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STRUCTURING IMPACTS OF TRANSPORT ON THE SPATIAL DISTRIBUTION OF RESIDENTS AND JOBS

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ABSTRACT

There has been substantial discussion among planners about the structuring impacts of transport. The purpose of this paper is to analyse the size of the structuring impacts for commercial and residential land-use. The TIGRIS XL model has been used as analytical instrument in this analysis. The TIGRIS XL model is a newly developed land-use and transport interaction model for the Netherlands. The model has a strong empirical foundation and the influence of accessibility on the location choices of residents and firms has been estimated on revealed preference data.

The structuring impacts of transport policies (changes in accessibility) on the spatial distribution of jobs and residents have been tested by applying sensitivity runs with the TIGRIS XL model. Some key model settings have been changed to test their influence on the structuring impact of transport policies. Changing settings in the test runs are the future spatial policy of the government (free versus regulated market), the timing of changes in accessibility, scenario developments for the demography and economy, and size and sign of changes in accessibility.

The paper will conclude with a section on policy implications based on the findings for the structuring impact of transport. This final section will include recommendations on the need and role of a land use transportation interaction model such as TIGRIS XL in policy making.

KEYWORDS: land-use transportation interaction model, accessibility, structuring impacts

INTRODUCTION

Observations on the historical development of transport and spatial patterns in the Netherlands illustrate the strong impacts of transport on spatial development. The opening of the major railroad connections in the period from 1839 until 1870 resulted in a centric spatial settlement (population, industry) adapted to the mobility offered by the railway network. Following the 2nd World War the private car has become the dominant transport mode. The accessibility of especially rural areas, surrounding urban centres, has been improved and large-scale sub urbanisation could be observed. The trend of dispersion in urban land-use is still ongoing and driven by a continuously growing demand for land.

The above serves to illustrate the apparent strong causal relationship between changes in the transportation system and spatial developments. It contributes to the widely recognized relationship between transport and land-use. While long term effects from rather dramatic technology changes may be easily observed, it is another matter to prepare for day-to-day policy making. This requires addressing relatively small incremental land-use effects of particular projects (e.g. new road, railway station, etc). It is a challenge to detect the relationship between transportation and land-use for relatively small differences in accessibility. This paper analyses the effect of small changes in accessibility on the spatial distribution of residents and firms.

Although transport is an important precondition for the expansion of urban areas it has not been the primary cause. The sub urbanisation of residents has been the consequence of changes in the socio-economic context of urban life: increase in income, increasing female labour force, smaller households, shorter work hours and a consequential change in lifestyle and housing preferences towards quality of life, leisure and recreation. Firms started to decentralize later following their employees and markets; the firms also take advantage of ample parking space and lower land prices at the suburban locations. An approach conceptualising these processes, and making them operational, is needed to analyse the structuring impact of transport on the spatial distribution of jobs and residents.

The structuring impact of transport can be studied by reviewing the literature. Beside the "relatively" small number of empirical studies on the impacts of transport on land use, most of them suffer from methodological problems. For a state-of-the-art literature review we refer to Wegener and Furst (1999) or Miller (1998). Miller notes that in virtually no case the study design provided an adequately controlled experiment to properly isolate the impact of transport investments from other evolutionary factors at work in the urban region. He makes the point that only integrated land-use transport models can achieve this. A common feature of integrated land-use and transport models is the recognition that trip and location decision co-determine each other.

In this paper a newly developed integrated land-use and transport model for the Netherlands is used to analyse the structuring impact of transport on land-use. As a brief introduction to the model the paper addresses the position of the model in the policy making process and the structure of the model. Sensitivity analyses are performed with the model to analyze the structuring impacts and the results of this analysis are reported in this paper. Conclusions and policy implications conclude this paper.

LUTI MODELLING IN POLICY MAKING PROCESS

The development process of a new LUTI model consisted of several sequential phases. As a start the Transport Research Centre of the Ministry of Public Works and Transport in the Netherlands made an inventory of policy issues due to spatial development and its interactions with the transport system. This inventory outlines the need for such an instrument and sets the demands on the new model.

