USE OF GEOGRAPHICAL ACCESSIBILITY INDICATORS IN POLICY MAKING

Barry Zondag
Significance
Eric Molenwijk
Rijkswaterstaat -WVL

1. INTRODUCTION

Geographical accessibility indicators are accessibility indicators that account for both changes in land use (activities) as well as for changes in the transport system (e.g. travel times). These indicators are already for a long-time part of the academic literature on accessibility. In practice however these indicators still play a minor role in the actual policy making in most countries and cities. A reason for this is the sectoral set up of the government which results in a focus on mostly domain specific (rail or road) network indicators.

Over the last years this rigid sector approach is changing driven by a combination of climate and livability concern, especially for the urban areas, and idea that new road investments stimulate further demand. In line with this the Ministry of Infrastructure and Water management as well as the Ministry of Interior in the Netherlands have called in their vision statements for a more integrated approach towards transport and land use. Up to now this ambition was stated at a more abstract level and it is the challenge to include this in the actual policy making process. The forthcoming national transport market and capacity analyses (NMCA) 2020/21 offers a good opportunity for this. This study is executed by the Ministry of Infrastructure and Water Management, in general with intervals of four years, to inform the newly elected government about the future accessibility challenges. This paper reports on the findings of two pre-studies in 2018 and 2019 for the NMCA to explore the use of geographical accessibility indicators in policy making in the Netherlands.

This paper briefly addresses the literature on geographical accessibility indicators in section 2. Section 3 specifies the accessibility indicators as developed in this study in more detail. In section 4 we present how this indicator can be used in the forthcoming policy study and section 5 briefly summarizes the main findings.

2. GEOGRAPHICAL ACCESSIBILITY INDICATORS

Originating from different research disciplines, such as transport, geography and economy, a wide variety of accessibility indicators exists. Geurs and van Wee (2004) classify different types of accessibility indicators ranging from network indicators, geographical accessibility indicators to geographical economic indicators. These indicators can be described as:

- The most common network indicator is a congestion indicator expressed as travel time losses on the network in comparison with a free flow travel time. This indicator is frequently used by the department of transport as output indicator to measure the effectiveness of transport measures. The indicator is very responsive to changes in the network especially if bottlenecks are solved, but the indicator only responds indirectly to changes in land use following its impact on travel time losses. Any impact on the proximity of activities is not measured by this indicator;

- A geographical accessibility indicator responds both to changes in the transport network, Level-of-Service, as well as to changes in land-use, the proximity of activities. Typically this indicator consists of either number of population or employment, as measure for the attractiveness of destination, and a distance decay function. The decay functions can be more or less advanced consisting of travel times, generalised time (e.g. including waiting times) or generalised costs (including travel costs as well). Furthermore the functions can be modal specific or not and take into account for competition to activities. If possible, these functions are preferably estimated on observed travel behaviour, like National Travels Survey data, to represent heterogeneity in actual behaviour. The geographical indicator responds to both to changes in travel times (and frequencies) in the region as well as to changes in the spatial distribution of jobs and population;
- Economic-geographical indicators measures changes in land use and travel LoS via changes in the utility for travellers. These are therefore also referred to as logsum indicator. The logsum method is well suited to calculate the benefits of accessibility changes as a result of either a transport (generalised cost) change or a land-use change. For evaluation purposes the logsum indicator can replace the commonly used rule-of-half method to calculate the consumer benefits. The literature mentions as omissions of the rule-of-half method that it gives incorrectly measured welfare effects of land-use policy plans (e.g., Neuburger, 1971) and transport strategies where land uses are forecasted to change as a result of the strategy (Bates, 2006; Simmonds, 2004). A limitation of the logsum indicator is that it is not suited to present developments in accessibility over time and therewith identifying future policy challenges.

Traditionally policy makers in the field of infrastructure have been using network indicators to identify the bottlenecks in the infrastructure and to evaluate policy measures. The wish of policy makers to use wider geographical accessibility is rather new regardless the longstanding experiences of the academic research community of developing and using these geographical accessibility indicators. Therefor practical experiences with these indicators as part of larger policy studies is still limited. In this study accessibility indicators were selected for the policy aim of identifying future challenges as part of the national outlook for the transport market and capacity. The geographical accessibility indicators are most suitable for this policy focus and we limit further discussions in this paper to this type of indicator.

More elaborated reviews on geographical accessibility indicators, including examples of applications, can be found in Geurs K. and Ritsema van Eck 2001, Hilbers H. and E. Verroen 1993 and Scheurer J and C. Curtis 2007. The study of Geurs K. and Ritsema van Eck 2001 differentiates geographical accessibility measures among others by contour measures (e.g. number of opportunities within fixed time limit), potential accessibility measures (e.g. use of distance decay function reducing potential of more distant opportunities) and accessibility measures including the aspect of competition for opportunities. The study of Bath et al. 2000 examines factors for inclusion in an ideal accessibility measure. The conceptual definition they use is defined as the ease with which one can reach a desired location by a given mode to pursue an activity of a desired type at a desired time This study also highlights the importance of good access to non-work activities in addition to more commonly included access to work activities.

