

Policy scenario modelling with the land-use transport interaction model MARS Austria

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ABSTRACT

This paper presents an attempt to setup the land use transport interaction model MARS (Metropolitan Activity Relocation Simulator) for a nation wide case study for Austria. Interaction between transport planning, land-use planning and the economy is highly complex. The numerous feedback loops within and between transport, land-use and economy are effective on different temporal and spatial levels. The MARS Austria model was designed to capture the most important feedback loops between these systems.

With this model policy scenarios concerning transport and land-use shall be implemented to predict effects on transport behaviour and migration of households and workplaces on the district level of Austria. A relevant development in Austria over the last years was the constant growth of CO₂ emissions in the transport sector. The model shall help to evaluate which policy measures are most effective in terms of CO₂ reduction in the transport sector.

1. INTRODUCTION

Concern over transport problems, a constant issue in past decades, recently depended in the context of climate change because of the significant – and ever increasing – transport related CO₂ emissions. Policies that aimed to mitigate transport related problems based on measures merely within the transport systems, proved to be inadequate in the past. Consequently a wider scope of analysis is called for. The notion that transport and land-use are strongly interrelated is accepted common knowledge. There are numerous feedback loops within and between transport, land-use and the economy and these are effective on different temporal and spatial levels. As a result even effects caused by the change of a single policy instrument can be difficult to predict. For example, form and density of human settlements can affect transport distances and number of trips within a city, between neighbourhoods, home and work, and home and services like city centres and shopping areas. Especially commuting distances are affected by physical planning that influences location choice by firms and households.

As result, a series of land-use and transport interaction (LUTI) models have been developed in the past decades. Today, the approach has reached a stage of maturity in theoretical and methodological terms and was implemented in a number of operational models (Wegener 2004).

However, most of these model concern cities or urban agglomerations. This seems reasonable as land-use- transport and environmental related problems, such as congestion, various forms of pollution, scarcity of natural land, etc. are most apparent in densely populated urban areas. But, neither a theoretical point of view nor empirical evidence indicate that land-use transport interactions are absent in rural areas. Quite the opposite seems to be the case many of them have been subject both to significant transport infrastructure construction and to considerable migration processes.

To my knowledge also pure transport models modelled in system dynamics concern mostly cities or urban agglomerations (Han and Hayashi 2008, Khanna et al. 1985, Wang et al. 2008).

Another aspect is that it appears that most urban models are relatively custom tailored implementations for specific urban case studies, sometimes only loosely related to more generic model environments. This raises the question of generality of LUTI models.

To undertake the application of the LUTI model MARS to rural areas and investigate the generality of the urban MARS model, the Institute of Transportation – Research Center of Traffic Planning and Transport Engineering, set up a nation wide case study version of the existing urban LUTI model MARS (Pfaffenbichler 2003) for Austria (Haller et al. 2007, Haller et al. 2008). This process is still in progress, the wider geographical scope made some changes in structure necessary.

Not only do the models mostly deal with cities or urban agglomeration but it appears, that also the implementation of transport and land-use policies and the analysis of their effects seem to take place often in urban case study settings (Löchl 2006, May et al. 2000, May et al. 2003).

The abstract starts with a description of the MARS model in section 2. This covers a short description of the MARS sub models as well as a depiction of the case study area. Section 3 presents the main research questions which shall be covered in the doctoral thesis. These concern the implementation and possible effects of land-use and transport policies on a national level, and research questions related to the generality of LUTI models and their applicability for rural areas. Section 4 covers the question, why system dynamics modelling is an accurate tool for LUTI modelling. The abstract closes with an outlook in section 5.

2. THE MARS MODEL

The MARS model is a dynamic land-use/transport interaction (LUTI) model, which is based on the principles of synergetics (Haken 1983). To date the MARS model has been applied to 10 European (Edinburgh, Gateshead, Leeds, Madrid, Trondheim, Oslo, Stockholm, Helsinki, Vienna and Bari), 2 Asian (Hanoi, Ubon Ratchathani) and 1 South American (Porto Alegre) city. Ongoing projects cover setting up the MARS model for Hoh Chi Minh City in Vietnam and Washington D.C. in the US.

