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Metropolitan Activity Relocation Simulator (MARS) Model for Chiang Mai City

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ABSTRACT

This paper presents experiences gained from the set up process of the Metropolitan Activity Relocation Simulator (MARS) model for Chiang Mai city in Thailand. MARS is an integrated strategic and dynamic land-use and transport model, which can evaluate urban transport and land use policies, in order to achieve sustainable development. The model was used to assess several scenarios. The results show a number of interesting phenomena, such as non-linearity behaviour, synergy effects, and time-lags. The results also illustrate that measures which improve a particular criterion can worsen the overall performance of the system, and vice versa. These characteristics are fundamentally features of system behaviour, which are complex to understand, yet it is essential to comprehend them to achieve a successful transport and land use plan.

Keywords: *sustainable transport development, land-use and transport model, Metropolitan Activity Relocation Simulator (MARS) model, Chiang Mai city*

1. INTRODUCTION

Sustainability is the challenge cities face today. Land use and transport are two major key elements to reach this target. However, a main difficult task for many cities is prediction of impacts of possible policy instruments. To enable decision makers to identify strategies which can lead to sustainability, modern tools should be used.

At present most of the practice transport models are based on the traditional four stage sequential algorithm. In terms of demand changes in the medium and long term these models are static models. Within these models transport demand is derived from exogenous indicators like population, distribution of income, car ownership, etc.. This derived demand is then used as input for next stages of the model. No feedbacks between infrastructure supply, the transport system and the land use development do exist.

Newer developments in the domain of transport planning take a different approach. Land-Use-Transport-Interaction (LUTI) models combine the interaction between urban transport systems and land use development in one common model. The advantage of such a model is, that the exogenous input data for one part of the model can be calculated in the other part of the model endogenously and vice versa. These interactions need a temporal connection between the land use model part and transport model part. One appropriate method is System Dynamics to incorporate this dynamic dimension within the model.

This study applies the Metropolitan Activity Relocation Simulator (MARS) model which was initially created for Vienna, and later was applied successfully to many developed cities. MARS is an integrated strategic and dynamic land-use and transport model, which can evaluate urban transport and land use policies, in order to achieve sustainable development. This paper presents experiences gained from the set up process of MARS model for Chiang Mai city in Thailand.

2. LAND USE AND TRANSPORT MODEL

The four stage model is a demand forecasting model for personal travel. Its first comprehensive application was the evaluation of a road construction project against traffic engineering improvements of existing structures (Bates et al., 2000; McNally, 2000). The model has become a conventional tool used to appraise and predict future demands of a transportation system.

In recent years, the four stage model has received increasing criticism on its suitability to evaluate transportation systems, which have increased in detail and complexity over recent years (Bates et al., 2000; McNally, 2000; Stopher and Greaves, 2007; TRB, 2007). McNally (2000) indicates that while the four stage model is an application of the Transportation Systems Analysis (TSA), the connections between Network Flows (F) and Location/Supply Procedure (L and S) are removed in the four stage model. This, in effect, assumed that the demand for travel is fixed; i.e. it severed the relationship between the transport demand and the transport system. The forecast of the activity system is carried out in isolation.

The complexities of land use and transport interaction, and the rise of transport modelling technique instigated the development of the integrated land use-transport interaction model (LUTI). Lowry's (1964) Model of Metropolis is believed to be the first operational LUTI model. Its pioneering efforts paved the way for many modelling approaches. For example, it provided a framework for many subsequent LUTI models such as those reviewed by Wegener (2004). The increase in computing power, better data availability, and improved theoretical understanding, have all contributed to the development of urban land use transport modelling (Wegener, 2013). For detailed classification of LUTI see Department for Transport (2005).

Land-Use-Transport-Interaction (LUTI) models combine the interaction between urban transport systems and land use development in one common model. The advantage of such a model is, that the exogenous input data for one part of the model can be calculated in the other part of the model endogenously and vice versa. For example, the number of households is calculated in the land-use model, which then is passed onto the transport model as an exogenous input. On the other side, accessibility is calculated endogenously in the transport model, which is then used as an input for the land use model. These interactions need a temporal connection between the land use model part and transport model part. One appropriate method is System Dynamics to incorporate this dynamic dimension within the model.