The European COST project was an international project to explore the use of geographical accessibility measures in planning practice in various European countries at various spatial scale levels (Hull A et al., 2012). This study reveals that these measures are not so commonly used as would be expected from their theoretical advantages. According to Papa E. et al., 2016 the sectoral structure of policy making within governments is often the reason to use sector specific measures, like congestion, instead of more multi-sector measures like geographical accessibility measures which respond to both changes in transport infrastructure as well as land use.

This study does not aim to define the theoretical ideal accessibility measure but to bridge the gap between available geographical accessibility measures and the upcoming policy study. As a starting point we have used the accessibility measures as described by Geurs K. and Ritsema van Eck 2001 and take advantage of applying the potential accessibility measures in previous policy studies (Significance,2017; Zondag, 2016).

3. SPECIFICATION OF ACCESSIBILITY INDICATORS TO SUPPORT NATIONAL TRANSPORT MARKET AND CAPACITY ANALYSIS

Historically the National Transport Market and Capacity Analysis (NMCA) has focused on bottlenecks in the transport infrastructure to cope with growing transport demand. Several developments over the last years, like attention for climate change and integrated urban and transport developments, have supported the call for a broader analysis more focused on societal goals. Ultimately the analysis should support the quality of life in the Netherlands in a sustainable manner. In the redesign for the NMCA a decision tree has been developed from the perspective of quality of live and detailing the themes and indicators to consider. Main themes are supporting developments options for individuals, supporting economic activities and realizing a sustainable and safe transport system.

An important switch in the new set-up that network accessibility, focus on speed, is not an aim itself but should contribute to how well people or companies can perform their activities such as working, shopping or finding employees. This broader perspective also calls upon the use of broader indicators and especially geographical accessibility indicators, that are well capable to address changes in the accessibility of activities for firms and people. These indicators do not only consider changes in travel speed but also in the location of activities, both at the origin side (e.g. location of residence) and destination side (e.g. location of shops). Focus of this research was to evaluate alternative methods to calculate geographical accessibility indicators, select the most appropriate method and illustrate its usefulness for applying this indicator in the NMCA context. In this paragraph we will discuss the characteristics of the selected indicator, for a comparison of methods we refer to (Ritsema van Eck et al. 2001, or Significance 2018).

3.1 Specification of geographical accessibility indicator

The essence of the geographical accessibility indicators is that it includes both travel times (depending on speeds) and location and number of activities (proximity). For the NMCA geographical accessibility indicators have been developed for various travel purposes like the accessibility of jobs (perspective of individuals), accessibility of working force (perspective of firms) and accessibility of education, shopping and healthcare. In this discussion we focus on the indicator for the accessibility of jobs. As data for this indicator we have used zonal data on number of jobs and level-of-service data for car, public transport and bicycle from the National Model System in the Netherlands.

The aim of the geographical indicator is to calculate the potential number of jobs that can be reached within an acceptable travel time. The acceptable travel time to use should avoid being too long (weighting activities nobody will travel to), avoid hard barriers (small changes in travel might have big impacts) and depends on the travel mode (e.g. people are more willing to sit in the train for 45 minutes than to bike 45 minutes. In this study we have used empirical travel survey data to estimate purpose and mode specific acceptable travel times from observed behavior. As the behavior of people is heterogenous this results in a mode-purpose specific travel time decay function as demonstrated in figure 1 to 3.

