APPLICATION OF THE EUROPEAN LANDUSE-TRANSPORT-INTERACTION MODEL MARS TO ASIAN CITIES – CUPUM 05 LONDON

Guenter Emberger
Senior Researcher
Institute for Transport Planning and Traffic Engineering
Vienna University of Technology
Gusshausstrasse 30/2
1040 Vienna
Austria
Tel: +43 1 58801 231 12
Fax: +43 1 58801 231 99
E-mail: Guenter.Emberger@tuwien.ac.at

Paul C. Pfaffenbichler
Prof. Visitante
Centro de Investigación del Transporte
Universidad Politécnica de Madrid, Ciudad Universitaria
E-28040 Madrid
España
Tel: +34 91336 6657
Fax: +34
E-mail: ppfaffen@caminos.upm.es

Sittha Jaensirisak
Assistant Professor
Department of Civil Engineering,
Faculty of Engineering,
Ubon Ratchathani University,
Ubon Ratchathani, 34190
Tel: +66 45 288400
Fax: +66 45 288378
E-mail: sittha@eng.ubu.ac.th

Abstract: Sustainability is the challenge cities face today. Land use and transport are two major key elements to reach this target. To enable decision makers to identify strategies which can lead to sustainability, modern tools have to be used. One tool, the Land Use Transport Interaction model MARS is introduced in this paper. MARS will be applied on two South East Asian cities and experiences gained from that process are reported. Challenges faced beside others are: the translation of MARS into the System Dynamics language, the extension of MARS by additional means of transport (motorcycles, bicycles); and the evaluation of the transferability of MARS inherent cause-effect relations regarding land use and transport development to Asian cities.

Keywords: Land use, transport, dynamic modelling, Case study Asian cities

1 BACKGROUND

Sustainability is the challenge our societies face today. Transport and land use are two key elements for achieving sustainability in an urban context. In the past land use and transport were treated separately – their interdependency was not realised in full. Presently at least in the research world it is recognised that sustainable development can only be achieved when transport and land use are treated simultaneously. This knowledge has now to be transferred to our decision makers and into our organisation structures of our communities.

In general models are developed to support decision makers by their work. Especially in the field of transport planning and infrastructure provision the so called four-stage models were applied. These models consist of a sequential algorithm, which includes the estimation of transport demand, transport distribution, modal split and assignment [Ortúzar and Willumsen 2001]. These models were mainly applied to identify bottlenecks in existing road networks and based on that new, additional infrastructure was justified. But these models do not include all means of transport nor long term effects on land use caused by this additional supply and so wrong decisions were made.

Newer developments in the domain of transport planning realised this shortcoming of four-stage models and took a more holistic approach. They combined land use models with transport models to display the interaction of urban transport systems and land use development over time in a combined model. An overview of existing Land Use Transport Interaction (LUTI) models is provided in [Wegener, 2003]. An advantage of this approach is, that the exogenous input data which are needed e.g. the transport model can be calculated in the land use part and vice versa.

As known changes/adaptations in land use take longer time compared to transport system adaptations. E.g. the planning and construction of a new road takes about 3 to 10 years (in Europe). After opening a road, road-users adapt their behaviour in less than one year. On the land use side new settlements and relocation of companies take place, too, but these processes are very slow and take at least decades. To model these interactions a temporal connection between the land use model and the transport model is needed. By now the application of this kind of models is not widely spread in Europe. On the other hand Asian cities face, caused by their booming economy, very similar challenges our cities faced 20 to 30 years ago. As we have seen infrastructure improvement alone cannot solve transport problems, an adequate land use planning is a likely instrument to achieve sustainability and adequate economic prosperity.

In this paper we introduce the integrated Land Use Transport Interaction (LUTI) model MARS and report obstacles occurred in the transfer process of MARS from an European context into an Asian context. The research exercise is funded by the European Commission under the Asia Pro Eco Programme. This exercise is called Sustainability Planning for Asian Cities making use of Research, Know-How and Lessons from Europe (SPARKLE).

