Application of a LUTI model for the assessment of land use plans and public transport investments

AUTHORS

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ABSTRACT

Integrated land-use and transport interaction models (LUTI) are praised for their ability to evaluate land-use and transport planning in an integrated and consistent modeling system. However, applications of empirically estimated land use models are rare. This paper will present the application of the Dutch national land-use/transport interaction model TIGRIS XL in a recent land-use and transport policy appraisal. This case study concerns integrated transport and land use policy plans for the largest housing development site in the Netherlands. It concerns a doubling of the size of the new town Almere located near Amsterdam. In Almere, about 60 000 dwellings are to be built and 100 000 additional jobs are to be created in the period up to 2030. The land use policy plans consist of different spatial development patterns, each with a tailored public transport investment programs. In addition, a national system of road pricing is assumed to be realized. The combination of land use plans with supportive public transport investment plans makes it a typical planning issue to be evaluated with an integrated land-use and transport interaction model.

The evaluation of the case study includes the analysis of effects on population development and job location, mobility and accessibility impacts, including indicators such as modal split, motorway road traffic levels, congestion levels and travel time benefits. The paper shows that the different land-use policy alternatives do not differ strongly in terms of transport and accessibility benefits, mainly due to the road pricing scheme.

KEYWORDS: Integrated land-use and transport interaction models, Land use policy appraisal, Public transport investments

1 Introduction

This paper presents an appraisal of in integrated land-use and transport policy appraisal for a large housing development site in the Netherlands. It concerns a doubling of the size of the new town Almere located about 30 kilometers east of Amsterdam (see Figure 1). The ambition is to build about sixty thousand dwellings in Almere and to create a hundred thousand additional jobs in the period up to 2030. The current Dutch national spatial planning policy projects a demand of half a million new dwellings for the Randstad area for the period up to 2040. As the Randstad area already is the most urbanized part of the country, where the four largest cities of the Netherlands are located, available land for urbanisation is scarce. Doubling the size of the new town Almere will be the largest housing project in the Netherlands in the next decades aiming to fulfill a major part of the demand for new dwellings in the north wing of the Randstad area.

Figure 1: New town Almere, 30 kilometers east of Amsterdam (source Google maps)

Local governments developed different spatial policy plans for Almere with tailored public transport investment programs. Transport is of crucial importance for the further development of Almere. Almere is a new town built on reclaimed land (a polder) with two bridges linking two motorways (A6 and A27) and a railway (parallel to the A6) to the mainland. The current rail and road connections are already severely congested, and doubling the population of Almere is not possible without major infrastructure expansions. As part of the decision making process, a social cost-benefit analysis was conducted comparing three land use alternatives and more than 10 rail project alternatives (Zwaneveld *et al.*, 2009). A national system of road pricing, currently under discussion, is also examined.

The results of the LUTI model were not directly used as input for the CBA. In the CBA, a stand alone regional transport model was applied – as prescribed by Dutch appraisal guidelines - to estimate transport demands and transport benefits (Randstad Urgent, 2009; and Zwaneveld et al., 2009). This model is a regional version of the national transport model included in TIGRIS XL. One of the reasons to use an integrated modelling approach was to validate the projection of population and employment for Almere and the surrounding region under the proposed growth scenario. The housing scenario's that were proposed were fixed and more or less undisputed. Reason for this is that historically the Dutch government had a strong influence on the development of other large residential development sites. For example, the town of Almere itself is a clear result of planning of housing development sites in the Netherlands. Such planning practice does not exist regarding the location choice of firms and to a large extend market forces dominate the location choice of firms. Local governments aim to attract 100 thousand additional jobs in Almere. About half of the job growth is assumed to result from the population growth, the other half from stimulus strategies. The assumed job growth was highly disputed and research was requested to validate the job growth projections. The land use and transport interaction model TIGRIS XL was used to generate consistent population and employment forecast for Almere and surrounding regions (Significance and Bureau Louter, 2009a).

A second reason for using TIGRIS XL is that the combination of land use plans with supportive public transport investment plans makes it a typical planning issue to be evaluated with an integrated land-use and transport interaction model (LUTI). These models are praised for their ability to evaluate land-use and transport planning in an integrated and consistent modelling system (see Simmonds, 2004; Waddell et al., 2007; Wegener, 2004), however, compared to the large amount of literature, applications of empirically estimated land use models are rare. Its added value can be analyses when results are compared with the standard practice in the Netherlands, where stand alone transport models are used in economic appraisals of transport investments.

The spatial and transport scenarios for Almere consist of three different spatial options for the construction of 60 thousand houses in Almere in combination with a supportive public transport investment program for each spatial option (Significance and Bureau Louter, 2009b). The scenarios were analysed for their spatial effects on population and employment, and on their transport and accessibility effects. These transport effects include general transport indicators such as modal split, motorway road traffic levels and congestion levels. In addition, the travel time benefits of the public transport measures are calculated with the conventional rule-of-half method and second derived from the mode/destination choice logsums in the transport model.

The purpose of this paper is to describe how the TIGRIS XL land use transport interaction model is applied in the analysis of combined spatial and public transport planning scenarios and to present the main findings for the different development scenarios for Almere. The paper firstly describes the modelling framework and how accessibility effects are calculated. Secondly the alternative growth scenarios for Almere are introduced. The next sections present the model results for the different scenarios regarding the population and employment results in section 4 and the mobility and accessibility effects in section 5. Finally section 6 discusses the main findings.

2 The TIGRIS XL model for land use and transport

2.1 Overview of TIGRIS XL

Land-use and transport policies both affect the accessibility for firms and residents. A land-use and transport interaction model is capable of calculating accessibility changes, resulting from land-use and transport strategies. This includes the mutual interactions between land use and transport, over time, and the outcome is different from the sum of the two measures evaluated individually. In this study, the changes in accessibility are calculated by the TIGRIS XL model; an integrated land-use and transport model that has been developed for the Transport Research Centre in the Netherlands (RAND Europe, 2006; Zondag, 2007).

The TIGRIS XL model is a system of sub-models (or modules) that includes dynamic interactions between them. The modelling system consists of five modules addressing specific markets. Figure 2 presents an overview of the model and the main relationships between the modules. Its land-use model comprises of the land market, housing market, commercial real estate market and labour market. These modules are applied with time steps of one year, which enables the user to analyse how the land use evolves over time. The land-use model is fully integrated with the National Transport Model (LMS) of the Netherlands, and both the land-use and the transport model interact every five years. TIGRIS XL operates at the spatial resolution of local-transport zones (1308 zones, covering the Netherlands).

