of travel speed (before and after construction, step 7)

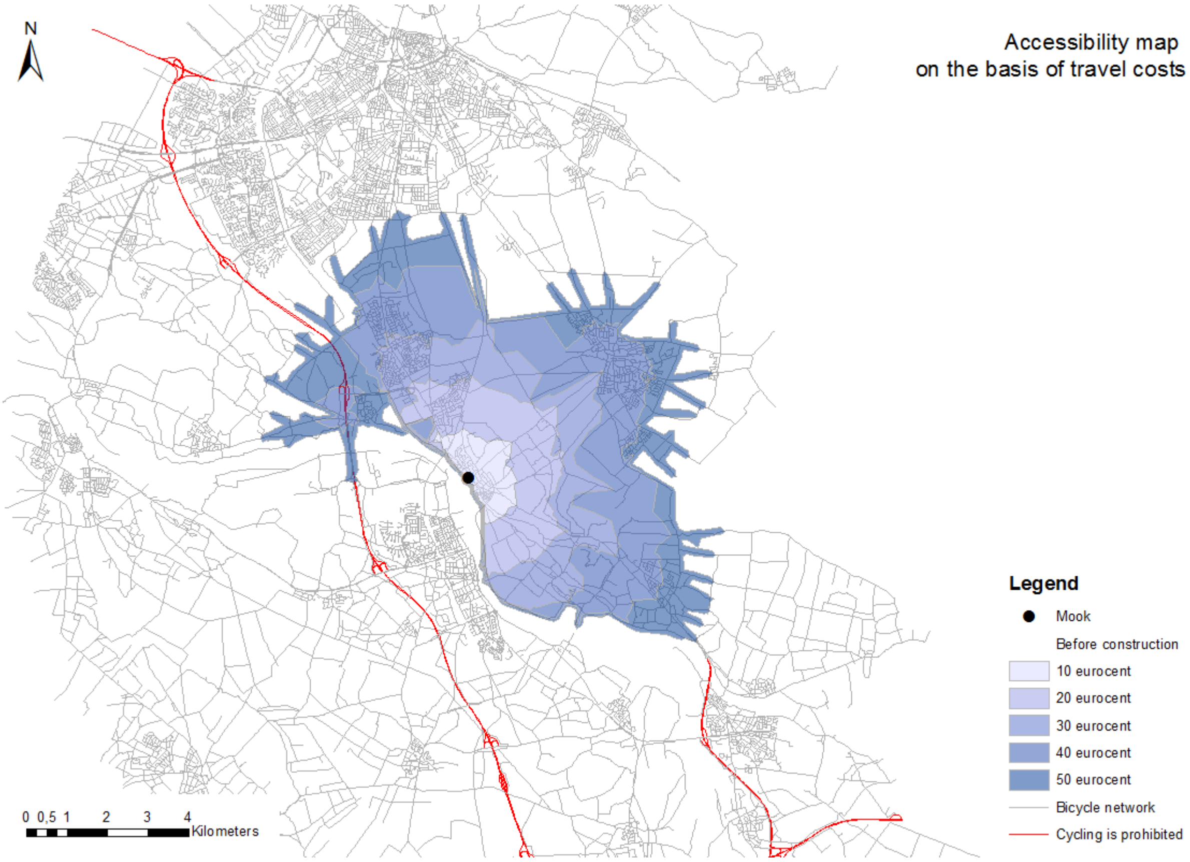

Figure C.32: Accessibility map on the basis of travel costs (before construction, step 7)

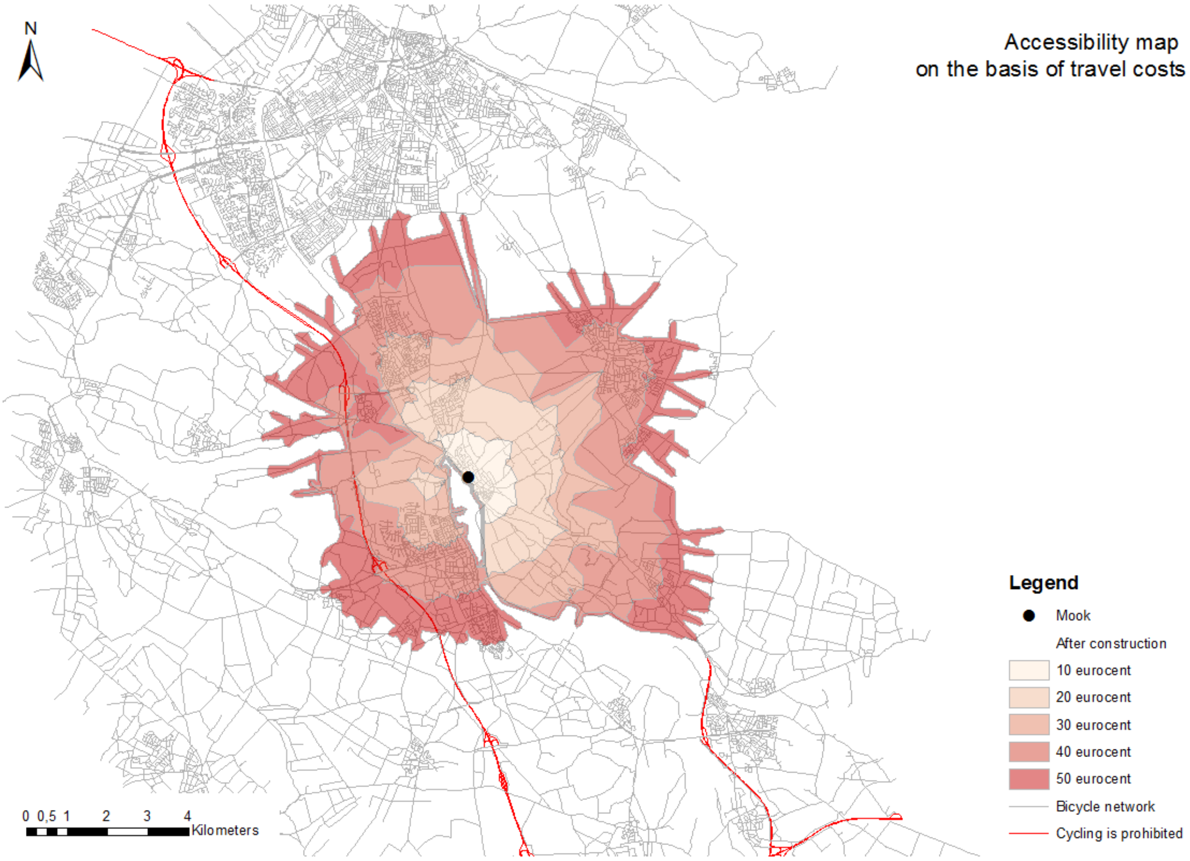

Figure C.33: Accessibility map on the basis of travel costs (after construction, step 7)

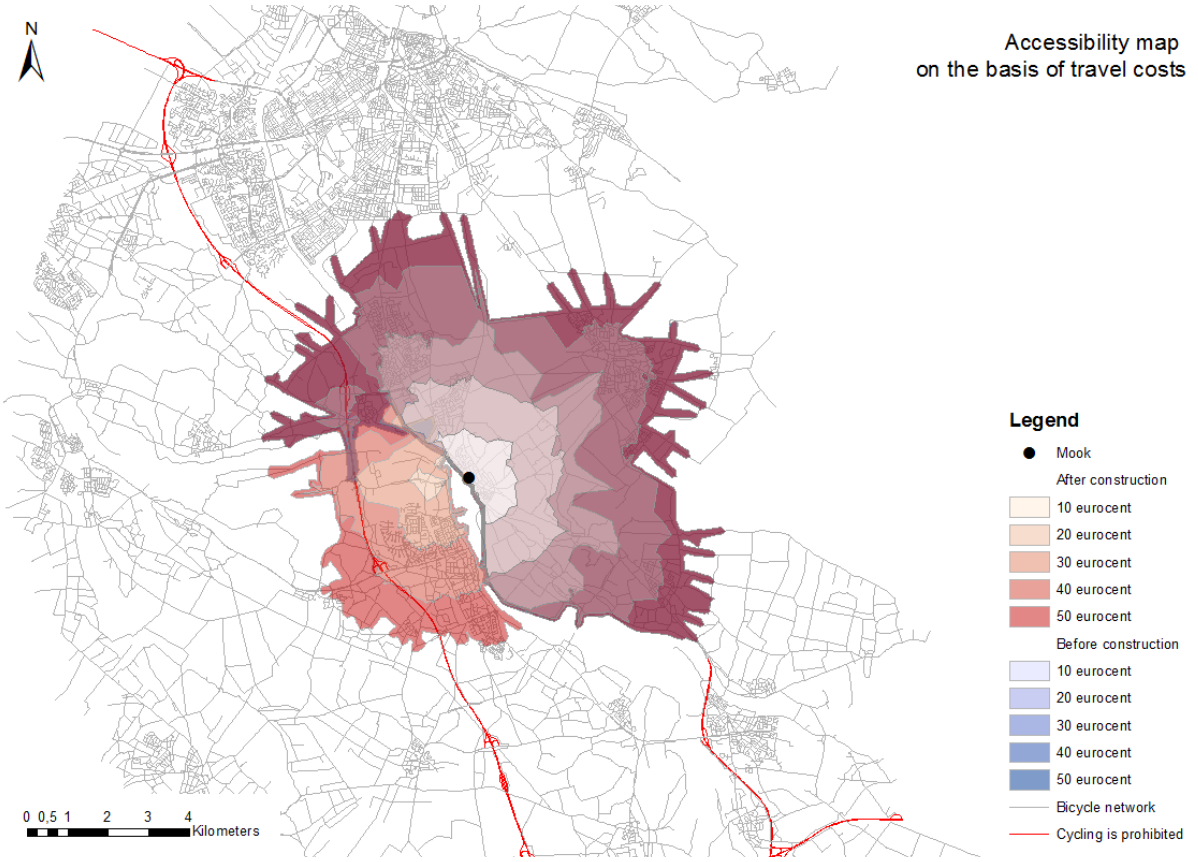

Figure C.34: Accessibility map on the basis of travel costs (before and after construction, step 7)