The main conclusions of this inventory are:

- The structuring role of transport on the settlement pattern of residents and employment is important for assessing spatial development in line with the spatial targets and assessing the economic impacts of transport measures;
- The long-term impacts of transport policies on the transport network. E.g., measures to improve accessibility leads to locations of new activities, new activities leads to new transport demand and new transport demand leads to new congestion problems;
- The impacts of spatial policies on the transport system. In principle this can be analysed with a standard transport model, however there is often a big gap between land-use policies formulated, for example as zoning or revitalisation policies, and the detailed population and household segments needed as input for the transport model. LUTI-models can bridge this gap between the spatial plans and required input to calculate the transport effects;
- The influence of non-government actors like residents and firms on the spatial development. The model should be capable of modelling the preferences of the actors and their influence on spatial developments.

These main issues are transformed in model requirements for the TIGRIS XL model. Important is that the Ministry of Transport focused on the most useful model for main policy questions related to land-use and transport, rather than on designing the 'best' theoretical model ever. There is a clear difference in interest between the scientific challenge of a LUTI model development and the policy challenge. Often in the development process the focus is too strongly set on the scientific challenge. There is a risk that these models end up as state-of-the-art, but are not widely used.

The main model requirements set for the TIGRIS XL model are:

- The model should be flexible to address a wide range of policy questions (transport policies and spatial and housing policies) and the model has to produce relevant outcomes for the evaluation of these policies;
- TIGRIS XL is actor based and founded in economic/behavioural theory;
- A key requirement of the Transport Research Centre is that the model parameters should be calibrated on real world data. It is not intended to build a kind of modelling framework with expert judgement values for the parameters. This means that data availability sets serious constraints on the modelling options;
- TIGRIS XL is a linkage module model and includes specific modules for each of the land markets;
- The spatial level of the land-use model is consistent with the transport subzone-level (1308 zones) of the National Model System (NMS).

At this moment the prototype of the TIGRIS XL model has been developed (see next section) and a case study has just been started to test the field of application of the model. The Transport Research Centre expects to use the model for the following tasks:

- To provide insights and information to strengthen the national and regional policy documents in the field of transport and land-use;
- To understand processes related to transport, land-use and the role of the government in it;
- To develop integrative strategies combining various land-use and transport policies;
- Contribution in long-term forward studies, problem analyses and strategic visions with uncertainty in the land-use context;
- To analyze the impacts of alternative long term scenario studies;
- To prepare socio economic data for the future for the NMS. At this time the disaggregation of this data takes place by expert rules.

THE TIGRIS XL MODEL

RAND Europe, and its partners BureauLouter and Spiekermann & Wegener, has developed a new Land-use and Transport Interaction model (TIGRIS XL) for the Transport Research Centre of the Ministry of Public Works and Transport in the Netherlands. The TIGRIS XL model can be addressed as a model following a system approach including dynamic interactions between the sub models. The land-use model uses time steps of one year, which enables the user to analyse how the system evolves over time. The land-use model is fully integrated with the National Transport Model (NMS) of the Netherlands and the two models land-use and transport, interact every five years.

TIGRIS XL is a linkage module model and it consists of five modules addressing specific markets. The advantage is that each module can be developed in a flexible way to address it specific characteristics, local policies and data availability. Core modules in TIGRIS XL are the housing market and labour market module; these modules include the effect of transport changes on residential or firm settlement behaviour and link changes in the transport system with changes in land-use. A land and real estate module simulates supply constraints following available land, land-use policies and construction. The module defines different levels of government influence, ranging from completely regulated towards 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 social-economic forecasts.

