

A Land-Use/Transport interaction model for Austria

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ABSTRACT

This paper presents an attempt to set up the land-use transport interaction model MARS (Metropolitan Activity Relocation Simulator) for a nation wide case study of Austria. The purpose of the model is to capture the most important interactions and feedback mechanisms between the land-use- and the transport system. To this end we adapted the urban MARS model. Particular attention was paid to the structural changes of the model 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 modelling software Vensim by minimizing the sum of squared deviations between observed and predicted data. We present the model fit, estimated parameters and results of a first model run (30 years).

1 INTRODUCTION

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. 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). One distinctive feature of this interrelation is that changes within these two systems occur at significantly different speed. Whereas transport users respond relatively fast to changes in the transport system, 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. This makes system dynamics modelling powerful in modelling land-use/transport interactions.

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, etc. 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 LUTI model MARS, we set up a nation-wide case version of the existing urban LUTI model MARS (Pfaffenbichler 2003a) for Austria.

The paper starts with a short description of the different model parts and their structure in section 2. In this section the focus lies in 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 first results from model calibration of the different model parts are presented. We describe the methodology as well as model fit and estimated parameters. While in section 5 first forecasts concerning population and workplace development are shown. The paper closes with conclusions and an outlook in section 6.

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). 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 modules relevant for the issues addressed in this paper. For a more comprehensive presentation, we refer the reader to Pfaffenbichler (2003a, 2008).

2.2 General model structure

The MARS model consists of sub models which simulate passenger transport, housing development, household migration and workplace migration; additionally accounting modules calculate assessment indicators and pollutant emissions. The overall structure of the model is shown in Figure 1. The main link between the transport model and the location choice model are accessibilities (formulated as potential to reach workplaces and shopping opportunities), which are passed on from the transport model to the location choice models and the spatial distribution of households and employment which are input from the location choice models to the transport model. The land price influences both the residential location- and the workplace sub model whereas these two sub models change the availability of land.

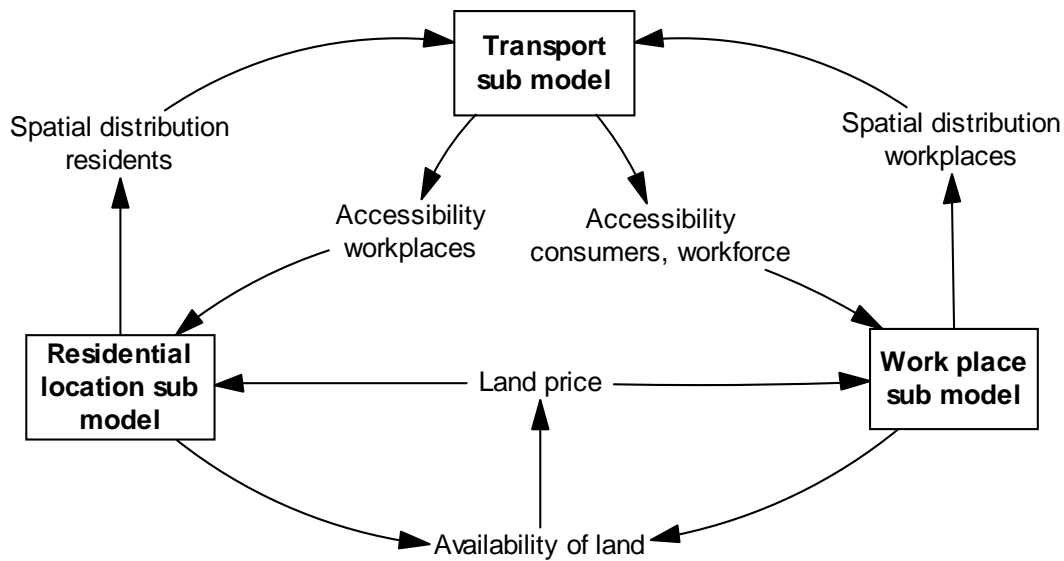


Figure 1 Subsystem diagram with the three main sub models

2.3 Time dynamics

An important feature of MARS is that it considers rapid transportation dynamics and slow migration dynamics.

The transport users can react immediately (from one time step to the next) to changes in the transport system.

Residents who want to change their location need available housing space in the zone of destination (the time to build new housing units is three years). This availability of housing units is checked via three time steps, going sequentially from the first best choice to the third best choice of destination zone. Residents who could not move into their destination zone, due to the lack of available housing space are added to the potential in-movers in the next time step.

A similar procedure is valid for the migration of workplaces, in order to move into another zone MARS controls whether there is enough spatial capacity for workplaces in the destination zone or not.