Core modules in TIGRIS XL are the housing-market and labour-market module; these modules include the effect of changes in the transport system on residential or firm-location behaviour and in this way, link changes in the transport system to changes in land use. The parameters for both modules have been statistically estimated. The residential location choice module has been estimated by household type on a large four-annual housing market survey in the Netherlands with over 100,000 households[1]. The parameters of the firm (simulated as jobs) location choice module have been estimated on a historical data set (1986 – 2000), including employment figures 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. At the regional or national level, the model output is consistent with existing socio-economic forecasts.

The *transport* module calculates the changes in transport demand and accessibility. The TIGRIS XL model is integrated with the National Transport Model (LMS). The LMS consists of a set of discrete choice models for various choices in transport (including tour frequency, transport mode, destination and departure time). 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), 'utility-

[1] The different disaggregate data sets used (e.g. the national travel survey OVG for the LMS and the housing-market survey for the residential location model) are not linked at the disaggregate level, nor are the models. Consequently, there may be unobserved correlation across the different sub-models, which may affect the results.

based' accessibility measures (logsum accessibility measure), and measures of consumer surplus (rule-of-half and logsum measures). In this paper we focus on the results from the rule-of-half measure of consumer surplus.

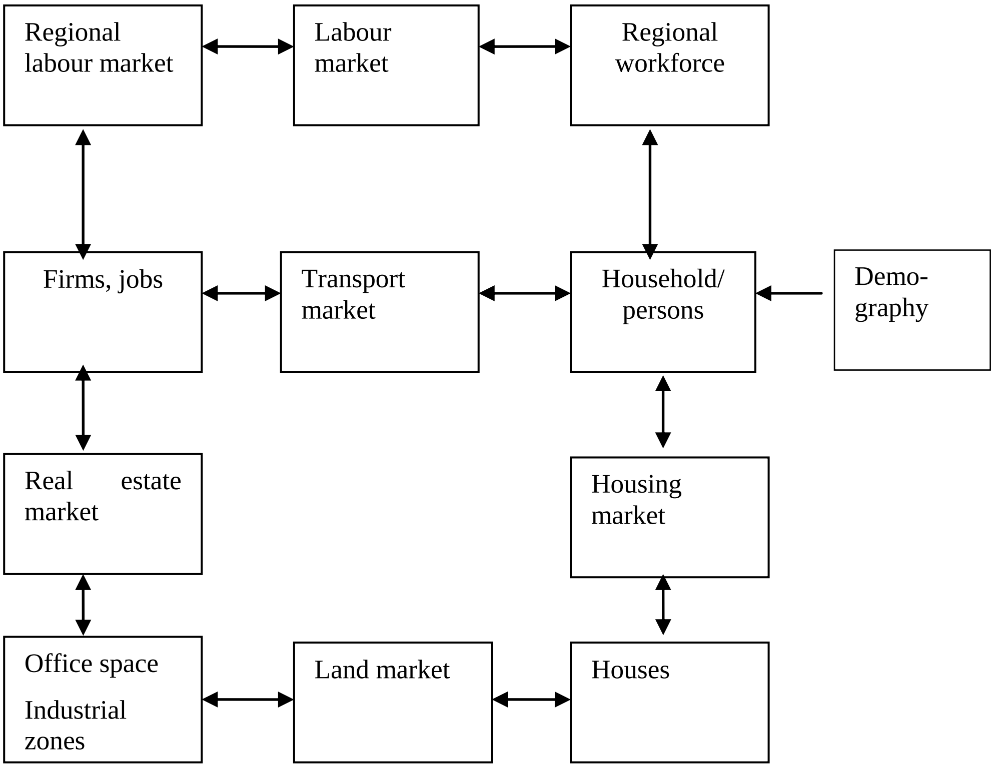

Figure 2: Functional design of the TIGRIS XL model

2.2 The logsum measure using TIGRIS XL

For a more elaborate description of the derivation of logsum accessibility benefits from TIGRIS XL see Geurs et al. (2010). The logsums in the TIGRIS XL model are derived from the National Transport Model (LMS). These logsums are computed for tours (round trips) at the individual level, and express a traveller's utility from a choice set of travel alternatives. This choice set contains five different transport modes (car driver, car passenger, train, bus/tram/metro, walking/cycling) to all 1327 possible destinations. For each origin zone *z* in the TIGRIS XL model, the logsum is computed from the travel alternatives to all destinations and transport-mode combinations *j* for each person type *i* (490 person types segmented to 5 household income classes, 2 gender classes, and 49 age classes), and travel purpose *p*:

$$L_{piz} = \log\left(\sum_j \exp\left(\mu_p V_{pijz}\right)\right) \quad (1)$$

where:

V_{pijz}: is deterministic utility for person *i* in zone *z*, choosing mode and destination combination *j* for travel purpose *p*

μ_p: is the logsum coefficient for travel purpose p (this coefficient appears here, because we are using a nested logit model for each travel purpose)

First, the logsums are translated into travel times by the time coefficients β_p and next into costs by external values of time, *VoT*. The travel-time coefficients are purpose specific and estimated for the mode/destintion choice model in the LMS. The values of time VoT_{ph} per travel purpose *p* and household income category *h*, in equation (2) come from Stated Preference research, and are the officially recommend values for transport appraisal in the Netherlands. The monetary value of the accessibility of zone *z* for a person of type *i*, that belongs to household income group *h*, is, thus, computed as (with β_p being in time units):

$$CS^{L}_{piz} = VoT_{ph} \cdot \frac{1}{\beta_p} \cdot L_{piz} \tag{2}$$

Please note that this term does not represent the absolute value of utility, for it does not include constant *C*, see equation (4). By definition, this constant is unknown and can not be measured. equation (2) represents the accessibility value for a tour. For accessibility evaluation, the accessibility benefits are computed over all actors in the transport model, by multiplying the accessibility value by the number of people A_{piz} in that population segment i that make a tour for that purpose p from that zone z (or more exactly: the number of tours in this population segment for this purpose from this origin).

$$\Delta E(\mathrm{CS}_{piz}) = (1/\alpha_n)\ [\ A^{1}_{piz} \ln \left(\sum_{j=1}^{J^1} e^{V^1{}_{nj}}\right) - A^{0}_{piz} \ln \left(\sum_{j=1}^{J0} e^{V0_{nj}}\right)] \tag{3}$$

Where the superscript 1 refers to the situation with the policy to be evaluated and the superscript 0 to the situation without the policy (reference).

3 The Almere growth scenario

3.1 Description of growth scenario’s

The case study for the growth scenario of Almere consists of three different spatial development scenarios for the simulation period 2010 to 2030. These scenario’s are translated to TIGRIS XL input in the form of housing program (yearly demolition, reconstruction and green field development by zones) and industrial site development (office space and industrial sites). Each of the three development scenarios has a dedicated supportive public transport investment program. This case study evaluates the effectiveness and benefits from each measure.