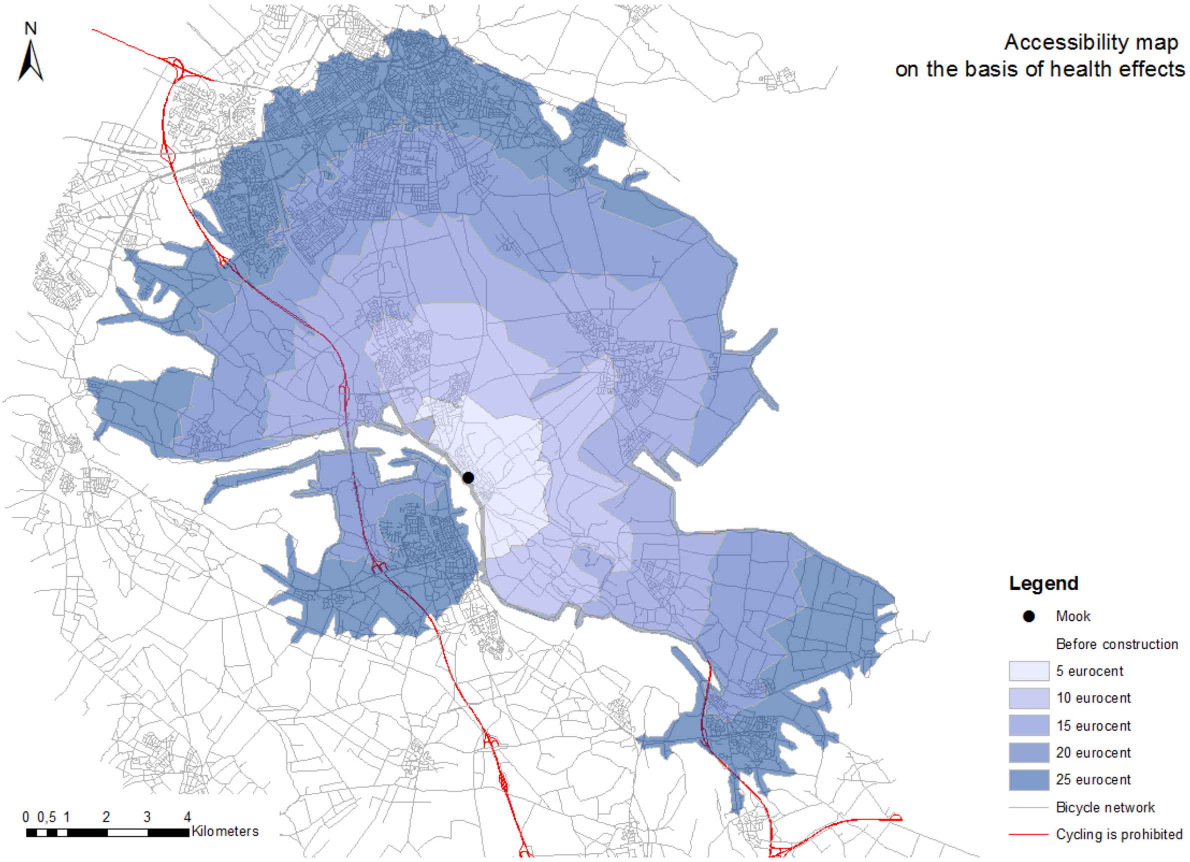

Figure C.35: Accessibility map on the basis of health effects (before construction, step 7)

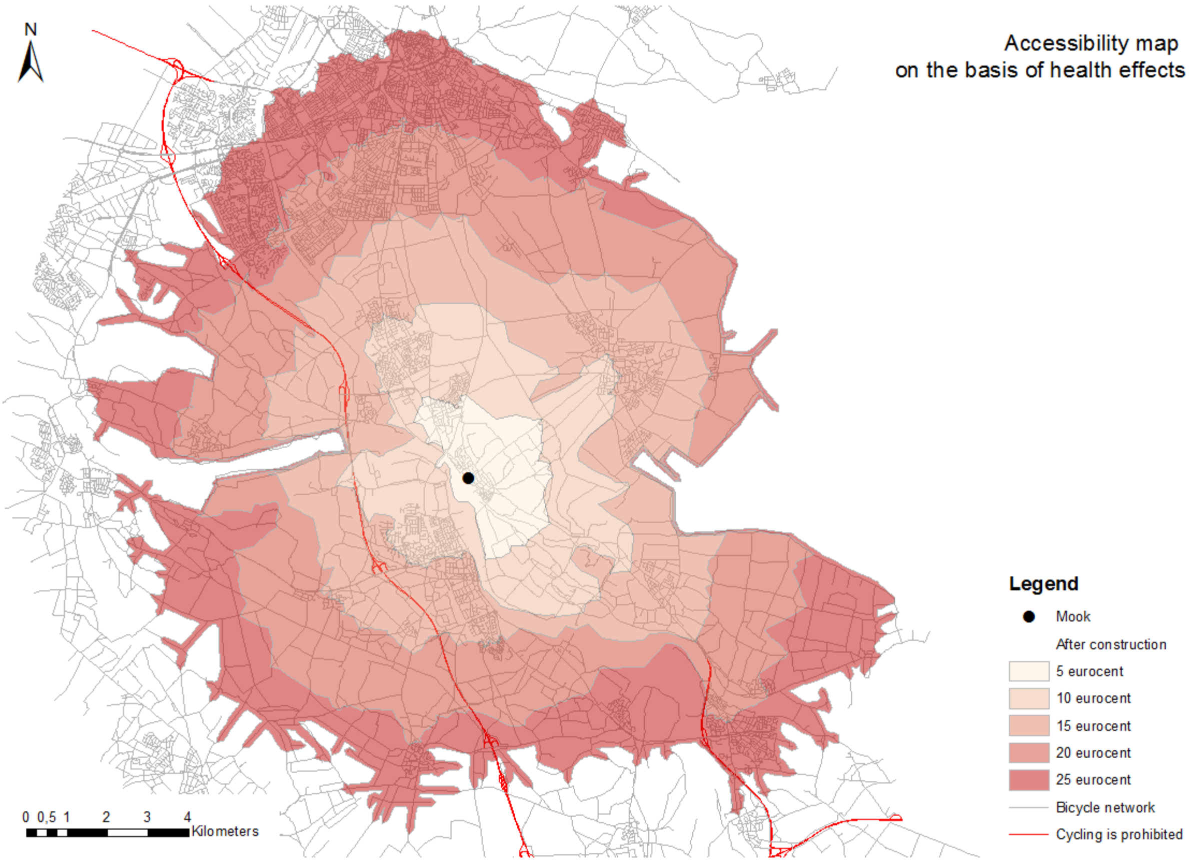

Figure C.36: Accessibility map on the basis of health effects (after construction, step 7)

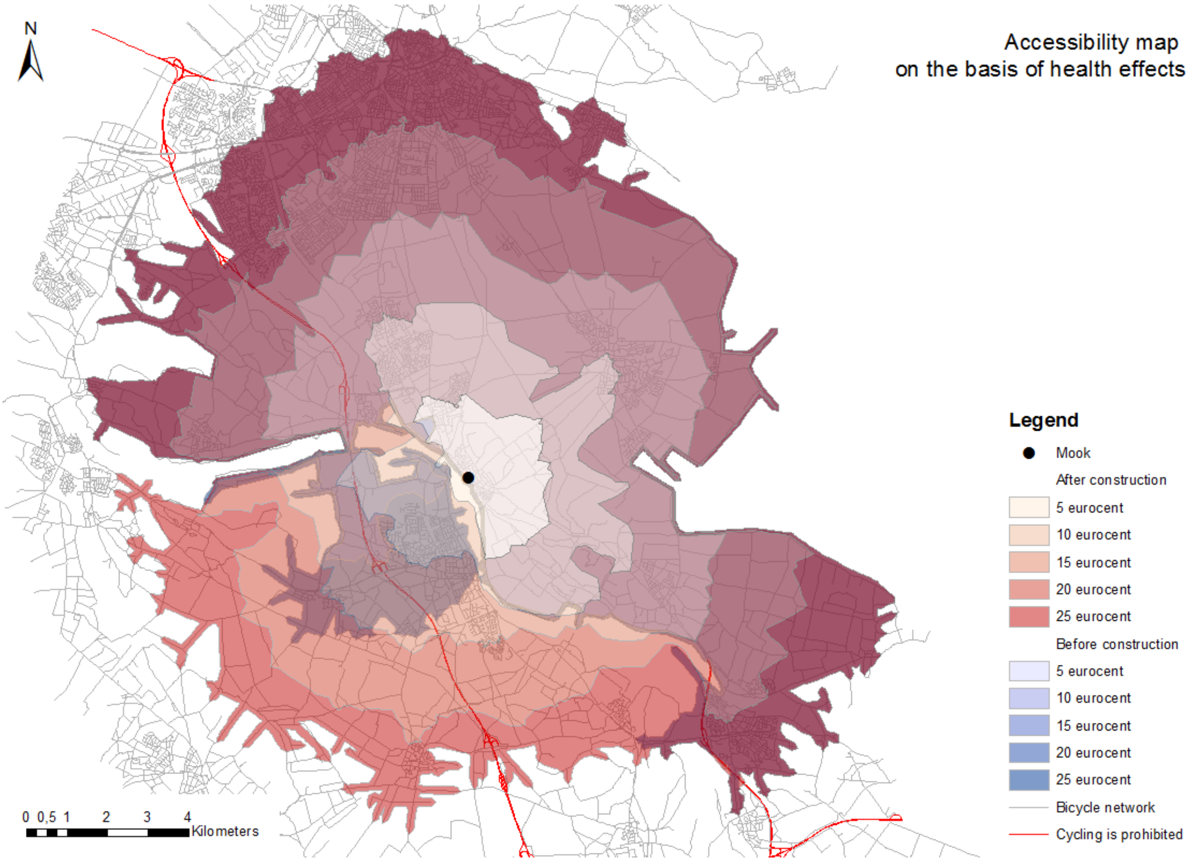

Figure C.37: Accessibility map on the basis of health effects (before and after construction, step 7)

