

THE TIGRIS XL LAND USE AND TRANSPORT INTERACTION MODEL FOR THE NETHERLANDS; APPLICATIONS AND FURTHER DEVELOPMENTS

Barry Zondag*, Michiel de Bok
Significance

(*until the first of July PBL Netherlands Environmental Assessment Agency)

1. INTRODUCTION

The TIGRIS XL land use and transport interaction model for the Netherlands is developed for and owned by the Ministry of Infrastructure and Environment and the Netherlands Environmental Assessment Agency. Because of this ownership it is that in comparison with other LUTI-models this model has a strong practical focus. Since the finalization of the first version of the model in 2006 the model has been applied in a number of policy studies. Currently a new version of the model is close of being operational and we use this opportunity to reflect on several of these applications and their lessons.

The applications presented in this paper reflect the different functionalities of the model and include:

- Add spatial component to scenario studies to addressing uncertain future developments.
- Strategy formulation studies exploring the potential of future land use and transport strategies.
- Land use and transport project evaluation study.
- Urban development and Cost-benefit analysis.

2. TIGRIS XL

The TIGRIS XL model is part of the family of Land-Use and Transport Interaction (LUTI) models and has substantial similarities to other LUTI models following a dynamic system approach, such as the DELTA modeling package in the UK (Simmonds, 1999), the Urbansim model (Waddell, 2001) and the IRPUD model for the Dortmund region (Wegener, 1998). The TIGRIS XL model is an integrated system of sub-models addressing specific sectors. The model uses time steps of one year for most of its modules, and the modules influence each other outcomes either within a year or in the next year. The underlying assumption is that the system is not in equilibrium at a

certain moment in time; therefore no general equilibrium is simulated within one time step, but that the system moves towards an equilibrium. For example, a high demand for houses at a certain location can result in additional housing construction at that location in the following years. The land-use model is fully integrated with the National Transport Model (LMS) of the Netherlands and the land-use modules and transport model interact, for reasons of computation time, every five years.

TIGRIS XL is a linkage module model and it consists of five modules addressing specific markets. Figure 1 presents an overview of the model and the main relationships between the modules. TIGRIS XL operates at the spatial resolution of local-transport zones (1379 zones, covering the Netherlands). For a detailed specification of the modelling system see Significance and Bureau Louter (2010) and Zondag (2007).

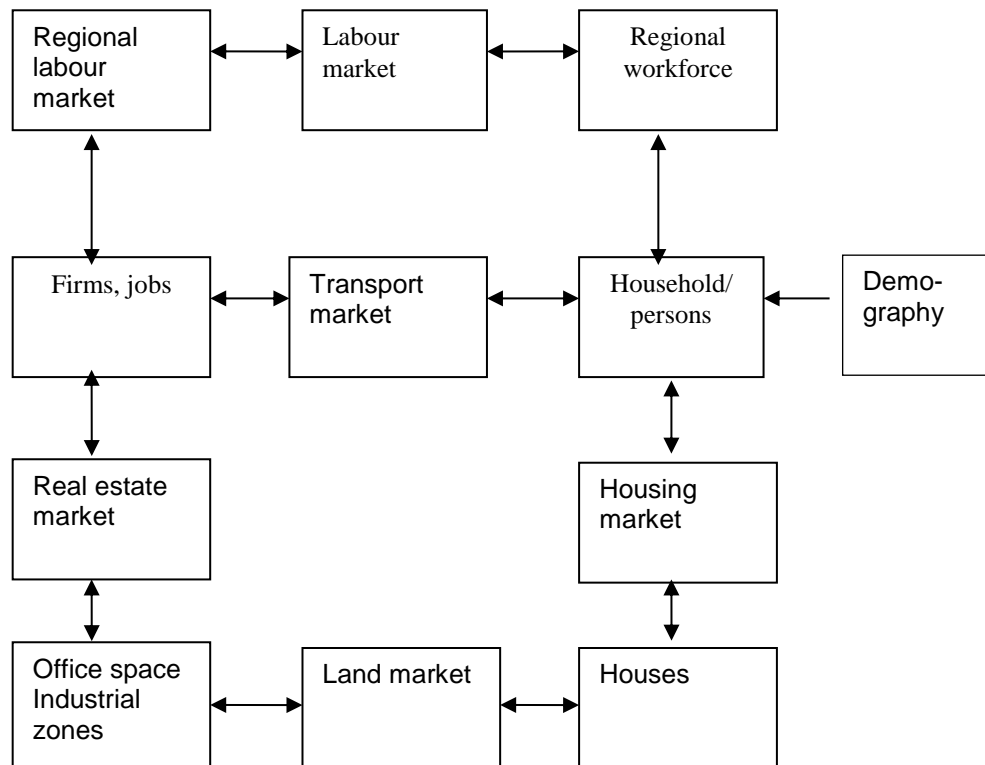


Figure 1: Functional design of the TIGRIS XL model

Core modules in TIGRIS XL are the housing-market and labour-market modules; these modules include the effect of changes in the transport system on residential or firm-location behaviour. The parameters for both modules have been statistically estimated. The residential location choice module has recently been revised and updated with two large three-annual housing market surveys in the Netherlands, the WoON 2006 and 2009 with over

100,000 households (Significance, 2012). The labour market module in TIGRIS XL models the changes in number of jobs by seven economic sectors and changes in workforce at a regional and zone level. The explanatory variables include among others the population development and developments in other economic sectors (de Graaff en Zondag, 2012). The parameters of the firm (simulated as jobs) location choice module have been estimated on a historical data set (1996 – 2010), on number of jobs by seven economic sector at a local level.