The reference scenario incorporates planned national road and rail investments for the period up to 2020, including motorway capacity increases between Amsterdam and Almere and rail investments allowing a doubling of train frequency between Amsterdam and Almere from 6 to 12 trains per hour. A national road charging scheme is also assumed to be introduced in 2015 in most project alternatives. The road charging scheme involves the abolishment of existing road taxes and 25% of vehicle purchase taxes and introduction of a kilometre charge (of about 4 eurocent/kilometre for each kilometre driven) and a congestion charge on the main motorway network.

Three possible scenarios exist for the Almere growth scenario: the westwards oriented *Almere Water Town* scenario, the eastwards oriented *Almere Polder Town* and the ‘combination’ scenario *Almere Town of Water and Green*.[2]

[2] Translated from the original Dutch names: ‘Waterstad’, ‘Polderstad’ and ‘Stad van Water and Green’.

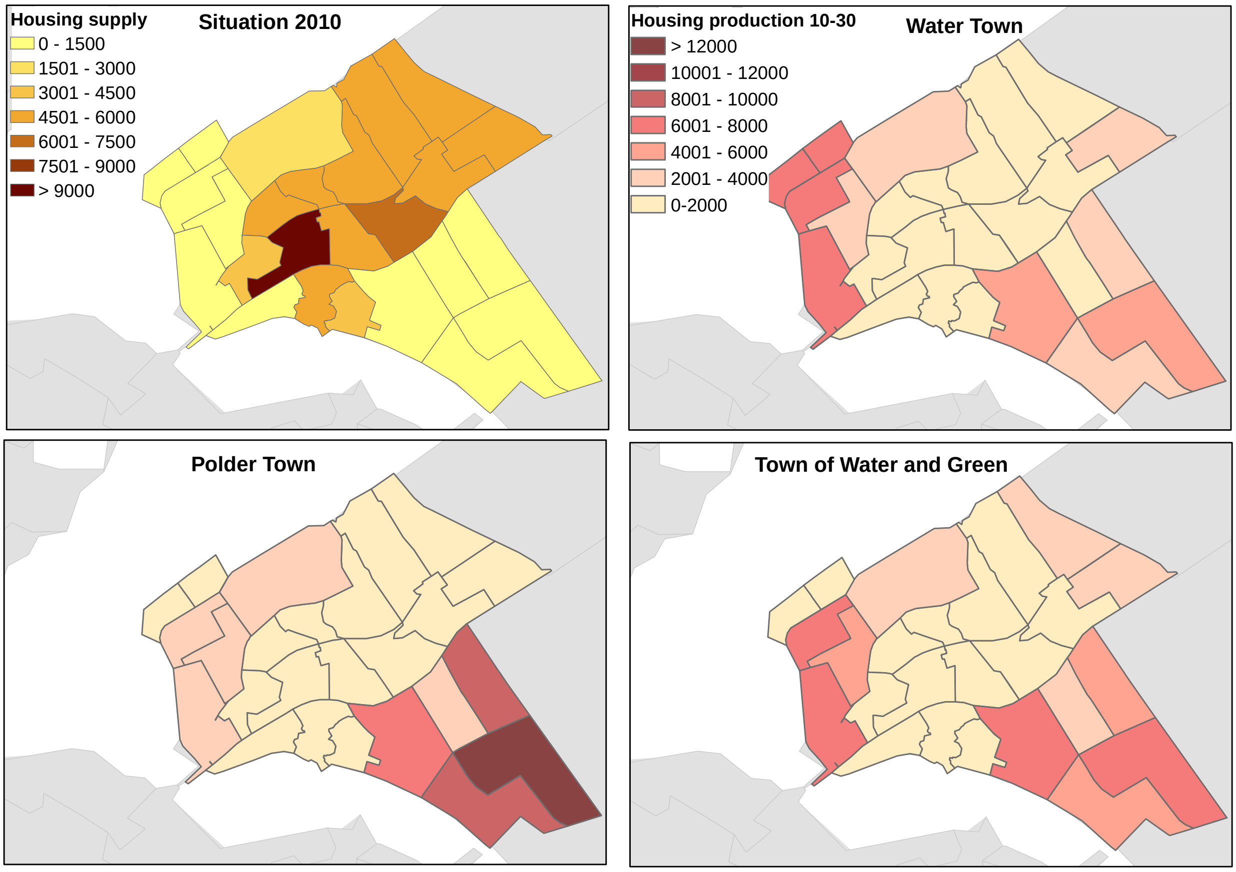

Figure 3: Clock wise from top left: housing supply in 2010 (reference), housing production between 2010 and 2030 in Water Town scenario, Town of Water and Green scenario and Polder Town scenario

Almere Water Town Scenario

The spatial development in Almere Water Town is very much oriented on a land development program in the lake IJmeer/Markermeer to the west of the existing town Almere. This land development project consists of an ecological land reclamation in the IJmeer/Markermeer, directing the focus of urban development to the western part of Almere, Almere-Pampus. In addition to the housing production on the land reclamation areas, part of the housing production target takes place in the existing town and the green field sites east of the town, but with low urban density. The open and rural character east of the town is maintained. The public transport program invests in 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 (see Figure 3).

Almere Polder Town Scenario

In this scenario the urban growth is oriented on green field development to the east of Almere, shifting the town centre of Almere to Almere-Oost. The public transport investments include an upgrade of the existing rail link across the Hollandse Brug (south west) and the construction of a new rail link, the 'Stichtselijn' to the south, connecting Almere to Hilversum and Utrecht by regional rail. The western part of the town, Almere Pampus, will not have a direct rail connection. The development to the east of the town requires an upgrade of the road network as well (an additional 3rd lane on each direction on the A27 from Almere to the South).

Almere Town of Water and Green Scenario

In this scenario the urban growth takes place more evenly across the town. To the west Almere Pampus will grow, but without land reclamation. To the east, green field development will take place but more scattered, around three smaller urban centers with lower urban densities. The public transport investments include an upgrade of the existing rail link across the Hollandse brug.

