ROBUSTNESS OF ACCESSIBILITY CHALLENGES TO LAND USE CHANGES

Barry Zondag
Significance

Eric Molenwijk
Rijkswaterstaat WVL

1. INTRODUCTION

The Ministry of Infrastructure and Environment of the Netherlands executes, in general with intervals of four years, a national transport market and capacity analyses to inform the newly elected government about the future accessibility challenges (IenM, 2017). The insights from this analysis are used to select and prioritize in which regions a further exploration of the accessibility challenges will be started potentially resulting in an investment program. The future accessibility challenges are explored under two long term demographic and socio-economic scenarios to address uncertainties in economic and demographic developments. Additionally in this study the robustness of the future accessibility challenges is explored for alternative land use developments for urban regions within the Netherlands.

The study aims to deliver insights on: a) robustness of accessibility challenges to land use developments by region b) contribution of spatial strategies to improve regional accessibility. The study addresses these research challenges at two different levels of spatial detail. At the national level, land use developments for all urban regions in the Netherlands are tested on their impact on accessibility. At a regional level this is done for the larger Amsterdam region. The national analysis is used to differentiate between regions where the accessibility challenges are more or less sensitive for alternative land use developments.

The impacts of the various land use alternatives are calculated by applying the TIGRIS XL model, a land use and transport interaction model for the Netherlands. The accessibility challenges are discussed by a broad set of accessibility indicators covering accessibility of jobs by car, public transport and bicycle, network aspects, such as congestion, and accessibility benefits in monetary terms. In the regional analysis for the Amsterdam region this set is extended with a bottleneck indicator for the road network enabling to address the impacts of land use developments on specific bottlenecks.

The paper is structured as follows. In the next section the research framework and policy indicators for accessibility are described. Section 3 and 4 present the results of the national and regional cases. Finally Section 5 presents conclusions and recommendations based upon this study.

2. RESEARCH AIM AND APPROACH

As part of the national market and capacity analysis this study explores the robustness of accessibility challenges to land use changes (abbreviation RRB in Dutch for spatial robustness accessibility). The study defines RRB as follows:

> "RRB describes the sensitivity of relevant accessibility indicators for changes in land use developments and planning strategies. This can give an alternative view on the accessibility challenges and bottlenecks in an region as well as insight on the potential of land use policies to improve accessibility in the region"

The research aims to:

- Inform policy makers on the regions where it is valuable to perform a sensitivity analysis of the infrastructure bottlenecks to land use changes. In sensitive regions there is a chance that possibly the wrong bottleneck is prioritized if land use developments turn out differently than assumed in the reference scenario;

- In regions where the accessibility performance is sensitive for land use changes there is a good potential to actively influence accessibility by designing land use strategies. This study shows how this can be done and what the potential impacts are of these land use strategies on accessibility.

Figure 1 presents the conceptual framework for this study. It highlights the iterative process between formulating land use strategies, calculating their impacts on the land use and transport system and evaluating the consequences on different accessibility indicators. The land use strategies in this study do not vary on the overall volumes, which is typically done in scenario studies, but vary between the type of locations where housing developments take place within larger urban areas (e.g. urban densification versus suburbanization).