A land and real-estate module simulates supply constraints arising from the amount of available land, land-use policies and construction. The module can be used for different levels of government influence, ranging from completely regulated to a free market, and various feedback loops between demand and supply are available. A demographic module is included to simulate demographic developments at the local level. The demographic features at the local level, like birth, mortality, international migration and household formation, are consistent with the regional demographic model PEARL (de Jong et al., 2005).

The transport module, an integrated version of the National Transport Model (LMS), calculates the changes in transport demand and accessibility. The LMS consists of a set of discrete choice models for various choices in transport (including tour frequency, transport mode, destination, departure time and route choice). These choice models can be based on the micro-economic utility theory, enabling the derivation of utility-based accessibility measures. TIGRIS XL calculates a wide range of accessibility indicators, ranging from 'infrastructure-based' accessibility measures (e.g., travel times, vehicle hours lost in congestion), 'location-based' accessibility measures (e.g., number of jobs or other opportunities which can be reached within 45 minutes by car or public transport), to 'utility-based' accessibility measures (logsum accessibility measure).

3. APPLICATION 1: SCENARIO STUDIES – SPATIAL OUTLOOK

3.1. Aim of study

The aim of the Dutch Spatial Outlook study is to provide insights in possible future regional changes and in the interaction between demographic, economic and mobility developments, as background information for integrated future-oriented spatial policy. The Netherlands Environmental

Assessment Agency PBL has executed the study to add a regional perspective to the existing long-term outlooks at the national level. The available long-term scenario study WLO (Welvaart en Leefomgeving or Welfare, Prosperity and Quality of the Living Environment; CPB/MNP/RPB 2006) does not give any spatial details below the level of three large regions: core, intermediate zone and periphery. The relevant spatial developments however can vary significantly at a lower geographic level. For instance both in the core and in the periphery there are regions that have experienced demographic and economic decline in recent years, next to other regions that have shown a persistent growth. More insight in these future developments of the spatial pattern of population, employment and mobility is highly relevant for spatial planning and for large investments such as residential and office construction, industrial estates and infrastructure.

3.2. Application of model

In order to explore the bandwidth of regional developments the two most extreme national scenarios (extreme in terms of demographic, economic and mobility developments) have been taken as starting point. The TIGRIS XL model was used to calculate the multi-sector regional projections; the model was used to address regional variation while taking into account regional interactions and ensuring consistency between the different sectors (e.g. employment response to population changes). Regional variation exists because:

- The model allows for regional differences in birth rate, mortality and international migration;
- Regional zoning policies and housing construction plans are different and at the demand side of the housing market the attractiveness of a location depends of demand preferences of the households and regional variables;
- Development in regional employment by sector depends on national projections of employment by sector, and from sectoral preferences like amenities of location, accessibility and available space.
- The accessibility indicators by region respond to changes in the infrastructure, prices (oil, toll), traffic congestion and land use changes.

The modelling computations are done on the level of (443) municipalities and 1327 zones, but the results are presented for 47 regions (comparable to the NUTS 3 level of 40 regions for the Netherlands).

In both scenarios it was assumed that the existing urban planning system would continue. Further in addition to this two policy variations were modelled with TIGRIS XL for each of the two scenario's:

1. *less restrictive policy for the location of residential developments.* This variation was inspired by the new proposals from the Dutch government for decentralizing spatial planning which potentially results in more liberal spatial planning. In this policy variation only some hard legal restriction exists at the supply side and we assumed that the location of new residential developments is largely determined by the preferences of new and moving households within the Tigris xl model.
2. *reduction of infrastructure investments.* The second variation is a reduction of infrastructure investments after 2020. Stopping in 2020 would mean that no new investments take place; this would result in a cost reduction of 40 billion Euros relative to the base scenarios. Stopping in 2030 would mean realisation of 20 billion Euros of investment between 2020 and 2030 but not after that period; resulting in a cost reduction of 20 billion Euros relative to the base scenarios.

3.3. Findings

The two scenarios show that the Dutch population will continue to grow in the near future and national decline of population is not to be expected before 2020 in the low growth scenario. Further the number of households will increase in both scenarios, even more than the population due to declining average household size. Even when population stabilises or declines, the additional demand for housing will continue for some time. Mobility (number of kilometres travelled) will also continue to grow, both in a low and high scenario. In increase in the amount travelled per person is the main driver here. Employment is likely to drop, due to a decreasing size of the working population that is to be expected on a relative short term since our population is ageing rapidly. If and when decline will set varies per theme (population, employment, mobility) and per scenario.

The band with between high and low is often quite large and at regional level there are many regions showing population growth in the high scenario and population decline in the low scenario (see figure 2).