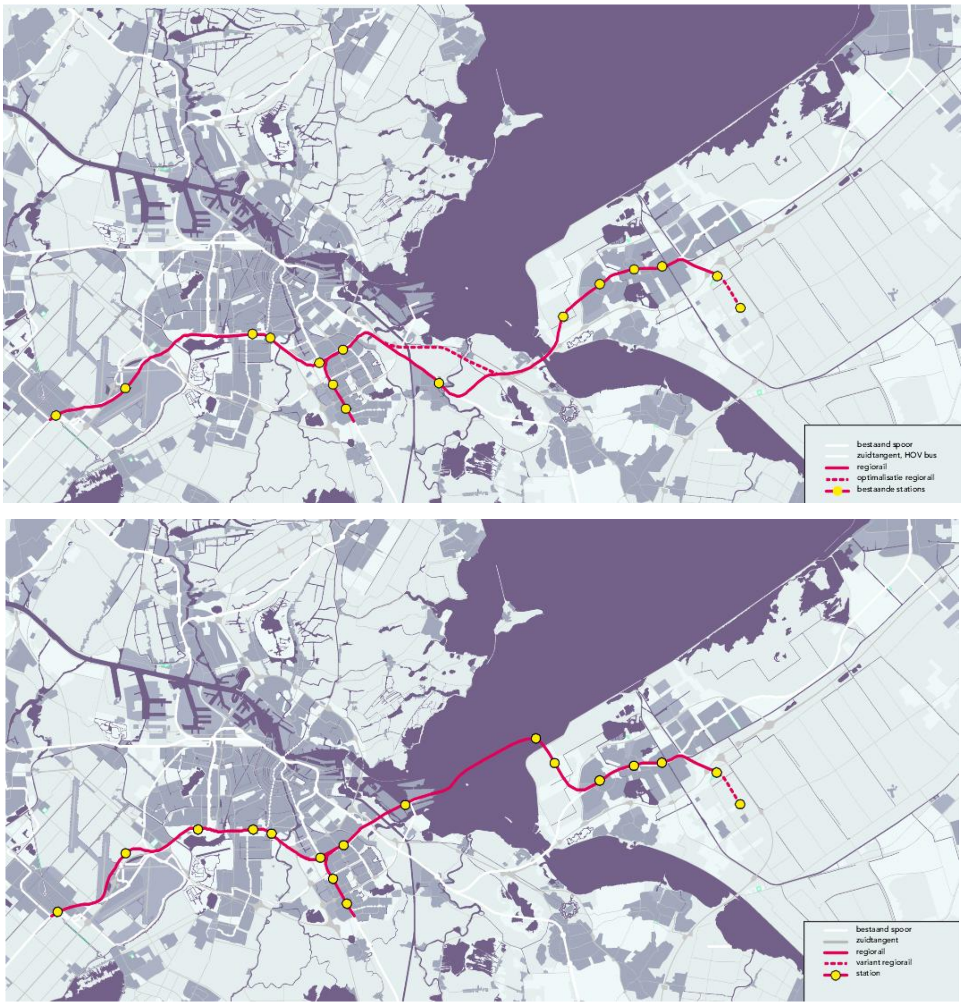

Figure 4: Upgrade of existing 'Hollandsebrug' link (upper figure) and the new: IJmeer rail link project alternative with a local train service (lower figure)

Rail investments costs

The investments cost of all rail project alternatives are quite high. Investment cost range from 2.9 to 6 billion Euros (Table 1). The project alternatives with new railway links are obviously the most expensive (4 to 6 billion Euro) as they involve construction of a new bridge and/or tunnel connecting Amsterdam to Almere. Upgrading the existing railway link is also quite expensive (2-3 billion Euro) due to complex construction works south of Amsterdam. The new IJmeer rail link has been examined with different train types (local train, metro and maglev). In this paper, the focus is on the alternative with local train services.

Table 1: Investment costs (nominal, billion Euro, 2008 prices, incl. VAT) Source: Zwaneveld et al. (2009)

	Low estimate	High estimate
Upgrade existing rail link	**€ 2.9**	**€ 2.9**
New IJmeer rail link, local train service	**€ 5.7**	**€ 5.7**
Upgrade existing link and new Stichtselijn link	**€ 5.9**	**€ 5.9**

3.2 Overview of TIGRIS runs

For the evaluation of the public transport measure relative to a reference investment scenario two TIGRIS XL runs were required. Table 2 gives an overview of the spatial and infrastructure dimensions in each run. The first six runs were used to calculate the modal shift and travel time benefits resulting from the investment programs. Four additional sensitivity runs were performed to test the influence of the enormous growth of Almere itself on the benefits of the public transport investments, and the influence of the introduction of road pricing on the travel time benefits.

Table 2: Overview of TIGRIS XL runs[3]

Nr	Spatial scenario	Infrastructure
Main runs:		
WS	Almere Water Town	Reference
WSR	Almere Water Town	Construction of IJmeer rail link
PS	Almere Polder Town	Reference
PSS	Almere Polder Town	Upgrade of existing (HB) rail link and Construction of Stichtselijn rail link
SWG	Almere Town of Water and Green	Reference
SWR	Almere Town of Water and Green	Upgrade of exiting (HB) rail link
Additional sensitivity runs:		
REF	Reference	Reference
REFR	Reference	Construction of IJmeer rail link
WS_ZRR	Almere Water Town	Reference, no road pricing scheme
WSR_ZRR	Almere Water Town	Construction of IJmeer rail link, no road pricing scheme

4 Population and employment results

4.1 Population and employment effects of land use plans

The effects of the land-use plans for Almere on the population and employment were compared with the reference scenario. The reference scenario is a business as usual scenario in which Almere still grows but at a more modest level. The reference scenario assumes that the number of houses in Almere increases with 30 thousand houses in the period 2010-2030 while in all Almere cases an increase of 60 thousand houses is assumed.

The housing production program of 60 thousand new dwellings in Almere leads to a population growth of around 133 thousand inhabitants between 2010 and 2030 (Table 3); more than a doubling of the number of inhabitants compared to the reference case. The

[3] All runs assuming introduction of road pricing scheme, except for WSR_ZRR

relative strong population increase is not only due to new dwellings offering residence to migrating households to Almere from the surrounding region but also the housing program facilitates the housing demand following from a general trend of household size decrease. Part of the houses constructed in the reference case is needed to accommodate the housing demand from the decreasing average household size. In Almere, this average household size decreases from 2.5 persons per household in 2010 to 2.37 persons in 2030. This is above the national average, and follows from the high representation of young families in this relatively new town, facilitating part of the housing demand surplus for this group in the region (mainly from Amsterdam).