1.1 Introduction to SPARKLE

SPARKLE started in Nov 2004 and ends in August 2006. The project objective is to promote and transfer knowledge to the countries of South East (SE) Asia on the process of developing sustainable urban land use and transport policies, and to provide technical training to local planners and decision-makers on how to use scientific and logical approaches to formulate a sustainable land use and transport policy. SPARKLE provides decision makers and planners in SE-Asia with an understanding of the importance of sustainable urban land use and transport system using knowledge from our European funded research projects PROSPECTS and PLUME and takes account of the different circumstances in SE-Asia. The vehicle to transfer knowledge are seminars and training courses in SE-Asia (including Thailand, Vietnam, Lao PDR, and Cambodia) supported by guidance manuals and modelling case studies for the city of Ubon Ratchathani (Thailand) and Hanoi (Vietnam) to demonstrate the role of appropriate models as an important tool to support policy-making.

1.2 Introduction to MARS

MARS is an integrated strategic and dynamic land-use and transport (LUTI) model. The basic underlying hypothesis of MARS is that settlements and the activities within them are self organising systems. Therefore it is sensible to use the principles of synergetics to describe collective behaviour [Haken 1983a; Haken 1983b].

MARS assumes that land-use is not a constant but is rather part of a dynamic system that is influenced by transport infrastructure. Therefore at the highest level of aggregation MARS can be divided into two main sub-models: the land-use model and the transport model. The interaction process is implemented through time-lagged feedback loops between the transport and land-use sub-models over a period of 30 years.

In the European version of MARS two person groups, one with and one without access to a private car are considered in the transport model part. The transport model is broken down by commuting and non-commuting trips, including travel by car, public transport and non-motorised modes. Car speed in the MARS transport sub-model is volume and capacity dependent and hence not constant. The energy consumption and emission sub-models of MARS utilise speed dependent specific values. The land-use model considers residential and workplace location preferences based on accessibility, available land, average rents and amount of green space available. Decisions in the land-use sub-model are based on random utility theory. Due to its strategic characteristic a rather high level of spatial aggregation is used in MARS. In most case studies this means that the municipal districts are chosen as travel analysis zones. The outputs of the transport model are accessibility measures by mode for each zone while the land-use model yields workplace and residential location preferences per zone.

MARS is able to estimate the effects of several demand and supply-sided instruments whose results can be measured against targets of sustainability. These instruments range from demand-sided measures, such as public transport fare (increases or decreases), parking or road pricing charges to supply-sided measures such as increased transit service or capacity changes for road or non-motorised transport. These measures, furthermore, could be applied to various spatial levels and/or to time-of-day periods (peak or off-peak).

To date the model MARS was applied to the following six European case study cities Edinburgh, Helsinki, Leeds, Madrid, Oslo, Stockholm and Vienna. As said MARS is adopted and applied to the Asian cities Ubon Ratchathani, Thailand and Hanoi, Vietnam. The model was validated through an extensive back casting exercise for Vienna. A full description of MARS is given in [Pfaffenbichler 2003].

2 Differences between Asia and Europe

There exists a series of differences between European and Asian cities and their corresponding transport systems. In Europe most of the cities have a long history and historical development was close related to the development of means of transport. Medieval cities were based on pedestrians and horse carriages, and later in the late 19th century influenced by tramways and track based public transport systems. Only in the recent past (since the 1950-ties) cities started to suffer of urban sprawl caused by private car traffic [Knoflacher 1993; Emberger and Pfaffenbichler 2001].

Asian cities have also a long tradition and had similar developments in their history. The main difference took place in the 2nd half of the 20th century where car ownership grew slower in SE-Asia compared to Europe due to wars and slower economic development. However presently the time lags between European cities and Asian cities are vanishing rapidly.

As it can be seen in Europe and America transport planners in the first world did not find a solution to solve transport problems caused by growing motorized traffic. A provision of (car-) infrastructure did not and will not solve any problem, it just reinforces the problems respectively moves environmental thresholds further back.

2.1 Socio economic data (growth rates)

In Table 2-1 socio-economic data for SPARKLE partner countries are listed. The main differences regarding population are significant higher growth rates in Asian countries and a lower median age. GDP in SE-Asian countries are just a tenth or below compared to Austria or UK. Only Thailand has GDP which is just a fourth compared to Europe. However GDP growth rates are significantly higher in Asia, but it will still take 22 years for Thailand and 63 years for Cambodia to reach the same GDP per head as Austria assuming no change in the present growth rates. One major challenge is to quantify the implications of these different starting points and development speeds with the MARS model.