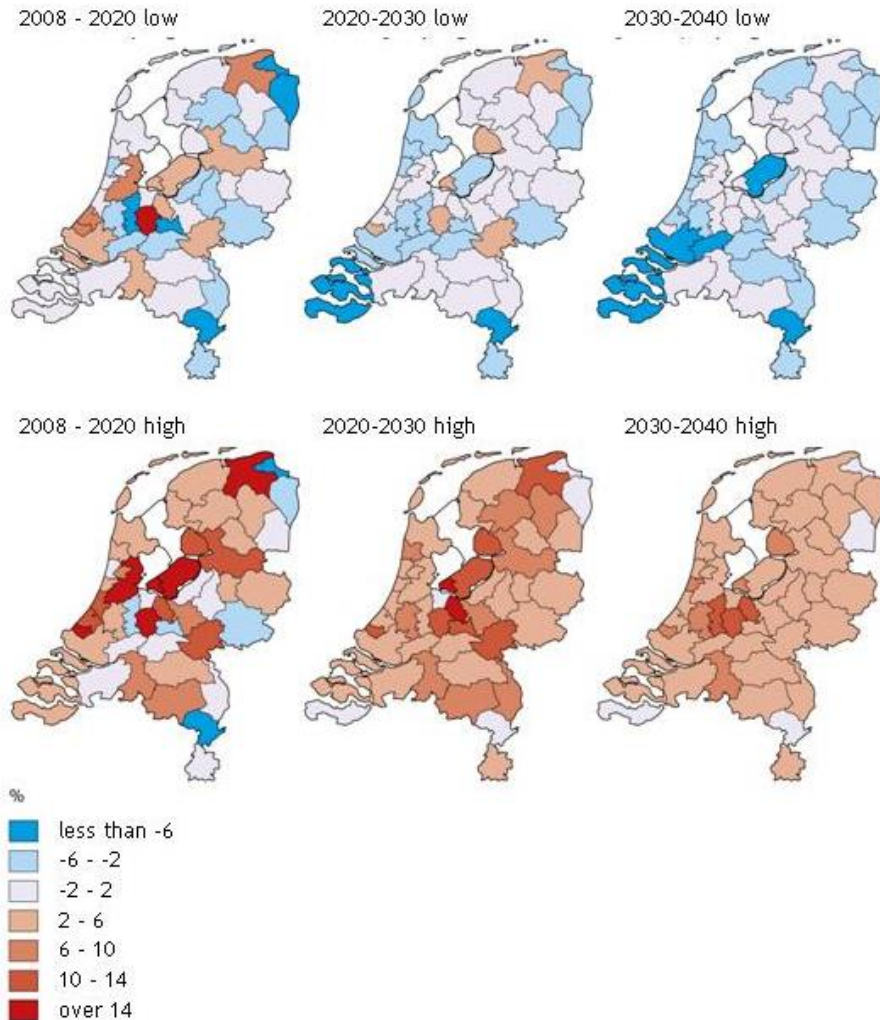


Figure 2: Growth, stabilisation and decline of population based on low and high scenario.

Similar figures were produced for the developments in households, work force, employment and mobility at the regional level. The results of the two scenarios were analysed to identify regions with a likely growth in population or households, a likely decline and a regions with an uncertain future. The regional outlook was also presented time period specific, for example stable growth for the period up to 2020 and uncertainty or likely decline after 2020. This information is of importance to assess the robustness of long term investments in infrastructure or housing, further it has also raised the issue to apply more flexible measures to address a temporary peak in 2020 or 2030.

An example of a more flexible measure is to use pricing instead of infrastructure investments to manage a temporary peak in car mobility.

The policy variation on the scenarios of a less restrictive policy for the location of residential developments would lead to a much stronger concentration of developments in the core region, increasing the agglomeration mass of this area but also increasing decline of population and jobs in more peripheral regions. Within the core region a stronger suburbanization is predicted as result of the increased land supply for residential constructions. The main transport impact is that the road network of the core area will experience more traffic, increasing already high levels of congestion.

The effects on mobility, congestion and accessibility of no longer investing in new infrastructure after 2020 show that in the high scenario congestion levels double (compared to 2008 levels this will be four times increase in congestion levels in 2040). In the low scenario the effects are much more modest and instead of a decline in congestion levels, if investments are made after 2020, the stop in investments will result in 2040 in comparable congestion levels with 2008. At a regional level some regions are much more sensitive, facing a decreasing accessibility, for lowering investments than other regions. The regional results can be used to indicate the regions where robust investments can be made and where not.

4. APPLICATION 2: STRATEGY FORMULATION

4.1. Aim of study

The Netherlands Environmental Assessment Agency conducted a major land-use policy evaluation study entitled 'The Netherlands in the Future' (MNP, 2007). In this study, a land-use baseline scenario and several alternative land-use and transport policy strategies were constructed, some of which were quite extreme, for the entire territory of the Netherlands, for the period from 2000 to 2040. The strategies were explored to get insight in attractive development options. The strategies were evaluated by using a wide range of sustainability indicators, including climate adaptation, flooding risks, biodiversity, traffic noise and urbanisation costs. Here, we focus on the transport and accessibility effects of the land-use/transport scenarios, estimated with the TIGRIS XL model

4.2. Application of model

The TIGRIS XL model was applied to calculate the land-use changes at a local level following a national baseline scenario (incl. demography and economy) and assuming the continuation of land-use trends and existing policies. The model was also applied to calculate the land-use and transport effects of different land-use variants, transport variants and combined variants.

