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Accessibility modeling and evaluation: The TIGRIS XL land-use and transport interaction model for the Netherlands

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ABSTRACT

In current practice, transportation planning often ignores the effects of major transportation improvements on land use and the distribution of land use activities, which might affect the accessibility impacts and economic efficiency of the transportation investment strategies. In this paper, we describe the model specification and application of the land use transport interaction model TIGRIS XL for the Netherlands. The TIGRIS XL land-use and transport interaction model can internationally be positioned among the recursive or quasi-dynamic land-use and transport interaction models. The National Model System, the main transport model used in Dutch national transport policy making and evaluation, is fully integrated in the modeling framework. Accessibility modeling and evaluation are disaggregated and fully consistent, which is not common in accessibility modeling research. Logsum accessibility measures estimated by the transport model are used as explanatory variables for the residential and firm location modules and as indicators in policy evaluations, expressing accessibility benefits expressed in monetary terms. Modeling results indicate that accessibility changes from transport investments in the Netherlands have a significant but modest positive influence on the location choice of residents and firms. This is probably mainly due to the spatial structure and already dense and well developed transport networks, and the large influence of national, regional and local governments on the Dutch land use markets.

1. Introduction

Common sense and a good deal of research suggest that major changes in the transport system influence patterns of urban development and location choices of households and firms, and that major changes in land use patterns influence the number of trips, and their destinations and modes. In short, land use and transportation systems are closely intertwined, and models used to support transportation planning need to be integrated with land use models to capture these effects (Waddell, 2011; Chang, 2006). The TIGRIS XL model is an example of such a land-use and transport interaction model.

The TIGRIS XL land-use and transport interaction model can internationally be positioned among the recursive or quasi-dynamic models, in which the end state of one time period serves as the initial state of the subsequent time period (Simmonds, Waddell, & Wegener, 2013). The TIGRIS XL model has further its composite structure, combining differently constructed submodels for different processes, in common with other LUTI models such as the DELTA modeling package in the UK (Simmonds, 1999), the Urbansim model (Waddell, 2001, 2002, 2014) and the IRPUD model for the Dortmund region (Wegener, 2011).

The paper contributes to the literature by presenting a comprehensive overview of how accessibility is included in the TIGRIS XL model, in the model estimations, its applications and evaluations in planning practice. The paper also highlights several features of particular interest, which are related to the availability of data and planning tradition in the Netherlands. Specific contributions are:

- Firstly, accessibility modeling and evaluation are disaggregated and fully consistent, which is not common in accessibility modeling research. The inclusion of the National transport Model System (NMS), a disaggregate discrete choice based transport model in the modeling framework enables using person type and purpose specific utility-based accessibility indicators (so-called logsums) in the TIGRIS XL model and in policy evaluations.

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- Secondly, improved insight in influence of transport on land-use as both the coefficients of the labor and housing market module are based upon formal statistical estimations using detailed large scale spatial data sources. While in international practice, often due to data limitations, informal calibration procedures or estimations based upon small scale surveys are more commonly applied to fit most LUTI models.
- Thirdly, the model is tailored to be applied in actual planning practice. Regardless of the large research efforts and growing number of available models is their use in practice still not common (e.g., see Waddell, 2011; Waddell, Ulfarsson, Franklin, & Lobb, 2007). The TIGRIS XL model, is developed for and owned by the Ministry of Infrastructure and Environment, which provide an operational focus. This means that the model need to be adjusted to and/or integrated with other planning instruments and procedures. This gives other constraints and opportunities than the models developed in a more academic environment. The model has furthermore been designed to operate in interaction with sector specific models, like the demographic model and National Model System for transport, as applied by the Dutch government.

Section 2 of this paper describes the structure of the modeling framework and Section 3 describes the applied accessibility measures in more detail. Section 4 describes the residential location choice model and its estimation results. A similar description is made in Section 5 for the employment location module. In both sections specific attention is given to how accessibility drives the location of households and employment. Section 6 presents a model application examining the accessibility effects of land use and public transport investment programs. Finally, in Section 7 presents the conclusions and discusses the results.

2. Structure of the TIGRIS XL model

2.1. Functional design

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 model is a recursive or quasi-dynamic type of model, in which the end state of one time period serves as the initial state of the subsequent time period. 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 depending on time lags 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 System (NMS) of the Netherlands and the land-use modules and transport model interact, for reasons of computation time, every five years.

The TIGRIS XL model consists of five modules addressing specific markets. Core modules in TIGRIS XL are the housing market and labor market module; these modules include the mutual interaction between the population and jobs and the effect of changes in transport on residential or firm location behavior. The model has a multi-level set-up and different spatial scale levels are distinguished, namely the regional level (COROP, 40 regions in the Netherlands) to simulate interregional flows, the municipality level and finally the level of local transport zones of the National Model System (1379 zones covering the Netherlands). Fig. 1 presents an overview of the TIGRIS XL (TXL) model and the main relationships between the modules, for a more detailed description reference is made to Zondag (2007). In this section, we briefly describe the demography module and land and real estate module. The transport market, housing market and labor market modules are described in more detail in Sections 3–5.

The features of the transport market, housing market and labor market module are described in Section 3–5.

2.2. Demography module

The TIGRIS XL model uses the regional demographic model PEARL (de Jong, 2013) of the National Bureau of Statistics and Netherlands Environmental Assessment Agency as basis for its demographic module. The module works bottom-up and the transition processes of the population and households at the zonal level. The population is administrated by year of age, gender and household position and the transitions, such as birth, mortality and changes in household position, are applied at this level of detail as well. Besides the demographic characteristics the population and household data is enriched with socio-economic information regarding status of employment and household income.

2.3. Land and real estate market

The land and real estate market module processes the changes in land-use and buildings, office space and houses, and addresses both brown field and green field developments. The land and real estate market module interacts with the housing market and labor market module. The module distinguishes the land market, including land regulation policies, and the real estate market addressing the development or restructuring of buildings. The modeling of the changes in land-use depends on the user settings for the level of market regulation by the government. This can vary from a regulated residential land-use planning system to a unregulated residential land market. In a regulated market, all supply changes are planned by the government and handled as exogenous input for the model. In a less regulated market, supply changes are triggered by the preferences of the actors.

These land developments are restricted by the availability of land and depend on the behavior of land owners and project developers. The development ratio, part of the available land that will be taken into development, depends here on how profitable a location is. And profit is here calculated as the difference between the market price of a building minus the construction and land costs. The development ratio further depends on the overall market conditions. The land and real estate market in the Netherlands is considered as an oligopolistic market with a few large players regulating housing production. In its specification the TIGRIS XL model benefits of the experiences with the Houdini housing market model of the Netherlands (Eskinasi, Rouwette, & Vennix, 2011).

3. Transport market and accessibility measures

TIGRIS XL uses the National Model System (NMS) of the Netherlands as transport model (Hofman, 2002; Joksimovic & van Grol, 2012). This model is rooted in discrete choice theory and a first version of the model has been operational in the Netherlands since the mid 1980s. The version of the NMS transport model in TIGRIS XL distinguishes 8 travel purposes, 5 modes, 1379 zones and over 354 person types, (depending on the travel purpose). The transport modes are car driver, car passenger, train, BTU (Bus, Tram, and Underground), and slow mode (split into cycling and walking). Five home-based travel purposes are included (home-work, home-business, home education, home shopping and home-other) and three non-home travel purposes (work-business, work-education and work-other).