Table 2-1: Overview social demographic data

Source: http://www.maps4free.com/ accessed: 30.11.2004

Continent	Country	Population (mio.)	Annual growth rates population	Median-Age (years)	GDP per inhabitant (US-$)	GDP growth rate	population below poverty level in %
Asia	Cambodia	13.4	1.8%	19.5	1,700	5.5%	36%
	Lao	6.1	2.44%	18.6	1,700	5.7%	40%
	Thailand	64.9	0.91%	30.5	7,400	6.3%	10.4%
	Vietnam	82.7	1.3%	24.9	2,500	7.3%	37%
Europe	Austria	8.2	0.14%	40.0	30,000	0.8%	3.9%
	UK	60.3	0.29%	38.7	27,700	2.1%	17%

2.2 Case Study Cities - overview

Within SPARKLE it was decided to set up two MARS models for the cities Ubon Ratchathani (Thailand) and Hanoi (Vietnam). Ubon Ratchathani is a regional province in the North-East of Thailand. Hanoi is the capital city of Vietnam. Figure 2-1 shows the location of the case study cities:

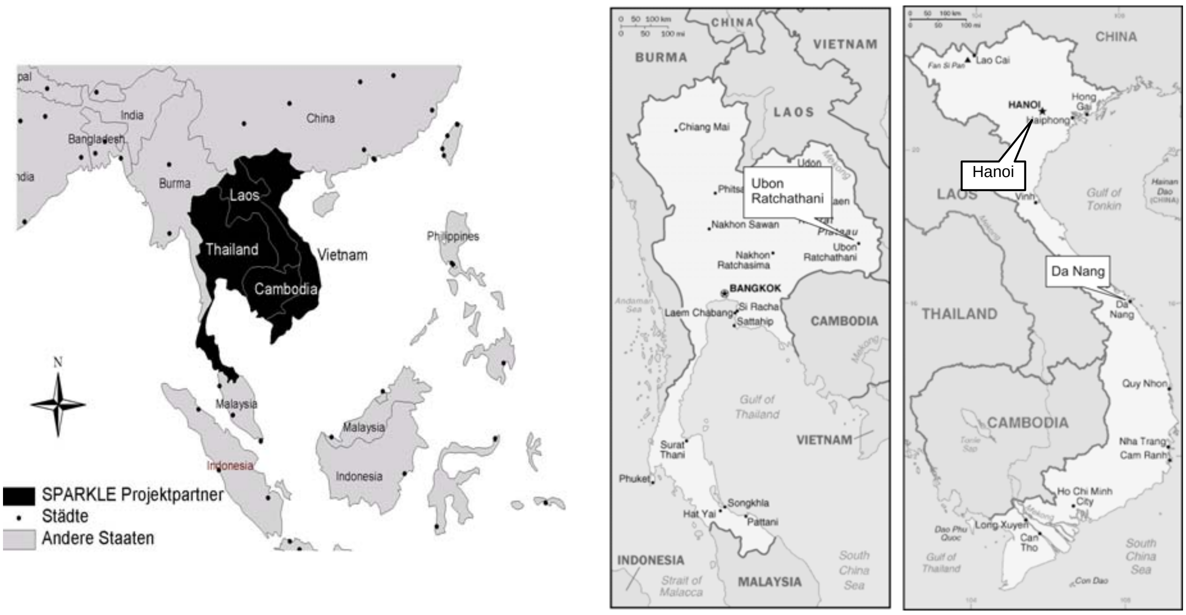

Figure 2-1: Overview SE-Asian case study cities

Table 2-2 shows key data of existing European and selected SE-Asian case study cities. A comparison of the modal split figures reveals that motor cycles play a dominant role in Asia whereas this mean of transport is practically not existent in European cities. On the other hand private car is presently dominating the transport systems in Europe and looking at the forecasts in

Asia private cars will also become soon more widely spread. Public transport systems are completely different organized in Asia and Europe, in Europe public transport is mostly a high quality track based system whereas in Asia public transport consists of low quality bus/truck services and special forms of para-transit like Songtaew, Tuk-tuk (see Figure 3-1), Samlor[1] and motorcycle taxis[2] [Barter, 1999].