Because of this inertia embodied in the system, policy measures affect the different sub systems of MARS over different timeframes. For example, a transport policy measure like an increase of parking fees might have an immediate effect on transport users (a shift in modal split to other transport modes), but might also in the long run change the settlement structure of residents and firms (for example people choose to live closer to their workplaces to reduce the need for commuting).

2.4 Model parts

2.4.1 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. 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).

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 spilt up to 5 distance classes, where mode split and number of trips are calculated separately for each zone and distance class.

2.4.2 The land-use sub model and its modules

The residential location 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 0.06 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_j , and in-migration, IM_j , are modelled based on a LOGIT function of the form:

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

Formula 1 Out-migration formula

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

Formula 2 In-migration formula

| | |
|---------------------------|---------------------------------------|
| $\alpha_0 \dots \alpha_3$ | Parameters |
| 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 |

The same set of variables is assumed to influence out-migration and in-migration as described above. 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 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.

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). 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.

An earlier attempt to implement the model for Austria without structural changes revealed the inappropriateness of this structure for a larger spatial scale (Emberger 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.

The assumption of unconstrained destination choice was perfectly justifiable given the urban applications of the model. In most cases, the case studies were small enough to make it possible for migrants to maintain large parts of their “everyday life” (including place of work, social networks, spare time activities, etc.) irrespective of their choice of residence.

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 monetary costs include actual 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 reflect an information aspect of migration, as people are usually deterred from moving to more distant place they know less about.

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.

Workplace location sub model

The workplaces migration sub module has a structure, very similar to the residential migration 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:

$$Attr_j^{out} = e^{(\alpha_1 * ACC_i + \alpha_2 * Land_price_attr_{i,sector} + \alpha_3 * HHI_i)}$$

Formula 4 Attractiveness to move out for workplaces

| | |
|--------------------------------|--|
| $\alpha_1 \dots \alpha_3$ | Parameters |
| ACC_i | Access attractiveness in model zone i |
| $Land_price_attr_{i,sector}$ | Land price attractiveness per zone i and sector (production/service) |
| HHI_i | Household income in model zone i |

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)

Housing development 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.
- 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 comprise 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. 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 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).

We used the optimization functionality implemented in Vensim (Ventana Systems Inc. 2007) 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.

4.2 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.

| Mode | 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 .

4.2.1 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 Vesim built in calibration function.

| Trip purpose | car | pt bus | p rail | slow |
|--------------|------|--------|--------|------|
| Home – Work | 1.96 | 0.28 | 0.24 | 0.21 |
| Home – Other | 1.03 | 0.56 | 1.03 | 0.70 |

Table 2 Mode and trip purpose specific parameters k peak/opeak of the calibration

4.2.2 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 even 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 2.4.1).

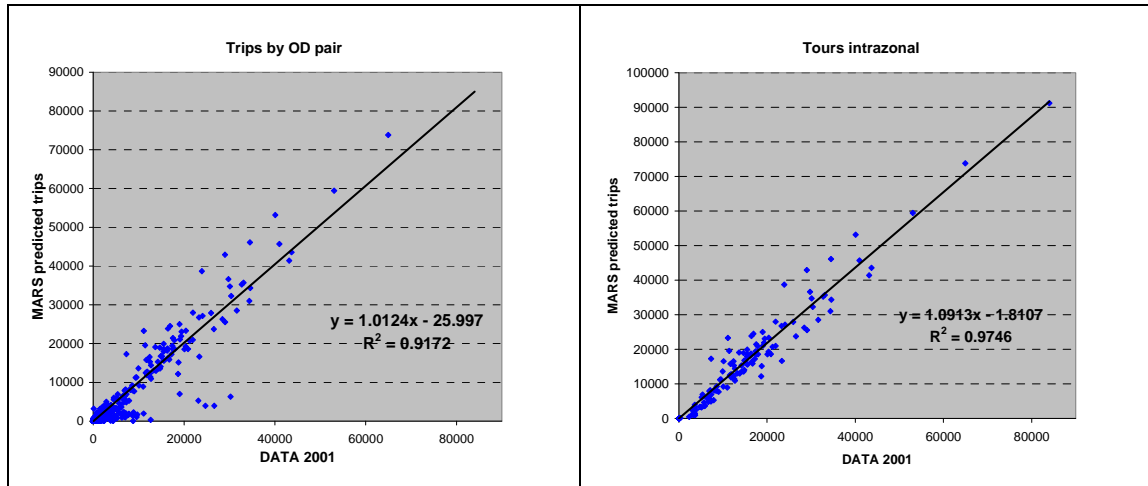


Table 3 Comparison data of commuting trips to MARS results – all commuting trips and intrazonal trips. Source: (Statistik Austria 2002a)

4.3 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 0).

