

Modelling land-use and transport at a national scale - the MARS Austria model

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ABSTRACT

This paper presents the attempt to set up the dynamic land-use transport interaction (LUTI) model MARS (Metropolitan Activity Relocation Simulator) for a nation wide case study of Austria. To this end we adapted the existing urban MARS model. The purpose of the model is to capture the most important interactions and feedback mechanisms between the land-use and the transport system. The MARS model consist of a transport model, a housing development model, a household location choice model, a workplace development model, a workplace location choice model, as well as a fuel consumption and emissions model. In terms of transport and land-use policies which can be modelled, MARS was developed to investigate strategic level issues over a long time period; 30 years. It is therefore an aggregate model. The development of MARS at the Research Center of Transport Planning and Traffic Engineering started some 10 years ago, partly funded by a series of EU-research projects. To date MARS has been applied to 13 cities (10 European, two Asian and one South American).

In this paper particular attention was paid to the structural changes of the model (from urban to national scale) and the estimation of the transport model parameters as well as the land-use model parameters, which are modelled with a gravity model approach. For this purpose we used the build-in optimizer of the system dynamics modelling software Vensim by minimizing the sum of squared deviations between observed and predicted data. We present the model fit and estimated parameters.

1 INTRODUCTION

Interactions between transport planning, land-use planning and the economy are highly complex. For example, form and density of human settlements 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.

The numerous feedback loops within and between transport, land-use and the economy 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. Because of the notion that transport and land-use are strongly interrelated, a series of land-use and transport interaction (LUTI) models have been developed in the past decades (Wegener 2004).

Most of these models though concern cities or urban agglomerations. This is understandable as transport and land-use related problems, such as congestion, various forms of pollution, scarcity of natural land, ect. are most apparent in densely populated urban areas. However, neither a theoretical point of view nor empirical evidence suggest 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.

Another important notion is that it seems 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 two research themes outlined above, namely the application of LUTI modelling to rural areas and an investigation of the generality of the urban LUIT model MARS, we set up a nation wide case version of the existing urban LUTI model MARS (Pfaffenbichler 2003a) for Austria.

The MARS model is methodological a system dynamics (SD) model. SD, originally called industrial dynamics, was developed at the Massachusetts Institute of Technology (Forrester 1961). It derives its roots from system theory, cybernetics, information science, organizational theory, feedback control theory, military games and tactical decision making (Abbas and Bell 1994). SD is a methodology designed to help understanding the dynamics of different real-world systems, by investigating a system, represented in the form of causal feedback relations.

The paper starts with a short description of the different model parts and their structure in section 2. In this section the focus lies on the structural changes that were necessary for the nation wide case study setup. Section 3 describes the application of the model to Austria and depicts the case study area. In section 4 the calibration approach and first results from model calibration of the different model parts are presented. We describe the methodology as well as model fit and estimated parameters. The paper closes with a conclusion and an outlook in section 5.

2 THE MARS MODEL

2.1 Introduction

The MARS model is a dynamic land-use/transport interaction (LUTI) model, which is based on the principles of synergetics (Haken 1983) and implemented as a system dynamics model (see section 1) (Sterman 2000). 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 focus on the overall model structure and some specific changes relevant for the shift from an urban to a national case study setup. For a more comprehensive model presentation, we refer the reader to Pfaffenbichler (2003a, 2008).

2.2 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 model, and the spatial distribution of households and employment which are input from the residential location- and workplace sub model 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.