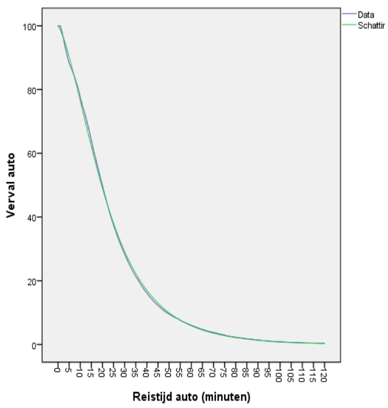

Fig 1. Travel time decay car

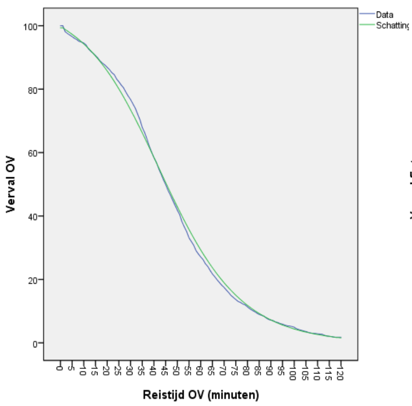

Fig 2. Travel time decay PT

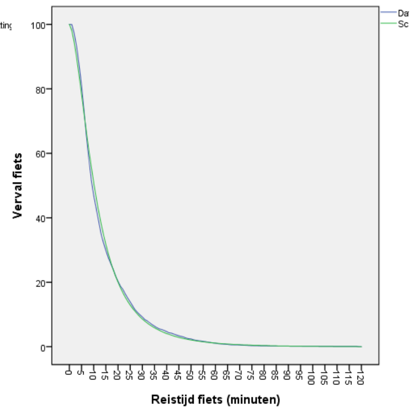

Fig 3. Travel time decay bike

The car travel times used in the estimation are including congestion based on the average between the morning and the evening peak hour travel times. For public transport door-to-door travel times are included consisting of all travel time aspects like access/egress times, waiting times and in-vehicle time. As representative time we use the fastest door-to-door PT option available, this could be either bus, tram/metro or train. For the travel time of the bicycle we rely on the available LoS for the bicycle in the NMS which includes the skim of specific bicycle routes.

Applying the above functions in combination with data on the location of jobs, provides insight in the accessibility of jobs for each of these three travel modes. In discussion on the use of these indicators with policy makers the main omissions in their view was the role of competition, attractiveness of the number of jobs you can reach also depends on the number of competitors (other job seekers), and the need for an integrated measure combining the three modes and their respective relevance into a single indicator.

3.2 Issue of competition

The standard geographical accessibility formula, which is applied mode specific, is extended with a correction factor for competition C. In the final implementation we have scaled this factor assuming this factor to be one for the zone with the lowest level of competition.

$$T_i = \sum_{j=1}^{nzones} \frac{B_j}{C_j} f(t_{ij})$$

$$C_j = \sum_{k=1}^{nzones} I_k f(t_{kj})$$

C: Competition at LMS-zone j
Ti: Accessibility of jobs from LMS-zone i
Bj: Number of jobs in LMS-zone j
f: travel time decay function
tij: travel time of zone i to j
I: number of inhabitants in zone k

The formula as presented calculates for inhabitants of zone i the accessibility of jobs in all other zones (j). Without competition this depends on the number of jobs in all other zones, the travel time between i and these zones and the coefficients of the estimated travel time decay functions. Including the aspect of competition means that for each destination zone (j) we calculate how accessible this zone is from all other zones (expressed as k) weighted by their number of inhabitants. Please note that the travel time decay function for ij is equal for kj.

3.3 Integrated measure for all modes

The mode specific accessibility of jobs indicators are of great value to present for each mode the accessibility of jobs per region or to present the developments in accessibility over time (increasing or decreasing accessibility in 2040). However, an overall picture for each region was missing and should consist of a combined value for all modes reflecting the relative importance of each mode. A stepwise procedure has been developed to assess for each OD relationship the market share of each mode, including:

- To assess the market share for biking (and walking) a function is estimated on all OD pairs in the model relating the market share of bike (and walking) to the travel distance. As can be expected, this function has a steep decline and these modes are only relevant on the shorter distances. For each relationship the bicycle accessibility values account for x% and car and PT for (100-X)%;
- The market share for car and PT is divided between car and PT based upon the travel time difference between PT and car. Data from the NMS model has been used to estimate a function relating the travel time factor (travel time PT/travel time car) with the market share of PT;
- Combining the first steps gives for each OD the expected market share for bicycle, car and PT. The overall accessibility of a region consists of the sum of the various modes weighted for their expected market share**.**

4. USE OF INDICATOR IN POLICY STUDY

The policy purpose of the new indicator is twofold:

- Identifying future accessibility challenges, and defining policy options;
- Evaluating the accessibility impacts of transport and/or land-use measures.

In this paragraph we focus on the first ambition which is the purpose of the NMCA study. Starting point is the existing level of accessibility of jobs, which can be illustrated by mode and at an integrated level. The maps below present the existing level of accessibility of jobs for car, PT, bike and the integrated measure for all modes in the Netherlands. Not surprisingly follows that accessibility by bike is mainly relevant within the urban areas, accessibility by PT follows the rail network connecting the urban corridors and accessibility by car is more diffuse diminishing in all directions from the urban areas.