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.

4.3.1 Calibration of the residents migration model parameters

As mentioned above (see section 4.1) we used the built in optimizer of Vensim (Ventana Systems Inc. 2007) to calibrate the parameters of the moving-out and the migration-flows model. In estimating parameter values, the optimizer draws on the same criterion as (ordinary) least square 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 is not linear in 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.

We build two stand-alone models for the calibration (see Figures below), 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).

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

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

om - rate Average out-migration rate throughout Austria

$\alpha_0 \dots \alpha_4$ Parameters

HC_j Housing cost in model zone j

ACC_j Access attractiveness in model zone j

POP_j Population in model zone j

LS_j Living space in model zone j

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

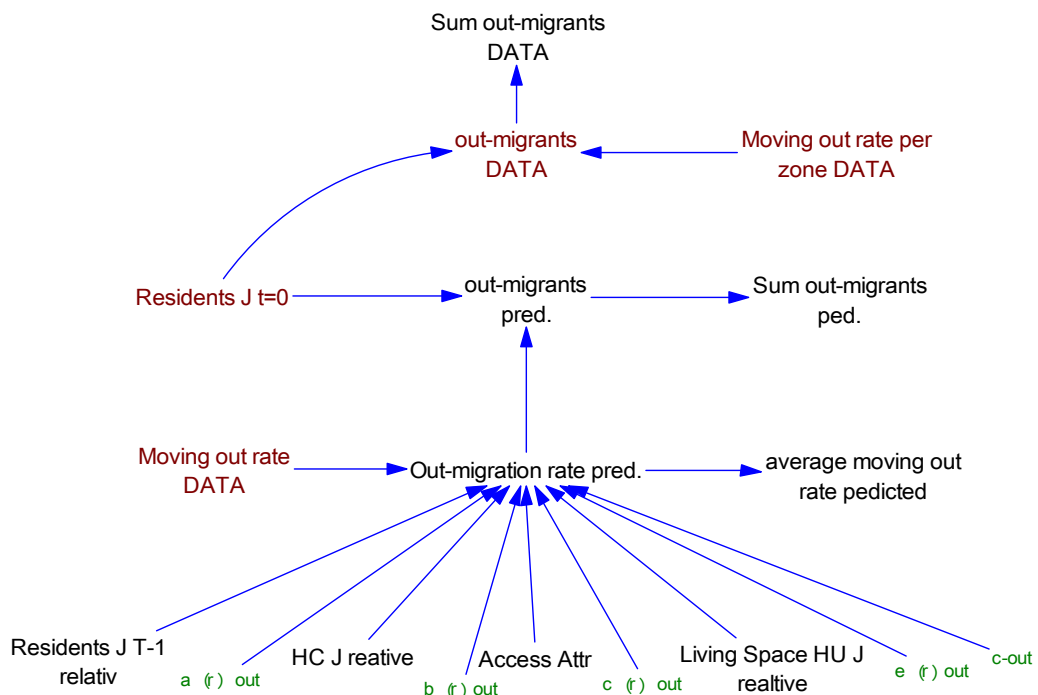


Figure 2 Structure of the out-migration calibration model

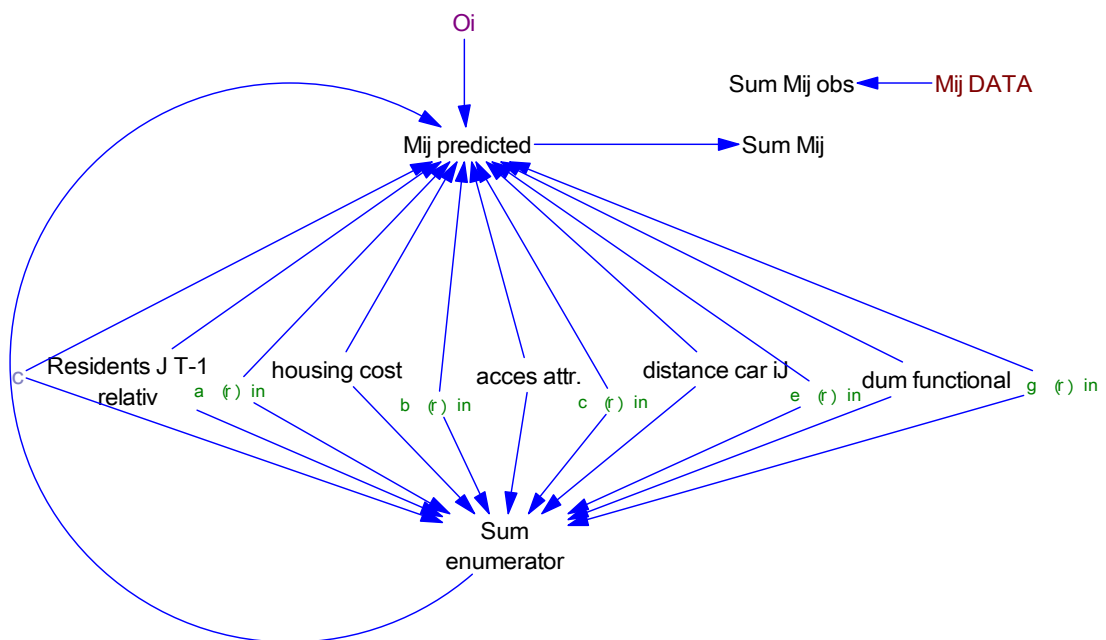


Figure 3 Structure of the migration flow model

| 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 2.4.2 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.

4.3.2 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 R^2 value of 0.93. The migration-flow model yields to an R^2 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.

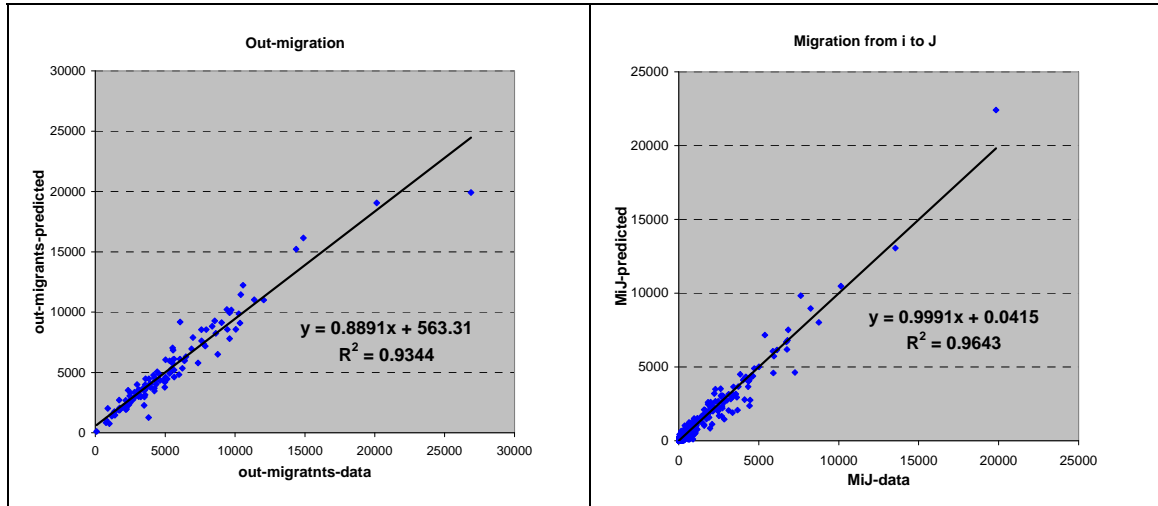


Table 5 Goodness-of-fit of the estimated models: scatter plots of predicted vs. observed out-migrants and migration flows

4.3.3 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 4.3.1).