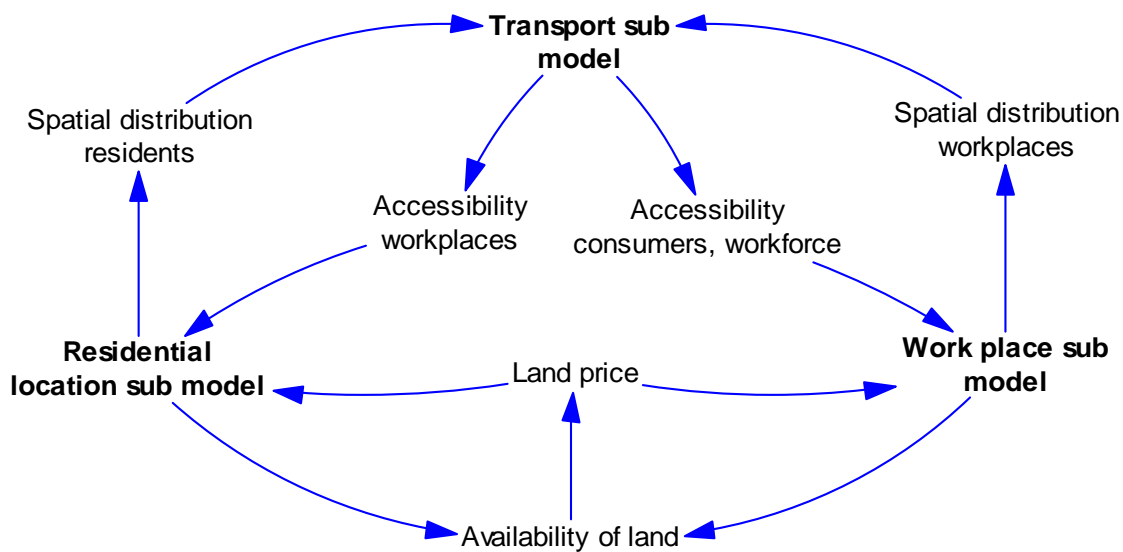


Figure 1 The three main sub models and their linkages

2.3 The transport sub model and model adaptations

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. Due to the zone size in the MARS Austria model, this mode is almost exclusively relevant for intrazonal trips (except for interzonal trips in Vienna where the model zones represent municipal districts).

2.3.1 Transport model adaptations

Trip distribution and mode choice in the MARS model are calculated per origin-destination (OD) pair. Due to the heterogeneity of the case study area (see section 3.1) we had to improve further the possibility of modelling commuting trips distribution for intrazonal trips. The model setup was perfectly suitable for the urban case studies, but the wider geographical scope made some changes in the structure of it necessary.

Therefore we extended the model zones for intrazonal distance classes. For each of the 121 model zones the intrazonal trips are now split up to 5 distance classes, where mode split and number of trips is calculated separately for each zone and distance class.

2.4 The land-use sub model, its modules and model adaptations

2.4.1 The residential location sub model

In the urban MARS model, migration is modelled in a three step approach: first, out-migration per model zone is estimated. The overall out-migration of the whole case study is constrained to a given rate; this rate was usually assumed to be 0.066 per year, equivalent to an average time between two residential moves of 15 years, which is reasonable for European cities (ODPM 2002). Second, migrants were pooled over the whole case study. In a third step, the migrants are distributed to destination zones.

Both out-migration, OM_i , and in-migration, IM_j , are modelled based on a LOGIT function of the form:

$$OM_i = e^{\alpha_0 + \alpha_1 POP_j + \alpha_2 LR_j + \alpha_3 GL_j + \alpha_4 ACC_j}$$

Formula 1 Out-migration formula

$$IM_j = e^{\alpha_0 + \alpha_1 POP_j + \alpha_2 LR_j + \alpha_3 GL_j + \alpha_4 ACC_j}$$

Formula 2 In-migration formula

The same set of variables is assumed to influence out-migration and in-migration:

- POP_j : Number of residents in a zone J
- LR_j : Land rents in model zone J
- GL_j : Area of green land in model zone J
- ACC_j : Access attractiveness in model zone J

However, the direction and strength of the link between the explanatory variables and migration, i.e. the parameters of the model, is different for out- and in-migration.

The choice of variables considered (accessibility by car and public transport, level of housing costs and share of recreational green land) is based on several different lines of argument: Firstly, they repeatedly rank among the most important determinants of migration in empirical migration research (ODPM 2002, Fotheringham et al. 2004). Secondly, own empirical studies focusing in particular on Vienna confirmed this importance (Pfaffenbichler 2003b). Third, each of the variables is highly endogenous especially from a land-use/ transport perspective

and in an urban context. As an example, in an urban context the share of green land is both an important cause of migration – in that it constitutes a major amenity perceived by potential migrants – and is simultaneously influenced by migration – as new development can significantly reduce this amenity in urban areas.

Residential location sub model adaptations

In the urban MARS residential location sub model the geographical location of origin and destination zones is not taken into consideration. In other words, the model assumes that the destination choice of migrants is not influenced by the location of their current domicile.

An earlier attempt to implement the model for Austria without structural changes revealed the inappropriateness of this structure for a larger spatial scale (Haller et al. 2007). One major shortcoming was that the observed length distributions of migration were not reflected in the model output: whereas domestic migration in Austria (and elsewhere) is largely short-distance, the model predicted significant population shifts from the West to the East of the country, i.e. over a couple of hundred kilometres.

To improve on the model we reviewed literature on migration theory (e.g. Greenwood 1985, Muth 1971, Bode and Zwing 1998) and applied migration models (e.g. ODPM 2002, Flowerdew and Amrhein 1989, Roy 2004). Migration theory states that migrants evaluate benefits and costs of migration. Migration related costs include actual monetary costs of migration, the loss of social networks. In most applied work on migration, due to the intangible nature of these effects, distance is taken as a surrogate for the various types of migration costs. Moreover, distance also reflects an information aspect of migration, as people are usually deterred from moving to more distant places they know less about. In the first place we used crow-fly distances (Haller et al. 2008), which because of the heterogeneity of the study area (see section 3.1) seemed to be inappropriate. In fact, there are great differences comparing crow-fly and real road network distances, because Austria consists of many mountainous regions. In the final implementation road network distances were used.