3. METROPOLITAN ACTIVITY RELOCATION SIMULATOR (MARS) MODEL

MARS is a dynamic land-use/transport interaction model developed at the Research Centre of Transport Planning and Traffic Engineering, Institute of Transportation, Vienna University of Technology (TUW-IVV) (Pfaffenbichler, 2003). The basic underlying hypothesis of MARS is that settlements and the activities within them are self-organising systems. MARS assumes that land-use is not constant; it is rather a part of a dynamic system that is influenced by transport infrastructure. MARS is a spatial aggregation level, closed-loop, system dynamic model. The simulated results about its transport and land use are calculated with inputs from one another (i.e. their interactions are replicated). The model is constructed with the aim of providing a supporting tool for sustainable city planning and decision-making on transport and land use policy with its transparent simulation process and its short run-time.

MARS is set up to simulate over a time period of 30 years and is able to estimate the effects of several demand-sided instruments (such as public transport fare, parking charges and road pricing) and supply-sided instruments (such as increased transit service and capacity changes for road or non-motorised transport). The simulated results are then measured against targets of sustainability.

At the highest level of aggregation, MARS is 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 these two sub-models.

The land use sub-model is divided further into a residential and a work place location sub-model (Figure 1). The two sub-models compete for limited land and are connected by the availability of land and price. The spatial distributions of work places and residents are the land use sub-model's outputs into the transport sub-model. Levels of accessibility, a function of time taken to access work place or services, are the outputs from the transport sub-model into the land use sub-models. The number of work places and residencies and accessibility of the year t are used to calculate the work place distribution and accessibility for the year t+1 for each zone.

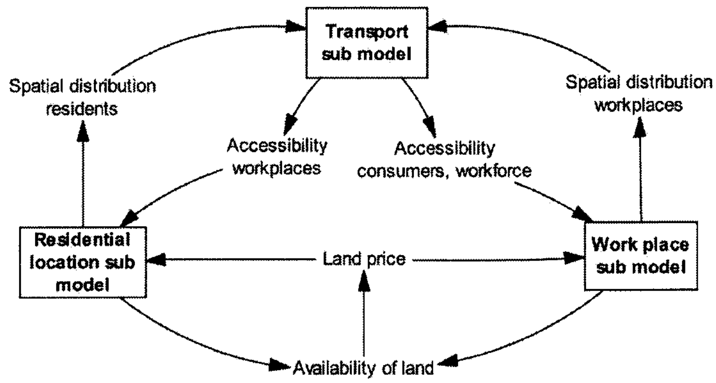

Figure 1: MARS transport sub-model and two land use sub-models

Source: Mayerthaler, 2009

The connections of the sub-models in each iteration are shown in Figure 2.

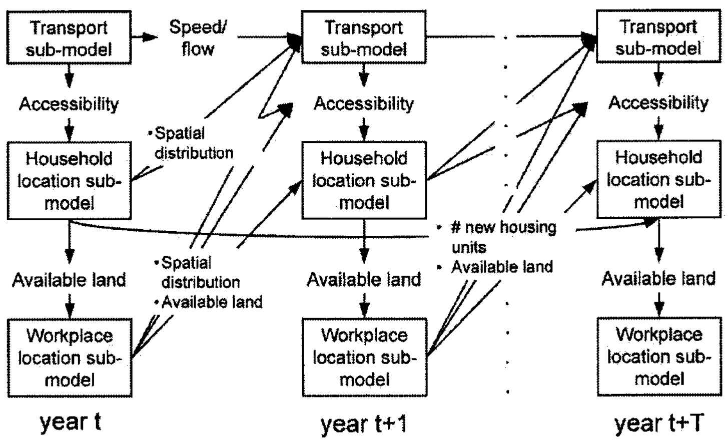

Figure 2: Connection of MARS sub-models in different time steps

Source: Pfaffenbichler, 2003, p. 71

In each iteration the calculations within the Transport sub-model begin first. The output of the transport sub-model, accessibility, is then input into the household location sub-model. The household location sub-model uses the accessibility for each zone to calculate land availability and feeds its output into the workplace location sub-model.

The following information is passed between the sub-models from each iteration to the next:

- The transport sub-model reports the speed flow calculation results over to the next iteration.
- The residential spatial distribution from the household location sub-model is passed to the transport sub-model and the household location sub-model of the next iteration.
- The numbers of new housing units developed are retained within the household location sub-model until the time lagged period t+T when a particular number of housing units are ready.
- The work place spatial distribution and land availability information, from the work place location sub-model, are passed to the transport sub-model, the household location sub-model, and the workplace location sub-model of the next iteration.