Figure 1 presents an overview of the model and the main relationships between the modules, for a more extensive description reference is made to RAND *Europ*e (2003). In figure 1, two spatial scale levels are differentiated, namely the regional level (COROP, 40 representative regions in the Netherlands) and local transport zones of the National Model System (NMS sub-zones, 1308 sub-zones covering the Netherlands). TIGRIS XL has a modular set-up and each module has been addressed on its own characteristics.

<Figure 1>

Accessibility variables

Accessibility is the main ‘product’ of a transport system. It determines the locations’ (dis-)advantage of a region relative to other regions. Indicators of accessibility measure the benefits households and firms in a region enjoy from the existence and use of transport infrastructure relevant for their region. The key task of a LUTI-model is to address the effects of changes in the transport system on land-use and vice versa. Selection of accessibility indicators for households and firms is therefore an important process.

A detailed overview of accessibility indicators can be found in Hilbers and Verroen (1993) or in Geurs & Ritsema van Eck (2001). Geurs categorizes accessibility measures into three groups following different perspectives, the three groups are:

1. Infrastructure-based accessibility measures. These measures are used to analyse the (observed or simulated) performance of transport infrastructure;
2. Activity-based accessibility measures. These measures are used to analyse the range of available opportunities with respect to their distribution in space and the travel impedance between origins and destinations. Activity based measures can be further subdivided into geographical (or potential) and time-space measures;
3. Utility based accessibility measures. These measures are used to analyse the benefits individuals derive from the land-use transport system.

The utility-based accessibility measures are selected as preferred accessibility measure. Reasons for this choice are:

- The utility based accessibility measures have a strong theoretical foundation in economic theory;
- The utility-based accessibility measures include personal characteristics and preferences besides characteristics of the transport and land use system. Including the individual component of accessibility means that more realistic accessibility indicators, resembling the individual activity pattern more closely, can be included as explanatory variable in residential or firm location choices.

The utility-based accessibility measures for TIGRIS XL are derived from the National Transport Model of the Netherlands. The NMS is a discrete choice type of transport model based on micro economic utility theory. With such a model it is possible to generate the logsum value, an aggregate value expressing the utility of diverse alternatives. Well-known references for such type of models and the logsum variable are McFadden (1981), Ben-Akiva and Lerman (1985) and Daly and Zachary (1976).

The NMS produces for the housing market submodel person type and purpose specific logsums. These logsums express the utility of different mode and destination options, and indirectly time-of-day choice. In formula:

$$L_{m,p,o} = \ln \sum_{j} e^{V_{m,p,o,j}}$$

where $L_{m,p,o}$ is the logsum of purpose m, person type p in origin zone o, v is the systematic part of the utility by purpose m, person type p, origin zone o and combination of mode and destination zone j.

Residential location choice decision are made at a household level and therefore, the person type specific logsum indicators, need to be transformed into household type specific logsum indicators. Furthermore a logsum indicator including all purposes is needed. The following formula has been applied:

$$L_{h,o} = \sum_{m,p} f_{m,p,h,o} L_{m,p,o}$$

where $L_{h,o}$ is the logsum for household type h in origin zone o, $L_{m,p,o}$ is the logsum of purpose m, person type p in origin zone and $f_{m,p,h,o}$ is average number of tours for purpose m, person type p, household type h and origin zone o. All logsum values are for an average working day. The fractions of person types by household type are available in the National Model System and they have been derived from the national travel survey.

Similar "logsum" accessibility measures have been generated as explanatory variables for the labour market module. These variables address the accessibility of a firm for its employees and the accessibility of other economic activities for trips departing from a firm (business purpose).

The performance of the transport system also affects the size of the zonal housing market. The market size varies with changes in the transport system and a travel time indicator is included in the residential location choice module to model the impedance between the old and new location.

Estimation results for accessibility variables

This paragraph presents a brief summarizes of the main estimation results of the TIGRIS XL model. The text focuses on the impact of accessibility in the household location choice model and the labour market model and conclusion regarding other variables is not described. In both models, the housing market and labour market model, a wide set of explanatory variables have been included and tested on their significance. For more extensive descriptions of the model estimation results we refer to RAND et al. (2003) or Zondag and Pieters (2005).