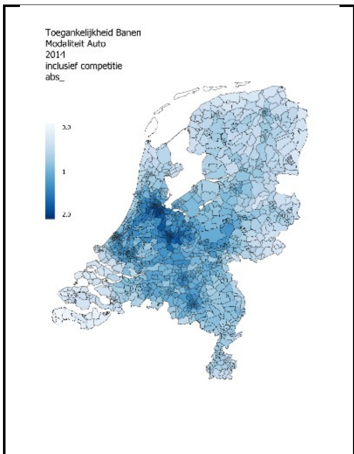

Fig 4. Existing levels of accessibility jobs x car (2014)

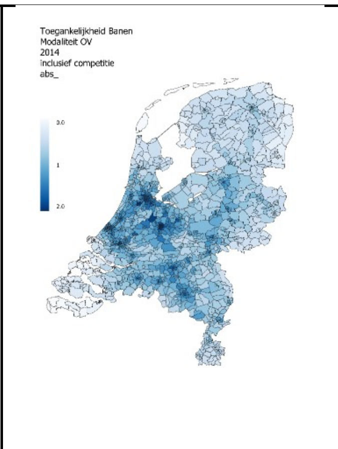

Fig 5. Existing levels of accessibility jobs x PT (2014)

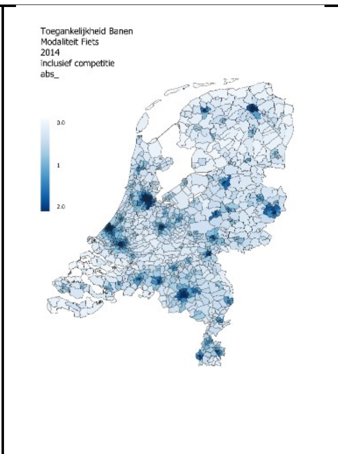

Fig 6. Existing levels of accessibility jobs x bike (2014)

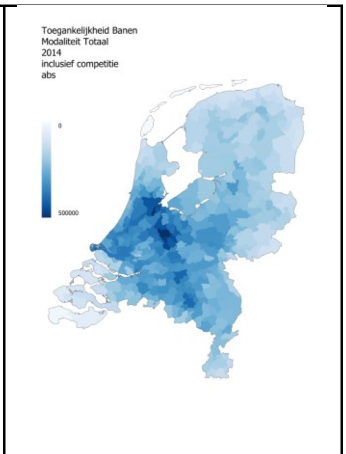

Fig 7. Existing levels of accessibility jobs x all modes (abs 2014)

These status maps, presenting the level of accessibility, are intuitively correct but are from a policy perspective not very relevant. The level of accessibility is to a large extent depending on the location of urban areas and most urban areas are there already for centuries. To tell a more interesting story, influenced by policies and developments in the coming decades, we focus on the changes in accessibility that can be realized. Our story follows a top-down line starting by illustrating the relevant exogenous scenario developments at a regional level in the Netherlands. Figure 8 and 9 illustrate the developments in number of jobs and working force towards 2040 for the so-called high growth scenario.

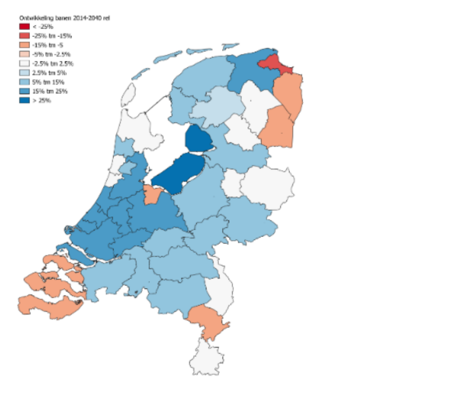

Fig. 8 – scenario developments in job growth towards 2040

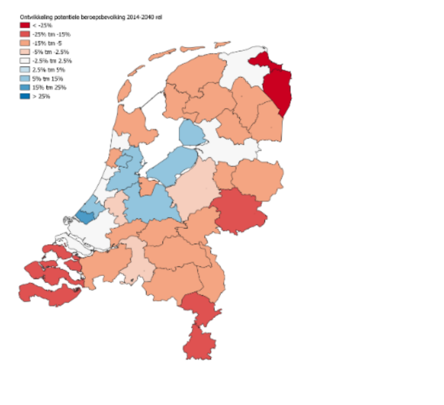

Fig. 9 scenario developments in working force towards 2040

The accessibility indicators are influenced by these scenario developments. For example, the accessibility of jobs indicator develops in line with the scenario developments for the number of jobs, meanwhile taking into account competition from the workforce. Other developments influencing the accessibility of jobs for people are changes in the proximity of activities, e.g. location of residential and job developments, or transport conditions affecting travel times. In Fig 10 we see that the accessibility of jobs is declining in many regions although the number of jobs is sometimes increasing in these regions towards 2040. At a national level there is a job growth of 14% and a growth in accessibility of 0.2%, this means that the potential increase in accessibility offered by the exogenous scenario developments is not realized.

To get a better insight in the relationship between scenario developments and changes in accessibility we discuss three different type of regions in more detail.

