Metropolitan Activity Relocation Simulator (MARS)

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Background

In the mid 1990ties sustainability became a major research concern within the EU and therefore within the EU-funded research, especially in the field of transport. Since transport is a complex field, heavily interwoven with day to day life of transport users, societies and economy, new tools to support decision making were looked for. Traditional modelling approaches used already in transport planning, so called 4 stage transport model or even simpler models, such a traffic assignment models were not capable anymore to answer upcoming research question regarding future development of sustainable transport and sustainable societies. Therefore new approaches to develop decision support tools were initiated. At this time a research project, called OPTIMA (OPTIMA 1996-1997) was launched. In OPTIMA the research question was to identify which transport policy instrument combination in space and time will deliver the most sustainable settlement structure. To be able to do so the modelling approaches in the field of transport research were combined with modelling approaches used in land use science. It was recognised that also the time dimension, in other words, the development path over time is important – so the modelling approach also included a simulation period of 30 years to show how the final state in the year 30 of the underlying settlement structure was reached. The so called MARS (Metropolitan Activity Relocation Simulator) was born. Since then MARS was further developed and applied in a series of EU and national funded research projects (FATIMA 1997-1998; PROSPECTS 2000-2003; TRANSPLUS 2003; SPARKLE 2004-2006; STEPS 2004-2006; DISTILLATE 2006-2008; GHG Transpord 2009-2011) and applied in numerous case study cities/regions.

Conceptual framework and theoretical underpinnings

Within MARS accessibility is used in two separate ways: 1) to estimate the attractiveness on one side for people moving from one place to another (= short term mobility - trips for commuting and other purposes) and 2) accessibility is used to estimate the future land use (=long term mobility – mobility of housing and workplace movements within the zones).

In more technical terms accessibility as used in MARS is a weighted potential taking into account the transport supply between the origin and destination zones (general travel costs separated for different means of transport, such as walking, cycling, public transport and car traffic), the potential at origin (for e.g. the number of population) and the potential of the destination zone (e.g. the number of workplaces in a certain economy sectors such as service or production).

The main innovation in MARS is that the different reaction speeds of the two systems (passenger transport system and land use system) are taken into consideration. These different speeds generate a dynamic process which is looking for a dynamic equilibrium, which is disturbed by external transport or land use policy measures, such as road capacity increases, public transport supply changes or land use instruments, such as e.g. a land value capture tax.

MARS calculates the accessibility for each zone for each means of transport for each simulation period and uses this information to redistribute the daily trips of population as well as the relocation of workplaces and housing within the case study area for a simulation period of 30 years.

Further information regarding MARS can be found in (Emberger and Ibesich 2006; Pfaffenbichler, Emberger et al. 2006; Emberger and Riedl 2007; Haller, Emberger et al. 2007; Pfaffenbichler 2008; Pfaffenbichler, Emberger et al. 2008; Mayerthaler, Haller et al. 2009; Pfaffenbichler, Emberger et al. 2010).

Operational aspects

MARS is implemented in a System Dynamics Software environment called VENSIM®. The MARS model consists of a transport and land use element and can be divided into a series of sub models as shown in Figure 1.The input data are stored in Excel® to enable an easy handling of the data. The data requirements of MARS are similar to data needs for traditional transport models supplemented with information to describe the land use of a zone.

MARS was/is already implemented for about 20 metropolitan areas around the world (Vienna- A, Madrid- E, Leeds – UK, Strasbourg- B, Ho Chi Minh City – VN, Chiang Mai- TH, Washington DC – USA, Porto Alegre – BR, etc). The setup process takes about 3-5 weeks depending on data availability and number of zones.

Besides other indicators and variables MARS calculates the number of trips on an origin destination basis, the travel times for each means of transport separated for access, in-vehicle time and egress time, the monetary cost for each trip, the fuel consumption, the noise and CO_2 emissions, the accident rate, etc. These values can be displayed for every simulation period, for each individual zone, for each zone pair (origin destination), for each means of transport, for peak and off peak period and can also be cumulated to a system wide sum.

A free demo version of MARS can be downloaded and tested from our homepage http://www.ivv.tuwien.ac.at/forschung/mars-metropolitan-activity-relocation-simulator.html.