The household location model is a disaggregated model and six different types of households are characterized based on household size, labour participation and age. For each household type a specific model is estimated. The household location choice model consists of two parts: in the first part a household decides whether or not to move, and in the second part, when it decides to move in which zone it would like to relocate. For both modules the key data sources is the four annual housing market survey in the Netherlands (WBO2002), with over 100 thousand records.

In the move/stay choice module accessibility, defined by the logsum, has a significant impact on the decision. The probability of moving decreases when the accessibility of the current residential zone is good, relative to other zones. This finding supports the fear that more isolated regions are facing a migration of residents.

In the location choice module accessibility, expressed in logsums, has a modest impact on the preferred new location of a household. For three out of six household types in TIGRIS XL the logsum has a significant, although minor role in the location choice. The travel time accessibility variable, defining the impedance of the household move, have a much larger impact on location choice. Decreasing travel times lead to a higher probability that an area falls within the search area of a household. Improvements in the transport system will mainly affect land-use by increasing the size of the housing market.

The labour market in TIGRIS XL is divided in seven economic sectors, agriculture, manufacturing, logistics, retail, other consumer services, business services and government. The detail in economic sectors is important to address the large variety in preferences between economic sectors. The economic sectors differ in many aspects, such as land-use, interaction with the population and in their response on changes in accessibility. The seven sectors in TIGRIS XL have been defined on expected differences in behaviour and on consistency with economic sector classifications used at the national level. The labour market model has been estimated on time series data on employment by sector at a local level for the period 1986-2000.

The parameters of logsum accessibility variables in the labour market model are significant for the economic sectors: manufacturing, other consumer services and business services. Freight accessibility, the travel time from the transport model, is significant for the logistic sector. The sectors retail and government benefit indirectly from improvements in the transport system as they respond to a change in the population in the region.

SENSITIVITY ANALYSIS

The TIGRIS XL models forecasts the population and labour force distribution over the Netherlands. For transportation policy makers the influence of transport on land use is an important issue. TIGRIS XL is capable to model these impacts, but the sensitivity of the model on changes in the transport system is unknown. A sensitivity analysis where accessibility measures and travel times are varied has been performed.

In the sensitivity analysis a prototype of the TIGRIS XL model is used where the land-use and transport component are not fully integrated. In this version the transport model runs stand-alone and produces exogenous input files, accessibility indicators, as input for the land-use module. In this case the socio-economic data of the transport model is not automatically updated by changes in the land-use modules and, if needed, these data files can be exchanged manually. This version of TIGRIS XL has been selected for its relatively short calculation time and the need to perform a large number of test runs.

The sensitivity analysis includes the following steps:

- Step 1 identifies realistic changes in accessibility variable of TIGRIS XL by analysing existing NMS-runs.
- Step 2 analyses the impact of changes in accessibility on settlement behaviour of residents and firms. The changes in accessibility, determined in step one, are input for the land-use model in TIGRIS XL.

Determine realistic changes in accessibility

The accessibility measures for the housing and labour market generated by he NMS are as follows:

- Logsum by household type
- Logsum business purpose
- Logsum commuting

The effect of policy measures on accessibility has been tested for the following policy measures:

- Changes in time for the reference case, for the reference runs the change in accessibility has been analysed between 2010 and 2020;
- Change in accessibility due to new transport infrastructure;
- Change in accessibility due to pricing policies like congestion pricing;
- Change in accessibility due to different land-use alternatives.

The analysis does not intend to present an overview of the impact of transport and land-use policies on accessibility. The aim is to develop a feeling for the magnitude of changes in accessibility due to realistic, defined as policies considered in practice, policies.

Accessibility, expressed as a logsum variable, changes over time due to growth in welfare, changes in population segmentation and transport and land-use policy measures. An analysis of developments in accessibility over time, like comparing reference runs for 2010 and 2020, presents the result of all these developments and it is not possible to isolate the effect of one individual factor. However for a single forecasting year the influence of policy measures on accessibility can be compared with a reference scenario run.