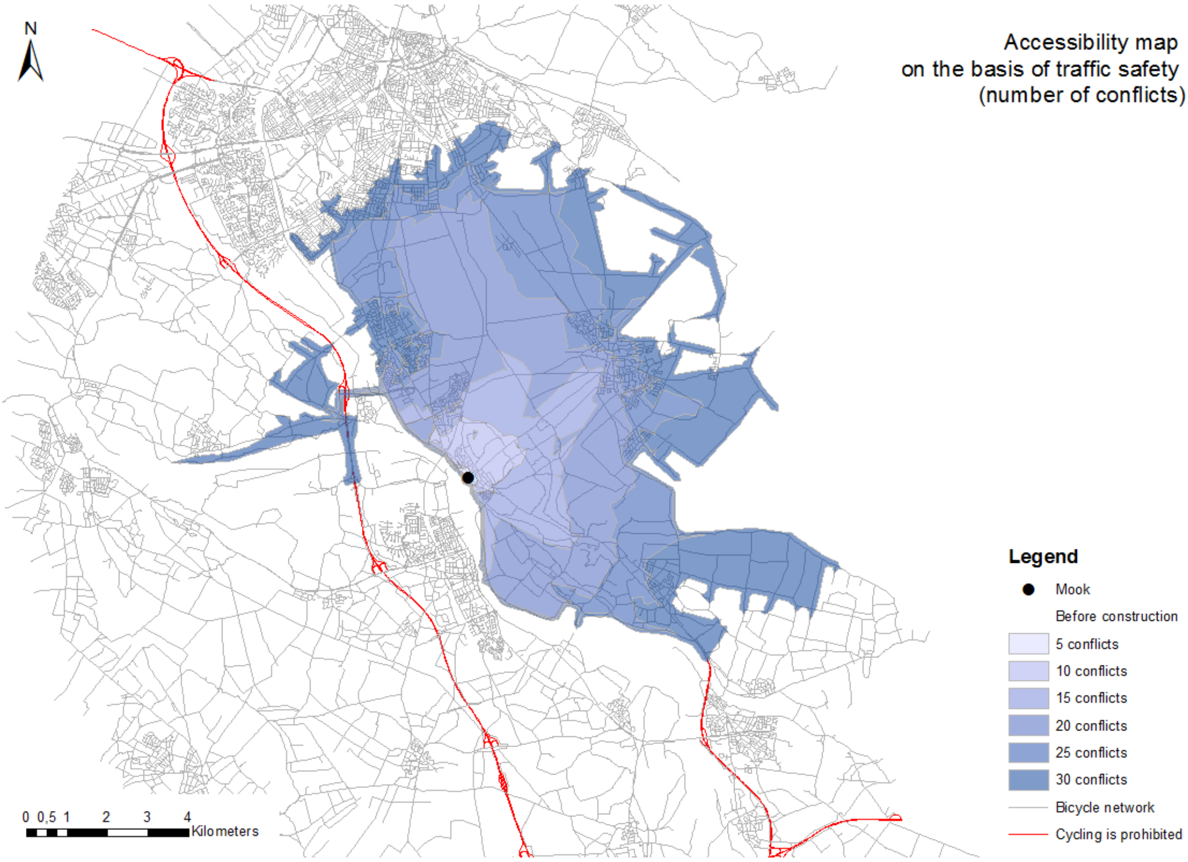

Figure C.38: Accessibility map on the basis of traffic safety (before construction, step 7)

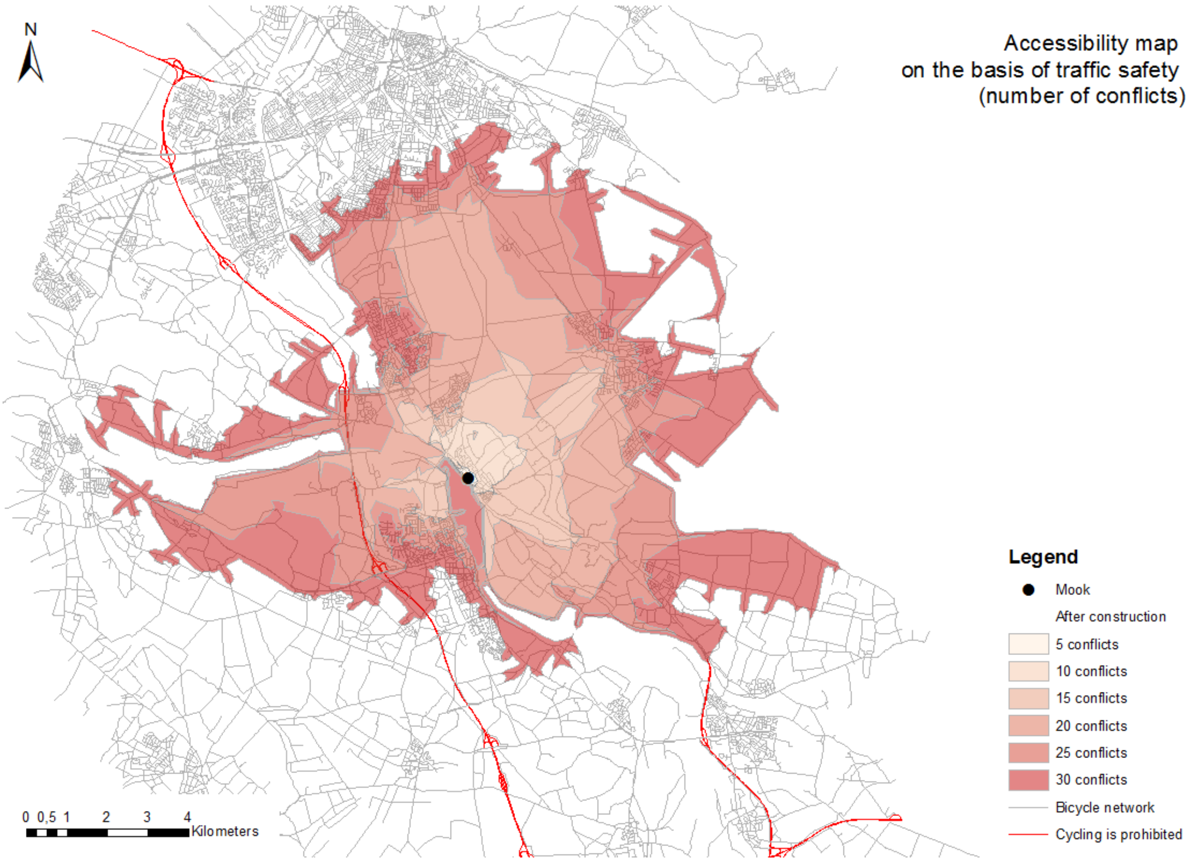

Figure C.39: Accessibility map on the basis of traffic safety (after construction, step 7)

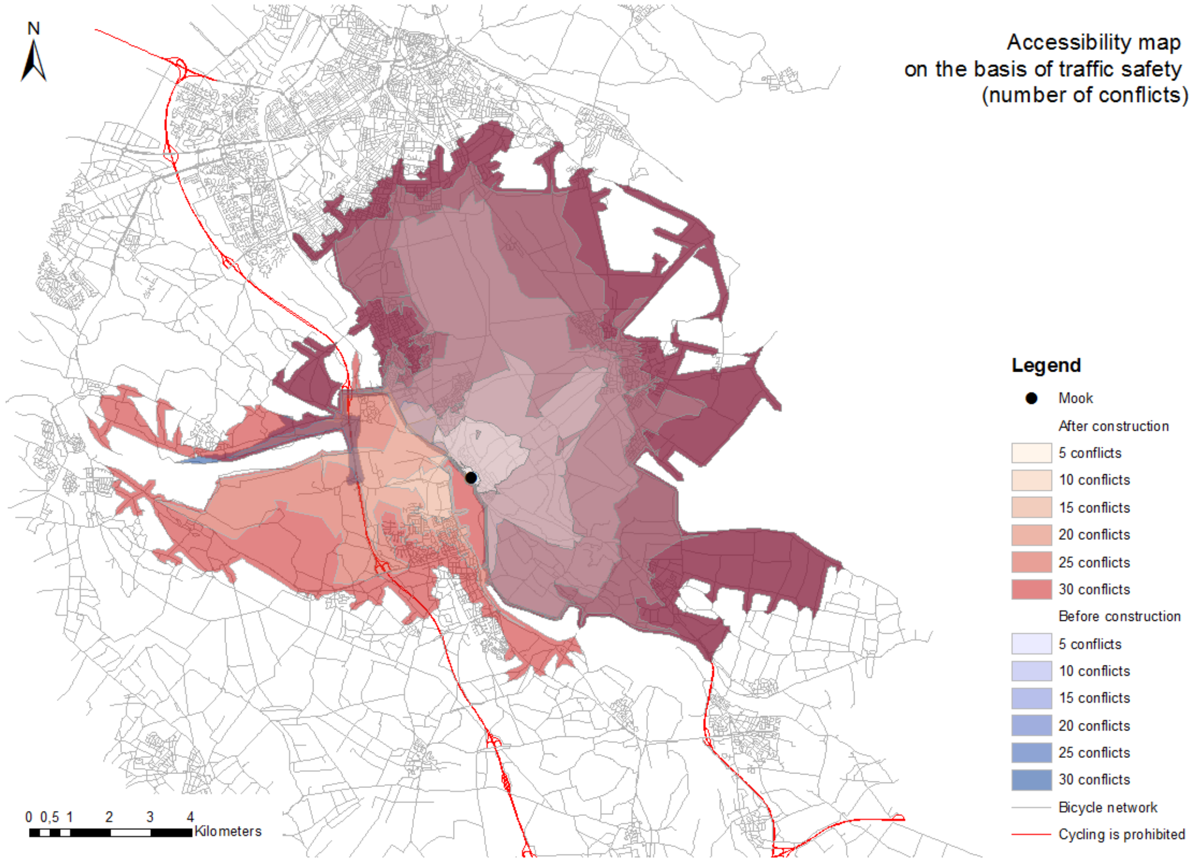

Figure C.40: Accessibility map on the basis of traffic safety (before and after construction, step 7)