The model description in this paper will just focus on the overall model structure. For a more comprehensive presentation, see Pfaffenbichler (2003, 2008).

2.1. Model structure

The MARS model consists of sub models which simulate passenger transport (transport sub model), housing development, household migration (residential location sub model) and workplace migration (workplace sub model).

Additionally accounting modules which are attached externally calculate assessment indicators and pollutant emissions. Furthermore there is the possibility to include external scenarios like demographic transition or growth and changes in car ownership. Figure 1 shows the three basic sub models and their main linkages between them. These linkages are accessibilities (formulated as potential to reach workplaces and shopping opportunities), which are passed on from the transport sub model to the residential location- and workplace sub models, and the spatial distribution of households and employment which are input from the residential location- and workplace sub models to the transport sub model. Land price influences both the residential location- and the workplace sub model, whereas these two sub models change the availability of land.

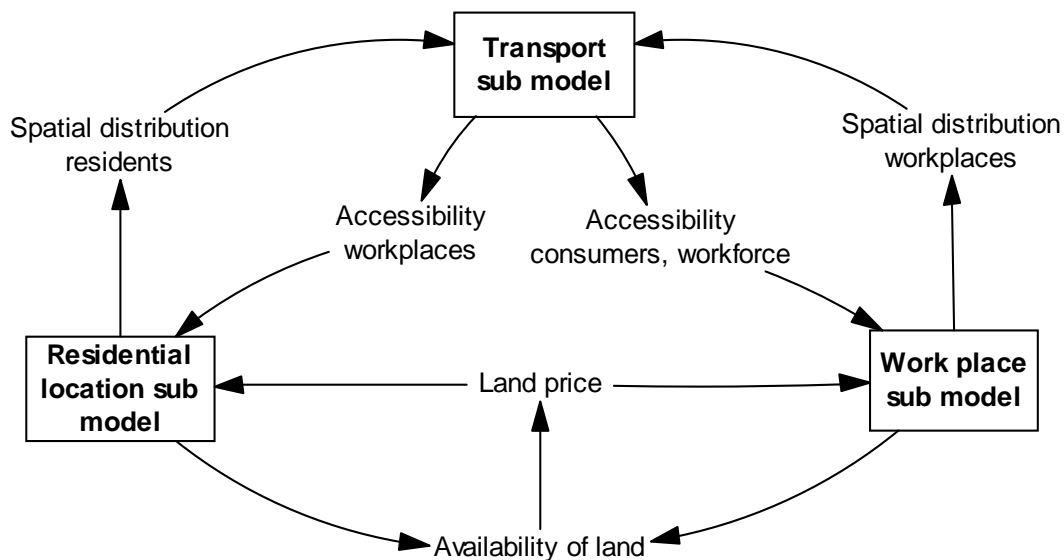


Figure 1 The three main sub models and their linkages

2.2. The Transport sub model

The transport model in MARS simulates passenger transport and comprises trip generation, trip distribution and mode choice. Trip distribution and modal split are calculated simultaneously by a gravity (spatial interaction) type model.

In the trip generation the number of trips originating or designated for a particular model zone are calculated. The trip distribution, allocates the total number of trips to all origin-destination (OD) pairs and the mode choice is the distribution of the trips to the different modes of traffic, normally specified as percentage share.

The modes considered in the model are slow, car, public transport (bus) and public transport (rail). The slow mode represents the non-motorized modes walking and cycling.

2.3. The land-use sub model and its modules

The land-use sub model consists of a location (household and workplaces) and a development module (housing only). The location modules simulate migration of households (residents) and workplaces. For housing, the development of housing units is explicitly modelled, whereas it is assumed that businesses develop their own premises. Therefore, residential migration is constrained by the availability of housing units, while workplace migration may be subject to land shortage.

2.4. Study area and model zones

The study area comprises the whole territory of Austria, totally 120 model zones which are based on the district subdivision ('politische Bezirke') of Austria plus the 23 municipal districts of Vienna. A first attractive feature of the district structure is that it includes the so-called 'independent cities' (Statuarstädte) which are administratively separated from their hinterland districts. Hence, it is possible to represent core-periphery interactions (such as commuting flows and suburbanization) for these districts in the model. Second, for many statistics, the district level is the most detailed level for which data are available. Third, the number of districts (120) is a good compromise from a technical point of view in that it keeps calculation time of the system within a reasonable limit.