Table 2-2: Overview social demographic data case study cities

Citiy (Country)	Population	Area [km²]	Modal Split				cars per 1000 inhabitants	Motorcycles per 1000 inhabitants
			Non motorised	Motor-cyclesr	Public transport	private car		
Asia								
Hanoi (Vietnam)	2,756,000	921	19%	59%	14%	8%	58	n/a
Ubon Ratchathani (Thailand)	139,138	42	0.3%	39.5%	24.4%	35.8%	98	162
Europe								
Edinburgh (UK)	1,071,768	53*	22.1%	-	24.5%	53.4%	371	-
Helsinki (FI)	920,732	742	29.5%	-	26.3%	44.2%	346	-
Leeds (UK)	727,700	559	23.4%	-	23.9%	52.7%	307	-
Madrid (ESP)	5,022,289	8,011	37.2%	-	33.8%	29.1%	448	-
Oslo (N)	396,974#	454	17.0%	-	22.7%	60.3%	400	-
Stockholm (S)	1,682,595	5,866	37.0%	-	19.3%	43.7%	279	-
Vienna (A)	1,550,123	415	27.6%	-	27.2%	45.3%	354	-

- negligible, * built-up area – not comparable, # inhabitants older than 12 years

Sources: Asian cities Transport Development and Strategy Institute (TDSI), Vietnam and Ubon Ratchathani University (UBU), Thailand; European cities: [Emberger et al. 2003; Pfaffenbichler and Emberger 2004]

3 Challenges applying MARS on Asian cities

3.1 Data availability

In every modelling exercise the data availability is crucial. In Europe, since modelling has a "long" tradition (~40 years), several sources for transport relevant data exists. The quality, the quantity, the spatial disaggregation and the available time series vary from country to country and city to city significantly. However some data useful for modelling are available[3]. The most data time series in Europe start after 1950 (after World War II).

In Asia, secondary data availability for transport modelling is limited. Some transport related data are available but scattered in many different

1 http://sawadee.com/thailand/transportation/ visited on 2.12.2004

2 http://sawadee.com/thailand/transportation/ visited on 2.12.2004

3 Datasource in Europe: http://epp.eurostat.cec.eu.int (EUROSTAT), list of all governmental statistic providers in Europe http://www.statistik.at/_kontakt/link.shtml

government agencies and organisations. In Thailand, for example traffic count data for highways are collected by the Department of Highways since 1962. Also socio-economic data stemming from the Census survey carried out every 10 years are available.

As mentioned to set up a model a set of input data is needed. In the following overview the most important input data are listed and a confrontation between Europe and Asia regarding data availability is given.

Table 3-1: Overview of input data needed and their availability in Europe and Asia

Input data needed for transport model part	**Data sources / data availability in Europe**	**Data sources / data availability in Asia**
Avg. trip distance between and within the zones	city maps, GIS systems	city maps, GIS systems
Avg. travel speed for all modes (pedestrian, bike, bus, tramway, metro and private car)	existing transport models, monitoring	empirical investigations
Avg. distance between a parking space and source/destination for each zone	empirical investigations, expert guess	empirical investigations, expert guess
Avg. time to find a parking space for each zone	empirical investigations, expert guess	empirical investigations, expert guess
Avg. distance between a public transport stop and source/destination for each zone	empirical investigations	empirical investigations, expert guess
Avg. public transport waiting and change time for each source – destination combination	public transport operator	public transport operator, empirical investigations
Fuel costs per vehicle kilometre private car	official statistics	official statistics, empirical investigations
Other costs per vehicle kilometre private car	official statistics	official statistics, empirical investigations
Avg. occupancy private car	empirical investigations	empirical investigations
Parking costs private car	empirical investigations	empirical investigations
Costs per trip public transport	public transport operators	public transport operator
Input data needed for Land Use part		
Development of businesses in the FUR (Functional Urban Region)	official statistics, city specific e.g. land use development plans	official statistics, expert guess
Avg. rent per modelled zone i (and time)	empirical investigations	empirical investigations
Building costs per modelled zone i (and time)	empirical investigations, secondary literature reviews	empirical investigations, official statistics
Potential floor space per land in each zone i	city specific, land use development plans	city specific, land use development plans, expert guess
Development area available in each zone i (and year)	city specific, land use development plans	city specific, land use development plans, expert guess
Number of residents in the FUR	official statistics and forecasts	official statistics and forecasts
Number of new- and relocating households in the FUR	official statistics, (e.g. every 10 years in Austria)	official statistics, expert guess
Number of dwellings per zone i in year 0	official statistics	official statistics
Density of living per zone i	can be derived from official statistics	can be derived from official statistics
Indicator for quality of living (percentage green areas,...?)	empirical investigations, expert guess	empirical investigations, expert guess
Number of workplaces per zone i in year 0	official statistics	official statistics, empirical

		investigations
Available premises per zone	official statistics	official statistics, empirical investigations