1. The Amsterdam region shows as scenario developments a high increase in jobs and a more modest increase in the

workforce. The accessibility of jobs for people in this region is however more or less constant. This is due to worsening travel conditions as a results of increasing congestion levels. Part of the decline in car accessibility is compensated by an improved accessibility for PT and bike (see fig 12 and 13);

2. Northern part of the province of North Holland. This region shows a decline is the accessibility of jobs while the scenario development is stable. Inhabitants of this region depend for accessibility of jobs to a large extent on the neighboring Amsterdam region. Fig 11 shows a decline in car accessibility due to additional congestion while PT accessibility is stable and accessibility by bike plays only a minor role;
3. Rural area in Eastern part of the country. This is a region facing a decline in population and employment. In this region job accessibility is slightly improving due to a sharper decline in workforce than in jobs (there is less competition). In this region there is as good as no congestion now and in future years.

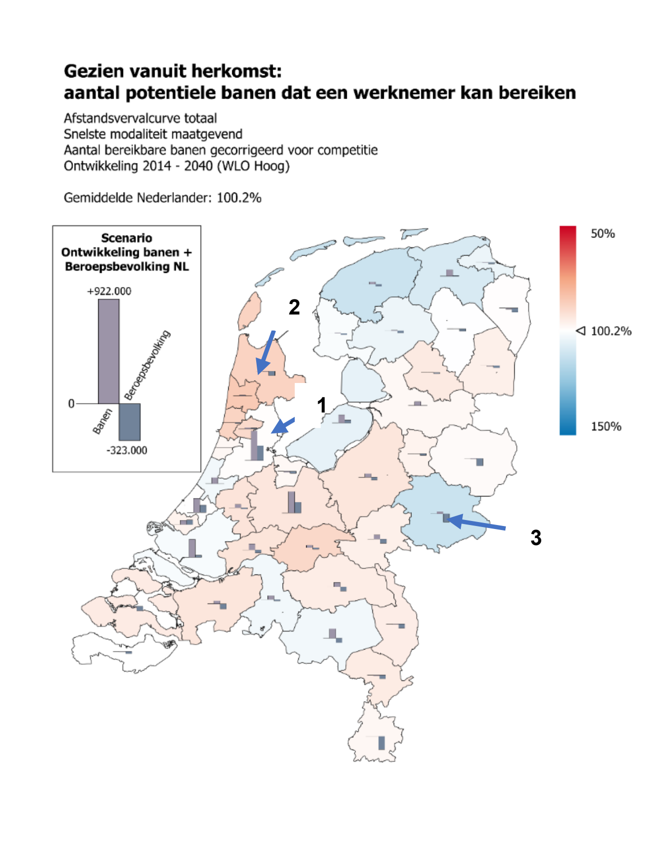

Fig 10 evolution of job accessibility (grid) plotted against increase in no. jobs and workforce (two bars)

The maps below presents the developments in job accessibility in more detail distinguishing between car, PT, bike and integrated developments in accessibility.

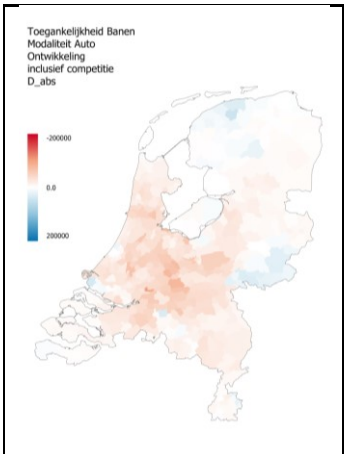

Fig 11. Accessibility jobs x car (delta 2014-2040)

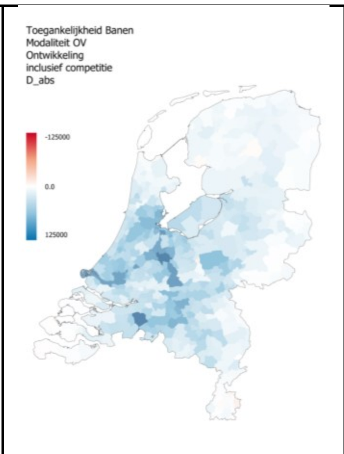

Fig 12. Accessibility jobs x PT (delta 2014-2040)

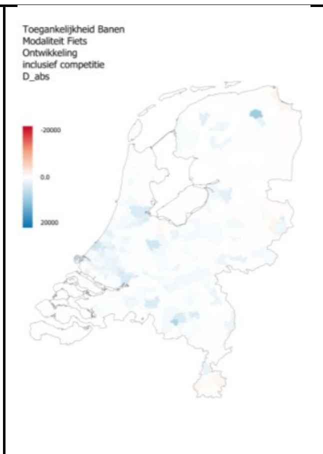

Fig 13. Accessibility bike (delta 2014-2040)