There are two important features of the case study worth mentioning. First, the model zones are very heterogeneous amongst each other. It comprises highly urbanized, service-sector oriented zones with highly positive commuting balance; sparsely populated zones with significant agricultural production and high out-commuting rates; mountainous regions influenced by tourism where settlement areas are concentrated or constrained by alpine valleys to name just a few examples. All in all, diversity is much greater than in usual urban agglomeration models.

Second, as the case study covers the entire Austrian territory, it is apparent the model area is polycentric and, additionally, comprises several levels of central places.

3. RESEARCH QUESTIONS

The main focus of the planned research concerns the effects of land-use transport policies on a nation wide scale as mentioned in section 1. First extensive literature review will be carried out to get an overview of already accomplished national case studies (Schade 2005, Schade 2007, Steininger et al. 2006).

This gives rise to following questions for the wider geographic scope:

- What overall effects do transport and land-use policies have on a nation wide scale?
 - On the transport behaviour
 - On migration of residents
 - On location of workplaces
- What about LUTI models in larger, more disperse and polycentric regions?
 - Dominant development in urban land-use since 20th century: suburbanisation. Predicting population spreading is relatively easy in a monocentric setting.

- Modelling land-use in polycentric areas is “harder task”, i.e. a more stringent model test.

The research questions concerning transport and land-use policies shall cover the following:

- Which policies seem to be most effective, in terms of reducing CO₂ emissions on a national scale?
 - CO₂ reduction in the transport sector

4. REASONS FOR MODELLING LAND-USE AND TRANSPORT IN SYSTEM DYNAMICS

One distinctive feature of interrelations between the transport and the land-use system is that changes within these two systems occur at significantly different speed. Transport users respond relatively fast to changes in the transport system, whereas the land-use system is characterized by a considerable degree of inertia, mainly due to the fact that land-use systems are embodied in physical structures such as buildings and infrastructure.

In more detail even four different speed levels of changes (Wegener 2004) within the transport/land-use systems can be identified, they are ordered from slow to fast processes:

- Very slow change: networks and land use.
Transport, communications, and utility networks are the most permanent elements of the physical structure of cities and also rural regions. The land-use distribution is equally stable; it changes only incrementally.
- Slow changes: workplaces and housing.
Buildings have a life-span up to 100 years and take several years from planning to completion. Workplaces exist much longer than the firms or institutions that occupy them, just as housing exists longer than the households that live in it.
- Fast change: employment and population.
- Immediate change: goods transport and travel.
The location of human activities in space gives rise to a demand for spatial interaction in the form of goods transport and travel.

As already mentioned feedbacks and interrelation between the land-use and transport system are numerous (see section 1):

- The distribution of land uses, such as residential, industrial, or commercial, over the spatial area determines the location of human activities such as living, working, shopping, education, or leisure.
- The distribution of human activities in space requires spatial interactions or trips in the transport system to overcome the distance between the location of activities.
- The distribution of infrastructure in the transport system creates opportunities for spatial interactions, and can be measured as accessibility.
- The distribution of accessibility in space co-determines location decisions and so results in changes of the land use system.

This different system speeds and complex interrelations between and within the land-use and transport system, makes system dynamics powerful in modelling land-use/transport interactions.

5. OUTLOOK

By conducting this research, it is expected to have a dynamic land-use transport interaction model on a national level, namely for Austria. With this model policy scenarios concerning land-use and transport shall be implemented to predict effects on transport behaviour and migration of households and workplaces on the district level of Austria. It shall be evaluated which policies are most suitable for this aggregate level of observation like the national scope and which policies are most effective in the sense of a reduction of CO₂ emissions in the transport sector.

System dynamics is an adequate tool in addressing this research questions because of the strong interrelations of the underlying systems. These interrelations make predictions of outcomes of single- or a combination of policy instruments difficult, and SD is expected to help in understanding these complex mechanisms.

Further interest lies in the predicted effects of national policies on rural, loosely populated areas, because studies concerning these effects seem to be few and in the case of Austria the model zones are especially heterogeneous.

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