The main findings of the test runs are:

- Additional road infrastructure, increased capacity as well as new roads, improves the logsum accessibility indicators as well as travel time indicators. The largest effects occurs in the zones nearby the additional infrastructure and the effects decline with distance;
- Congestion pricing has a positive effect on travel time indicators and a negative effect on the logsum indicators at the national level. In the logsum indicators an increase in utility, due to a decrease in travel time, is outweighed by a decrease in utility, due to higher travel costs;
- Alternative land-use policies result in local effects on the travel time and logsum. The logsum indicator increases in the zones surrounding the new residential location due to additional traffic attractors. However travel times in the surrounding of the location will increase due to additional traffic demand. In the logsum indicator the change in utility due to additional opportunities seems to be dominant over the change in utility due to changes in travel time.

Table 1 presents the bandwidth of changes in accessibility indicators based on the performed test runs with the NMS. The bandwidth is presented by type of policy measure and presents the maximum observed change in value of an accessibility indicator. The bandwidth for the logsum is by zone and for the travel time indicator the bandwidth is by origin-destination relationship.

<Table 1>

Table 1 presents that infrastructure and pricing policies have a larger effect on accessibility than land-use policies. However land-use policies can have significant local effects on accessibility. The table also illustrates that travel time indicators are more sensitive for policies than logsum indicators. The effects on logsum indicators are small because logsum indicators include social-economic, spatial as well as transport factors. A transport policy only affects one of the three factors and the other factors are unchanged between the policy and reference run.

Findings of sensitivity runs

The structuring impacts of transport measures are affected not only by the changes in accessibilities but many other conditions affect the size of the impacts. In the modelling various settings can be changed to test their influence on the structuring impact of transport policies. Key settings are the setting for the future spatial policy of the government, point in time of change in accessibility and size and sign, positive or negative, of change in accessibility. In this analysis each of these settings has been changed to analyse the impact of these settings on the structuring impacts of transport.

Table 2 presents an overview of the sensitivity runs. The changes in travel time and logsum variables have been derived from the bandwidth as presented in table 1. The forecast period of the sensitivity runs is between 2000 and 2020.

<Table 2>

The changes in accessibility need to be spatially allocated and for each variant they have been applied to two zones and two regions in the Netherlands. In each variant the same zones and regions has been changed, namely:

- The accessibility changes for employment has been applied to the region (COROP) Leiden and ZO Friesland;
- The accessibility changes for the housing market has been applied to all zones within these two regions and to two individual zones, one in the Province of Utrecht and one zone in the Province Limburg (Houten and Meersen).

Table 3 presents the effects of changes in accessibility on the population (population in the variant/ pop reference scenario).

<Table 3>

Table 3 presents clearly the differences in response between a free market and a regulated situation. In a completely supply regulated market household responses may be higher in a case of oversupply at the market. In that situation households have the opportunity to move to better accessible locations, however in the current regulated reference situation in the Netherlands shortages exists at the housing market.

The population changes simulated with the model for the free market variant are significant but modest. The changes are conforming the expectation and the population will grow if a location gets better accessible and the population declines if a location becomes less accessible. The table illustrates that the time effect is significant, introduction of a policy measure in 2001 instead of 2011, can almost doubles the effect on the population growth. The time effect is not for all zones the same and for example in Meersen the full response have been achieved after ten years. This might be related with overall future decline in population in the area surrounding Meersen.

A decline in accessibility (V3 and V4) does result in a decline in population as well. However the effect is less strong than the effect of improved accessibility on population growth. A reason might be that a household leaving a zone leaves a vacant house behind, which is an alternative option for house seeking households to locate in.