3.2 Modes of transport

The means of transport used in Asian cities differ a lot from that in European cities. E.g. in a study about the transport and land use system of Delhi [Tiwari, 2003] p. 446 defines and uses seven different types of transport:

- *Public transport buses, normally 12.5 m long*
- *Rural transport vehicles originally designed for rural operations that are 6 m long, have high floors, and can carry 12–15 people [currently also used in urban areas, see* Figure 3-1*]*
- *Minivans and large commercial vehicles are used as route taxis*
- *Small three-wheeled scooters [called Tuk-Tuk, see* Figure 3-1*] are used as taxis*
- *Small- and mid-size passenger cars and motorized two-wheelers used as personal motorized transport*
- *Motorized two-wheelers: scooters and motorcycles*
- *Bicycles, three-wheeled bicycle rickshaws, and walking*

Figure 3-1: left picture: Tuk-Tuk ; right picture modified pick up truck (Songtaew)

There is conflict among different modes (see Figure 3-2). As it can be seen in Figure 3-2 the utilization of road infrastructure differs significantly between Europe and Asia. In modelling terms this means that existing parameters of speed-flow relations as used in European models are not longer applicable in an Asian context. Here additional empirical investigations have to be carried out within this project.

Ubon Hanoi

Figure 3-2: Conflict among different modes

Asia and Europe are also different in the ways of using public space (see Figure 3-3), for example, footpaths are used for commercial activities, and for parking and loading. That is common and difficult to manage since it is part of Asian culture.

Ubon Hanoi

Figure 3-3: Ways of using facilities in Ubon and Hanoi

Moreover, there are some other issues needed to be considered:

- Walking trips are considered as not very important by transport planners and decision makers and therefore no adequate attention is given to this mean of transport regarding data collection, modelling, policy design and measures implementation.
- Cycling is rarely used for main purposes of travel, particularly in highly developing countries (e.g. Thailand). Cycling is used mainly by students and low income people. In Vietnam, cycling is noticeably declining.
- Tuk Tuk (used as taxi) may be more important (higher proportion) than walking and cycling.
- There is a high proportion of motorcycle (very high mode share in Vietnam).

The current European version of MARS uses three main modes: non motorized travel, public transport and private car. The modes non motorized and public transport are further subdivided: Non motorized into walking and cycling and public transport into separated from road traffic and not separated from road traffic. During a model run a user pre-defined share between this subdivisions is kept constant.

Concerning public transport at least differences in capacity of different vehicles used in Asia and Europe have to be considered. The necessity to model more than the current two sub-modes will have to be tested.

The empirical socio-demographic data from Asian cities show that unlike in European and North-American cities it is essential to consider “motorcycles” as an independent mode (see Table 2-2). Literature about traffic flow and heterogeneous traffic involving motorcycles is very rare. Nevertheless the necessity to develop new models is recognized [Tiwari, 2001]. A first approach how to tackle the issue of speed-flow relationships in heterogeneous traffic is shown in section 3.5.

3.3 Captive ridership

In Asian cities a high share of the population lives below the poverty line (see Table 2-1). Therefore it is necessary to extend captive ridership [Tiwari, 1999].

Car users and motorcyclists are highly captive, because of poor public transport. Particularly, motorcycle use is very convenient and cheap. Status-quo is very important (more than in Europe), but difficult to quantify how much important.

The current versions of MARS applied to European cities consider that part of the population which does not have access to a car. These residents have only limited choice of using either the non motorized modes or public transport. The situation in Asian cities is different. *Even a subsidized public transport system remains beyond the means of a significant segment of the population* [Tiwari, 1999] p. 53. The choice of this population segment is limited to walking and cycling. This fact has to be reflected in the MARS model adopted for Asian cities.

3.4 Captivity housing

A significant proportion of the population of Asian cities has, for the same reasons as above, a limited choice where to live. *Nearly 40 to 65 per cent of the population of South Asian mega-cities live in sub-standard living areas* (Tiwari, 1999) p. 51.