Appendix D: Maps regarding capacity extension A67 Venlo - Eindhoven

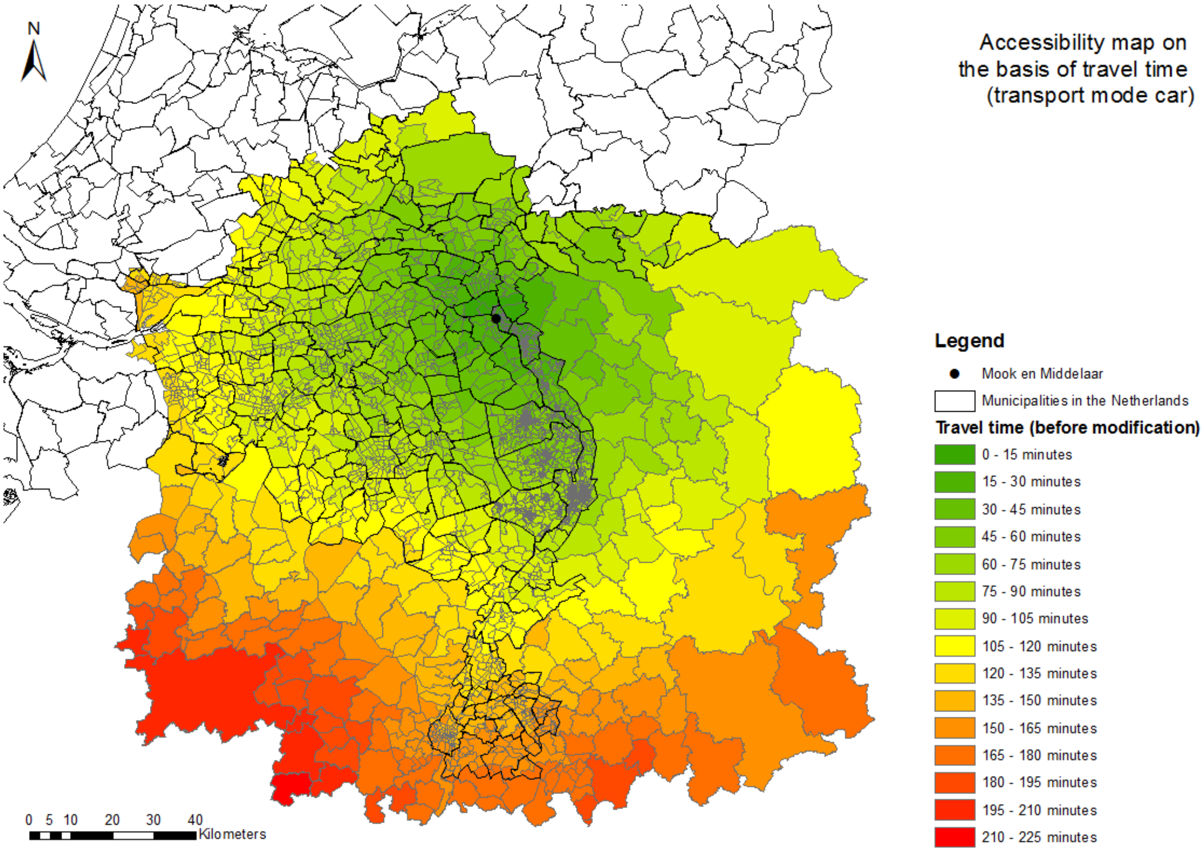

Figure D.1: Accessibility map Mook en Middelaar (before modification, step 6)

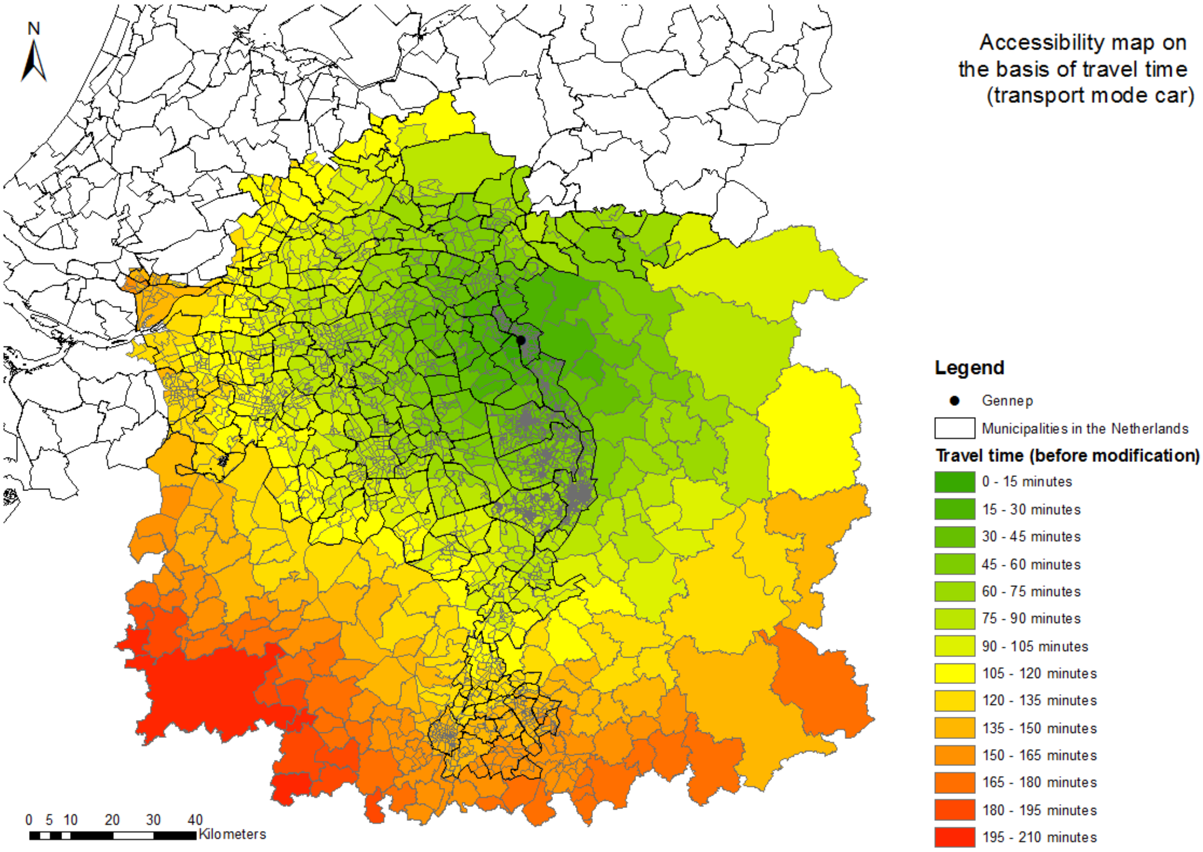

Figure D.2: Accessibility map Gennep (before modification, step 6)