4. DEVELOPMENT OF MARS MODEL FOR CHIANG MAI CITY

Since its inception, MARS has been applied successfully to a number of cities across Europe, North America, and South America. In Asia, MARS was initially developed for Ubon Ratchathani (Thailand), Chiang Mai (Thailand), and Hanoi (Vietnam) as parts of an EU-funded project, SPARKLE - Sustainability Planning for Asian Cities making use of Research, Know-How and Lessons from Europe (SPARKLE 2004). These versions were only used for demonstration of policy impacts in training courses for decision makers. Later, MARS was developed for Ho Chi Minh City (Vietnam) for the "Megacity Research Project TP. Ho Chi Minh – Integrative Urban and Environmental Planning Framework Adaptation to Global Climate Change", initiated by the German Ministry of Education and Research (BMBF). It was used to quantify and assess the impacts of the policy strategies laid out in the Ho Chi Minh City Transport Master Plan (Emberger, 2014). These track records suggest the model has an adequate level of transferability. Nevertheless, each city has a unique land use pattern and transport systems.

In the previous version of MARS two person groups, one with and one without access to private vehicles are considered in the transport model part. Two types of private vehicle are included; the car and the motorcycle. The transport model is broken down by commuting and non-commuting trips, including travel by car, motorcycle, public transport, and non-motorised modes. Car and motorcycle speeds in the MARS transport sub-model are 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. A full description of MARS is given in Pfaffenbichler (2003).

Chiang Mai province is a hub of transport, economy, and tourism for the North Thailand. The urban area of Chiang Mai is 430 km^2 and includes Muang Chiang Mai district (Chiang Mai city) and seven adjacent district-level municipalities. There are 630,591 people (in 2012) in the urban area. Major networks of roads in the urban area employ the radial and ring road system, with lateral roads spreading out in different directions serving as connections between urban centres and sub-urban areas or rural districts. Traffic congestion on the main roads within the inner ring system is common, especially in the areas surrounding educational institutes or other major activity areas. The main public transport system consists of shared taxis (known as Song taew or Red-cab), which are pick-up trucks with covered seating areas. The service routes are unregulated and Red-cap drivers drive around to pick up passengers going to the same destinations. The fare in the city is fixed at 20 Baht (1 USD ≈ 35 Baht in 2015) but trips in outer areas depend on agreements between individual drivers and passengers.

For developing Chiang Mai city MARS (CNX-MARS) model, two types of data sources were used: primary data and secondary data sources. The secondary data can be divided further into two types: statistical data and administrative data. The primary data was based on Chiang Mai Mobility and Transport Survey (CM-MTS). This is a household travel survey carried out in 2011/12. The survey captured mobility data that represents 19,385 trips carried out by 6,189 persons in 2,319 households within Chiang Mai city area. This data provides a comprehensive snapshot of the travel behaviour of the city's residents.

The development of the model is detailed with a focus on its principle assumptions. Three improvements have been made to increase the model's effectiveness: (1) quality of life indicator adjustment (the quality of life indicator in this study is a composite index based on three attributes: average household income, average rent, and average land price in each zone.), (2) addition of the Shared-taxi (Song Teaw) mode, and (3) updating of emission and fuel consumption module.

The calibration process of the Chiang Mai MARS model was carried. The mode share values of the model in the peak and the off-peak periods are compared against the survey results (CM-MTS). Various parameters were adjusted to minimise the differences between the two values.

MARS has the ability to simulate possible development paths of the study area under different policy instruments. The model inputs, such as the demographic transition and the vehicle ownership model, can be adjusted to replicate different background conditions of the study area. The policy instruments are other model inputs that can be altered to simulate desired land use and transport policies. The model outputs, such as generalised costs (in terms of monetary factors and time), kilometres travelled by different modes, and vehicular emissions, enables the policies to be evaluated quantitatively. The development and application of MARS model for Chiang Mai city in details is presented in Jittrapirom and Emberger (2015).

5. SCENARIO ASSESSMENT

In a planning context, a vision is a desirable ideal state of the future set by an individual, groups of decision makers, or in consensus with other stakeholders. The vision can be broken down to provide specific goals and objectives that will deliver the desired results. Objectives provide guidelines toward goals and help to identify obstacles, challenges, and constraints that need to be overcome (May & Minken, 2003).