Some other key facts are that:

- land use is mixed between residential and business areas,
- commercial buildings are often used for residents on the upper floors,
- some areas are low density, but are not preferable in general because of some specific reasons e.g. high risk of flooding. These areas are occupied by low income people.

In the current version of MARS residents have the choice to relocate freely to every place within the study area. This assumption is by no means adequate for Asian cities. A kind of "captive settlers" will have to be included in the Asian version of MARS.

3.5 Technical issues VENSIM

Figure 3-4 shows the cause–effect relations of a first attempt to consider the speed-flow relationship of mixed car–motorcycle traffic in the Asian version of MARS. The basic assumption is that motorcycles consume less space than cars in free flow conditions and that motorcycles can move to the first position at red traffic lights. A trip is therefore subdivided into the time spent in flowing conditions (*Time flow (min)*) and the time spent waiting at crossings (*Time crossings car (min)* and *Time crossings moto (min)*).

$$t_{ij}^{fl} = \frac{\frac{D_{ij}}{V_{ij}^{fr}} * 60}{1 + \alpha * \left(\frac{M_{ij}^{car} + M_{ij}^{moto} / k}{C_{ij}} \right)^{\beta}} \qquad (1)$$

Equation 1 describes the speed flow relationship as used in the proposed model, with t^{fl}_{ij} (*Time flow (min)* as the time (min) in flowing conditions between *i* and *j*, D_{ij} (*Dij (km)*) the distance (km) between *i* and *j*, V^{fr}_{ij} (*V free (km/h)*) the speed in free flow conditions (km), M^{car}_{ij} (*Volume car (veh/h)*) the car traffic volume (veh/h), M^{moto}_{ij} (*Volume moto (veh/h)*) the motorcycle traffic volume (veh/h), k (*Motorcycle/*Car) the ratio of space consumption car/motorcycle (-) and C_{ij} (*Capacity (veh/h)*) the capacity of the road between *i* and *j*. The parameters α and β are set 0.15 and 4 [Singh, 1999].

The time a car loses at crossings $t^{cr,car}_{ij}$ (*Time crossings car (min)*) depends on the amount of time of red traffic lights t^{red}_{ij} (*Time red (min)*) coming across when driving from *i* to *j*, the traffic volumes and the capacity (Equation 2).

$$t_{ij}^{cr,car} = t_{ij}^{red} * \left(1 + \frac{M_{ij}^{car} + M_{ij}^{moto} / k}{C_{ij}} \right) \quad (2)$$

The time a motorcycle loses at crossings $t^{cr,moto}_{ij}$ (*Time crossings moto (min)*) depends on the amount of time of red traffic lights t^{red}_{ij} (*Time red (min)*) coming across when driving from *i* to *j*, a factor k^{moto} (*k congest moto*) considering that not all motorcycles can move to the first position during red light, the traffic volumes and the capacity (Equation 3).

$$t_{ij}^{cr,moto} = t_{ij}^{red} * \left(1 + k^{moto} * \frac{M_{ij}^{moto}}{C_{ij}} \right) \quad (3)$$

The total travel times from *i* to *j* are the sum of times in flowing condition and at crossings.