In order to account for the overwhelming importance of distance while changing model structure as little as possible, we implement a two stage migration model: First, the number of out-migrants per zone is estimated following the approach of the existing urban MARS model. Second, a migration destination choice model distributes the out-migrants (which it takes as an exogenous input from the out-migration model) over the possible destinations based on characteristics of the destinations and the distance between two zones.

The model takes the form of the well-know gravity/spatial interaction model. In general terms, the number of migrants between origin i and destination j, M_{ij} , is modelled as

$$M_{ij} = O_i \frac{\exp(\alpha_0 + \alpha_1 X_{1,j} + \alpha_2 X_{2,j} + \dots + \alpha_n X_{n,j} + \gamma_n Y_{ij}) d_{ij}^{-\beta}}{\sum_j \exp(\alpha_0 + \alpha_1 X_{1,j} + \alpha_2 X_{2,j} + \dots + \alpha_n X_{n,j} + \gamma_n Y_{ij}) d_{ij}^{-\beta}}$$

Formula 3 General form of the formula for calculating migration flows from zone i to J

where O_i represents the number of out-migrants of origin i (given exogenously to the distribution model); $X_{1,j} \dots X_{n,j}$ a set of n attributes relating to destination j with the associated parameters $\alpha_0 \dots \alpha_n$; Y_{ij} an origin-destination pair specific (dummy) variable with the associated parameter γ ; d_{ij} the distance between origin i and destination j.

2.4.2 Workplace location sub model

The workplaces migration sub module has a structure, very similar to the residential migration sub model. In the current version it consists of two parts: one for the production sector and one for the service sector.

At the moment the relative attractiveness of a zone for potential workplace migration considers:

- The zone's potential for activity participation (accessibility),
- the abundance of building land,
- the cost for building in a zone and
- the average household income.

Access attractiveness, formulated as potential to reach workplaces and shopping opportunities, presents the zones potential for activity participation. The possibility to build in a zone is just restricted by the limits of land availability in a zone. The cost of building in a zone is approximated by the land price. The average household income is a signal for firms whether there is consumption potential and is a proxy for labour cost.

For the out-moving model an average time workplaces move has to be defined, identified in empirical studies. The total number of workplaces in the study area multiplied by the reciprocal of the average time workplaces move, gives the total number of out-movers in the study area.

In a next step the attractiveness to move out a certain zone is calculated with the above mentioned influence factors, except for the land availability which of course is just relevant

for the in-moving sub model. This is modelled again as exponential function of the form, separately for each sector:

$$Attr_j^{out} = e^{(\alpha_1 * access-attr + \alpha_2 * Land-price-attr_{i,sector} + \alpha_3 * HHI_i)}$$

Formula 4 Attractiveness to move out for workplaces

The workplaces, which want to move in, are defined similar to the out-moving workplaces, but an external growth rate is added, which can be negative or positive depending on the sector. Then MARS calculates the amount of space available for business use and allocates the total potential re-allocating and newly developed workplaces to the different locations using a LOGIT model (see Formula 3)

2.4.3 Housing development sub model

In the MARS model developers decide whether how much and where to build new housing units. Their decision is based on four factors:

- The rent they can achieve after the housing units are ready for occupation. It is assumed that this is the rent paid in the year of the development decision,
- the land price in the decision year,
- the availability of land in the decision year and
- the demand from potential in-movers in the zones.

The potential for new domiciles is distributed to the zones according to the attractiveness to build in a zone, which is dependent on the above mentioned factors. These will be ready to occupy after an external defined time lag. MARS controls whether there is enough land for the planned developments. If not, the number of developments in the certain zones is constrained. There is currently no redistribution process to other locations in the development sub model. Changes in the available land influence land price and rent.

3 THE APPLICATION OF THE MODEL TO AUSTRIA

3.1 Study area and model zones

The study area comprises the whole territory of Austria, totally 121 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 (121) 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.

We set up the model with data from 2001 for all available data. Due to some lack in data expert guesses were necessary. This concerns first and foremost guesses in data for the transport model, like parking place search time, parking fees, etc. For the average rent data covers just the year 1991. Also for the calibration of the different model parts some exceptions due to data availability were necessary, which will be described separately in each section.

4 FIRST RESULTS FROM MODEL CALIBRATION

Model calibration and testing are currently in progress. This section therefore presents some insights gained from first model runs.

4.1 Approach to model calibration and testing

We define model calibration and testing based on Ortùzar and Willumsen (1994).

Model calibration consists in finding parameter values that optimize the goodness of fit between model outputs and observed data. Model validation is a related but not identical concept. It consists in comparing in model predictions with observed data based on a dataset not used in calibration. However, in line with Sterman (2000), we prefer the term model testing instead of validation, as model “validation” in the strict sense of the word is impossible as a matter of principle.