The land-use strategies that have been formulated are:

- Compact Urban Development scenario. This scenario concentrates dwellings within the existing built-up area (50% of all new dwelling) or, where possible, in newly-built designated clusters at close proximity of public transport stations;
- Controlled flooding scenario. In this scenario, a differentiation in safety levels is assumed, and the order in which sub sea level areas will flood is rearranged to cause the least possible damage. No new large-scale urbanisation is assumed to take place in areas where there is a relatively high chance of flooding;
- Uplands scenario. This makes a radical break from the past trend in spatial development in the Netherlands. New housing and employment areas, in the period from 2010 to 2040, are relocated from the low-lying, most urbanised western part of the Netherlands (the Randstad Area) to peripheral areas lying above sea level. This is a quite extreme climate adaptation scenario and based on current knowledge not needed in the near future.

The Compact Urban Development strategy is combined with four alternative transport policy variants to explore the impacts of combined land-use and transport policies:

- Variant 1: Planned road investments. Only planned road investments for the period up to 2010 and 2020 are assumed to be realised.
- Variant 2: Road pricing. A national road pricing scheme, based on a car kilometre charge differentiated by time, place and vehicle characteristics, and a congestion charge for all road traffic. The scheme is designed to be cost neutral for car owners; road taxes will be abolished and the car purchase tax will be reduced by 25% when the scheme is introduced.

- Variant 3: Road pricing and better quality public transport. This variant includes improvements in the quality of public transport, along with road pricing (as included in variant 2). It involves a doubling in the frequency of existing train services within and between the main urbanisation areas, the opening of some new railway stations and reduced waiting, interchanging and travelling times for buses, trams and metro.
- Variant 4: Road pricing and additional road investments from the Mobility Policy Document. This variant includes the additional road investment programme, which is also included in the Baseline Scenario along with road pricing (as included in variant 2).

4.3. Findings

Table 1 shows the impacts of the different land-use and transport scenarios on national passenger travel volumes and congestion (vehicle hours lost on the main motorway network), as estimated by the TIGRIS XL model.

Table 1: Passenger travel and congestion for the land-use/transport scenarios in the Netherlands in 2040, index 2000=100

	Passenger travel			Congestion (vehicle hours lost)
	Car use (veh.kms)	Train use (pass.kms)	Slow modes (pass.kms)	
Baseline scenario	135	98.6	98.5	171
Compact Urban Development scenario	132	99.5	97.2	163
Variant 1: Planned road investments	130	99.8	97.3	230
Variant 2: Road pricing	115	103.2	100.9	110
Variant 3: PT and road pricing	115	117.0	100.5	111
Variant 4: Road investments and pricing	119	102.5	100.3	79
Controlled flooding scenario	135	98.0	98.7	168
Uplands scenario	136	96.6	99.1	93

In the baseline scenario car use is forecasted to increase about 35%, while passenger rail travel and slow transport modes stabilises. Traffic growth is concentrated on the main motorway network resulting in an increase in congestion by about 70% in the baseline scenario. The impact of the land-use and transport policy strategies on national passenger travel is rather small, except for road pricing, but the impacts on congestion are much more substantial. This varies between a more than doubling when no additional road investments and road pricing are assumed (variant 1), and a reduction

by about 20% when additional road investments and road pricing are assumed (variant 4).

At the national scale, compact urban development makes only a small contribution to reducing car travel, but has more substantial impact on congestion. The Controlled Flooding Scenario has also modest impacts but the upland scenario leads to slightly increased mobility, but strongly reduces congestion on the main motorway network as it shifts population and jobs away from the heavily urbanised low-lying Netherlands to the more rural, elevated areas.

The accessibility benefits of the land-use and transport strategies have been calculated by using a disaggregate logsum accessibility measure (Geurs et al. 2012). The logsum measure is well suitable to calculate the benefits of land-use and transport policies as it accounts for both changes in (generalised) transport costs and changes in destination utility, and is thus capable of providing the accessibility benefits from changes in the distribution of activities, due to transport or land-use policies.