<Table 4>

The scenario assumption of a regulated or free market is of less relevance for the structuring effects on the number of jobs. This is a result of the dominant position of demand at the labour market. Even under regulated conditions local governments are willing to respond to preferences of the firms. Overall the responses for the regulated variant are slightly lower than the free market variants. In the free market variants the change in population will affect several so-called population following economic sectors.

The sign of the responses in number of jobs on changes in accessibility are conform the expectations. A positive effect on the number of jobs occurs if accessibility improves and a negative effect occurs if a region becomes less accessible. The influence of accessibility on the number of jobs is higher than on the number of residents. This is conforming general findings in the literature.

The region Leiden is more sensitive to changes in accessibility than the region ZO Friesland. This is related to differences in the structure of the economy. Leiden, for example, has a high share of business services and this sector is more sensitive to changes in accessibility than other sectors.

The structuring effects on employment differ widely by economic sector. Sectors that are closely related to population growth, such as retail and government, tend to follow the change in population, while the business services and industry show larger volatility in response to transport changes.

CONCLUSION AND DISCUSSION

The overall impression, based upon the estimation results and sensitivity analysis, is that accessibility has a significant but modest effect on land-use. In a country with a well-developed infrastructure accessibility cannot be considered as the dominant driver of land-use change. In this study the structuring impact of transport has been analyzed in a wider context including a large number of relevant explanatory variables.

The analysis shows that changes in number of residents as response to a change in accessibility are rather small and not more than a few percent. Furthermore the sensitivity analysis made clear that these changes are not instantly and it takes a long time before the full land-use impacts of a transport measure can be observed. The sensitivity analysis also illustrates that the structuring impact of transport on land-use depends on the spatial policy of the government. In a regulated market the actors are restricted in their options to take advantage of accessibility improvements. The structuring impacts are therefore higher under free market conditions than under regulated conditions.

In general the structuring impacts on the spatial distribution of firms is bigger than the structuring impact on the spatial distribution of residents. At a more detailed level the structuring impacts on the distribution of jobs differ widely for the different economic sectors. Manufacturing, logistics, other consumer services and especially business services are the most sensitive sectors for changes in accessibility. The sectors retail and government respond indirectly to changes in accessibility and follow changes in the number of residents.

The paper shows that the annual land-use changes in general, and more specific the structuring impacts of transport, are small and therefore one might consider ignoring these changes. However it is exactly this characteristic of slow dynamics that makes land-use changes so important. A change in land-use does have a very long-term influence on the urban and regional structure and can be considered as almost irreversible. This can be illustrated by observing the difficulties, which car-base low-density cities have with formulating alternative transport strategies. Land-use developments are therefore a critical element of any long-term transport strategy.

Another argument to address the land-use changes is the role they play in the evaluation of transport policies. A land-use change that is rather marginal compared to the total number of residents or jobs can be of real importance in the evaluation of an individual transport policy.

REFERENCES

Ben-Akiva M., Lerman S.R., *Discrete choice analysis: Theory and application to travel demand*, Cambridge MIT press 1985

Daly A.J. and S. Zachary (1976), Improved multiple choice models, in D.A. Hensher and M.Q. Dalvi (eds.), *Determinants of Travel choice,* Saxon House 1978; previously presented to PTRC Summer Annual Meeting, 1976.

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

Hilbers H.D. and E.J. Verroen (1993), *Het beoordelen van de bereikbaarheid van locaties, definiering, maatstaven, toepassing en beleidsimplicaties,* rapport INRO-VVG 1993-09, rapport in opdracht van Projectbureau Integrale Verkeers- en Vervoersstudies, Delft, The Netherlands

McFadden, D.L. (1981), *Econometric models of probabilistic choice*, in McFadden and Manski (eds.), Structural analysis of discrete data with econometric applications, MIT Press

Miller E.J., D.S. Kriger and J.D. Hunt, *Integrated urban models for simulation of transit and land-use policies,* TCRP web document 9, 1998, http://www.nap.edu/openbook/tcr009/html/R1.html