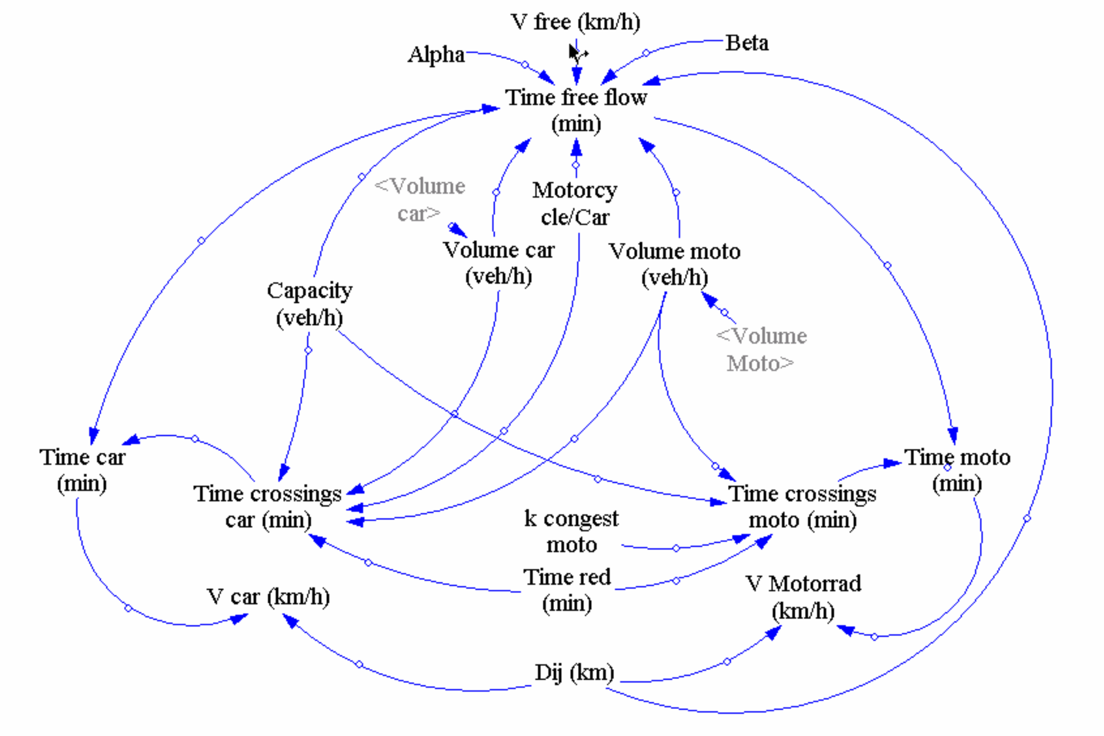

Figure 3-4: Vensim® model speed – flow relationship car – motorcycle

The example presented here uses the following parameters. The model user can define the relative consumption of space *Motorcycle/Car* is one car equals two motorcycles. *Time red (min)* is 5 minutes. *Dij (km)* is 10 km. *k congest moto* is 0.3. *Capacity (veh/h)* is 1000 vehicles per hour. The free flow speed *V free (km/h)* is 50 km/h. Figure 3-5 shows the resulting speed for an increasing car volume in combination with a decreasing motorcycle volume.

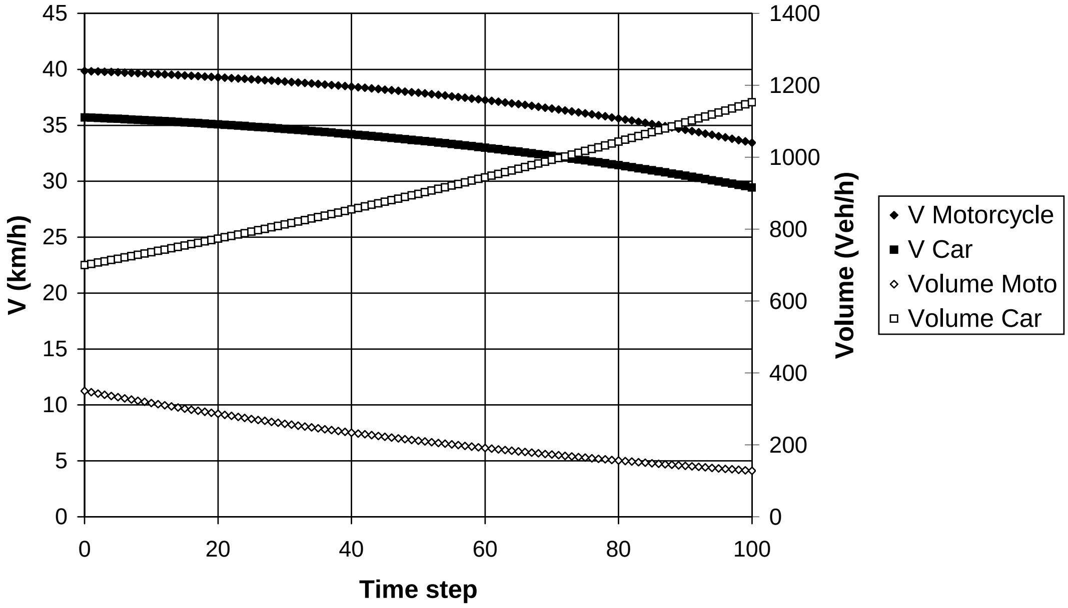

Figure 3-5: Results Vensim® model speed – flow relationship car – motorcycle

The next step in the model development will be testing the results with either empirical data on defined stretch of a road or with results from microsimulations.