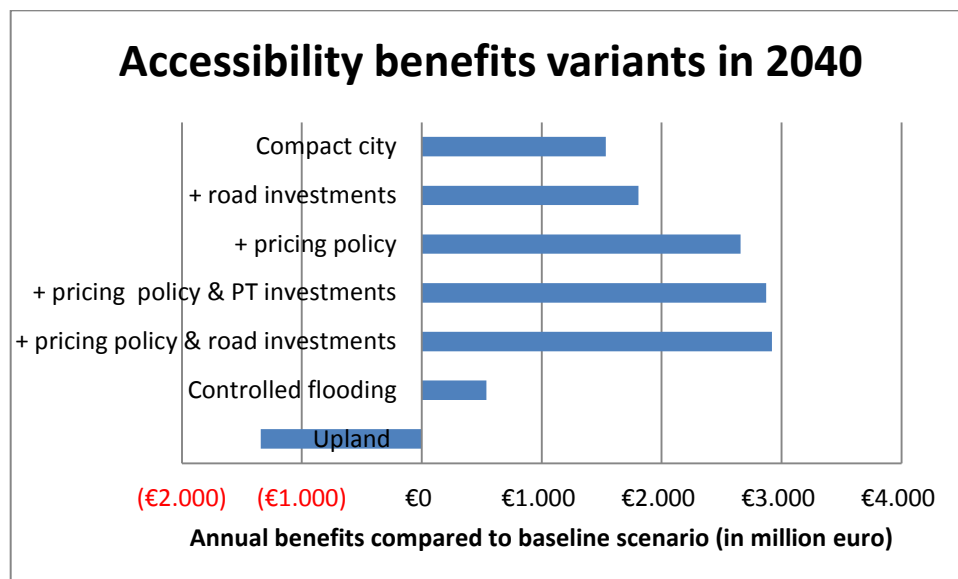


Figure 3: Accessibility benefits of land use and transport planning scenarios

Figure 3 shows that logsum accessibility benefits from land-use policy strategies can be quite large compared to investment programmes for road and public transport infrastructure. The accessibility impacts from the land-use scenarios are largely due to changes in trip production and destination utility, which are not measured in the standard rule-of-half benefit measure. In the upland scenario these benefits are negative as people experience a lower accessibility in the more rural part of the Netherlands than in the urban core.

5. APPLICATION 3: EVALUATION OF LAND USE AND TRANSPORT PROJECTS

5.1. Aim of study

Almere is a new town, located 30 kilometres east of Amsterdam, built on reclaimed land (a polder). It is linked with two bridges linking two motorways (A6 and A27) and a railway (parallel to the A6) linking to the mainland. Local governments developed spatial policy alternatives for the development of Almere with tailored public transport investment programs, involving adding 60,000 dwellings and 100,000 jobs between 2010 and 2030. The TIGRIS XL model has been applied to assess the robustness of these spatial plans, the accessibility benefits of the public transport investments and to examine the synergy between land use plans and public transport investments.

5.2. Application

The TIGRIS XL model was applied to calculate the effects of alternative land use scenarios and public transport investments options. Three different land-use scenarios were developed by the municipality of Almere, each containing a dedicated supportive public transport investment program: the westward-oriented Almere Water Town scenario, the eastward-oriented Almere Polder Town and Almere Town of Water and Green. To disentangle the effects of land use changes and public transport investments on accessibility, the three 'reference' land use variants have also been examined with the same spatial developments, but without the supportive public transport investments.

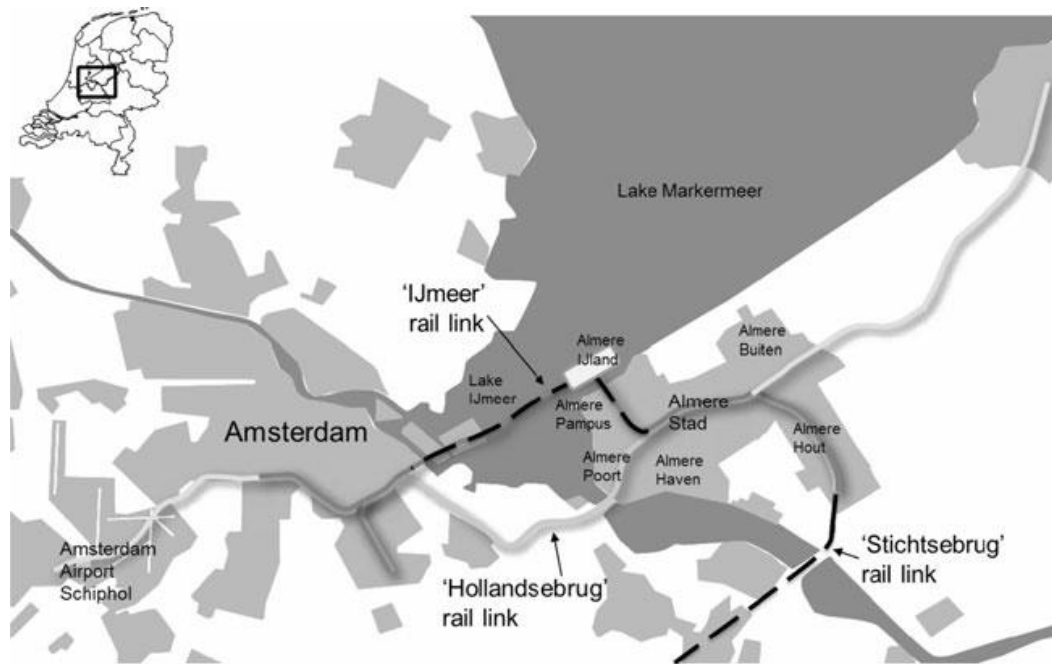


Figure 4: Location of alternative public transport investment options

In the Almere Water Town scenario, a large part of the land development program (35,000 dwellings, 17,000 jobs) is concentrated to the west of the existing town Almere (Almere Pampus) and new reclaimed land (Almere IJland). The public transport program includes the construction of a new IJmeer railway link, connecting Almere to Amsterdam and Amsterdam Airport Schiphol with a regional rail link through the IJmeer lake. The new rail link has been examined with different train types (local train, metro and maglev). Here, we only focus on the alternative with local train services, which reduces train travel times from Almere Pampus to Amsterdam with 17 minutes. To disentangle the effects of the land use changes and public transport investments on accessibility, sensitivity runs using Tigris XL were conducted to estimate the land use scenario Water Town with and without the new IJmeer rail link, as well as the reference scenario with and without the new IJmeer link.