Table 1: Indicators of Chiang Mai city sustainable transport planning

Objective	Sub-objective	Indicators	Unit
Environmental protection	1.1 Efficient in the use of resources	1.1a* Consumption of fuel per trip 1.1b* Cumulative fuel consumption	(litre)
	1.2 Reduce greenhouse to a reasonable level	1.2a* Greenhouse gas emission per trip 1.2b* Cumulative greenhouse gas emission	(CO2 equivalent)
	1.3 Reduce air pollution to a reasonable level	1.3 Level of PM and No_x[25] emit from transport per trip	(tons/trip)
	1.4 Reduce noise pollution to a reasonable level	1.4 Transport noise emission above 60dbA	(Leq or Leu)
	1.5 Proportion and quality of green area	1.5 Percentage of Green area	(% of area)
Accessibility	2.1 Provide reasonable accessibility	2.1* Change in accessibility	(% to base year)
	2.2 Reduce automobile dependency	2.2* Percentage of trips made by non-private motorised transport	(%)
	2.3 Enable reasonable freedom of movement for vulnerable user	2.3 Walkability index	
	2.4 Control urban sprawl	2.4a* Average trip distance	(kilometre/trip)
		2.4b Average distance of housing units to city centre (assuming a single centre)	(kilometre/trip)
Safety	3.1 Reduce transport accidents, including non-vehicular	3.1a* Cumulative traffic injuries	(injuries)
		3.1b* Cumulative traffic deaths	(death)

[25] a generic term for mono-nitrogen oxides NO and NO2 (nitric oxide and nitrogen dioxide)

Quality of living standard	4.1 Enhance the social, cultural, and recreation activities	4.1* Percentage of trips make by walking and cycling	(%)
	4.2 High housing standard	4.2 Residential area per capita	(sq. metre/inh.)
	4.3 Proportion and quality of public space	4.3 Percentage of public area	(%)
Equity and fairness within and intergeneration	5.1 Accessibility for non-vehicular users	5.1* Proportion of trips make by non-vehicular mode (i.e. waking and cycling)	(%)
	5.2 Accessibility for mobility impaired users	5.2 Walkability index	
	5.3 Compensation for today and tomorrow's losers	5.3 Equity impact tables	
	5.4 Ensure a fair distribution of benefits derive from taxpayer's money	5.4 Distribution of accessibility benefits by zone	
Culture and tradition heritage	6.1 Retain the unique culture and tradition of the city (self-immunity)	6.1a Unique culture and tradition of the city index from questionnaire	
Economy	7.1 Promote Sufficiency Economy in Economic dimension	7.1a Unemployment percentage	(% of population)
		7.1b Share of imported consumer goods	(% of total good consume)
		7.1c Average proportion of Household debt in relation to its monthly income	(average % of HH income)

Table 2: Background variables for Chiang Mai city sustainable transport planning

Type	Variables	Unit
Transport statistics	Average trip length by mode+	kilometre/trip
	Average trip time by mode+	minutes/trip
	Average travel speed by mode+	kilometre/hour
	Mode share by trip	share percentage

Seven categories of the objectives are suggested: (1) Safety, (2) Protection of the environment, (3) Accessibility, (4) Quality of living standard, (5) Equity and fairness within generation and between generations, (6) Cultural heritage and traditions, and (7) Economy. Nevertheless, they cannot be used to evaluate progress toward the goals, thus indicators are needed. The seven objectives can be broken down further to provide sub-objective and indicators for each one of them, as shown in Table 1.

Chiang Mai MARS (CNX-MARS) model can only produce 11 of these indicators (Note: Indicators with * are indicators that can be produced by MARS model). This is due to the limitation of the model and nature of the indicators. In addition to the indicators, a set of transport statistics variables is selected to provide a background data that will aid an understanding and explanation on the effects of the policies considered toward the behaviour of the transport system, shows in Table 2.

CNX-MARS model is used to evaluate the effects of transport policies in different scenarios. The scenarios tested quantitatively are presented in Table 3.

Table 3: Scenarios considered

Scenario	Summarised scenarios' description
A: Business As Usual (BAU)	A: A baseline case, the transport supplies and cost are not altered beyond its past trends
B: Motorised transport development	B: Road capacity expansion
C: Sustainable transport	C1: Full scale public transport network with a separate right-of-way C2: Decrease in road capacity; road narrowing and pedestrianisation of the central area C3: Enhancements to walking and cycling facilities C4: Management of parking spaces within the central area C5: Improvement to shared-taxi service C6: Land development control – effects of building height restriction in municipality area C7: Combined measures

Full results of the scenario test are demonstrated in Jittrapirom and Emberger (2015). Summary of results is presented as follows:

- Implementation of public transport (Scenario C1) improves the overall condition of the system. However, it seems to be in conflict with NMT modes and increases the number of transport casualties. The latter is questionable and points towards the need to revise the model's calculation of transport casualties.
- Decreasing road capacity (Scenario C2) slightly effects on the system. It encourages NMT trips and improves the overall condition of the system.