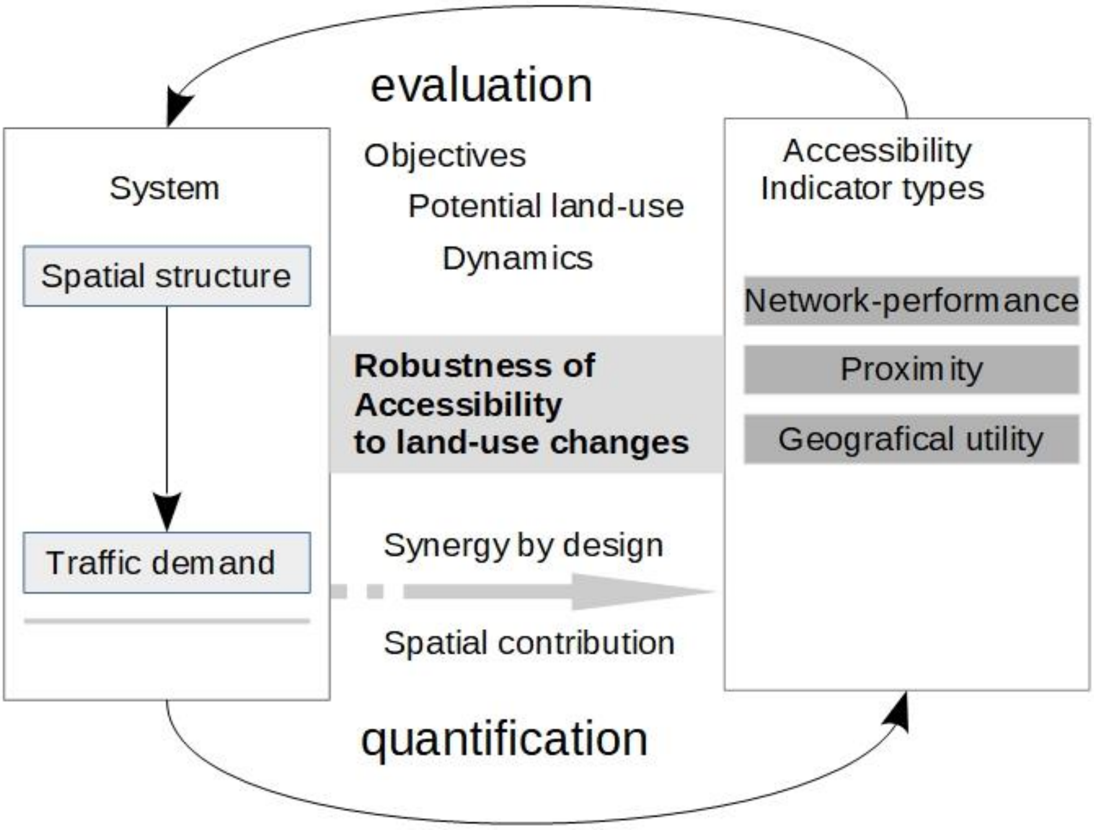


Figure 1: Conceptual framework

2.1. Analysis at national and regional level

This study performed similar analyses at different geographical scale levels answering at both levels the research aims of identifying the robustness of accessibility challenges to land use changes as well as the potential of land use strategies to improve accessibility. At both geographical scale levels we use the high growth scenario, set up for the whole country and regionally detailed, as our reference scenario. At the national level we apply generic land use developments, e.g. stronger urbanisation or more suburbanisation , in a similar way for all urban regions in the Netherlands. In the regional case study we test the influence of specific regional patterns, for example suburbanization mainly to the North, South or dispersed. The size of the land use changes applied in the regional case study is comparable for its region to the changes applied in the study at national level.

The analysis at two spatial scale levels allows us to control if the strategies work out in the same direction at different scale levels. Further the regional case study can demonstrate the additional benefits of a more regionally tailored strategy in comparison with a more generic strategy. At the regional level it is also possible to check the robustness of specific bottlenecks to land use changes. This makes it possible to identify more and less robust bottlenecks within a region. Further it gives insight whether an alternative land use development result in new, so far unobserved, bottlenecks.

2.2. Policy indicators

The accessibility indicators in this study cover different aspect of accessibility and serve different policy challenges. The accessibility indicators cover various modes of transport including car, all public transport and bicycles. In line with Geurs and van Wee (2004) we distinguish here between network indicators, geographical accessibility indicators and geographical economic indicators. A difference between these indicators is that network indicators focus only on the functioning of the network, mainly related to speed of travel, frequency or reliability. The geographical indicators focus on the combination of the functioning of network and spatial distribution of activities. These indicators are therefore influenced by both changes in speed as well as proximity of activities. The geographic economic indicators calculates the monetary benefits resulting from speed improvements as well as proximity improvements (Geurs et al 2010).

From a policy perspective the network indicators respond mainly to infrastructure investments or pricing policies and only indirectly to changes in land use (as they result in different travel patterns which might affect congestion levels). The geographical and geographic economic indicator respond directly to both infrastructure investments as well as changes in land use. Therefore geographical indicators are better capable to address the potential of land use policies to influence accessibility.