Table 3: Population and employment total for Almere under different scenarios

	Population (x1000) Almere 2030	Employment (x1000) Almere 2030
Almere in 2010	190	61
Almere 2030:		
Reference	248	84
Almere Water Town + new IJmeer link	323	106
Almere Polder Town + HB and Stichtselijn rail links	323	107
Almere Town of Water and Green + HB rail link	323	107

The ambition of the development scenarios for Almere is to create, besides the 60 thousand houses, 100 thousand additional jobs in the period up to 2030. In the Netherlands there is a long tradition of government planning of large residential development and the realisation of the 60 thousand houses can be largely influenced by the government. The ambition to create 100 thousand jobs is much less firm the influence of the government on the location choice of firms is very small in the Netherlands. Therefore simulations were made with the Tigris XL model, assuming the 60 thousand houses were constructed, to calculate the effects on the population and employment. For all three scenarios the calculated employment growth is much lower than 100 thousand and an increase in number of jobs of 46 thousand is predicted in the period 2010 to 2030.

Compared to the reference case the additional employment is 23 thousand jobs in the Almere development scenarios. At a more detailed level of economic sectors, the Tigris XL model simulates the development for seven economic sectors, the fast growing sectors are as expected population related sectors as the retail- and government sector but also sectors as logistics and business services (e.g. 8500 additional jobs) which are only indirectly influenced by the population developments.

The employment growth of 46 thousand jobs compared to 2010 influences slightly the typical residential character of the town by increasing the ratio between employment and labour population from 0.66 to 0.73 jobs per worker. In practice Almere will still have more commuters leaving the town than entering in the morning peak and vice versa in the evening peak. This is in contrast with the other big cities in the Netherlands which all have a net inwards stream of commuters. Therefore the town of Almere keeps his residential function to Amsterdam and to a lesser extent to Utrecht.

4.1.1 Regional population and employment effects

The development scenario for Almere had effects on the size of the population and number of jobs in municipalities in the surrounding of Almere (Significance et al., 2009a). The Tigris XL model is a distribution model which assumes that at the national level the number of people and jobs is an exogenous scenario input. Therefore an increase in inhabitants and jobs in Almere results in a decline in other municipalities. Figure 5 shows at the municipality level the population differences between the Almere development scenario and the reference case in 2030. It shows that the 75 thousand additional inhabitants for Almere in the development scenario predominantly originate from the Amsterdam en Utrecht region.

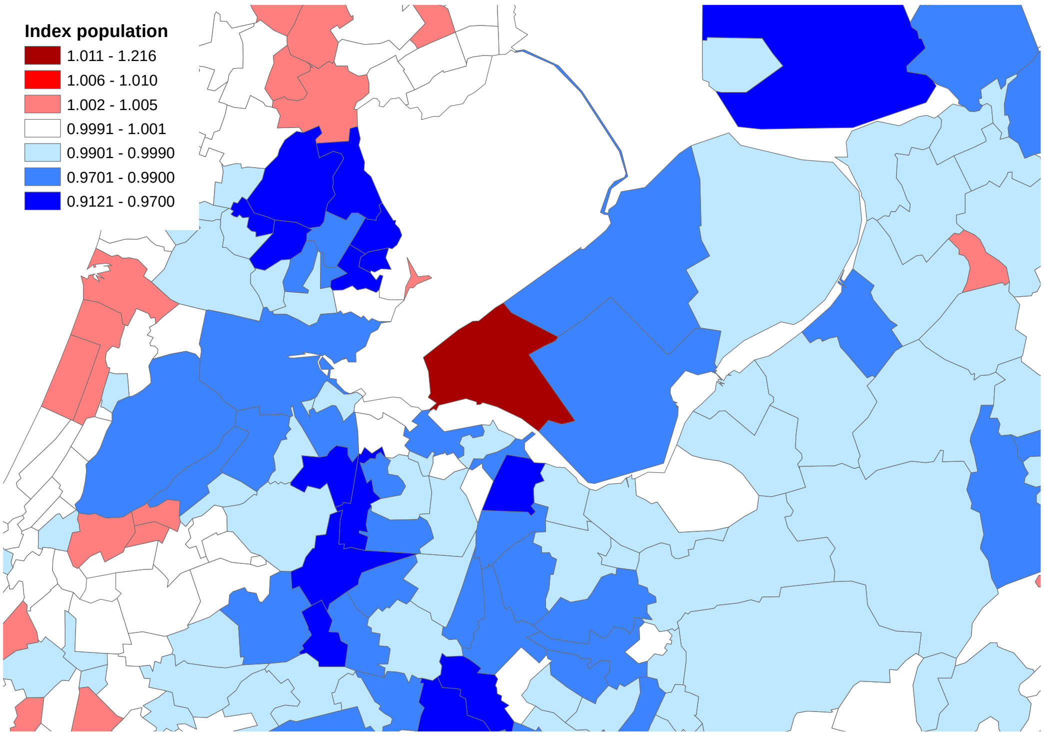

Figure 5: Population development in 2030 in Almere development scenario relative to the reference scenario, presented at municipality level.

The regional differences in employment between the Almere development scenario and the reference scenario are presented in Figure 6. The figure shows an index value which expresses the number of jobs for the Almere development scenario as an index of the number of jobs according to the reference scenario. The additional growth of 23 thousand jobs in the Almere development scenario compared to the reference scenario, is mainly at the cost of the job growth in municipalities within a radius of 50 kilometre of Almere. The directly neighbouring municipalities to the South benefit a little from the additional urban developments in Almere, especially their business sector grows and for these municipalities the overall result is positive.

The largest changes in number of jobs occur in the greater Amsterdam and Utrecht region. A difference is that in the Amsterdam region most losses are within the town itself and in the Utrecht region the losses are bigger in the municipalities surrounding Utrecht town. The relative differences, presented in the index map, are the highest in other suburban towns which compete with Almere