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. 4.3.1), migration flows are positively affected by this parameter.

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

Table 6 Parameter estimates for the residential location sub model

4.4 Workplace migration

As mentioned in section 2.4.2, the workplace migration sub model has a structure very similar to the residential migration model. Therefore we do not explicitly describe the calibration of the workplace sub model in this paper. Similar to the residential migration calibration of parameters a stand-alone model was built and again the built in optimizer of Vensim (Ventana Systems Inc. 2007) was used. We refer the reader to contact the author's for further information.

5 RESULTS FIRS MODEL FORECAST

With the calibrated model a first long term model run (30 years) was completed. In the following the results of the residents' migration and the workplaces migration model are presented.

For the transport model part, there are no substantial changes in the mode split and trip distribution. The growth in the mode share of cars, which could be observed in the last years, is continuing. The implemented fuel price rise is just approximately 1% per year.

For the population model a growth in population of 0.3% per year is assumed. Assumptions for the workplace model are a slight decrease for the production sector workplaces and a growth for the service sector workplaces.

5.1 Predicted population development

Figure 4 below shows the population development by district from the year 1991 to 2001 from data. The above (section 4.3) mentioned suburbanization processes can be seen as well as significant population losses in the province of Styria, due to structural economic changes. These districts were dominated by heavy industry.