Congestion, expressed in hours travel time losses, is used in this study as network indicator at a more aggregated level of regions or the whole country. At a more detailed level the newly developed highway indicator (HWN) is used which calculates the economic costs, based upon travel time losses, of the bottlenecks by location on the road network. As geographical accessibility indicators we have used the accessibility of jobs by within acceptable travel times, specified by mode of transport, as indicators (travel time functions are based upon survey observations). The geographic economic indicator includes at an aggregated level the accessibility benefits of all modes of transport and travel purposes of the National Model System (exclusion of freight transport). The options to visualize the scores on the indicators differ for the various indicators and are indicated in table 1.

Table 1: type of accessibility indicators used in this study

Mode	Presented	Type of accessibility indicator
Road	Network	Highway indicator for bottlenecks, consisting of travel time losses in economic terms. Presented by bottleneck above certain threshold values.
	Area	Congestion at regional level (total travel time losses in region) Accessibility of jobs by car
PT	Area	Accessibility of jobs by public transport
Bicycle	Area	Accessibility of jobs by bicycle
All	Region/ country	Accessibility benefits (as part of welfare benefits) consisting of travel time benefits as well as proximity benefits.

2.3. Use of model TIGRIS XL

The TIGRIS XL model is applied in this study to calculate the accessibility impacts of the land use strategies. TIGRIS XL is a so-called land use and transport interaction model for the Netherlands and can be characterized by its dynamic in structure, as it iterates between transport and land-use components, to model how the system evolves over time (Zondag 2007; Zondag et al. 2014). Main characteristics are that both the residential location choices and firm location choices are empirically estimated on detailed spatial data sets covering different economic sectors and household types. Further the model uses a flexible modular set-up and the standard National Model System is integrated as its transport module. Post-processing modules are attached to calculate the policy indicators of interest.

3. RESULTS AT THE NATIONAL LEVEL

3.1. National variants for land use changes

At the national level we test the robustness of accessibility challenges at the regional/Provincial level to alternative land use developments. In this way it is possible to identify region which accessibility challenges are more or less robust for these changes. Furthermore we can examine the potential of land use developments to improve accessibility. Various land use strategies have been set up and implemented in the model to calculate the impacts of the land use developments on the accessibility indicators. The table below presents an overview of the land use strategies that have been analysed at the national level.

Table 2: overview of land use strategies for the urban development in the Netherlands

Name	Description
Reference scenario	WLO2 high growth scenario for the Netherlands assumes an additional demand for 1.5 million houses. The highest growth rate is expected in the urban western part of the country. (PBL/CPB, 2015)
Compact city (urban 1)	This strategy assumes a further densification on urban locations of 200 thousand houses. In this strategy there is less housing development in suburban and more rural locations. At the level of urban regions the number of houses is similar to the referenced scenario.
Suburban regional (suburban 1)	This strategy assumes an increased housing development, of 400 thousand houses, at suburban and rural locations. This growth will be at the expense of housing developments at central urban locations. At the level of urban regions the number of houses is similar to the referenced scenario.
Suburban province (suburban 2)	This strategy assumes an increased housing development, of 400 thousand houses, at suburban and rural locations. This growth will be at the expense of housing developments at central urban locations. At the lower level of provinces the number of houses is similar to the reference scenario.

3.2. Accessibility impacts of land use strategies

The alternative urbanization strategies have a modest impact on number of tours and kilometres travelled by mode. In case of concentration of activities in urban areas there is a slight shift in number of tours towards public transport , both train and bus/tram/metro, and active modes. In case of concentration in urban areas a slight decrease in number of car tours and kilometres travelled can be observed. The impacts on *congestion*, as presented in figure 2, are much more substantial and vary between -4% and +9% for the variants. The additional developments at suburban locations increase the geographical mismatch between jobs and residents and result in more travellers on already heavily used connections.