In the Almere Polder Town Scenario, urban growth is concentrated towards greenfield development to the east of Almere (35,000 dwellings and 16,000 jobs). The public transport investments include an upgrade of the existing rail link across the Hollandse Brug (and doubling the train frequency from 8 to 16 trains/hour) and the construction of a new rail link, the 'Stichtselijn', connecting Almere to Hilversum and Utrecht by regional rail, to the south.

In the Almere Town of Water and Green Scenario, urban growth takes place more evenly across the town. The public transport investments include an upgrade of the existing rail link (across the Hollandsebrug).

5.3. Findings

The findings consider the robustness of the overall ambitions for the new town, the land use effect of public transport investments and the accessibility benefits of the public transport investments. Regarding the overall robustness of the ambitions of the town of Almere it can be concluded that the 60 thousand houses are only need in case of a combination of a high population growth scenario for the Netherlands and restrictive spatial policies in the larger Amsterdam area. Under most other circumstances, like in the reference scenario, a growth of 30 thousand households instead of 60 households seems more appropriate. The predicted employment figures are even in the case of high population growth in Almere (plus 60 thousand households) much lower, a factor 2, than the ambition of 100 thousand jobs.

The alternative public transport projects have a marginal effect on population growth, in particular if these changes are compared to the total growth of 133 thousand inhabitants between 2010 and 2030. The public transport projects are each compared to a reference scenario with the same spatial development plan. The housing and real estate supply was assumed to be fixed, regardless the public transport investments, so the population effects that we measure only result from the location preferences of the relocating households, and not from a change in housing supply. Therefore positive as well as negative population effects occur reflecting the different size of households that are attracted by the transport project.

Table 2: Population and employment effects of public transport measures, 2030

	Population in Almere 2030	Additional population in PT run	Employment in Almere 2030	Additional employment in PT run
Almere in 2010	190,000		61,000	
Almere 2030:				
Reference	248,000		84,000	
Water Town	323,000		106,000	
+ IJmeer rail link		- 245		+ 1000
Polder Town	323,000		107,000	
+ HB and SL rail links		+ 1115		+ 1615
Town of Water and Green	323,000		107,000	
+ HB rail link		- 730		+ 410

Employment effects of the improvement of accessibility are relatively larger than population effects. The public transport improvement increases the logsum accessibility from the mode/destination model, a significant location factor for economic sectors as industry, consumer services and business services. Most employment growth is accomplished in the Polder Town scenario and when the Hollandsebrug (HB) rail link is upgraded, and the new Stichtselijn (SL) rail link is built. The IJmeer rail link in the Water Town leads to an employment increase of around 1000 jobs in Almere. This rail scenario has a positive effect on the employment development of Amsterdam as well (+1200 jobs). The Town of Water and Green scenario has the most modest public transport investments program (upgrade of existing Hollandsebrug rail link) and there for the smallest increase in employment (+400 jobs).

Table 3 shows the travel time benefits for train passengers. The travel time benefits are calculated between a run with the public transport investment projects and the reference of each corresponding spatial growth scenario.

Table 3: logsum accessibility benefits for train users, 2030 [in million euros a year]

Scenario	Reference scenario	Logsum Train
New IJmeer rail link in Water Town	Water Town reference	72.9
HB regionrail and Stichtse rail in Polder Town	Polder Town reference	67.6
HB regionrail in Town of Water and Green	Town of Water and Green reference	33.1

The travel time benefits of the combined Stichtselijn construction and upgrade of the HB rail link are comparable to those of the IJmeer regional rail: around 70 million euro yearly computed with the logsum methodology. A comparison of the logsum benefits and the traditional rule-of-half benefits has been made in Geurs et al. 2010 and shows that the logsum benefits are slightly higher than the conventional rule of half (20 to 30%).

6. APPLICATION 4: URBAN DEVELOPMENT AND CBA

6.1. Aim of study

It has been over 10 years that the OEI-guideline has been in place in The Netherlands to give support and improve the consistency of Cost Benefit Analysis. Recently Cost Benefit Analyses are also applied to so-called integrated urban development projects, e.g. including housing, business locations and transport, besides its more traditional application to large scale infrastructure investments. A highly debated issue in the urban development applications is the definition of the reference scenario; the situation without the project. In practice we see often only a Cost Effectiveness Analysis, comparing various alternative projects, or a check whether the profitability of a project is higher than the interest rate as used by the government for investment projects. The first method is not a cost benefit analysis, and therefore we don't know welfare impacts of the projects, and the second approach is not project specific and does not take into account the spatial implications of the project.

The aim of this study was to prepare a practical guideline for setting up a reference case within the CBA of urban development projects (CPB/PBL 2012). The TIGRIS XL model was used to apply the approach in a case study.