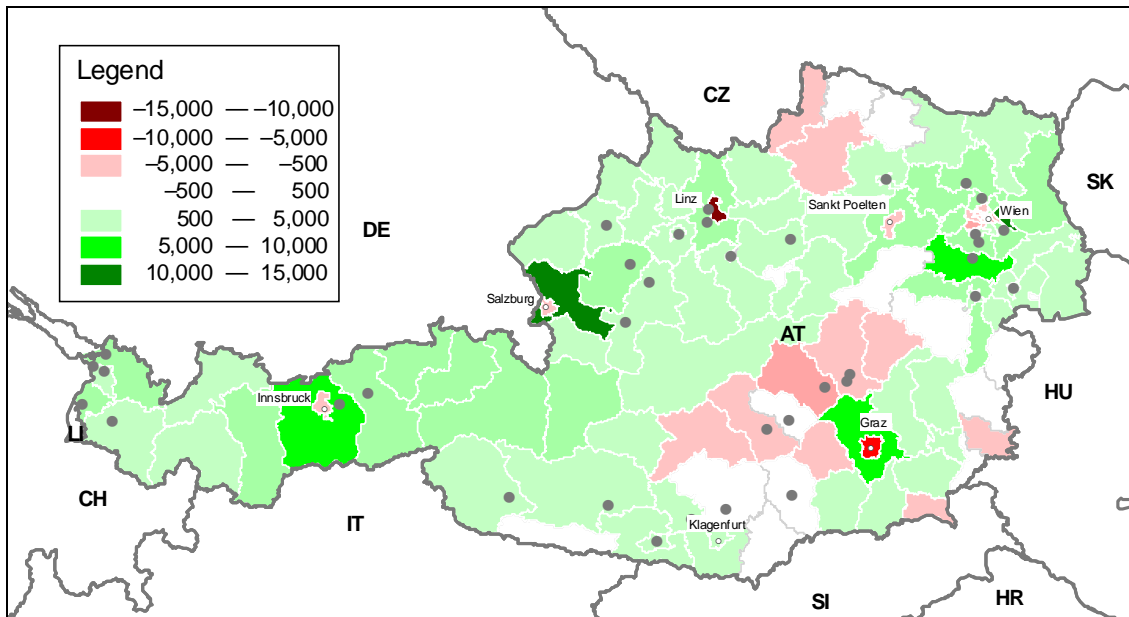


Figure 4 Change in population by district 1991–2001 (data). Source: (Statistik Austria 2002a)

Figure 5 shows the model output after a forecasting time of 15 years. In continuation with the observed development the model predicts an ongoing suburbanization process for some major cities, like Vienna, Graz, Linz and Salzburg; their hinterland districts gain in population. Apart from that there is a significant loss of population in a district at the western part of Austria. The styrian districts which had substantial population losses between 1991 and 2001 can gain population in the model prediction.

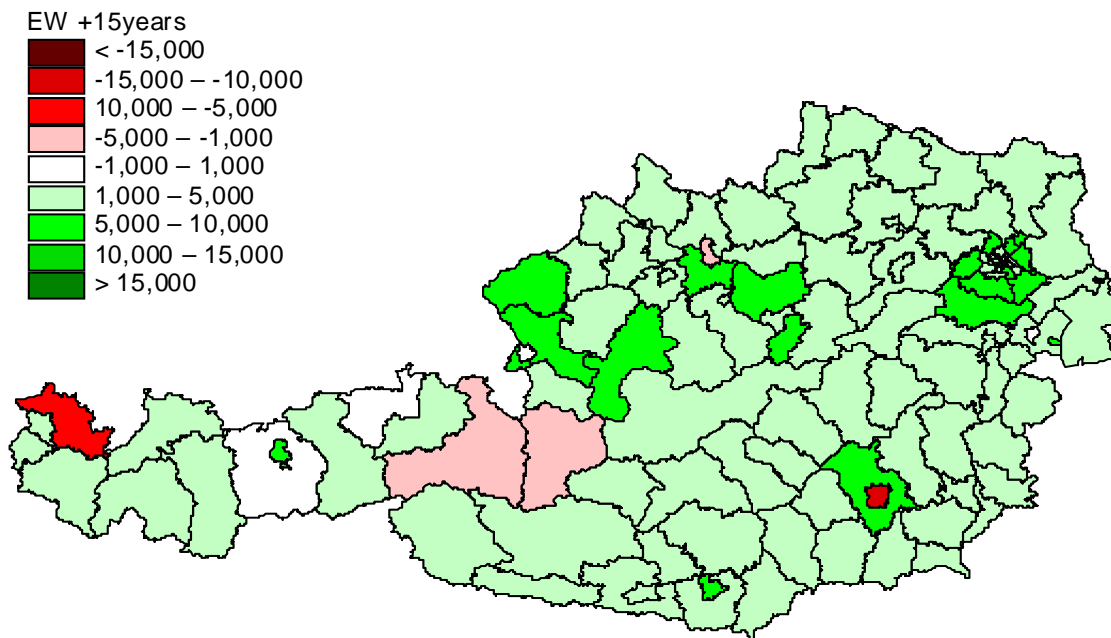


Figure 5 Predicted population changes after a forecasting time of 15 years (year 2016) to base year 2001. Source: authors' calculations