The transport sub model of MARS simulates transport flows within a time period. Model calibration is thus carried out on a cross-sectional basis to improve model fit in a base year.

The base year in MARS is 2001, although data on mode split for Austria was available only for the year 1995. For comparing commuting trips per OD pair with model results after calibration, data from 2001 was available.

In contrast, the land-use sub models simulate changes in a time interval which requires calibration of changes in observed land-use. Due to data availability reasons we had to restrict the data analysis to the period from 1991 to 2001 for employment data and from 2002 to 2006 for residential migration data in a first step. This implicates that migration trends in Austria which were happening between 2002 and 2006 are assumed to be valid also from the beginning of 2001 and that the development of employment in Austria between the years 1991 and 2001 also continued from the beginning of the year 2001 (the base year of the MARS Austria model).

4.2 Optimization/least squared residual

Vensim has a build-in optimizer functionality which can be used for two purposes (Ventana Systems Inc. 2007): (i) model calibration and (ii) policy optimization.

We used the optimization functionality implemented in Vensim for our calibration purposes. This automated calibration procedure was applied both to the transport and the land-use sub models. The optimizer consists of an algorithm (Powell) which numerically maximizes or minimizes an arbitrary objective function; in Vensim terminology the objective function is called “payoff”. In the calibration mode, the payoff is automatically specified by the software as the sum of the squared deviations between the observed values and the model output for one or more user-specified variables; a weight can be attached to each of the variables. Parameter values are chosen in an iterative process to minimize payoff. The optimizer (calibration mode) draws on the same criterion of goodness-of-fit as (ordinary) least squared estimation (OLS) in regression analysis. The difference to OLS is that the model need not necessarily be linear in parameters when estimated using the optimizer. The gravity model actually is not linear in parameters; the logarithmic transformation necessary to permit OLS estimation is at the root of some problems of OLS estimates for gravity models. This methodology is a fairly straightforward way to derive estimates of the model parameters.

A point of criticism of this method might be that there are no analytically known measures of model significance. However, through simulation some experimental indications on model and parameter significance can be obtained. Another method we will implement in the future for the parameter estimation process is “bootstrapping”(Moore and McCabe 2006, Dogan

2007). Bootstrapping enables to get the distribution of the parameter values and in further consequence allows conclusions about statistical significance of the estimated parameters.

4.3 Transport model

Table 1 shows the modal split calculation data to which MARS Austria is calibrated. The mode split for trips home – work is calculated using data from 1995 for commuting trips (Herry 2007). For the trips home – other, the average mode split weighed by the share of additional trip purposes (education, leisure, shopping, official business trips) in other trips is taken.

<i>Mode/Trip purpose</i>	Home-Work	Home-Other	Total
car	63.6%	47.6%	55.6%
pt bus	11.1%	10.2%	10.7%
pt rail	7.1%	6.9%	6.9%
slow	18.2%	35.4%	26.8%

Table 1 Mode split calibration data 1995. Source: (Herry 2007), own calculations

For the transport model the k factor (peak/opeak) for the trips HWH (home – work - home; commuting trips) and HOH (home – other - home; all other purposes) is estimated.

$$T_{ij}^m = \left[P_i * \frac{A_j * k_{peak/opeak} / f(t_{ij}^m, c_{ij}^m)}{\sum_{mj} A_j * k_{peak/opeak} / f(t_{ij}^m, c_{ij}^m)} \right]_{HWH / HOH}$$

Formula 5 Simultaneous trip distribution and mode choice

T_{ij}^m	Number of trips my mode m from source i to destination j
P_i	Production of trips at source i
A_j	Attraction of zone j as destination
t_{ij}^m	Travel time my mode m from i to j (min)
c_{ij}^m	Travel cost for a trip my mode m from i to j (€)
$f(t_{ij}^m, c_{ij}^m)$	Friction factor for a trip my mode m from i to j (min)
HWH	Tour home – work – home
HOH	Tour home – other activities – home

The friction factors are indicators to measure the subjectively perceived effort in terms of time and money which is necessary to travel from origin i to destination j .

4.3.1 Calibration of the transport model parameters

Table 2 shows the mode and purpose specific parameters derived from the calibration of MARS Austria of the base year result to the mode split data shown in Table 1.

The calibration was accomplished within the MARS Austria model using the Vensim built in calibration function (Ventana Systems Inc. 2007).

<i>Mode/Trip purpose</i>	Home-Work	Home-Other
car	1.96	1.03
pt bus	0.28	0.56
pt rail	0.24	1.03
slow	0.21	0.70

Table 2 Mode and trip purpose specific parameters k_{peak}/o_{peak} of the calibration

4.3.2 Model fit – transport model

The conformity between observed and calculated data was assessed by comparing home – work trips by OD-pair and intrazonal home - work trips as calculated by the calibrated version of MARS Austria and data from 2001. Unfortunately no similar data were available for trips home – other.