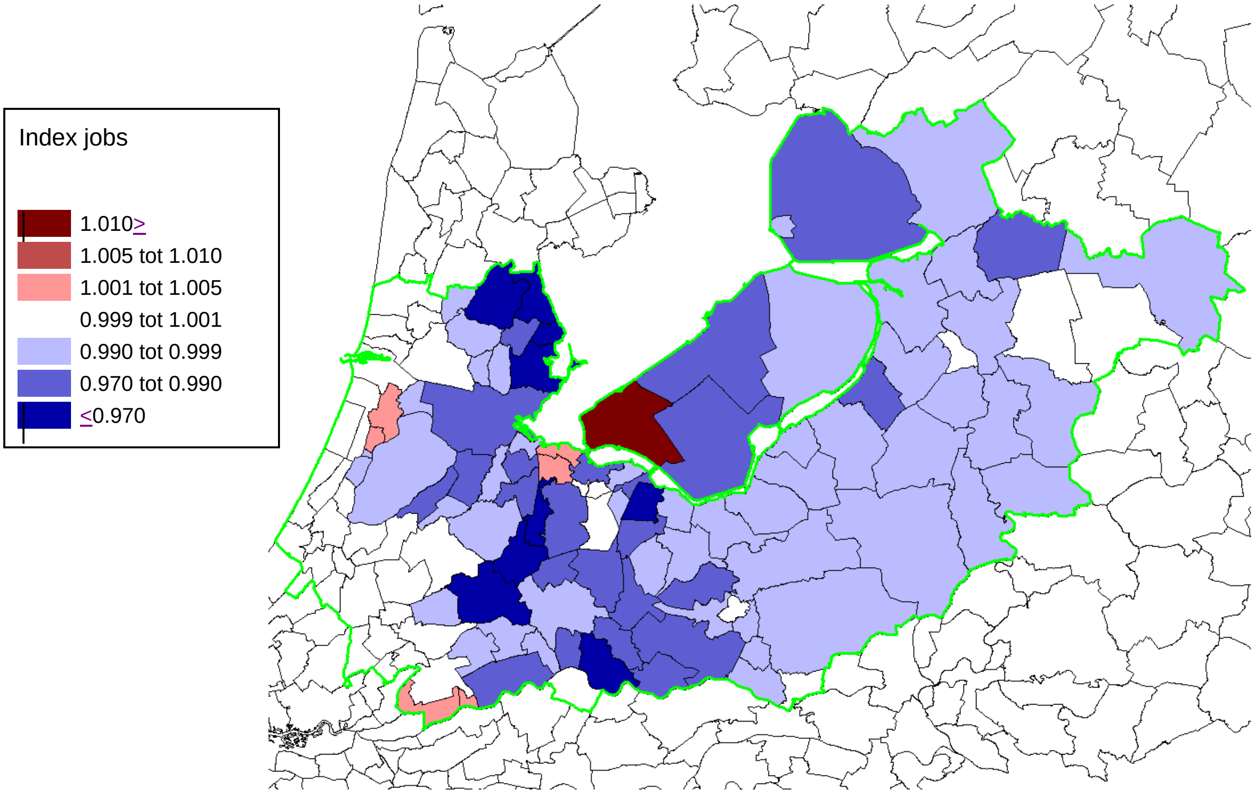

Figure 6: Change in employment at municipality level in 2030, the Almere development scenario results are presented as index of the reference scenario

4.2 Population and employment effects of public transport projects

Table 4 shows the population and employment effects of each public transport project. All of these 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 (see Table 3). 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.

The employment growth is relatively more responsive to the improvement of accessibility by the public transport project than population growth. 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 Hollandse Brug rail link is upgraded, and the new Stichtse lijn 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 Hollandse Brug link) and there for the smallest increase in employment (+400 jobs).

Table 4: Population and employment effects of public transport measures

	Population (x1000) Almere 2030	Additional population in PT run	Employment (x1000) Almere 2030	Additional employment in PT run
Almere in 2010	190		61	
Almere 2030:				
Reference	248		84	
Watertown	323		106	
+ IJmeer		- 243		+ 997
Greenfield Town	323		107	
+ HB rail and Stichte rail		+ 1115		+ 1613
Town of Water and Green	323		107	
+ HB rail		- 729		+ 407

The public transport investments influence employment through an increase in logsum accessibility. In addition to that employment in sectors like retail or government is affected by changes in the local population. The population growth following from the public transport improvement is marginal, so the effect on employment increase is mainly caused by the accessibility improvements by public transport. The employment effects of the public transport investments is significant, but relatively small compared to the total employment growth between 2010 and 2030. In regions with well developed infrastructure these effects can be expected to be small (SACTRA, 1999; Banister and Berechman, 2000).

The public transport investments have a wider spatial economic effect on region surrounding Almere. The regional rail link across the IJmeer proves to have a substantial positive effect on Amsterdam (+1260 jobs) and a few other municipalities along the track. The purpose of the TIGRIS XL model is to forecast the distributive effects of accessibility changes. At a more strategic level the effect of transport investments between Almere and Amsterdam is that the Northern part of the Randstad increases its competitive position which effects especially the employment development in the Southern part of the Randstad.

The Stichtselijn railway link construction and HB upgrade mainly have an effect on the axis from Almere to the South, and where Almere itself benefits the most of the employment growth. Both projects lead to a redistributive effect of employment from the Amsterdam region to Almere. The combined effect of the Stichtselijn construction and HB upgrade in the Polder Town scenario has a positive effect on Almere (+1613) en Utrecht (+363), but these effects are less compared to the IJmeer link. The employment effect of only the HB upgrade is relatively small.

5 Mobility effects

Each public transport project is analysed for different mobility effects. First of all the expected modal shift for travellers to and from Almere, and second differences on traffic flow on the highway network.

5.1 Modal shift

The IJmeer rail link results in nine thousand additional train tours to and from Almere. Each tour represents two trips: the away and returning leg from the home based tours. The modal shift mainly takes place between the Bus Tram and Metro (BTM), and slow modes (walk and cycle). To a lesser extent with car driver and car passenger. The Stichtselijn rail link and HB upgrade together lead to 10 thousand additional train tours. The modal shift with car modes is even more marginal in this scenario, revealing a low competition between the train and car alternative on the corridor Almere - Amsterdam and Almere – Utrecht.

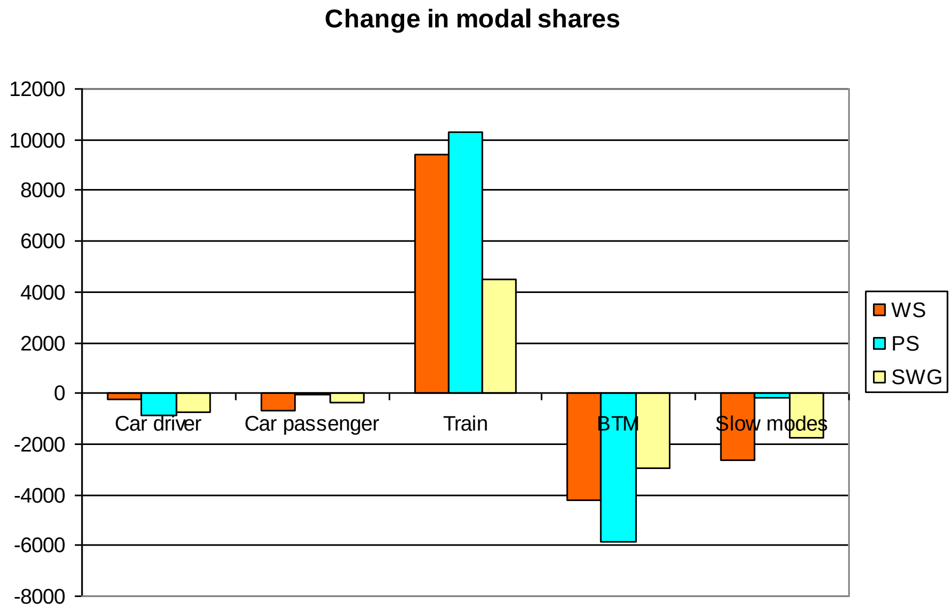

Figure 6: modal shift tarvellers to/from Almere from each public transport project: IJmeer rail link in Watertown (WS), Stichtselijn and HB upgrade in Poldertown (PS) and HB upgrade in Town of Water and Green (SWG)

5.2 Traffic flow and congestion

The public transport projects can have a positive effect on traffic flow on the highway network by modal shift from car to train. The previous subsection already showed that the modal shift from car to train is minimal, in particular relative to the total number of car travellers. As a consequence the intensities and congestion on the car network are hardly influenced.