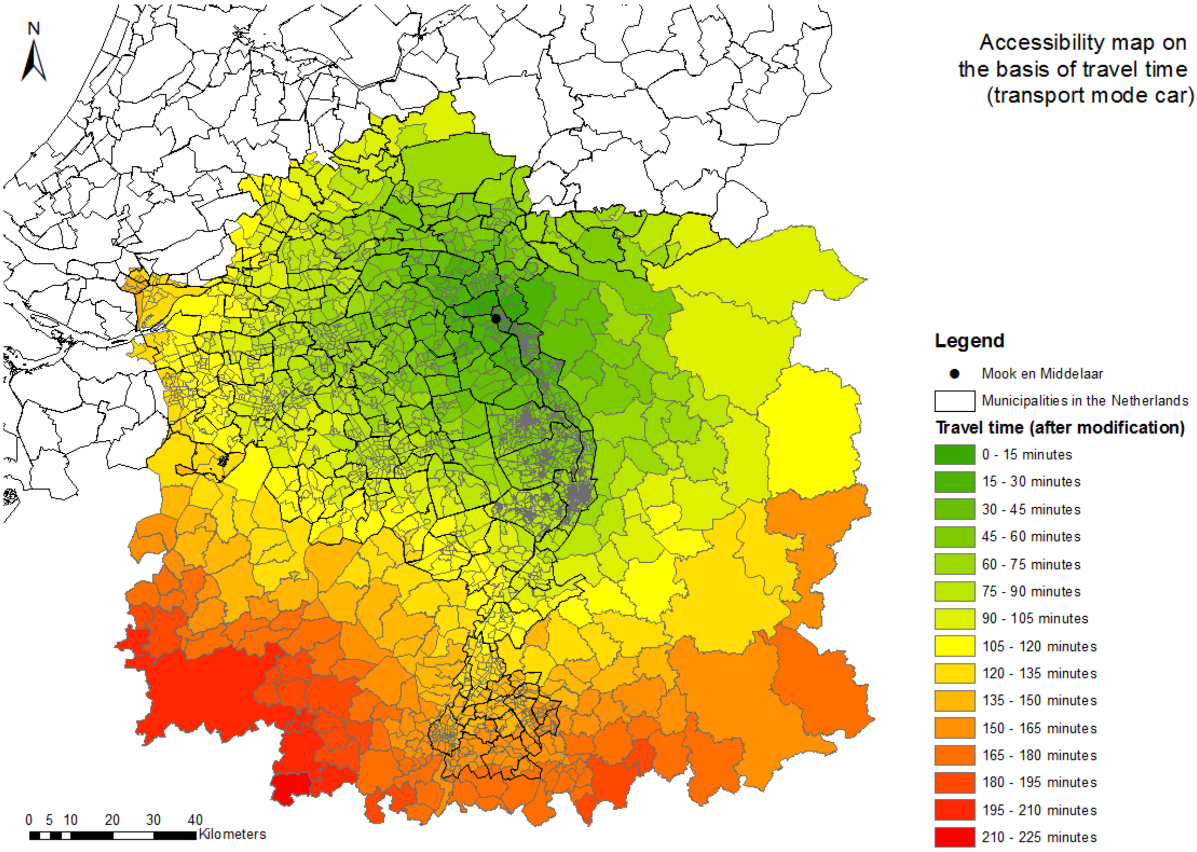

Figure D.3: Accessibility map Mook en Middelaar (after modification, step 6)

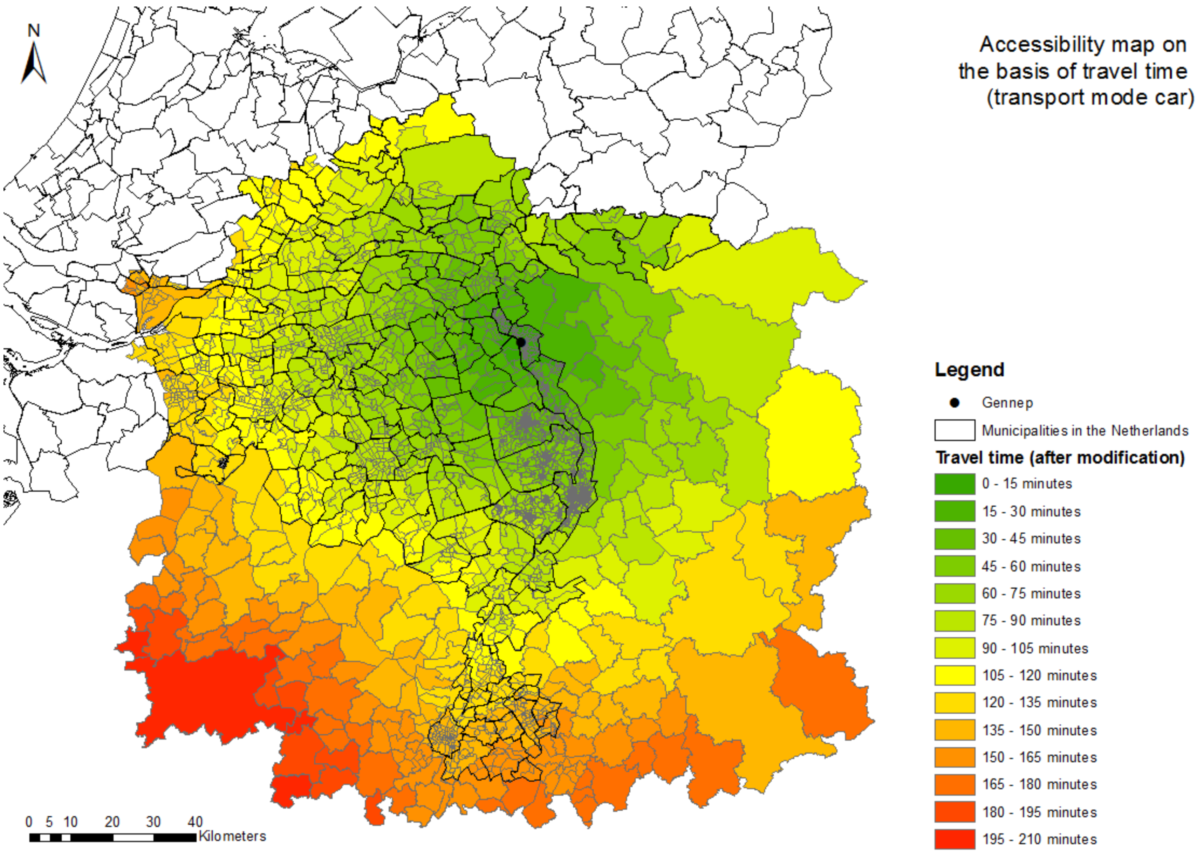

Figure D.4: Accessibility map Gennep (after modification, step 6)

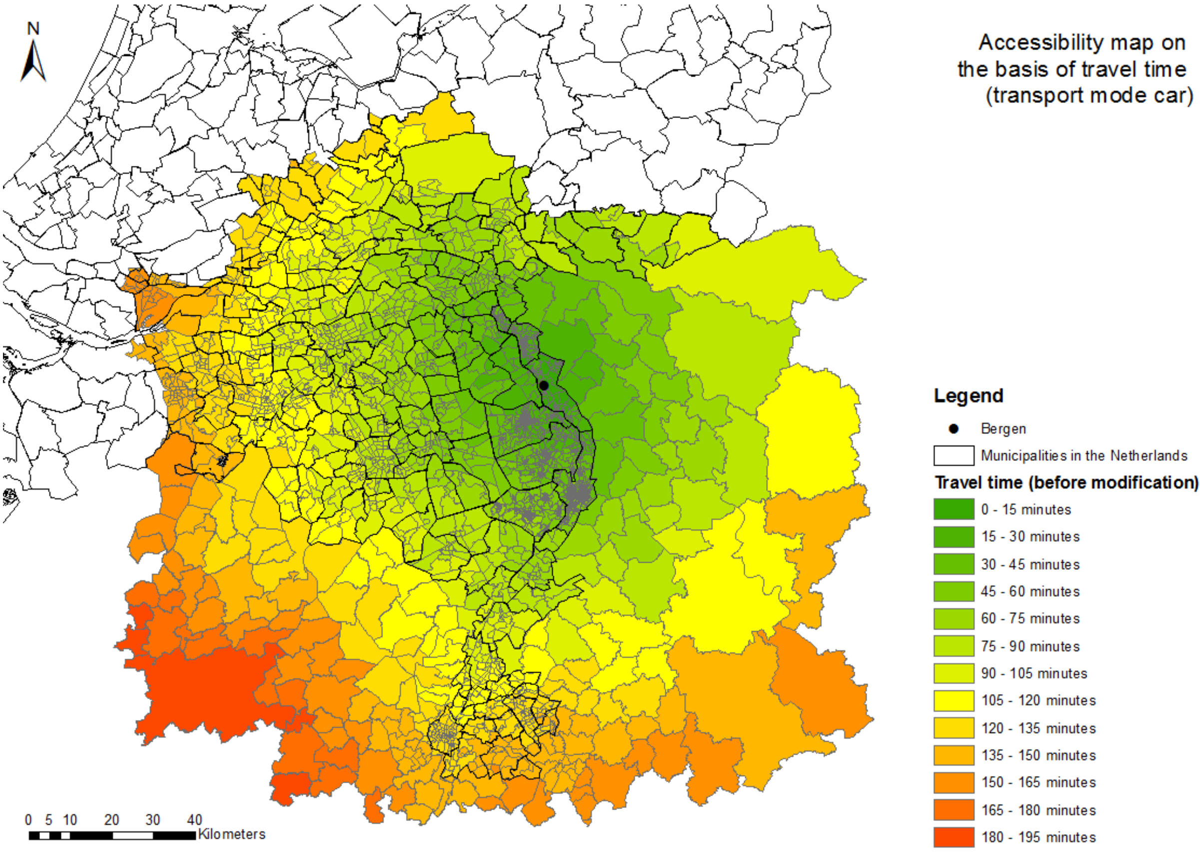

Figure D.5: Accessibility map Bergen (before modification, step 6)