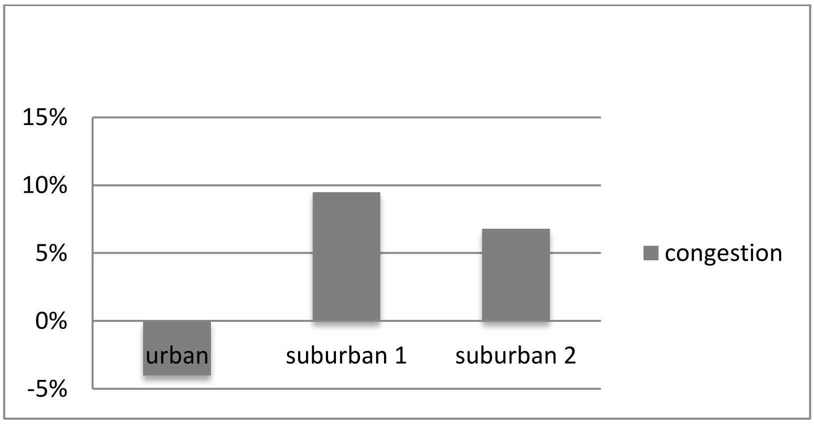


Figure 2: changes in level of congestion

The geographical accessibility indicator for the *accessibility of jobs* is mode specific and is influenced by travel times as well as the spatial distribution of residents and jobs. In this study the travel times for Public transport and bicycle are unchanged and the travel time by car various only with the changes in congestion levels. The location of housing developments in the variants influences directly the spatial distribution of residents and via the simulated relationship between people and jobs also indirectly the location of jobs. The direction and magnitude of the impact differs by economic sector depending on its estimated sensitivity for changes in the population.

Besides the land use variants additional calculations have been made for a large road investment programme, 28 years of investment (28 to 40 billion euro's) and a public transport investment programme for the same period. In figure 3 the changes in accessibility of jobs by mode are presented for the three land-use and two infrastructure variants.

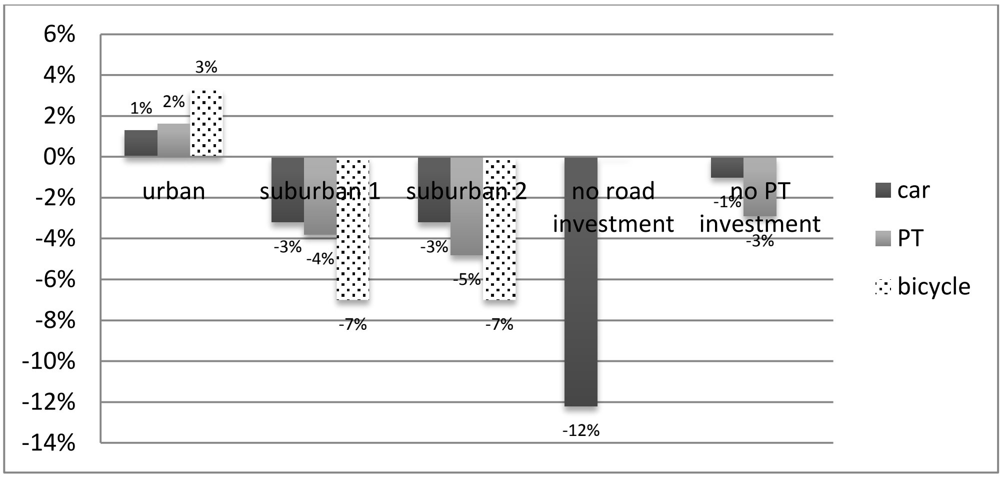


Figure 3: changes in accessibility of jobs by mode for land-use and infrastructure variants

The figure shows that land use variants have the highest impact on accessibility by bicycle followed by public transport. The impacts for job accessibility by car are going in the same direction but this mode is less sensitive. The road infrastructure variant has a large impact on accessibility by car as expected but obviously no impact for non-car users. The impacts of PT investments on the accessibility of jobs seem more modest.

The *accessibility benefits* are calculated for all three land use strategies and the road investment variant. As indicated under section two the accessibility benefits consist of both travel time benefits as well as proximity benefits. Table 3 shows that the land use variants have a large impact on the accessibility benefits ranging between + 300 and - 850 million a year. For the land use variants the largest component are the proximity benefits.