Figure 6 presents the predicted population development after a forecasting time of 30 years. All major agglomerations are now winner in absolute population values compared to the years 2001. Bregenz, the districts on the western part of Austria, which was losing population in the first 15 years, is a winner of population compared to the year 2001 and reaches a value (6000 people) higher than the population value of the year 2001. Also Graz which lost about 10.000 people in the first 15 years of simulation now reaches a population of about 250.000 people which is approximately 15.000 people more than in the year 2001.

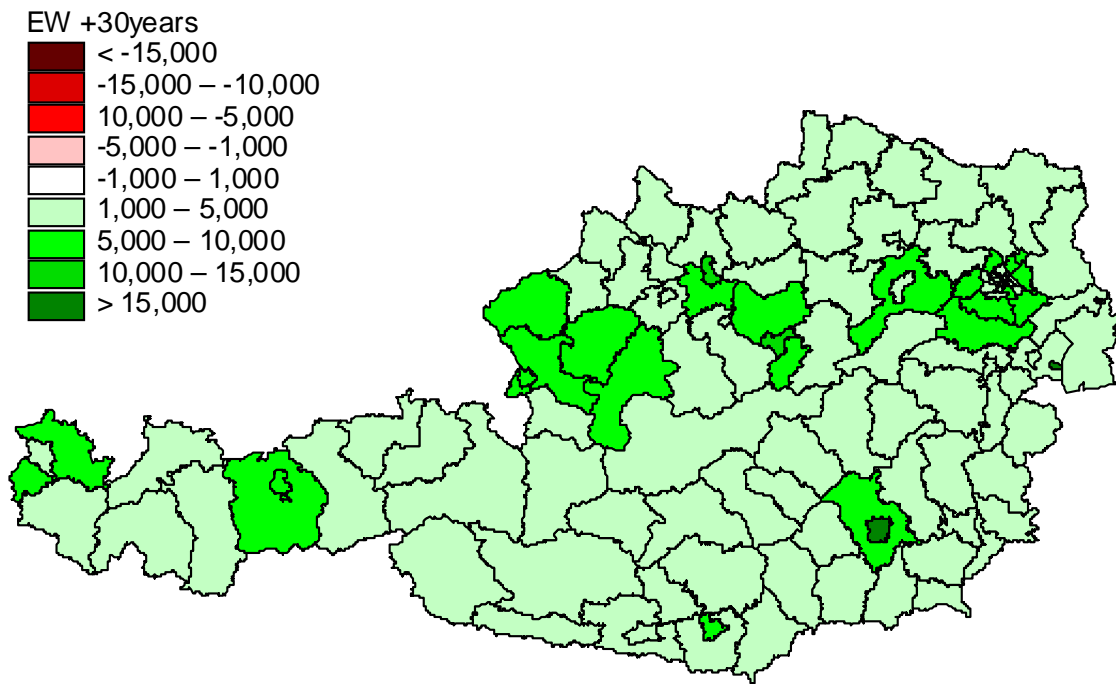


Figure 6 Predicted population changes after a forecasting time of 30 years (year 2031) to base year 2001. Source: authors' calculations

5.2 Predicted development of workplaces

In the following the predicted workplace development of the two sectors (production and service) are presented. The first two graphs depict the development in the provincial capitals, except for Vienna. The second two graphs depict 4 Viennese districts, two small and dense districts and two big and less concentrated ones.

Figure 7 shows the development of the workplaces in the production sector after a forecast of 30 years. All capital cities loose workplaces in the observed sector, except for Eisenstadt which is a capital with just little population (about 10.000 people), where the number of workplaces in the production sector slightly increases. This development follows an overall observed Austrian trend of the last years. Growth rates over the whole case study area in the production sector are assumed to be slightly negative.