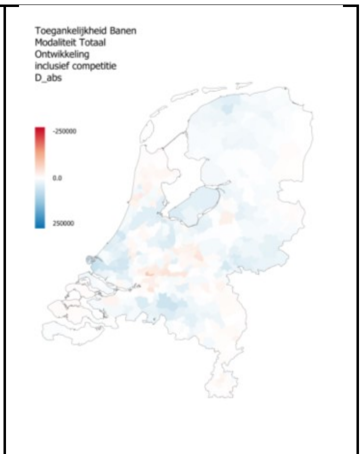

Fig 14. Accessibility all modes weighted (delta 2014-2040)

The maps show a substantial decline in the accessibility of jobs by car indicating that the increase in congestions, especially in the urban core of the Netherlands, has a stronger impact than the growth in jobs. The accessibility of jobs by PT shows an increase mainly benefiting of the job growth in urban locations with a good access to PT. The developments in accessibility of jobs by bike follows the local developments in number of jobs and is very sensitive to the location choice of urban developments.

4.1 National accessibility dashboard

The ambition for the NMCA is to look at various accessibility indicators influencing the options for people to develop themselves or companies to perform their activities. Included accessibility indicators presenting the development options for people are the accessibility of jobs, education and shopping. The accessibility of employees is included as indicator for the attractiveness of regions for economic activities. The so-called accessibility dashboard includes the developments for all these indicators and figure 15 presents this dashboard for the Netherlands for the High Growth Scenario.

The pie charts in the dashboard present for each indicator the development in accessibility, 2040 vs 2014, for the bicycle, public transport and car mode. The size of the pie slice depends on the market share of the mode. For example, the accessibility of jobs increases for bicycle and public transport travelers but decreases for car travelers. In terms of the number of affected people the market share of the car is larger than the market shares of bicycle or public transport. The increase for bike and PT follows the growth in number of jobs and an increasing level of urbanization in the Netherlands in this scenario. The accessibility of PT benefits also of an improved level of service in 2040, but this impact is more modest. The accessibility of the car worsens due to an increasing level of congestion and a large majority of the commuting trips are peak hour related. For the other activities, education and shopping, the relative importance of the modes differs. Although car accessibility of education diminishes this only affects a small share of all travelers. Most of them benefit of the increase in accessibility by bike and public transport. For shopping the car accessibility improves as well because these trips are mainly made outside peak hours and are less influenced by congestion.

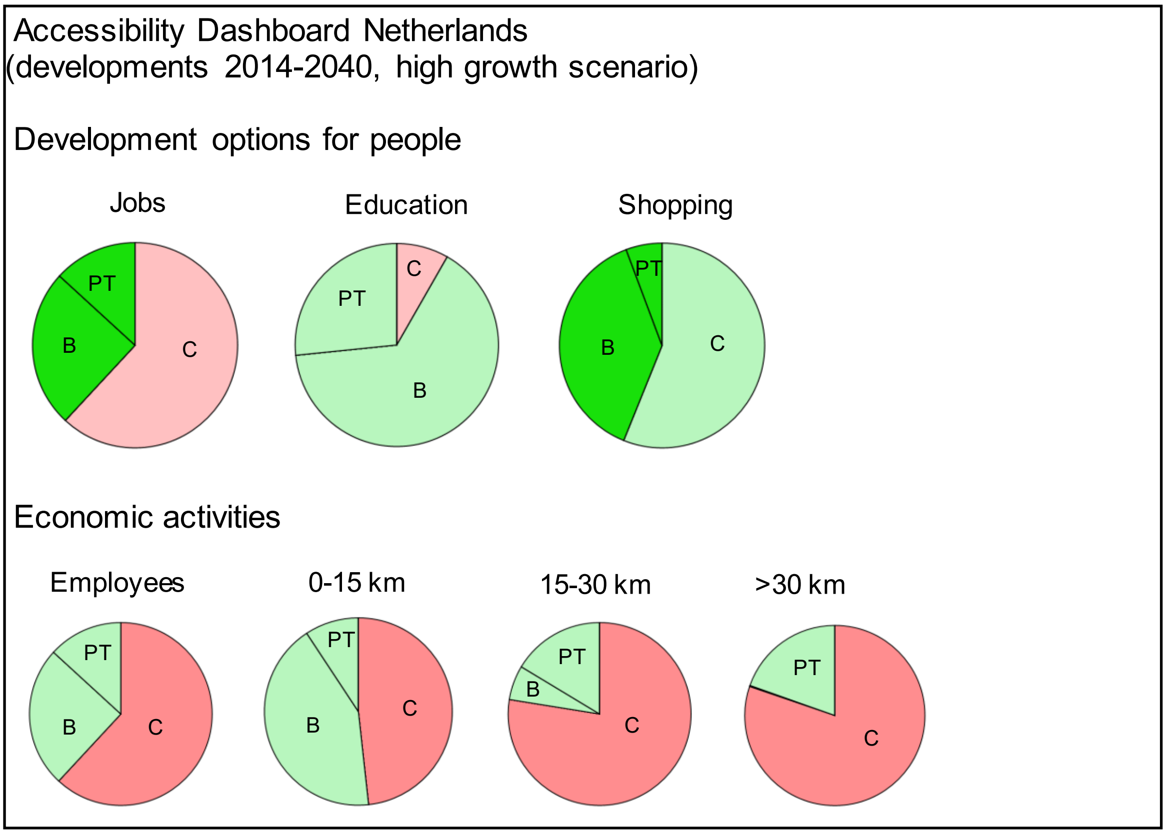

Figure 15: accessibility dashboard for the Netherlands (C = Car, B = Bike, PT = Public Transport)