Table 3: Accessibility benefits of the variants in 2040, in million Euro's per year (in 2010 prices)

	Commute	Business	Other	Total
Compact city	192	18	91	301
Suburban 1	-386	-37	-195	-618
Suburban 2	-512	-51	-288	-851
No road invest.	-521	-79	-188	-788

The accessibility benefits of the suburbanization variants are in size comparable to benefits resulting for a large scale road investment scheme. This means that if the Netherlands fail to realize the existing urban densification plans, as such included in the reference scenario, a road investment scheme comparable to the last three decades is needed to compensate the losses in accessibility benefits.

3.3. Robustness of accessibility challenges by province

The provincial level in the Netherlands, consisting of 12 provinces, is used as regional unit to assess the robustness of the accessibility challenges. Therefore results of the provinces on the various accessibility indicators have been collected into an overview table 4. In this table the range of scores for all variants have been translated into a qualitative measure stating if the accessibility indicator X in Province Y has a High (H), Medium (M) or Low (L) sensitivity to land use changes. The accessibility indicators included in the table are accessibility of jobs by car, public transport or bicycle and regional congestion.

Table 4: overview of the sensitivity of accessibility to land-use changes per province

Provinces	Jobs by car	Jobs by PT	Jobs by bike	Congestion	Sensitivity to land use
Groningen	H	M	H	M	M
Friesland	L	L	M	L	L
Drenthe	L	L	L	L	L
Overijssel	L	L	L	L	L
Flevoland	H	H	H	H	H
Gelderland	L	L	M	M	L/M
Utrecht	M	M	M	H	M
Noord-Holland	H	H	H	H	H
Zuid-Holland	M	M	H	H	M/H
Zeeland	L	L	L	L	L
Noord-Brabant	M	M	M	M	M
Limburg	L	L	L	L	L

The table shows that there are substantial differences between the provinces in their sensitivity towards land use changes. This information should influence the approach taken in the these provinces. Especially in provinces with a high sensitivity a robustness check of the bottlenecks on alternative land use developments is needed to ensure that the right bottlenecks are targeted. In these regions spatial planning options should also be explored as a potential solution to address the accessibility challenges. This in line with the new wider approach adopted in the Netherlands to solve accessibility challenges at the regional level. The next section demonstrates these two issues, robustness of bottlenecks and spatial policies to improve accessibility, for the larger metropolitan region of Amsterdam.

4. RESULT CASE STUDY AMSTERDAM REGION

The larger metropolitan region of Amsterdam covers an area including parts of two Provinces, North-Holland and Flevoland, and in total 32 municipalities. Both of the provinces are indicated as highly sensitive to land-use changes. The reference scenario predicts a growth in number of houses of 275 thousand in this region in the period up to 2040. The regional land use strategies developed for this study region all assume construction of the same number of houses as the references scenario. In the land use strategies the construction of 60 thousand houses varies by locations. This is in line with the number of houses involved in the national land use strategies for this region (see chapter 3).

In total five land use strategies are developed consisting of three suburbanization strategies, one strategy varying the location of suburban locations (not the total amount) and one Amsterdam strategy (intensified development within existing urban area). The three suburban strategies assume less development at the urban locations in Amsterdam and depending on the strategy: 1) more suburban developments to the North side of Amsterdam (above North Sea canal), 2) more suburban developments to the municipalities at the South side of Amsterdam and 3) increased developments to the East side among others in the new town of Almere.