Relevance for planning practice

With the MARS policy input module policy profiles over time of certain policy instruments can be handled. The user can specify the start and end-point and the start and end level of any policy instrument implemented in MARS. For example, it is possible to test the impacts of increasing “Public transport fare levels” starting in simulation year 3, with a start value of +20%. Increasing the public transport fare linearly to 50% in simulation year 12 and keep it constant at +50% until the end year of the simulation. So it is possible to specify these kinds of policy profiles for many policy instruments simultaneously. This enables us to test and assess the impacts (synergy effects) of policy combinations over time. Depending on the underlying case studies more than 15 different policy instruments can be combined in one single simulation run.

MARS is a very flexible tool and can be used for different application types, such as:

- Scenario testing
- Policy optimisation
- Decision makers training

When applied in the scenario testing mode MARS can be used to forecast the effects of certain policy instrument combinations on a set of output indicators such as energy consumption, mode share, CO_2 emissions, etc.

If MARS is used in the optimisation modus a quantitative objective function and a set of changeable policy instruments has to be defined. An objective function could for example comprise the total travel time within the system, the corresponding CO2 emissions and the monetary benefits/costs to implement a certain policy instrument combination. MARS then will search for the optimal policy instrument combination which delivers the highest possible objective function value.

Finally, MARS can also be set up in the so called “flight simulator mode” where it can be used in workshops to enable attendees (stakeholders) to understand the long term impact of their decisions regarding policy implementations. To provide the reader an impression how MARS looks like please see Figure 2.

Strengths and limitations

As mentioned before, MARS is implemented using System Dynamics. Within System Dynamics feedback loops which are widely present in the transport and land use system can be made explicit easily. The modelling language syntax of MARS respective the VENSIM programming environment is based on simple symbols and is therefore intuitively understandable also for programming laymen. MARS can be characterised to be a white box model, it can be seen which model entities are taken into consideration and how they are related, and also important, which entities and relations are excluded from the model.

A simplified example how model parts are represented within MARS/VENSIM can be seen in Figure 3. This way of presentation enables us/others to discuss implemented relations and change/improve MARS with relatively low effort.

MARS simulates the most likely development path of underlying land use transport systems of metropolitan areas and regions. Because of its low spatial resolution (e.g. ward or district level) no local analyses are possible.

As it is true for all kind of models the quality of MARS simulations depends on the quality of the underlying input data set. Since for transport and land use modelling a broad variety of input data, such as population, land use data, model split data, travel time and travel cost data and their prediction of their growth rates for the next 30 years are necessary, these forecasts are essential for the forecast results of the MARS case studies. Given the long term nature of such kind of analysis forecast uncertainty is an important issue, of which the developers are aware. At the moment sensitivity analyses are used to investigate the stability of found “optimal” solutions.

Beside these technical data issues also the lack of trained users of the MARS modelling suite is a potential limitation of the application of MARS. To overcome this limitation training courses for end users and maintenance contracts or MARS users are offered by the developers.

Beside other applications, MARS was used to identify the optimal policy combination of public transport frequencies, public transport fares and road capacity provision to minimise the public transport operators cost, minimise travel times and minimise CO2 emissions simultaneously. More information regarding policy applications of MARS can be found at the MARS publication link list under http://www.ivv.tuwien.ac.at/forschung/mars-metropolitan-activity-relocation-simulator/literature.html.

Detailed information regarding MARS and a free download of the software can be found under http://www.ivv.tuwien.ac.at/forschung/mars-metropolitan-activity-relocation-simulator.html.

A google map where all existing case studies regarding MARS are listed can be found under https://maps.google.at/maps/ms?msid=213722018576219655165.000466074e9fc941d4ef0&msa=0&ll=-29.13297,-46.625977&spn=15.62781,29.772949