The attractiveness for economic activities in the Netherlands is improved by a better accessibility of employees by bike and PT but diminished by a declining accessibility by car. This indicator has been analyzed in more detail by distinguishing short, medium and long-distance trips. The relative importance of the modes varies over these distance categories and for short distance trips the decline in car accessibility is compensated by the increase in B and PT. For longer distance trips the car is dominant and a decline in car accessibility makes it more difficult for companies to attract employees from further away.

4.2 Regional accessibility dashboard

Similar to the National dashboard it is also possible to presents these developments at a regional or local level in similar dashboard. Figure 16 presents the dashboard for the city of Amsterdam. This dashboard shows that in Amsterdam the bike and PT modes play a more important role in the accessibility of the city than at the national level. The expected high growth in number of jobs and population for the Amsterdam region increases the attractiveness for people and companies to find a suitable job or employee within the urban area. For PT travelers the accessibility by train is improving. Reasons for this are the growth in jobs and people in Amsterdam, the development of housing and office space nearby PT facilities and the improvements planned to upgrade the Level of service of PT. For car travelers, especially over a longer distance, the impact of increasing congestion is stronger than the positive impact of more jobs or people.

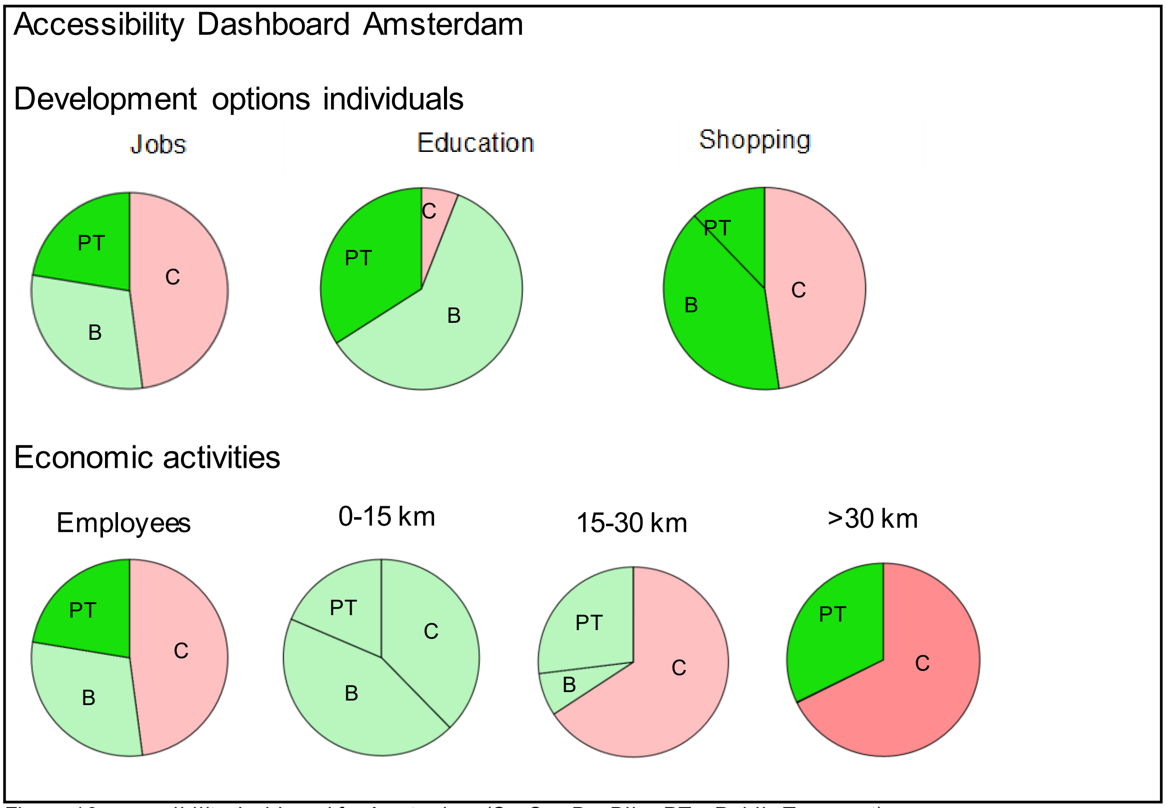

Figure 16: accessibility dashboard for Amsterdam (C = Car, B = Bike, PT = Public Transport)