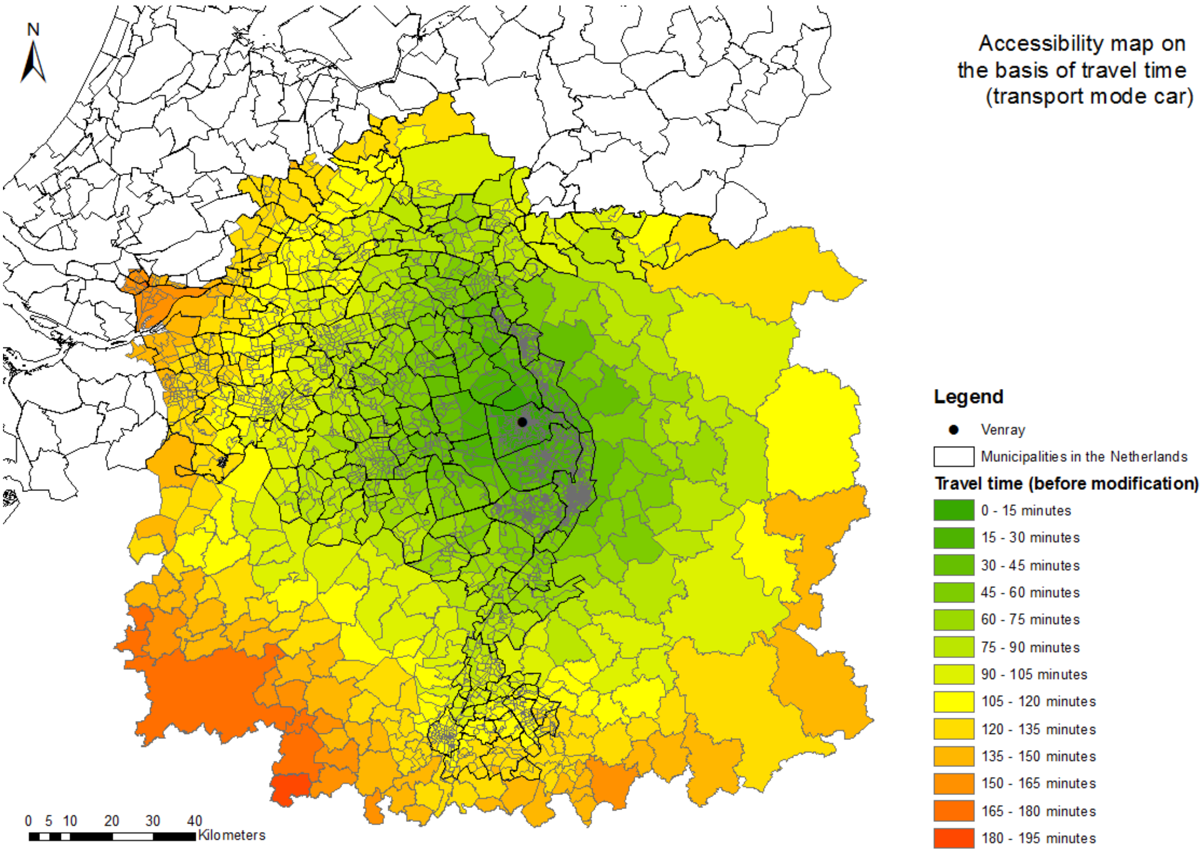

Figure D.6: Accessibility map Venray (before modification, step 6)

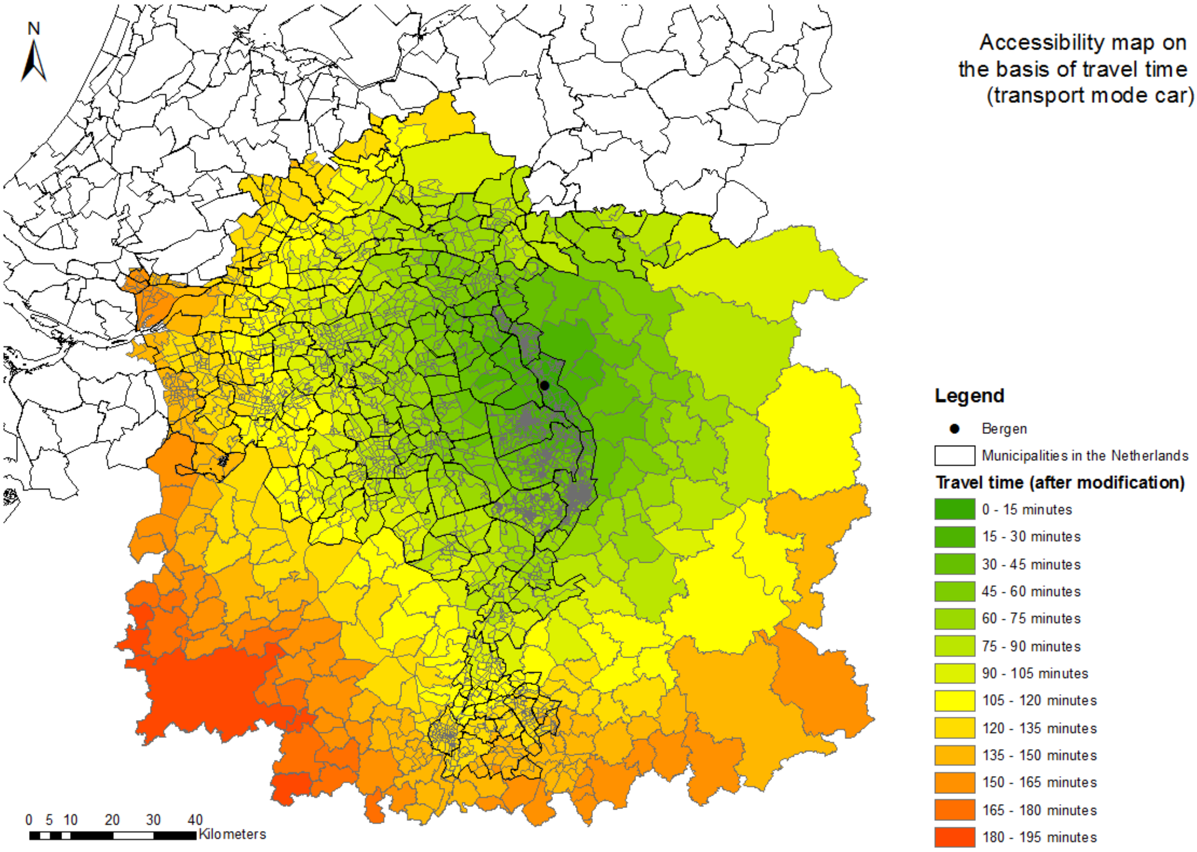

Figure D.7: Accessibility map Bergen (after modification, step 6)

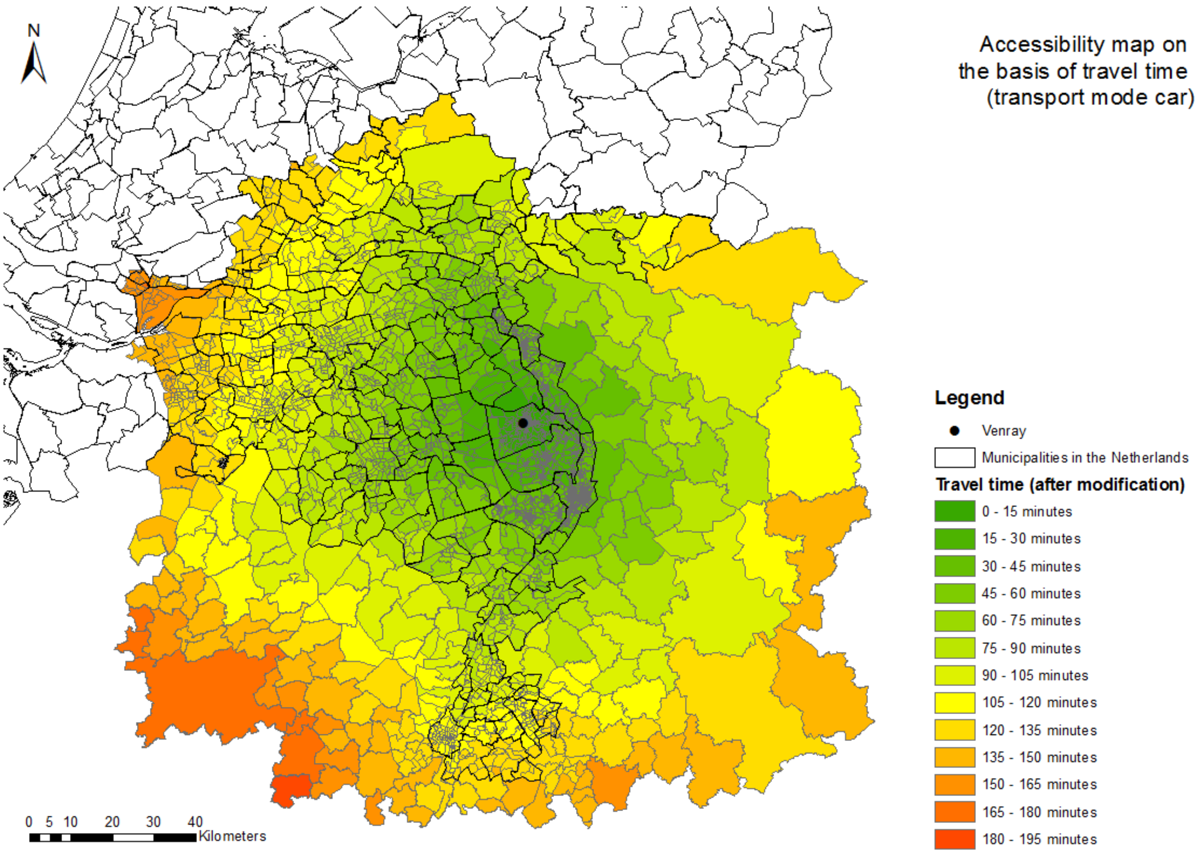

Figure D.8: Accessibility map Venray (after modification, step 6)