RAND *Europe*, BureauLouter, Spiekermann & Wegener (2003), *Functioneel ontwerp prototype TIGRIS XL,* prepared for the Transportation Research Centre of the Netherlands Ministry of Transport, Public Works and Water Management

www.vrom.nl, *Vragenlijst WBO 2002*, Ministry of Physical Planning, Housing and Environment, The Netherlands, 2003 (in Dutch)

Wegener, M., Fürst, F. (1999), *Land-Use Transport Interaction: State of the Art,* IRPUD, Dortmund

Zondag B, M.Pieters (2005), *Influence of accessibility on residential location cho*ice, 84th annual meeting of the Transportation Research Board, Washington (forthcoming in the Transportation Research Records)

TABLES

Table 1. Bandwidth of changes in accessibility indicators

Accessibility indicator	Reference development (2020-2000)	Infrastructure policy	Road Pricing policy	Land-use policy
Logsum (move/stay)	0.0% - 5.0%	0.0% - 1.0%	0.0% - 3.0%	0.0% - 0.5%
Logsum (non-working households below 65 years)	0.0% - 10.0%	0.0% - 0.5%	0.0% - 2.0%	0.0% - 0.5%
Logsum (working 2+ households below 65 years)	0.0% - 4.0%	0.0% - 1.0%	0.0% - 3.0%	0.0% - 0.5%
Travel Time	0.0% - 4.0%	0.0% - 7.0%	0.0% - 5.0%	0.0% - 0.5%
Logsum (business)	0.0% - 2.0%	0.0% - 0.5%	0.0% - 0.5%	0.0% - 0.5%
Logsum (commuting)	0.0% - 4.0%	0.0% - 0.5%	0.0% - 2.0%	0.0% - 0.5%
Freight travel time	0.0% - 3.0%	0.0% - 6.0%	0.0% - 3.0%	0.0% - 0.5%

Table 2. Overview of the sensitivity runs

Variant	**Change in travel time (%)**	**Change in logsum (%)**	**Scenario setting**	**Point in time**
Ref_free	-	-	Free market	-
Free_v1	-10%	+2.5%	Free market	2011
Free_v2	-10%	+2.5%	Free market	2001
Free_v3	+10%	-2.5%	Free market	2011
Free_v4	+10%	-2.5%	Free market	2001
Ref_reg	-	-	Regulated market	-
Reg_v1	-10%	+2.5%	Regulated market	2011
Reg_v2	-10%	+2.5%	Regulated market	2001
Reg_v3	+10%	-2.5%	Regulated market	2011
Reg_v4	+10%	-2.5%	Regulated market	2001