4.1. Findings compared to national level

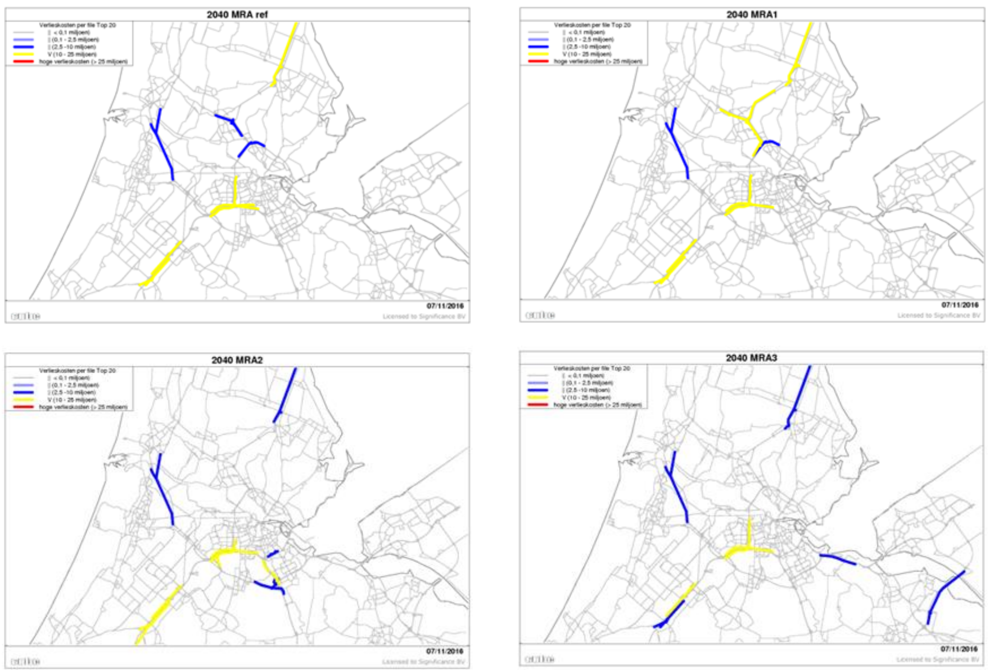
The regional suburbanization strategies result, similar to the national level, in an increase in congestion levels within the region. However the magnitude of change in congestion differs by regional suburbanization strategy ranging from relative small impacts, by suburbanization to the North (around +4%), to larger impacts up to +20% by suburbanization in Southern direction. The above results show that the regional fine tuning of the strategy can make a substantial difference.

The accessibility of jobs indicators show, in line with national variants, positive impacts for the increased urbanization strategy and negative impacts for the suburbanization strategies. Similar to the national findings the bicycle is the most sensitive mode followed by public transport and car. Also in the regional cases all modes are influenced in the same direction for a specific strategy. Comparing suburbanization variants shows that there are differences in the magnitude of the effects, for example suburbanization in a Southern direction has a smaller negative impact on the accessibility of jobs than suburbanization in other directions.

The accessibility benefits of the land use strategies are very high for the Amsterdam region ranging between -200 million a year, for the most negative suburbanization variant, and plus 180 million for an increased urbanization variant. The accessibility benefits show a similar direction as for the land use strategies at a national level. However the effects are relatively larger for the Amsterdam region than the national averages If the benefits are expressed by unit, house that changes location, than the benefits are almost a factor 2 larger. This indicates that the accessibility differences within this region are relatively large compared to other regions. A lesson for the methodology is that specific regional benefit calculations are needed as national averages give no more than a first indication about the direction and size of the benefits.

4.2. Local bottleneck analysis

An analysis at the regional level enables, additional to previously reported indicators, the option to study the impacts of the land use strategies on bottlenecks in the region. The highway indicator, as introduced in section 2, is used to identify the bottlenecks on the highway network in the region. For each of the five variants and the reference scenario (first map) a map is produced presenting a forecast on the main bottlenecks in the region in 2040. Comparing the maps show that both the location of the bottleneck and size, illustrated by different colours, varies for the land use strategies.



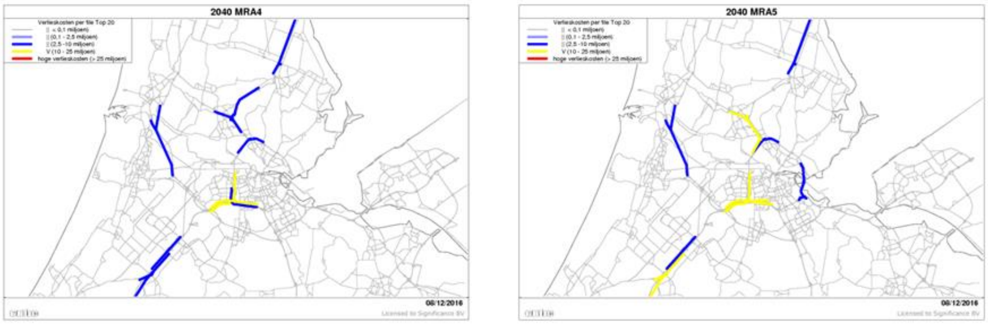


Figure 4: changes in accessibility, measured by location of bottleneck and economical costs, illustrated by different colours for the land use strategies