However, we will discuss some particularities about the assignment and reduction on the car network. In 2010 the road network faces considerable congestion levels (Figure 8), in particular between Almere and Amsterdam, an important commute pair. However, the introduction of a road pricing scheme (including a flat rate and a congestion charge) has a big impact on traffic intensities, reducing most of the congestion in 2030 (Figure 8). Public transport can be more competitive to car in situations where the car network is highly congested. Part of the sensitivity analysis was to test if the reference scenario with a low congestion level underestimates the travel time benefits of the public transport projects. Figure 9 shows that the car network in the Water Town scenario without a road pricing scheme is much more congested in 2030. The travel time benefits of each public transport project in the different scenarios are discussed in the following section.

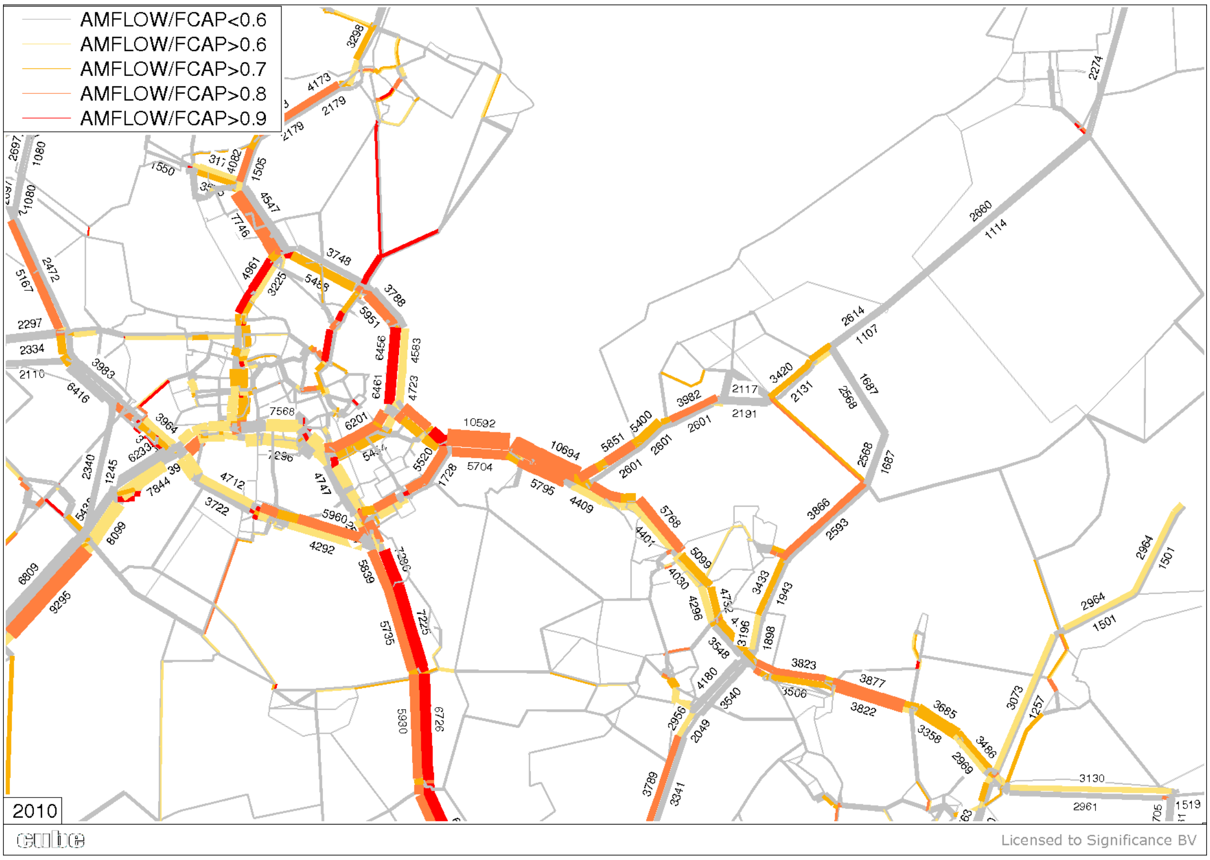

Figure 7: Congestion levels 2010 (morning peak)

Figure 8: I/C ration in 2030 in Water Town scenario with IJmeer rail WITH road pricing scheme

Figure 9: I/C ratio in 2030 in Water Town scenario with IJmeer rail, WITHOUT road pricing scheme

6 Accessibility benefits

6.1 Accessibility benefits of public transport investments

Table 5 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. In total 5 pairs of two runs were required to compute the accessibility benefits (see Table 2 for an overview of paired runs). In addition to the three standard investments programs (one for each spatial scenario) the travel time benefits of the IJmeer regional rail link are calculated for two sensitivity scenarios.

Table 5: Rule of half accessibility benefits for train users [in million euro a year]

Public transport project	Scenario	TIGRIS XL	Stand alone regional transport model
IJmeer regional rail	Water Town	56	55
IJmeer regional rail	Water Town, no road pricing scheme	53	n.a.
HB regiorail and Stichtse rail	Polder Town	56	48
HB regiorail	Town of Water and Green	32	25

The travel time benefits for rail passengers of the combined Stichtselijn construction and upgrade of the HB rail link are comparable to those of the IJmeer regional rail: around 55 million euro yearly computed from travel time benefits and value of time according to the rule of half method. The rule of half accessibility benefits computed by TIGRIS XL, which are use to verify the standard stand alone transport model results, are surprisingly similar to those used in the cost-benefit analysis and computed by the regional version of the transport model (Zwaneveld et al., 2009). As an alternative measure of consumer surplus, logsum accessibility benefits were also computed but are not presented here because of the innovative character of the methodology and political sensitivities in this stage of the planning process. These logsum effects are slightly higher compared to the rule-of-half method, which is a plausible difference, as the logsum method uses more detailed demand curves and weights simultaneously all the changes in the mode and destination alternatives.