4 Conclusions/Summary

A simple transfer and application of MARS on Asian cities is not possible. Very early in the research exercise it was recognized that there exist several challenges, which first have to be overcome to be able to transfer MARS from an European to an Asian context. Issues which have to be addressed encompass historical and cultural differences, different habits regarding the utilization of public space, the organization of public transport and the usage of cycles and motorcycles as a major mean of transport and a lack of transport and land use related data and data time series.

Following from that it is not possible to transfer existing mathematical land use transport models without major adaptations. These adaptations comprise on one hand the empirical collection respective estimation of necessary model input parameter and on the other hand, adaptations in the underlying design of mathematical relationships as shown in the example of a mixed speed-flow relationship.

Notwithstanding the complex concept of sustainability needs the use of adequate tools to support policy making. MARS and its adapted versions can be such a tool to support Asian transport and city planners towards their way to sustainability.

5 References

Barter, P. (1999). An International Comparative Perspective on Urban Transport and Urban Form in Pacific Asia: The Challenge of Rapid Motorisation in Dense Cities. PhD-thesis. Murdoch University, Perth, Western Australia, http://wwwistp.murdoch.edu.au/publications/projects/pbarter/pbarter.html

Emberger, G., and Pfaffenbichler, P. C. (2001). Verringerung des Flächenverbrauchs durch verkehrliche Massnahmen am Beispiel der Region Wien., In: Versiegelt Österreich? - Der Flächenverbrauch und seine Eignung als Indikator für Umweltbeeinträchtigungen, Tagungsberichte Bd. 30, Umweltbundesamt, Wien.

Emberger, G., May, A. D., and Shepherd, S. P. "Method to identify optimal land use and transport policy packages, Introduction of a Indicator/Target based appraisal approach." CUPUM'03, 8th International conference on Computers in Urban Planning and Urban Management, Sendai, Japan.

Haken, H. (1983a). Advanced Synergetics - Instability Hierarchies of Self-Organizing Systems and Devices, Springer-Verlag.

Haken, H. (1983b). Erfolgsgeheimnisse der Natur - Synergetik: Die Lehre vom Zusammenwirken, Deutsche Verlags-Anstalt, Stuttgart.

Knoflacher, H. (1993). "Zur Harmonie Von Stadt Und Verkehr. Freiheit Vom Zwang Zum Autofahren." Kulturstudien. Bibliothek Der Kulturgeschichte, 16.

Pfaffenbichler, P. C. (2003). "The strategic, dynamic and integrated urban land use and transport model MARS (Metropolitan Activity Relocation Simulator)," Technische Universitaet Wien, Vienna.

Pfaffenbichler, P. C., and Emberger, G. "Die Bewertung der Nachhaltigkeit innovativer städtebaulicher Maßnahmen mit dem Simulationsmodell MARS." CORP 2004 - Computergestützte Raumplanung,in: "Beiträge zum 9. Symposion zur Rolle der Informationstechnologie in der Stadt- und Raumplanung sowie zu den Wechselwirkungen zwischen realem und virtuellem Raum", Vienna, 689 - 694.

Singh, R. (1999).Improved Speed-Flow Relationships: Application to Transportation Planning Models.7th TRB Conference on application of Transport Planning Methods, Boston, Massachusetts.

Tiwari, G. (1999). Towards a Sustainable Urban Transport System: Planning For Non-Motorized Vehicles in Cities. *Transport and Communications Bulletin for Asia and the Pacific*, 68: 49-66.

Tiwari, G. (2001). Traffic Flow and Safety: Need for New Models for Heterogeneous Traffic, In: *Injury Prevention and Control*, Eds.: D. Mohan & G. Tiwari, London: Taylor & Francis, pp. 71-88.

Tiwari, G. (2003), Transport and land-use policies in Delhi, *Bulletin of the World Health Organisation,* 81 (6): 444-450.

Wegener, M. (2003). Overview of land-use and transport models. CUPUM03 –The 8 th International Conference on Computers in Urban Planning and

Urban Management, Sendai, Japan, Center for Northeast Asian Studies, Tohoku University.

Project Webpages:

PROSPECTS: http://www.ivv.tuwien.ac.at/projects/prospects.html

PLUME: http://www.lutr.net/index.asp

SPARKLE: http://www.ivv.tuwien.ac.at/projects/sparkle.html