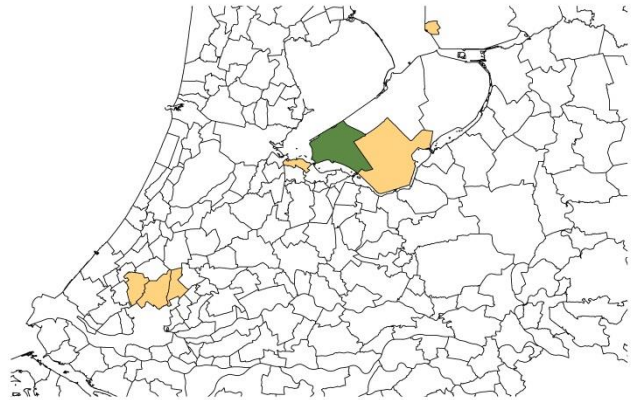
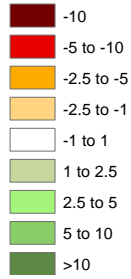
6.2. Application

The TIGRIS XL model has been applied to test the impacts of alternative reference scenarios on the CBA for one project, namely the construction of 30 thousand houses in the city of Almere. Please note that this is a particular experiment as in a normal CBA we would have one reference scenario and multiple project alternatives. The reference scenarios all assume that the total number of households and houses at the national level are similar as in the case of the project. We analyse therefore only the impacts of an alternative spatial distribution of the houses. The five reference scenarios have been differentiated by the assumed spatial scope of the project effects. The reference scenarios assume/calculate that if the project does not take place:

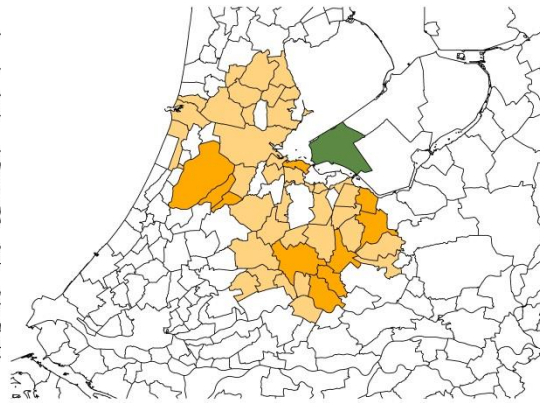
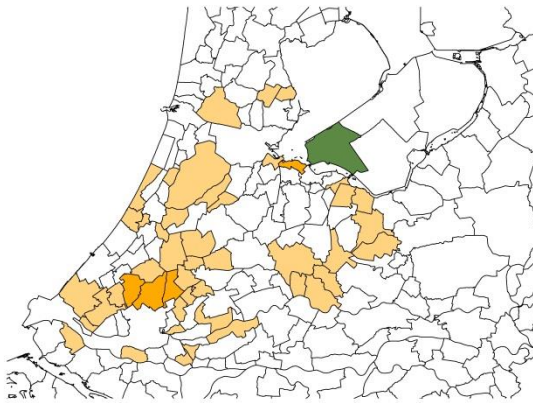
1. the 30 thousand houses would have been built equally divided all over the Netherlands;
2. would have been built in core Randstad region
3. would have been built in Noordvleugel, Northern part of the Randstad
4. Amsterdam
5. Following the housing market preferences of TIGRIS XL

Figure 5: Relative change in number of houses as a results of the housing construction on Almere

Mutatie aantal woningen (in %)

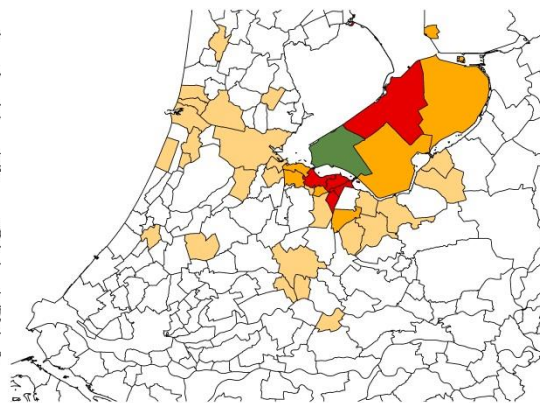
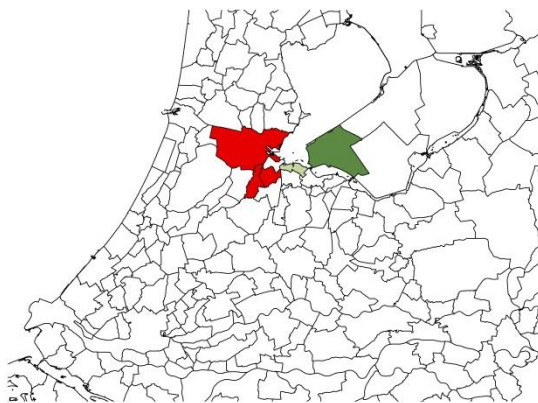


Netherlands



Randstad

Noordvleugel



Amsterdam

Housing preferences

The changes in housing supply are an exogenous input for TIGRIS XL, except for reference scenario number where supply depends on demand preferences. In the model the differences in housing supply result in a different spatial distribution of household and population. These changes in population also affect the spatial distribution of jobs, especially of sectors like retail and health care, and the traffic intensities on the highways.