The travel time savings for car drivers showed large implausible irregularities (random high benefits or disbenefits) that can be explained by the insufficient detail in the network assignment model. Car demand changes hardly in the public transport scenario, so the network assignment could only lead to marginal link time improvements. But instead, the dynamics of link travel times between successive iterations around the equilibrium of the network assignment, dominates the travel time differences between scenarios. When these (small) travel time changes are combined with car demand, the rule of half still yields significant random travel time benefits (or disbenefits) compared to the benefits accomplished in public transport. Car travel time savings were also ignored in the cost-benefit study (Randstad Urgent, 2009; Zwaneveld et al., 2009), in which a more detailed regional transport model was used. In spite the increased geographic detail of the more detailed transport model, the regional assignment results were still not accurate enough to predict (the minimal) travel time reductions on the car network due to modal shift from the public transport improvements.

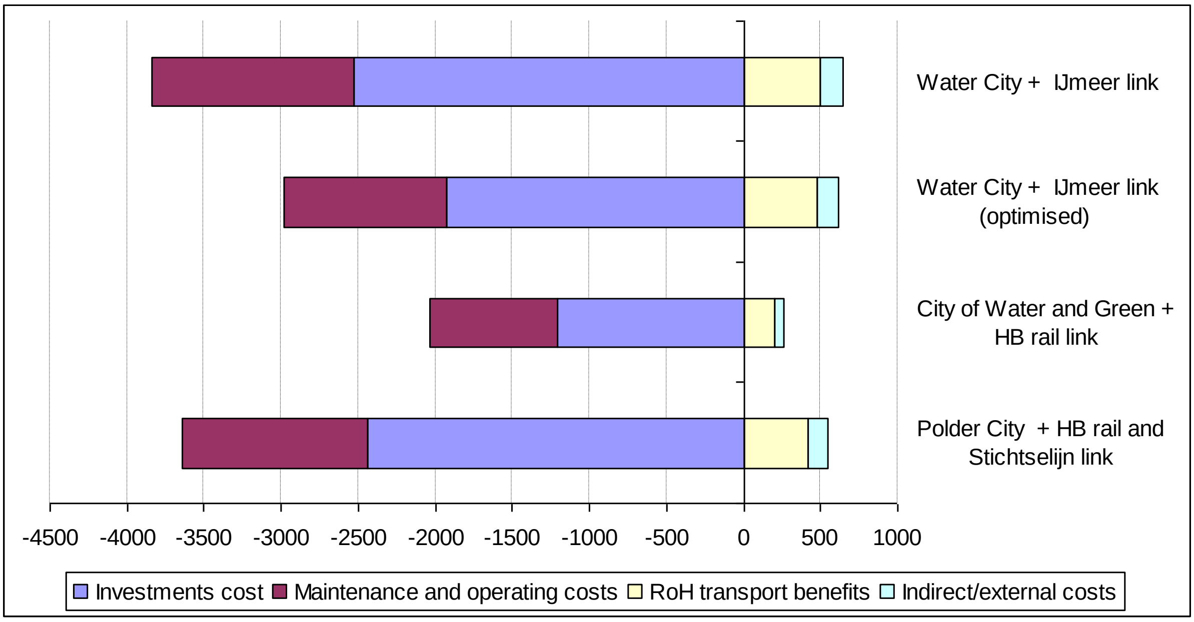

Figure 10: Costs and benefits of rail project alternatives (source: Zwaneveld et al., 2009)

The sensitivity run without the road- and congestion charge shows that the introduction of such price measures hardly influences the travel time benefits of the public transport projects.

In other words, congestion charge does not influence the efficiency of a public transport investments very much. Other studies have also shown congestion charges result in much stronger effects on time of day effects than mode choice (e.g., see Hess et al., 2007).

The accessibility benefits resulting from all rail projects are small compared to the investment costs. The accessibility benefits do not even outweigh maintenance and operational costs. All rail projects examined in the cost-benefit analysis (Zwaneveld et al., 2009) have strong negative welfare effects, mainly due to the high investment costs (Figure 10). There are three main reasons for this result. Firstly, investment costs of the projects are relatively high because of the complexity of the projects. Secondly, the rail service level is already strongly improved with planned investments (reference scenario), and additional investments show marginal returns. Thirdly, the new railway links reduce travel times to Amsterdam for residents in the new housing locations in Almere (up to 17 minutes) but not for existing residents in Almere (1 minute or less). Total travel time savings are by far not sufficient to justify the investment costs.

7 Conclusions

The population and employment developments resulting from the housing development plans in Almere, as calculated by TIGRIS XL model, showed that the goal to realize 100 thousand jobs as part of the development plan is very ambitious as the model results indicate an increase in jobs of slightly under the 50 thousand jobs. The jobs calculated with the TIGRIS XL model for seven economic sectors are affected in a dynamic matter by the changes in population (following the construction of 60 thousand additional houses), changes in accessibility and job developments in other economic sectors (e.g. business services). The TIGRIS XL model also illustrates the regional impacts of the large scale housing development in Almere on other cities and development sites in the region. The model results further indicate that the public transport measures result in a slight increase in employment for the city of Almere between the 500 and 1600 jobs.

The public transport projects tailored to the *Almere Water Town* and Polder Town scenarios yield similar accessibility benefits. The Town of Water and Green scenario has a more modest public transport investment program, and leads to smaller travel time benefits. The accessibility benefits, as calculated by the TIGRIS XL and rule-of-half method, were used to verify the outcomes of the standard appraisal process consisting of applying a stand alone regional transport model in combination with the rule-of-half method. The accessibility benefits of the two models were quite similar confirming the conclusions. The accessibility benefits resulting from all rail projects are small compared to the investment costs. The accessibility benefits do not even outweigh maintenance and operational costs. All rail projects examined in the cost-benefit analysis have strong negative welfare effects.

The public transport investment program results in significant increases in the number of train passengers in the corridor between Almere and Amsterdam but results only in a minor change in car demand on the main motorway network. It is not expected that the public transport projects will reduce congestion on the motorway network. The national road pricing scenario does not affect the travel time benefits from the public transport investments significantly.

Further research will be conducted to estimate the logsum accessibility benefits of the different transport alternatives which allows a comparison with the conventional rule of half measure of accessibility benefits. Moreover, the logsum accessibility benefits resulting from expansion of new town Almere will be examined. These accessibility benefits are not captured by the traditional rule-of-half benefit measure of accessibility benefits. It is expected that the land use policies can effectively increase accessibility as the number of activities which can be reached with the same amount of travel costs increases.

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