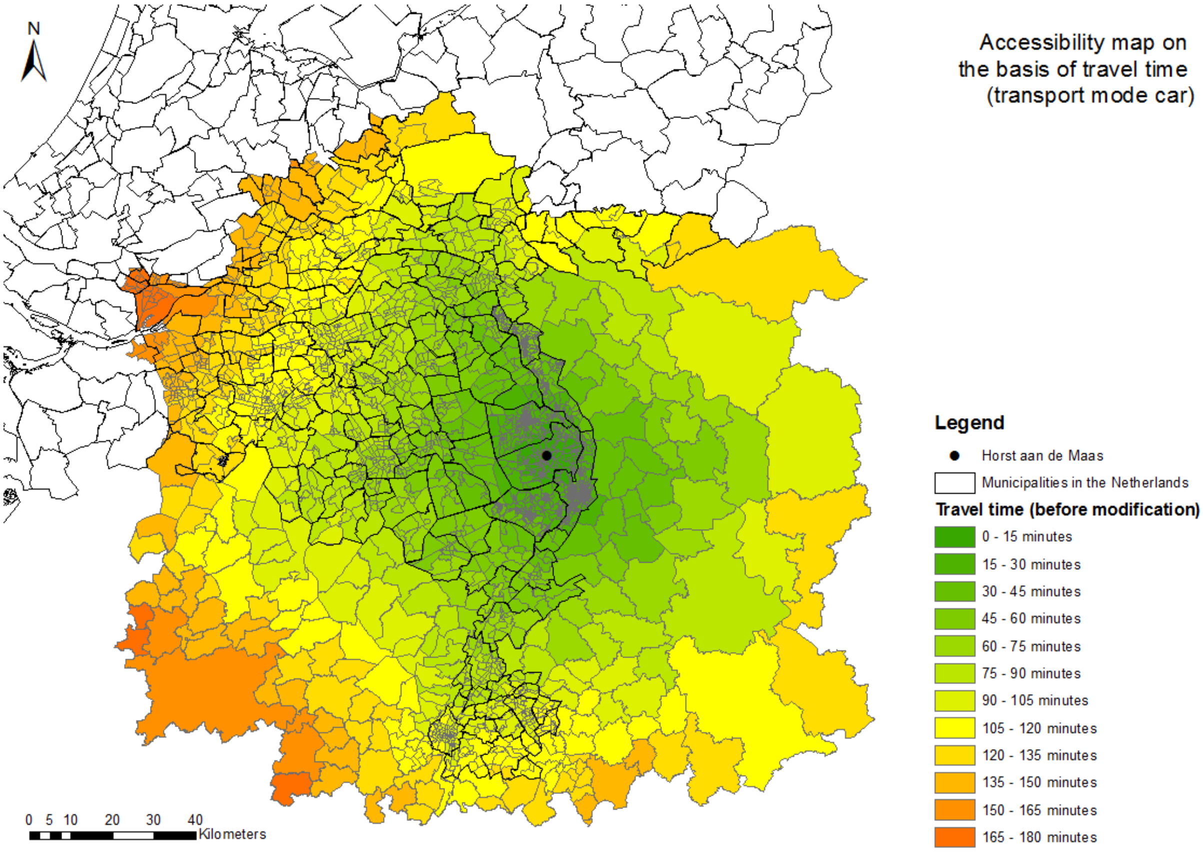

Figure D.9: Accessibility map Horst aan de Maas (before modification, step 6)

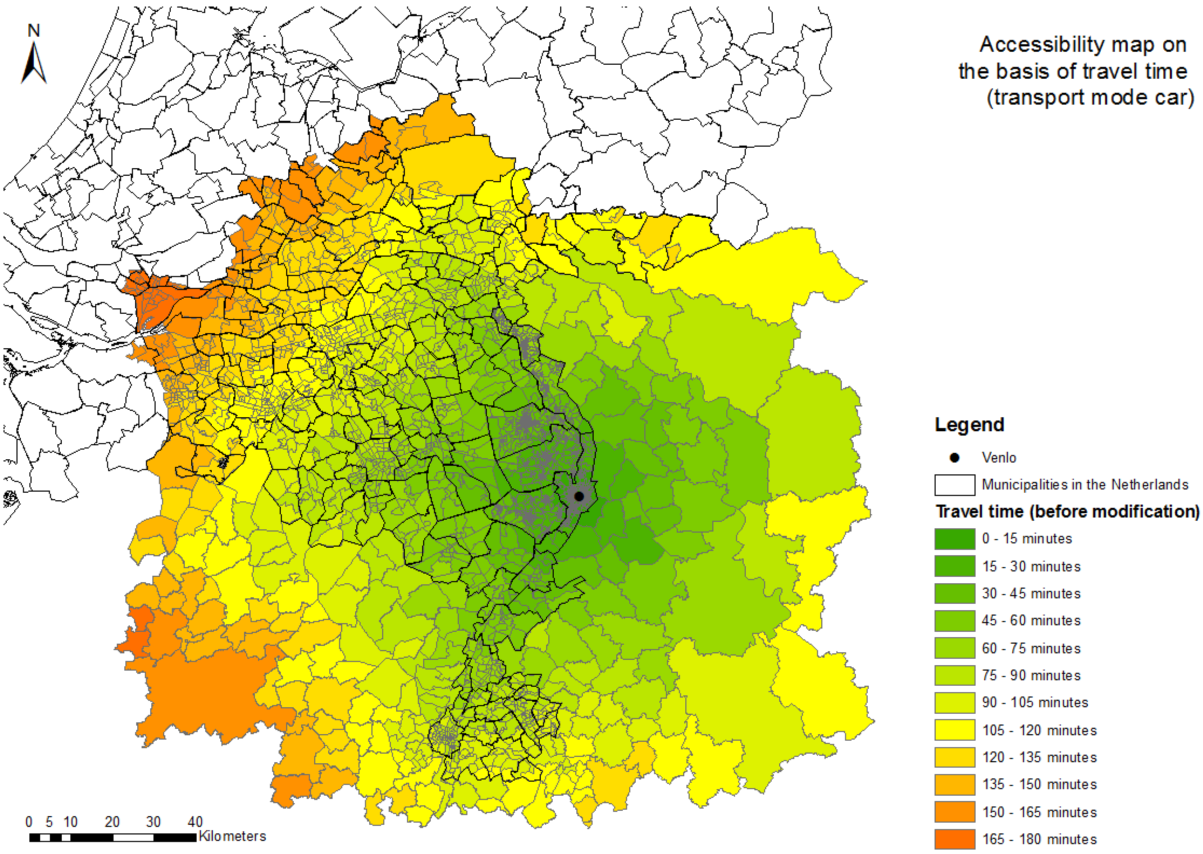

Figure D.10: Accessibility map Venlo (before modification, step 6)

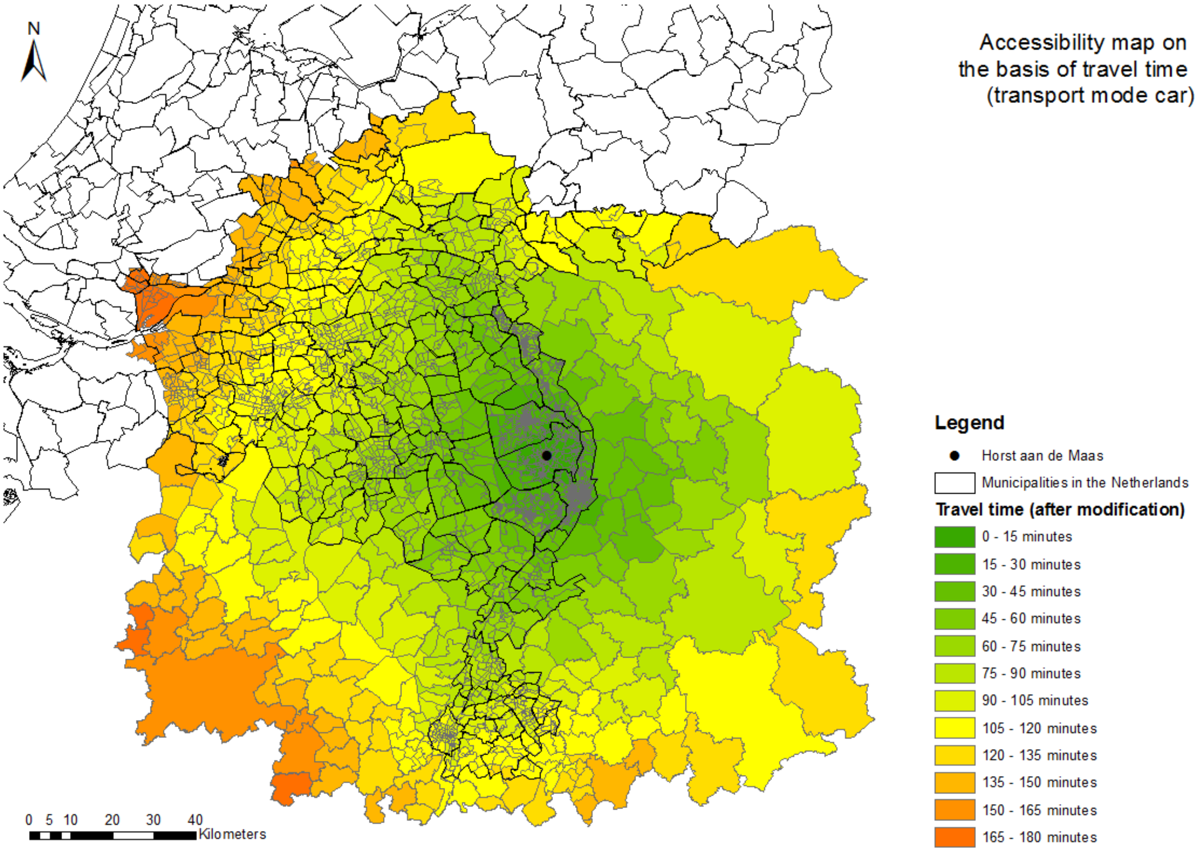

Figure D.11: Accessibility map Horst aan de Maas (after modification, step 6)