6.3. Findings

An indicative and partial CBA analysis has been executed to illustrate the impacts of alternative reference cases. The CBA table included quantified project effects on land revenue, transport benefits and agglomeration impacts on productivity. The quantitative effects have been estimated with TIGRIS XL in combination with a post-processing step relating job density and productivity (de Groot et al. 2011). The estimated agglomeration elasticity, between job density and income, is positive confirming agglomeration benefits as labour market matches or knowledge spill-overs. In addition to the quantitative effects it is possible to include qualitative effects on nature and landscape and for consumptive agglomeration effects

Tabel Indicative CBA-table, in million euro 2012 (2010 price level)

	Nederland	Randstad	Noord- vleugel	Amsterdam	preferences
Land revenue	151	-160	-223	-253	-202
Travel benefits commuters	0	39	77	-25	43
Agglomeration –effects productivity	31	6	-3	-13	1
CBA-balance*	182	-115	-149	-291	-160

* please note that this is indicative as we have not corrected for double counts

The table shows that the CBA-balance of the project is very sensitive for the selection of the reference case. It is therefore important that the reference case is selected based on a sound argumentation. Model exercises, like the housing preferences of TIGRIS XL, can be very helpful to get insight in a realistic bandwidth for the spatial implications of the project.

7. CONCLUSIONS

The paper shows that the TIGRIS XL model has been of value in scenario studies, strategy formulation studies as well as project evaluation studies in the Netherlands. In the scenario study the LUTI model has been of value to calculate different regional development patterns following the national scenario developments. For this purpose a LUTI modal has a specific advantage: the spatial and sector interdependencies within and between the

housing-, labour-, land- and transport market modules allow an analysis of regional redistribution of activities in a consistent manner.

Applying a LUTI model helps also to get insight in the impacts of different regional spatial planning and transport strategies on regional developments, accessibility and transport indicators. Similar insights can also be generated at the project level as is illustrated in the third case study. The impacts on the population, employment and transport are of value as volume effects for CBA evaluation methods. The value of the TIGRIS XL model is that it can feed a CBA process with quantitative information on volume changes (population, houses, employment, travel times). This is essential information for the CBA process and in a next step these volume changes can be valued.

Interesting upcoming research issues to analyse with a LUTI model like TIGRIS XL are the development of spatial and transport policies addressing the differences in regional developments. Further the TIGRIS XL model can be used to analyse the risk of inconsistencies between land use and transport developments in the Netherlands following the decentralizing of the spatial planning policies and the much more central transport policies. Finally we believe that the model can play a valuable role to bridge the gap between strategy formulation and evaluation. In this process the TIGRIS XL model can help to get insight in the size of volume changes regarding population, employment and transport.

BIBLIOGRAPHY

CPB/MNP/RPB (2006) Welvaart en leefomgeving (Prosperity and Living Environment Study). Netherlands Bureau for Economic Policy Analysis/Netherlands. The Hague/Bilthoven: Environmental Assessment Agency/Netherlands Institute for Spatial Research.

CPB/PBL (2012), Het nulalternatief van KBA's voor grote gebiedsgerichte projecten: Een verkenning op basis van de casus schaa sprong Almere, The Hague

de Graaff T. and B. Zondag (2013) A population-employment interaction model as labor module in TIGRIS XL, in *Employment in cities and regions: models and applications*, F. Pagliara, M. de Bok, D. Simmonds and A. Wilson (eds.). Amsterdam: Springer. 57-78

Groot, S., H. de Groot en M. Smit, 2011, Regional wage differences in the Netherlands: Micro-evidence on agglomeration externalities, CPB Discussion Paper 184

Jong, A. de, M. Alders, P. Feijten, P. Visser, I. Deerenberg, M. van Huis and D. Leering (2005). Achtergronden en veronderstellingen bij het model PEARL [Background and assumptions of the PEARL model, in Dutch]. Netherlands Institute for Spatial Research (RPB)/Statistics Netherlands (CBS). NAI Uitgevers, Rotterdam.

Geurs K.T., J.R Ritsema van Eck (2001) Accessibility measures: review and applications, Evaluation of accessibility impacts of land-use transport scenarios, and related social and economic impacts, RIVM report 408505 006 , National Institute of Public Health and the Environment, The Netherlands

Geurs, K., B. Zondag, G. de Jong and M. de Bok (2010), Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings. Transportation Research Part D. Vol 15(7), pp 382-393

MNP (2007) Nederland Later. Tweede Duurzaamheidsverkenning (The Netherlands in the Future. The 2nd Sustainability Outlook). Netherlands Environmental Assessment Agency, Bilthoven.

Significance: 2010, TIGRIS PEARL Documentatie. Report for Ministry of Public Works and Water management. The Hague: Significance. [in Dutch]

Significance: 2012, Schattingen verhuismodule TIGRIS XL – Specificatieonderzoek MIGRAT-module voor testfase. Report for the Netherlands Environmental Assessment Agency (PBL). The Hague: Significance. [in Dutch]

Simmonds, D. C. (1999) The design of the Delta land-use modeling package, *Environment and Planning B* 26, 665–684.

Waddell, P (2001) Between politics and planning:urbansim as a decision support system for metropolitan planning, in building urban planning support systems. Center for urban policy research

Wegener, M (1998) The irpud model:overview. Website of the institute of spatial planning, University of Dortmund.

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