The resulting regression coefficients are in general reasonably high. The R^2 for the total trips home – work is 0.91, the R^2 for the intrazonal trips is eve higher with 0.97.

At the bottom of the left hand figure in Table 1 it can be seen that MARS Austria is underestimating some commuting connections from the core cities (Linz, Salzburg, Graz and Innsbruck) to surrounding suburban districts. The intrazonal trip distribution is working very well, due to the fact that we implemented intrazonal distance classes (see section 2.3).

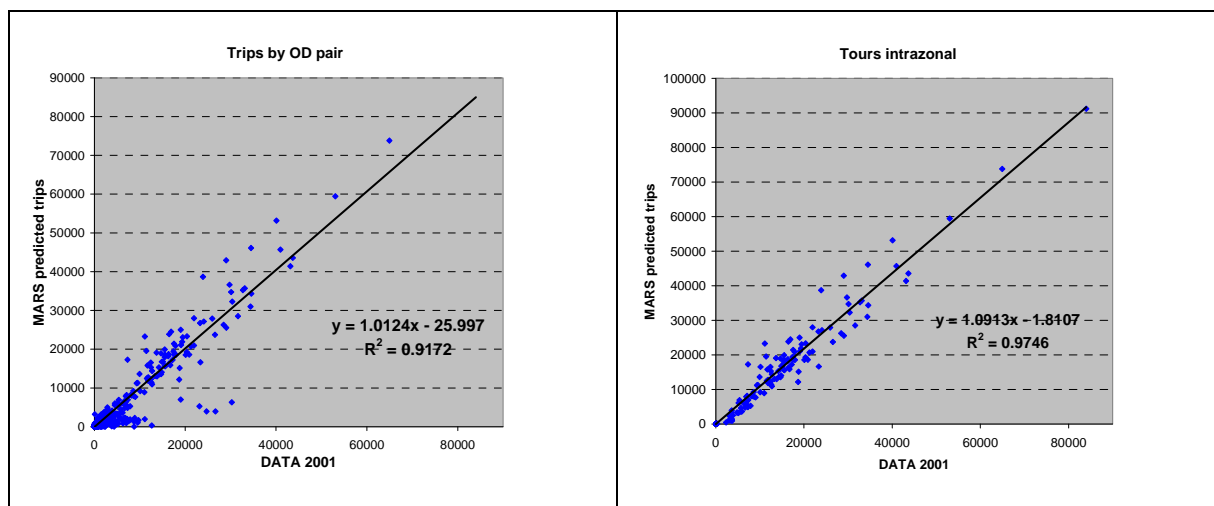


Table 3 Comparison data of commuting trips to MARS results – all commuting trips and intrazonal trips. Source: (Statistik Austria 2002a)

4.4 Residential migration

In order to assess the model output we briefly summarize domestic migration trends in Austria in the period from 1991-2001 (Statistik Austria 1995, 2002b) and 2002 to 2006, which is the period for which detailed data on migration are available in Austria (Statistik Austria 2005a, 2005b, 2006, 2007a, 2007b).

The most outstanding observation on domestic migration is that migration takes place at fairly short distances. The median distance (air-line) between an old and a new domicile is 12.6 kilometres; for 80% of the migrants the distance is shorter than 24.3 km, between the years 2002 and 2006. As a result, migration linkages are less quantitatively significant on higher levels of spatial aggregation; as an illustration may be noted that migration between the districts of Vienna exceeds the flows between all other Austrian provinces. This observation was a strong argument for explicitly considering the distance between the zones for migration choices (see section 2.4.1).

Between the years 1991 to 2001 the most striking trend was a suburbanization progress. Population shifts from the core to cities to surrounding suburban districts affected all major agglomerations. This includes all cities exceeding a population of 100.000: Vienna, Graz, Linz, Innsbruck and Salzburg.

In the following years urban agglomerations are the winners in domestic migration. With the exception of Salzburg and Bregenz, all provincial capitals, several medium-sized cities and the capital of Vienna experience population gains in the period. Within the major agglomerations, the process of suburbanization is continuing, population shifts from the core cities to surrounding suburban districts affect all major agglomerations.

4.4.1 Calibration of the residents migration model parameters

As mentioned above (see section 4.1) we used the built in optimizer of Vensim to calibrate the parameters of the moving-out and the migration-flows model.