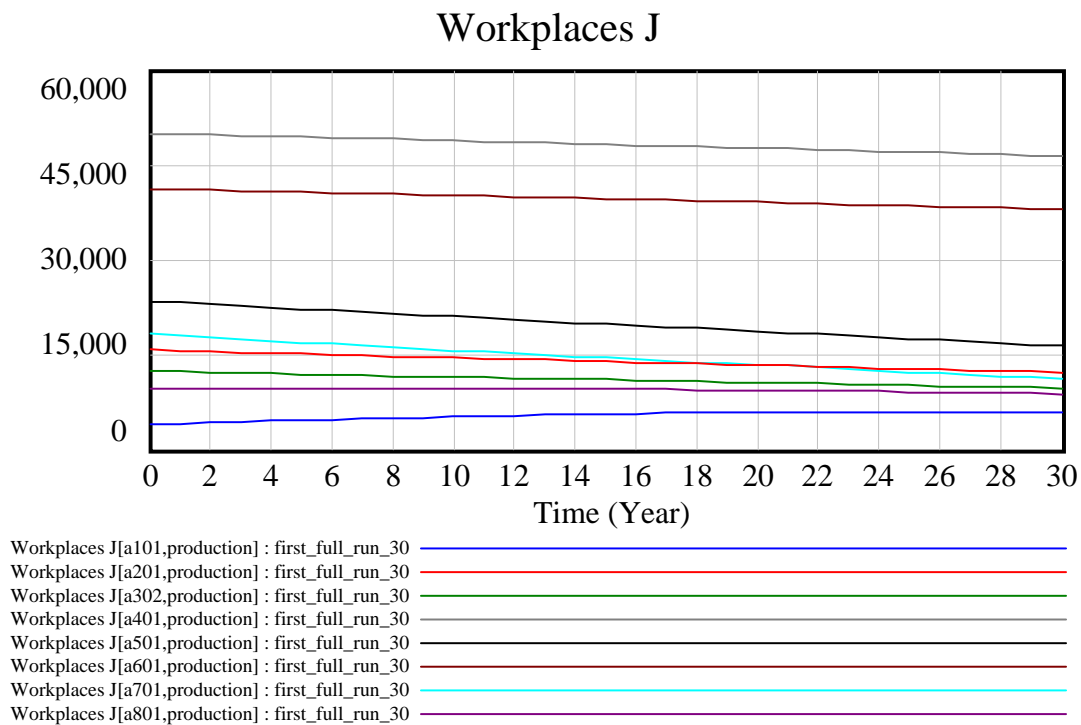


Figure 7 Workplace development of the production sector of the provincial capitals

The development of the workplaces in the service sector looks totally different (Figure 8). All observed capital cities experience gains in the number of workplaces. Also in this case Eisenstadt makes an exception, it wins relatively more workplaces than the other capitals. Also this development is in line with observed Austrian trends, the service sector gained workplaces in the last years.