Table 3. Effects of changes in accessibility on the population

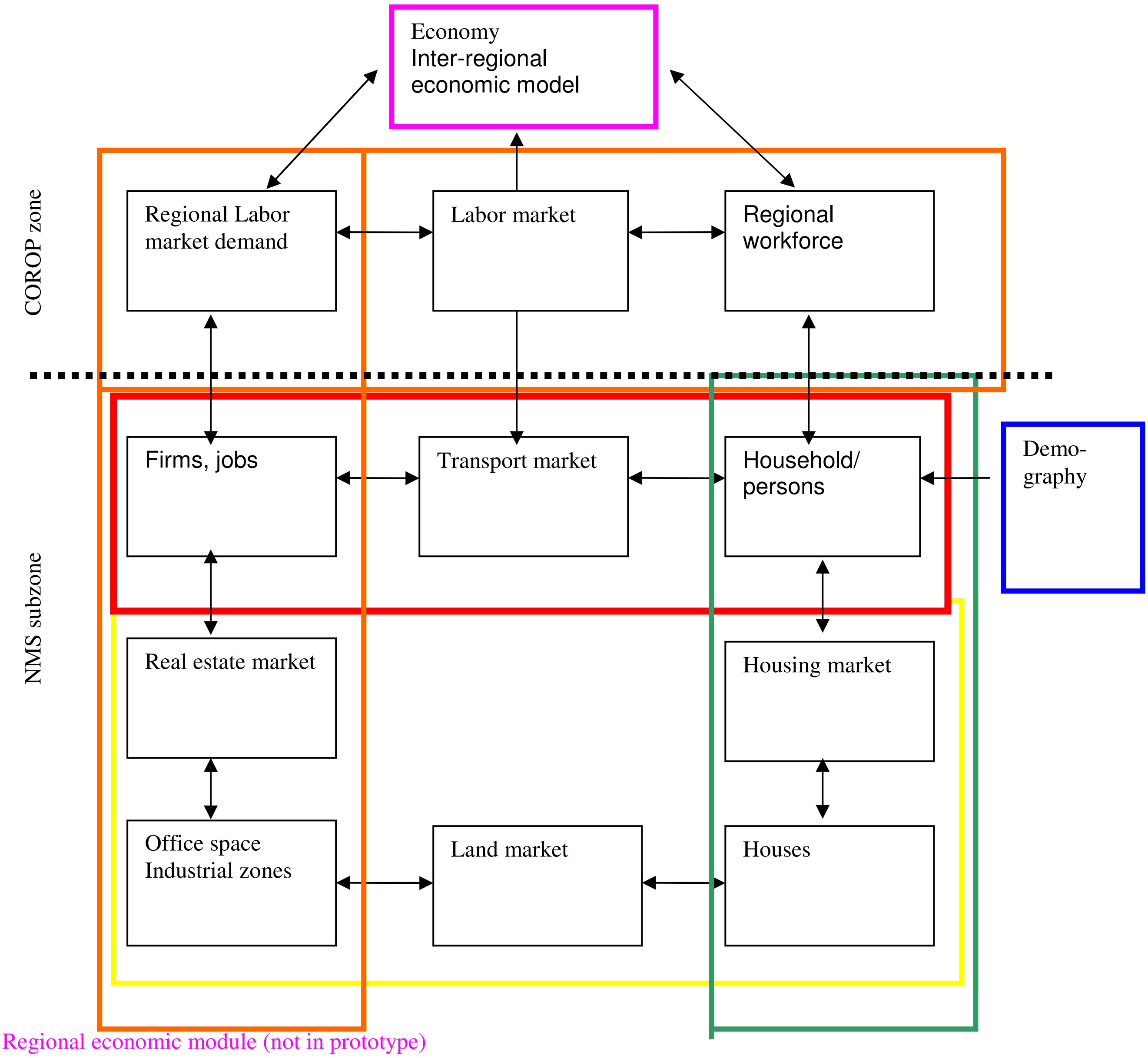
Variant	**Leiden**	**ZO Friesland**	**Houten**	**Meersen**
Ref_free (pop)	406775	227048	2646	14984
Free_v1	1.03	1.03	1.02	1.02
Free_v2	1.06	1.05	1.04	1.02
Free_v3	0.98	0.98	0.99	0.99
Free_v4	0.96	0.97	0.99	0.99
Ref_reg (pop)	396739	215814	2547	17746
Reg_v1	1.00	1.00	1.00	1.00
Reg_v2	1.00	1.00	1.00	1.00
Reg_v3	1.00	1.00	1.00	0.98
Reg_v4	1.00	1.00	1.00	0.98

Table 4. Effects on number of jobs by region, total number of jobs

Variant	**Leiden**	**ZO Friesland**
Ref_free (jobs)	172313	99337
Free_v1	1.12	1.09
Free_v2	1.66	1.48
Free_v3	0.91	0.92
Free_v4	0.76	0.79
Ref_reg (jobs)	169522	96434
Reg_v1	1.10	1.08
Reg_v2	1.62	1.46
Reg_v3	0.92	0.93
Reg_v4	0.78	0.80

FIGURES

Figure 1. Functional design of the prototype TIGRIS XL model



Regional economic module (not in prototype)
Labour market module (regional and local dimension)
Demography
Land market and real estate market
Housing market
Transport market