We build two stand-alone models in Vensim for the calibration to keep the time consumed for parameter calibration little. For the out-migration model the parameters for the out-migration rate per zone are estimated (see Formula 6).

$$OM - rate_i = om - rate * e^{(\alpha_0 + \alpha_1 HR_j + \alpha_2 ACC_j + \alpha_3 POP_j + \alpha_4 LS_j)}$$

Formula 6 Calculation of the out-migration rate in MARS Austria

For the migration flow model, parameters for the migration flows from model zone i to zone J are estimated (see Formula 3).

Variable	Description
<u>Out-migration model</u>	
Residents J T-1 relative	Population of destination J per 100.000 inhabitants
HC J relative	Ration of housing cost (rents) in a zone to average housing costs (rents)
Access attr.	Population accessibility potential with a quadratic decay function based on generalized cost between origin and destination
Living space HU J relative	Ratio of living space per housing unit (m ²) in a zone to average living space per housing unit (m ²)
<u>Migration-flow model</u>	
Residents J T-1 relative	Population of destination J per 100.000 inhabitants
Housing cost.	Housing rents at destination J
Access attr.	Population accessibility potential with a quadratic decay function based on generalized cost between origin and destination
Recreational green land	Share of green land as a percentage of total zone area
Dummy functional (FUA)	Dummy for the “functional urban areas”
Distance car iJ	Car distance between districts i and J

Table 4 Overview of the migration variables

Table 4 above describes all variables considered in the migration models in MARS Austria. The number of residents in the previous time step, the housing cost and the access

attractiveness are considered in both the out-migration and the migration-flow model. Moreover the living space is a variable for the out-migration model.

As mentioned in section 2.4.1, in the migration-flow model the car distance, for considering cost of migration is explicitly taken into account.

Furthermore it turned out that there were some core-hinterland relations, which result in migration patterns that cannot be explained by the variables already considered.

The dummy variable “functional urban areas” (FUA) tries to capture these core-hinterland relations. Functional urban areas based on patterns of major commuting catchment areas are defined. Inter-district relations within the same FUA are singled out in the estimation using this dummy variable.

The variable recreational green land, which in the urban MARS case studies has always been a very strong explanatory variable, turns out to have no influence in the nation wide set up any more. The aggregate level of observation leads to the situation that the amount of green area in a model zone is sufficiently large, therefore its signal effect as a variable for living quality is gone.

4.4.2 Model fit – migration model

The model fit both for the out-migration as well as the in-migration model is in general satisfactory. The out-migration model including the explanatory variables listed in Table 6 yields a R² value of 0.93. The migration-flow model yields to an R² value of 0.96. Further variables were also tested but generally did not notably improve the model fit; for reasons of compatibility with the existing urban MARS model, they are not included in the migration model from the time being.

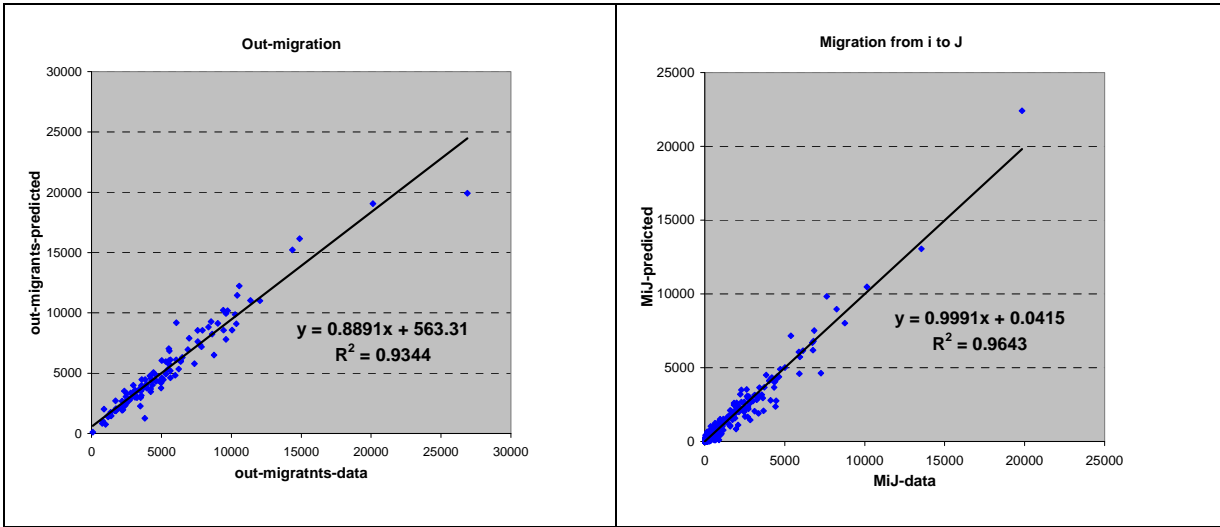


Table 5 Goodness-of-fit of the estimated models: scatterplots of predicted vs. observed out-migrants and migration flows

4.4.3 Parameter estimations for the residents location model

All parameter estimates are presented in Table 6. As expected the population parameter (Residents J T-1 relative) is negative for the out-migration and positive for the in-migration model.