Figures

Figure 1 Basic structure of the MARS including sub-models

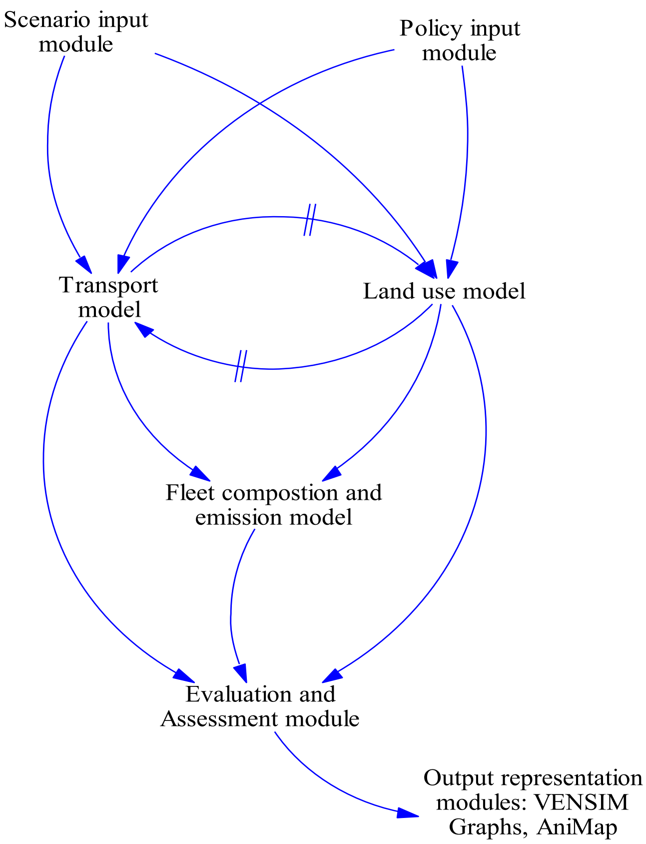
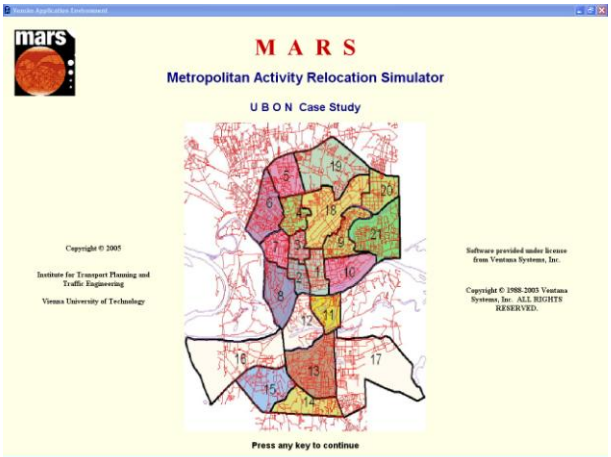
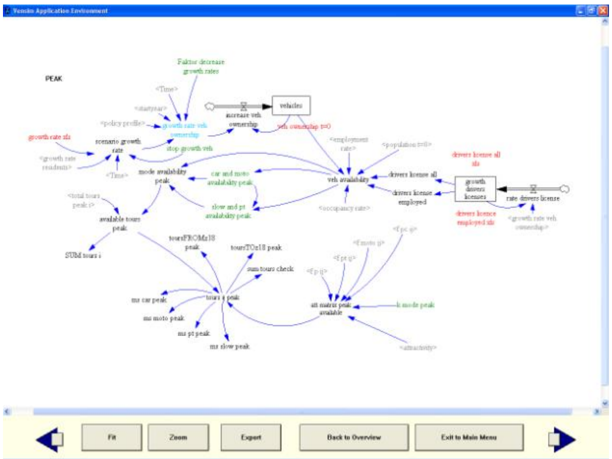