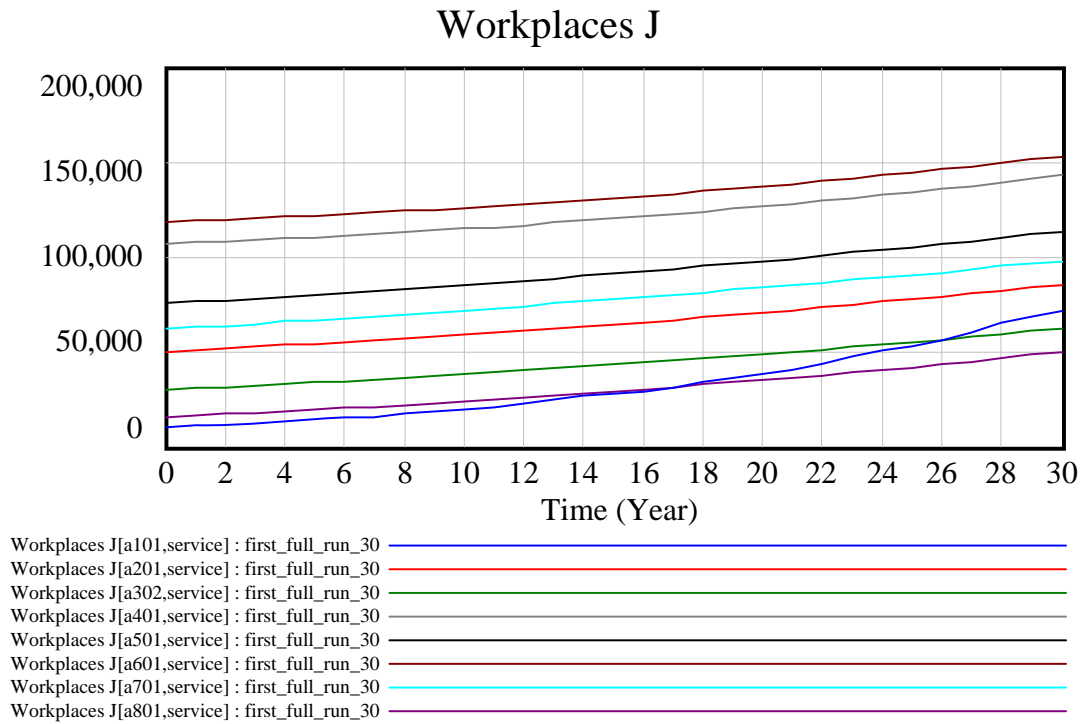


Figure 8 Workplace development of the service sector of the provincial capitals

The prediction of the development of the service sector workplaces for four Viennese districts is shown in Figure 9. All depicted districts experience a growth in workplaces except for the first district.

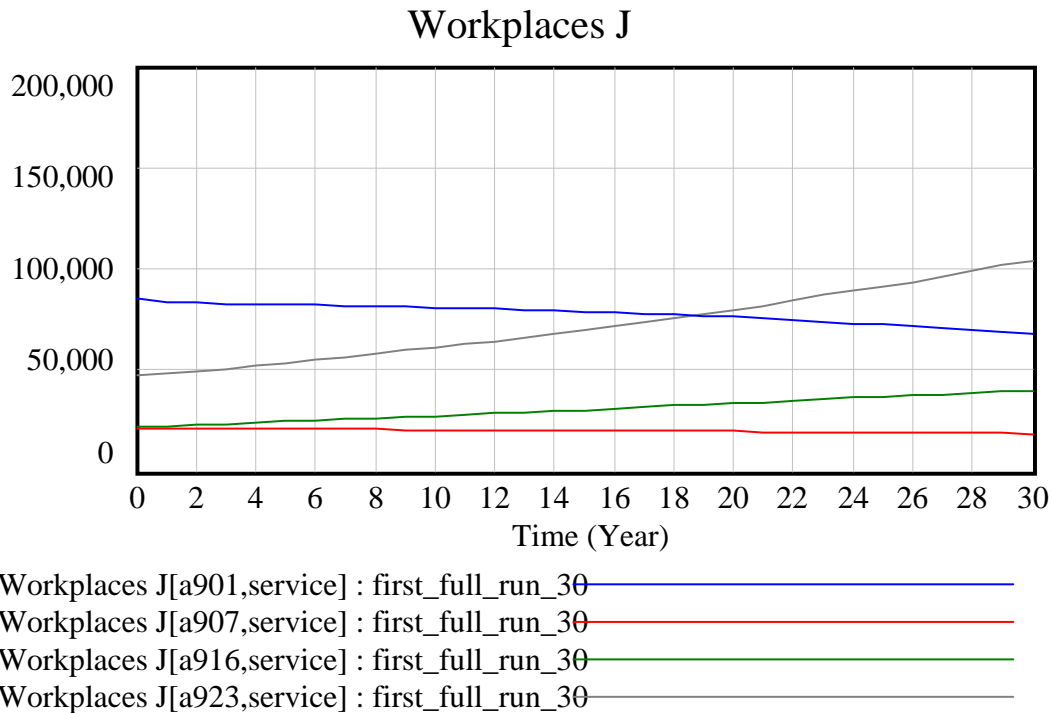


Figure 9 Workplace development of the service sector of four Viennese municipal districts

6 CONCLUSIONS AND OUTLOOK

This paper presents the experiences made in the setup of a national land-use transport interaction model for Austria. The objective of the exercise is to test how LUTI modelling can be applied in rural contexts and to assess the generality of an urban LUTI model at a higher spatial level.

Overall we showed that a nation wide setup of a land-use transport interaction model is possible. The LUTI model appears to be relatively generic in structure, just few model structure adaptations were necessary and it seems to be possible to model a very heterogeneous case study area. Without external system intervention (for example a transport policy) the model produces reasonable behaviour, where trends to date seem to continue into the future.

A next step will be to gain more insights from simulation. Policy scenarios will be designed to model whether and how the system takes other development paths.

There are of course some parts of the model structure that need revision and improvements. Especially the workplace migration model seems to be the most unsuitable for modelling a wide geographical scope like this. One major problem is the lack of migration-flow data in this field. Furthermore we want to include a more detailed sectoral disaggregation than the current two sectors or a differentiation according to business size (number of workplaces).

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

The calibration procedure will be repeated for the residents- and the workplace model part within the MARS structure, not just with the stand-alone models (see section 4.3.1). Furthermore the bootstrapping methodology will be tested and results will be reported

Another next step will be extensive model testing of the MARS Austria model. For this task, lacks in data base have to be filled.

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