The parameter on housing rents (HC J relative and Housing Cost) is also positive for the out-migration and negative for the migration-flow model.

The parameter related to accessibility (Access attractiveness) is positive for the out-migration and negative for the in-migration model. The negative sign for the migration flow model is a frequent finding in empirical models of migration and has been explained in terms of stronger competition between more accessible destinations (which are closer to major population concentrations) and in terms of lack of information on specific destinations in larger population “cluster” on the part of migrants (ODPM 2002).

The living space parameter (Living space HU J relative) has a strong negative influence on out-migration which is in line with common sense.

The recreational green land, which was a very important explanatory variable, influencing migration in the urban MARS models, has no influence on the national scale (see section 4.4.1).

Distance between two districts exerts a strong negative influence on migration between these two zones. And as in line with the argumentation of the dummy for the functional urban area (cf. section 4.4.1), migration flows are positively affected by this parameter.

Parameter	Value
<u>Out-migration model</u>	
Residents J T-1 relative	-0.276639
HC J relative	0.200801
Access attractiveness	0.180238
Living space HU J relative	-1.34024
c-out	1.08443
<u>Migration-flow model</u>	
Residents J T-1 relative	1.18259
Housing cost	-0.820271
Access attractiveness	-0.433847
Recreational green land	0
Distance car iJ	-1.50692
Dummy functional	1.35996
c	-1.93192

Table 6 Parameter estimates for the residential location sub model

4.5 Workplace migration

As mentioned in section 3.1 workplace data is available from census data of the year 1991 and 2001. One main difference to the residents migration data is, that concerning workplaces no data of workplace migration flows is available.

Bodenmann (2006a), divides the lifetime of firms into 5 phases:

1. foundation phase
2. growth phase
3. maturity phase
4. revitalization phase
5. aging phase

The main migration movements of firms are expected to happen in phase one and/or two. Mature and already established firms will not tend to move their location. Due to the lack of data concerning workplace migration-flows, it is not possible to distinguish whether firms that “appear” in certain districts are new founded or just moved their location from one district to another. Unfortunately getting data for firm foundations and firm cancellations is an elaborate process which could not be accomplished so far.

For the selection of explanatory variables for workplace migration we took selected variables from already applied urban MARS case study as well as variables proposed in the literature (Bodenmann 2006b, Pellenbarg 2005, van Wissen and Schutjens 2005, Bürgle 2006).

4.5.1 Calibration of the workplace migration model parameters

The workplace migration parameter calibration was also carried out in a stand-alone calibration model, using the calibration tool of Vensim.

Table 7 shows the chosen variables explaining workplace migration in the MARS Austria model. Access attractiveness, land price attractiveness and land available attractiveness are influencing the workplace in- as well as the workplace out-migration. The land available attractiveness is used only in the workplace in-migration.

Variable	Description
<u>WP in/out-migration</u>	
Access attr.	Population accessibility potential with a quadratic decay function based on generalized cost between origin and destination
Land price attr. workplace	Land price of possible building land in a zone
Land available attr. (in-migration only)	Availability of building land in a zone
Net income	Household income

Table 7 Overview of the workplace migration variables

4.5.2 Model fit - workplace migration model

For the workplace migration model the resulting regression coefficients are in general reasonably high. The R^2 value for the workplaces in the production sector is 0.85, the R^2 value for the workplaces of the service sector is even higher with 0.95. Scatterplots are depicted in Table 8. It depicts the comparison of workplace data from 2001 and the model predictions for the year 2001. The calibration model was started with data from year 1991, calibration process was proceeded over 10 years.