Figure 2 MARS simulator – screen shots

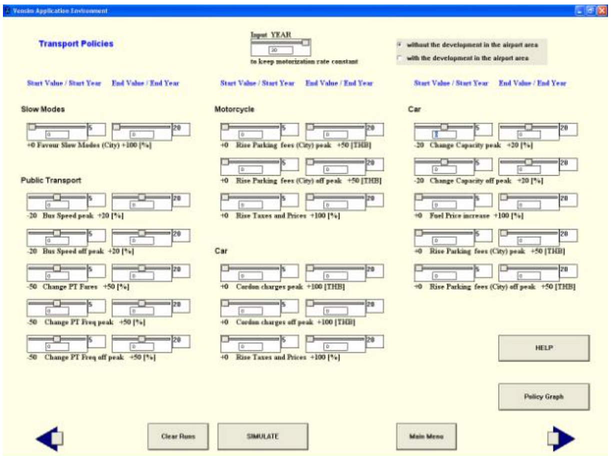
a) Introduction screen



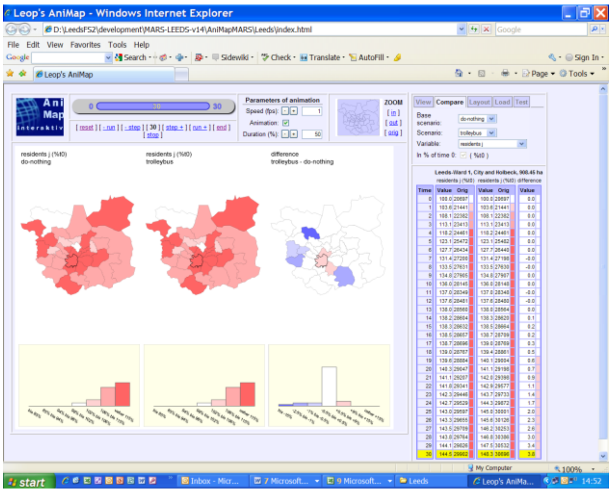
b) Model exploring screen



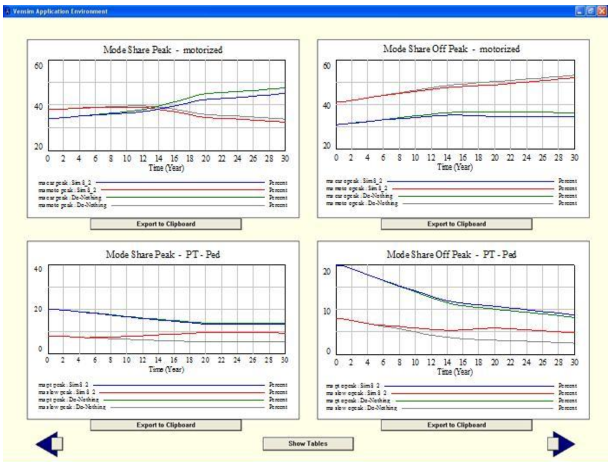
c) Scenario input screen



d) Scenario output screen – spatial – over time

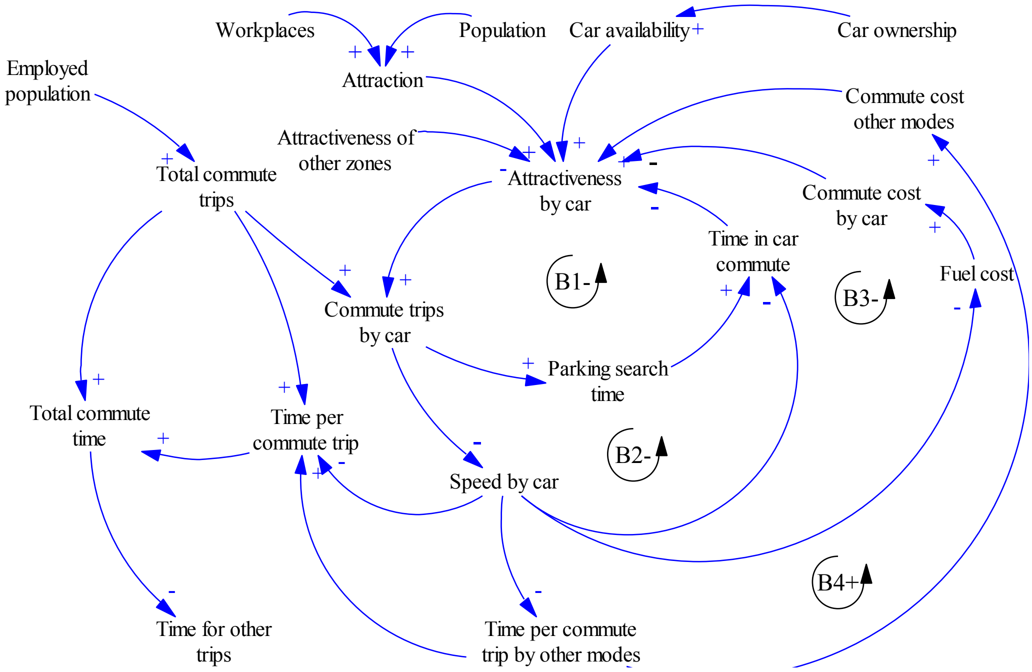


d) Scenario output screen – over time



f) Exercises in Ho Chi Minh City, 06

Figure 3 MARS representation of the transport model – commuting trips by car



Links

MARS homepage http://www.ivv.tuwien.ac.at/forschung/mars-metropolitan-activity-relocation-simulator.html

VENSIM homepage http://www.vensim.com/

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