The sensitivity shown in the maps supports the advice that a spatial robustness analysis is a valuable instrument to obtain insight on the robustness of the bottlenecks.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The insights from this study show that future spatial developments have a substantial impact on regional accessibility. A regional approach is needed to analyse these accessibility impacts: 1) to check on the robustness of existing accessibility challenges and 2) to improve accessibility by designing smart land use strategies. These findings are of relevance to both national and regional authorities and agencies involved in the field of either improving accessibility or urban planning. The main findings are:

- For many regions the accessibility challenges are depending on the land use developments and this uncertainty is not fully covered by applying the two “standard” high and low growth scenarios. Performing a regional analysis, for sensitive regions, will reveal which bottlenecks are more and which ones are less robust to land use changes. Such analysis can also reveal additional bottlenecks related to alternative land use developments;
- Regional land use strategies can improve regional accessibility significantly and have large accessibility benefits. For the bicycle and public transport mode land use strategies seem to be the primary instrument to improve accessibility. For the car mode both land use strategies and infrastructure investments have a substantial impact;
- The land use strategies are affecting the accessibility levels of all modes and population segments where infrastructure investments are more

strongly targeted to specific groups like car owners or high income segments;

- Use of broader accessibility indicators, including proximity besides speed, enables to demonstrate the potential of land use strategies to improve accessibility. Further the broader accessibility indicators are more closely related to wider policy goals such as increasing agglomeration benefits or social inclusion.

5.2. Recommendations for further use

The study shows that in sensitive areas the accessibility challenges need to be tested on their robustness to land use strategies by national and regional authorities. At minimum this is done as part of a sensitivity analysis to get insight on the robustness of potential investments. More actively we advocate that land use strategies are a valuable instrument to improve accessibility in a region. This is a new approach which can only be successful if the results are fairly evaluated, which means that both the speed and proximity component of accessibility is included in the evaluation criteria. The use of broader accessibility indicators is also more closely related to general policy goals such as improving economic conditions, by strengthening agglomeration forces, or including larger parts of the population by improving accessibility of non-car owners or low income segments.

It is highly recommended to incorporate this approach by addressing future challenges such as a high demand for housing construction in the Western and urban part of the Netherlands. Over the last years an increase in housing demand and prices, combined with slow construction rates following the economic crisis, has put high pressure on urban and regional authorities to stimulate housing construction. This might result in a simplified ambition to realize sufficient construction levels without using the potential of these land use developments to societal challenges as improving accessibility, strengthening agglomeration forces or social inclusion.

BIBLIOGRAPHY

Geurs, K., van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. Journal of Transport Geography 12 (2), 127-140

Geurs, K., B. Zondag, G.C. de Jong, M.A. de Bok, Accessibility appraisal of integrated land-use/transport policy strategies, published in journal of Transportation Research part D, Volume 15, issue 7, pages 382-393, 2010

IenM. (2017). Nationale Markt- en Capaciteitsanalyse 2017. https://www.rijksoverheid.nl/documenten/rapporten/2017/05/01/nationale-markt-en-capaciteitsanalyse-2017-nmca.

PBL/CPB. (2015). Toekomstverkenning Welvaart en Leefomgeving. Nederland in 2030 en 2050: twee referentiescenario's.

Zondag, B.: 2007, Joint modeling of land-use, transport and the economy. T2007/4, Trail Thesis series, Delft, The Netherlands

B. Zondag, M. de Bok, K. Geurs and E. Molenwijk, (2014), Accessibility modeling and evaluation: the TIGRIS XL land use and transport interaction model for the Netherlands , published in Computers, Environment and Urban Systems, 2014