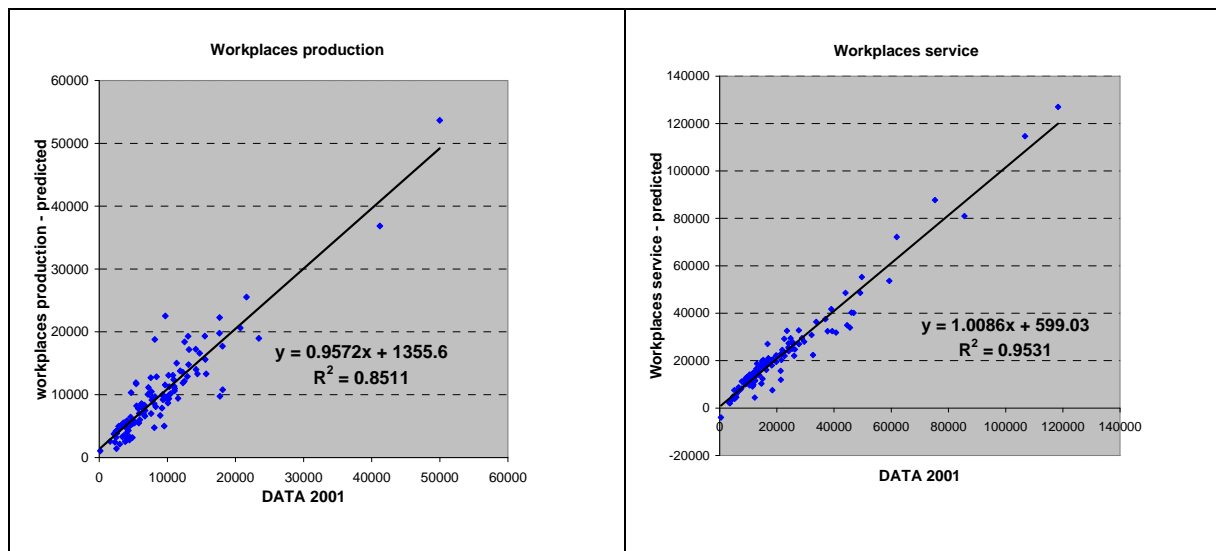


Table 8 Goodness-of-fit of the estimated models: scatterplots of predicted vs. observed workplaces (service and production) in the different model zones. Source: (Statistik Austria 2002a)

4.5.3 Parameter estimations for the workplace migration model

The parameter estimates for the workplace migration model are shown in Table 9. The “access attractiveness” parameter is negative for the workplace in-migration model for both sectors, it is also negative for the out-migration models. This makes interpretation of the net influence of the access attractiveness variable rather complicated, and further emphasises the fact that information on workplace migration-flows is needed (see section 4.5).

The same complexity arises in interpreting the positive sign of the “Land price attr. workplace” parameter, which is also positive both in the in-migration as well as in the out-migration model.

For the parameter of “Land available attractiveness” a more natural interpretation seems possible. It is positive for the in-migration of production workplaces, usually for producing firms availability of building land is an important influencing factor, for example also Bürgele (2006) came to similar findings. For the service sector the parameter shows a negative sign. The assumption in MARS Austria is that service workplaces generally need less space than workplaces in the production sector. For service sector workplaces, urban agglomerations are more attractive, which is signalled by the scarcity of available building land.

The net income parameter is negative for the in-migration of the production sector. A possible explanation could be that higher net incomes in a certain zone implies that the firms have to pay higher wages to their employees, which makes moving into that zone rather unattractive. For the service sector the opposite is the case, higher net incomes are a signal for higher purchasing power, which in the case of the service sector is a positive incentive to move there.

The signs of the parameters are exactly the opposite in the workplace out-migration model.

Parameter	Value
<u>In-migration production:</u>	
access attr.	-1.33668
Land price attr. workplace	0.46527
Land available attr.	0.224178
Net income	-0.4979
<u>In-migration service:</u>	
access attr.	-0.594052
Land price attr. workplace	0.138642
Land available attr.	-0.0752342
Net income	2.67814
<u>Out-migration production:</u>	
a out wp[production] (access attr.)	-0.494165
c out wp[production] (Land price attr. workplace)	0.362112
e out wp[production] (Net income)	-1.31719
<u>Out-migration service:</u>	
a out wp[service] (access attr.)	-1.42445
c out wp[service] (Land price attr. workplace)	0.299914
e out wp[service] (Net income)	2.3825

Table 9 Parameter estimates for the workplace migration sub model

5 CONCUSION AND OUTLOOK

In this paper first experiences in setting up a national land-use transport interaction model for Austria are presented. The main objectives are the exercise whether and how a LUTI model can be applied in rural contexts and to asses the generality of an urban LUTI model at a higher spatial level.

On the whole it seems that a nation wide case study setup of a land-use transport interaction model is possible. The system dynamics LUTI model appears to be relatively generic in structure, only few structural model adaptations were necessary and it seems to be possible to model a very heterogeneous case study area.

In all honesty we have to admit that, there are some parts of the model structure that need revision and improvements. Especially the workplace migration sub model seems to be unsuitable for modelling a wide geographical scope like this. One major problem is the lack

of migration-flow data in this field. Furthermore a more detailed sectoral disaggregation, which covers more than the current two sectors is reasonable. Also a differentiation according to business size (number of workplaces) should be considered.

Research will also be devoted to the way quality of life can be considered in the residential migration model of MARS Austria, since the urban variable “recreational green land area” is not influencing migration flows in the nation wide setup any more.

Furthermore we want to repeat the calibration procedure for the residents- and the workplace model part within the MARS structure, not just with the stand-alone models.

Beyond that the bootstrapping methodology will be tested and results will be reported (see section 4.5.1).

Another next step will be extensive model testing of the MARS Austria model with datasets not used in calibration. For this task, lacks in data base have to be filled.

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