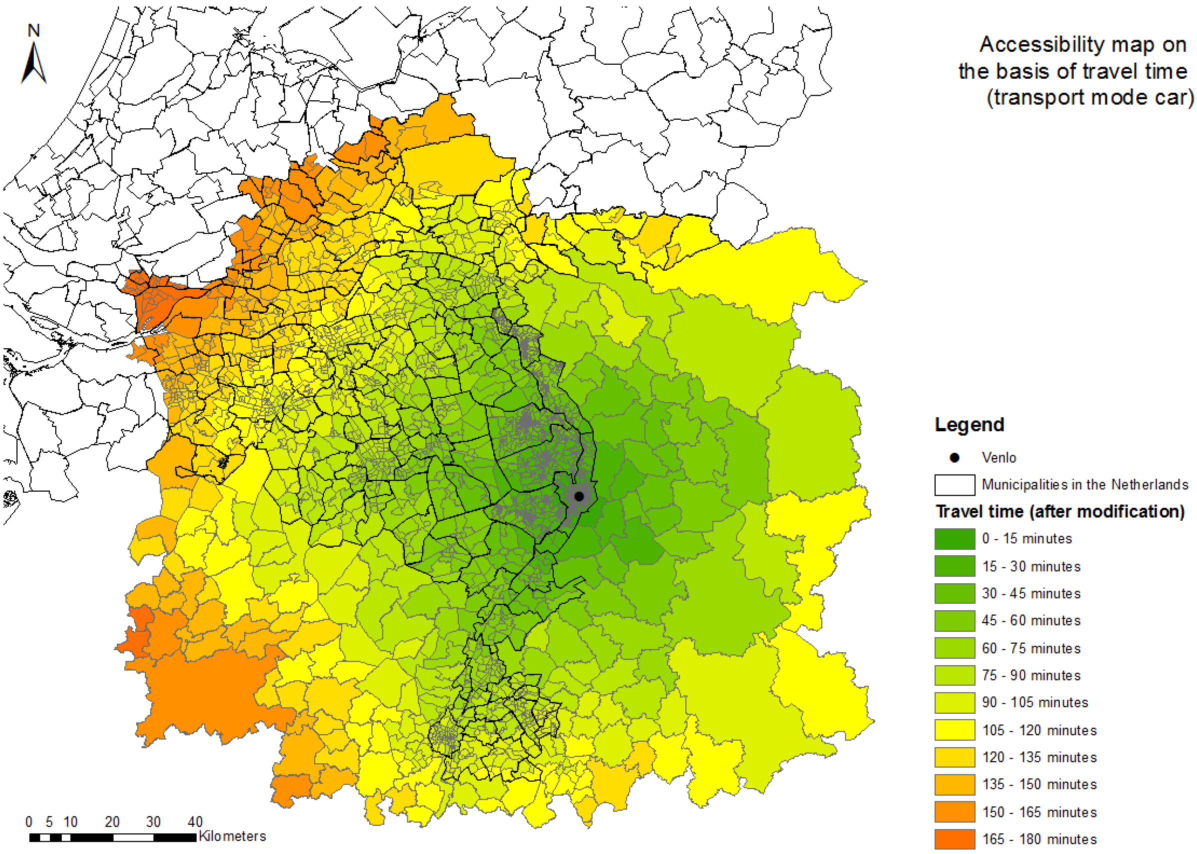

Figure D.12: Accessibility map Venlo (after modification, step 6)

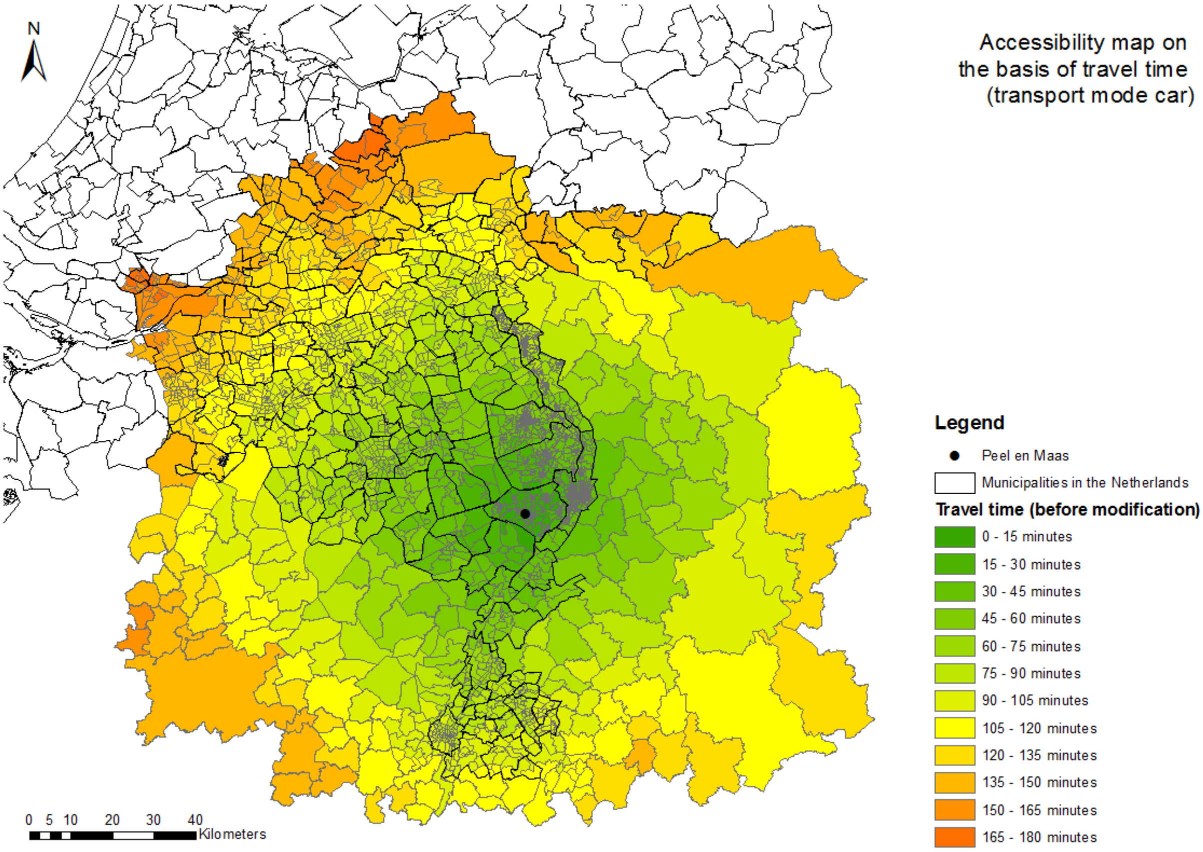

Figure D.13: Accessibility map Peel en Maas (before modification, step 6)

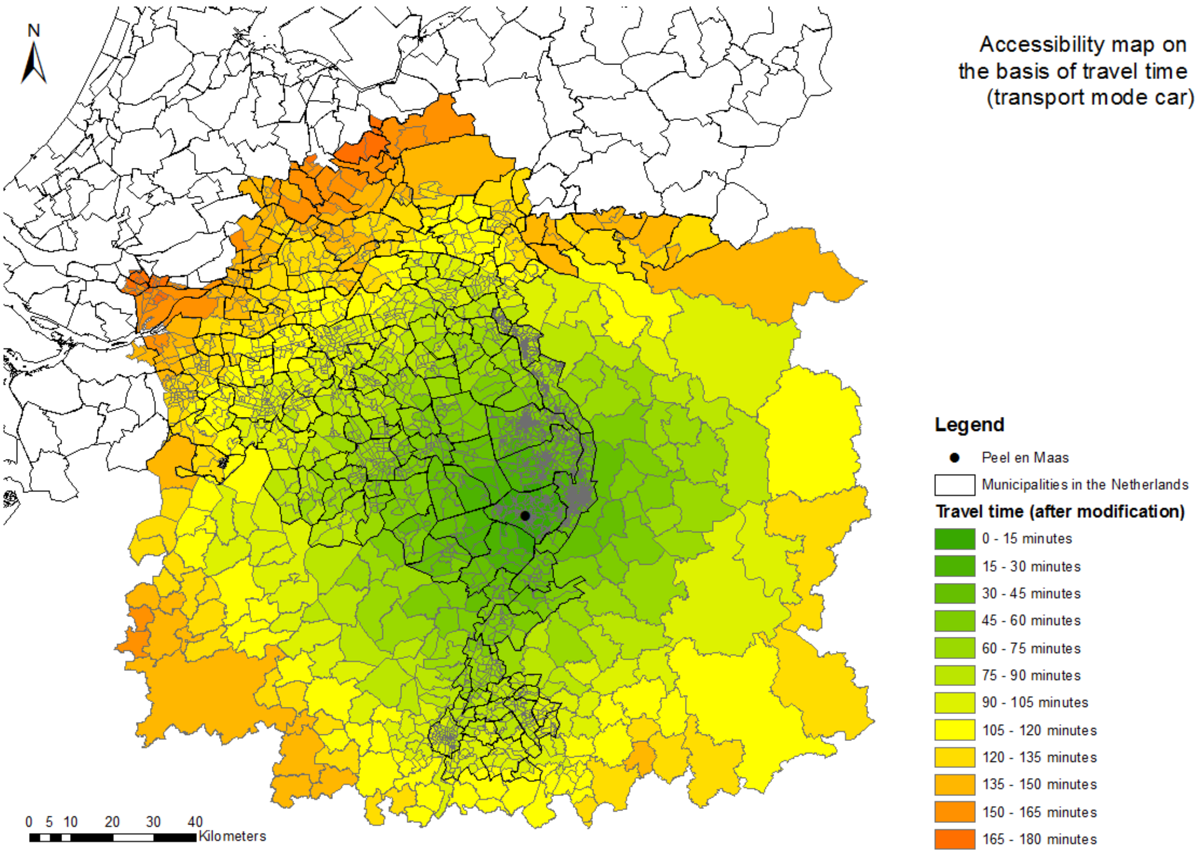

Figure D.14: Accessibility map Peel en Maas (after modification, step 6)