4.3 Policy options

The aim of the NMCA analysis is to identify regions where policy action might be needed to solve future accessibility problems. The idea is that figure 17 can be helpful to classify regions and identify the need for policy actions. Following this figure accessibility developments in each region are classified as desirable or undesirable. Whether policy action from the Ministry of Infrastructure and Water is needed depends on the cause of these developments. For quite some regions the development in accessibility depends mainly on exogenous scenario developments such as population or job growth and decline. If there are no transport issues under these circumstances, like declining travel speeds or capacity constraints, the need for policy action from the Ministry is limited. For these regions it is advised to monitor the conditions and if developments are undesirable interact with other Ministries on how to improve the conditions.

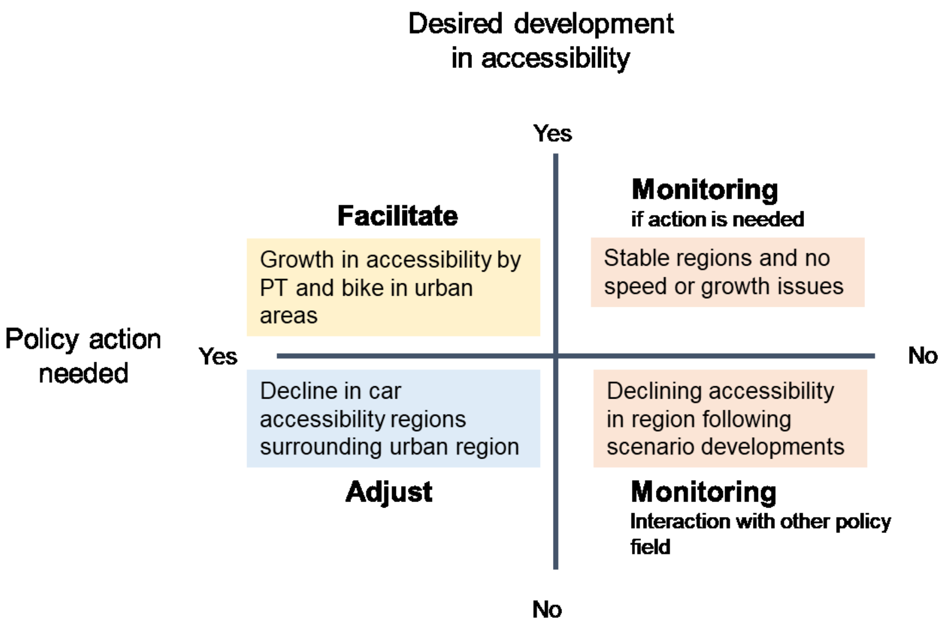

Figure 17: identifying need for policy action

For other regions policy action is more suited either because desirable developments need to be facilitated, like high growth in bike and PT accessibility in the urban areas, or because undesirable developments need to be adjusted, like for example the decline in car access to jobs in urban areas. The design and testing of policies is outside the scope of the NMCA. However, following the philosophy of these geographical accessibility indicators a wide variety of policy measures, including spatial and transport policies, can be explored.

5. CONCLUSIONS

This study aimed to bridge the gap between available geographical accessibility measures, as known in the literature, and the application of these measures in policy studies like the forthcoming NMCA study in the Netherlands. In our pre-studies we have explored in interaction with policy makers how to overcome the functional, technical and communicative barriers for use of these indicators. The framework as set out in this paper is the result of these pre-studies and will be used in the forthcoming NMCA.

A main functional challenge was to develop accessibility indicators that represent the mode specific characteristics, such as mode specific travel time decay functions, and are meanwhile suitable to be summed into one integrated accessibility indicator. This integrated indicator should reflect for each region accessibility values reflecting the relative importance of each mode without being depended on self-selecting mechanisms. Another functional challenge was to use for accessibility of jobs and employees indicators that were corrected for the level of competition.

The paper shows that the applied accessibility indicators proved to be useful to develop a comprehensive picture of the different elements that together determine the direction in which accessibility (for different functions and goals) is heading. The segmentations (functions/goals, modes, geographical scale, trip length) allows for a distinct top-down approach and brings together possible challenges and opportunities from different fields that would have otherwise remained undetected with a more sectoral based network-indicator approach.

The main communication challenge was to support the paradigm shift form a network-approach towards a more broaden geographical approach. During the years that the pre-studies were undertaken this shift was largely adopted by the involved policy makers, supported by the study results as well as societal and environmental changes. The accessibility dashboard in combination with an approach on how to link accessibility developments and policy options were important aspects to support the policy makers. This allows for a clear comprehensive storyline within the NMCA study and hopefully many more in-depth explorative studies in the years to come.

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