- NMT improvement (Scenario C3) unexpectedly reduces walking trip slightly but increases bicycle trips. Overall, it makes a higher level of enhancement to bicycle trips than walking trips and contributes positively to the system.
- Parking management (Scenario C4) is the most effective measure to reduce fuel consumption and emission per trip and increase the number of NMT trips. However, its impacts on cumulative fuel consumption and emission are of a lesser magnitude.
- Improvement to the shared-taxi operation by decreasing the detour factor (Scenario C5) does not reduce cumulative fuel consumption and emissions of the system; in fact it worsens the system as a whole. The only tangible gain is an increase of the shared-taxi ratio.
- Land development policy (Scenario C6) was found to have a positive effect on NMT trips. Inclusion of land use indicators will be necessary to assess this measure in more detail.
- The combined policy (Scenario C7) yield results which were not equal to the sum of all policies included. It depicts the nonlinearity behaviour of the complex system.

6. CONCLUSIONS

Interaction between land use and transport systems is rather complex. To enable decision makers to identify strategies which can lead to sustainability, modern tools should be developed.

This paper has presented the development of a dynamic land-use/transport interaction model for Chiang Mai city called CNX-MARS model. The CNX-MARS model was used to evaluate transport and land use policies with particular focus on sustainable transport measures for Chiang Mai city. A total of nine different scenarios were assessed. The appraisal shows that an improvement to the shared-taxi service without changing the nature of its operation can improve its mode share. However, the overall cumulative benefits are limited. Additional instruments that (a) discourage car use, (b) reduce shared-taxi emission, and (c) minimise shared-taxi's fuel consumption may increase the overall positive benefits slightly. The result, however, will be incomparable to the benefits gained from implementing a regulated public transport system.

The results of the appraisals show a number of interesting phenomena, such as non-linearity behaviour, synergy effects, and time-lags. The results also illustrate that measures which improve a particular criterion can worsen the overall performance of the system, and vice versa. These characteristics are fundamentally features of system behaviour, which are complex to understand, yet it is essential to comprehend them to achieve a successful transport and land use plan. CNX-MAR has proved a useful tool in helping to gain an insight into the complex effects of these different scenarios.

REFERENCES

1. Bates, J., 2000. History of demand modelling. In *Handbook of Transport Modelling*. Ed. Hensher, D. and Button, K. Pergamon, New York.
2. Department for Transport, 2005. Transport Analysis Guidance (TAG): Land-Use / Transport Interaction Models TAG Unit 3.1.3, (June). (www.webtag.org.uk)
3. Emberger, G., 2014. Ho Chi Minh City, Vietnam – Can HCMC reach its CO_2 targets in the Transport Sector?, In *Mobility and Transportation: Concepts for Sustainable Transportation in Future Megacities*, Ed. Wulf-Holger Arndt, JOVIS Verlag.
4. Jittrapirom, P. and Emberger, G., 2015. *Chiang Mai city's Metropolitan Activity Relocation Simulator (CNX – MARS) Report*, Institute of Transportation, Research Center of Transport Planning and Traffic Engineering, Vienna University of Technology, Austria.
5. Lowry, I. (1964). *A model of metropolis*. RAND Corporation.
6. May, A. and Minken, H., 2003. *Developing Sustainable Urban Land Use and Transport Strategies: A Methodological Guidebook.*
7. Mayerthaler, A., Haller, R. and Emberger G., 2009. A land-use/transport interaction model for Austria. In *Proceedings of the 27th International Conference of The System Dynamics, Albuquerque/USA*, pp. 1–21.
8. McNally, M., 2000. The four-step model. In *Handbook of Transport Modelling*. Ed. Hensher, D. and Button, K. Pergamon, New York.
9. Pfaffenbichler, P. C., 2003. *The strategic, dynamic and integrated urban land use and transport model MARS (Metropolitan Activity Relocation Simulator).* Technische Universitaet Wien, Vienna.
10. PROSPECTS, 2000. *Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems*, http://www.ivv.tuwien.ac.at/projects/prospects.html
11. SPARKLE, 2004. http://www.ivv.tuwien.ac.at/projects/sparkle.html.
12. Stopher, P. and Greaves, S., 2007. Household travel surveys: Where are we going? *Transportation Research Part A: Policy and Practice,* 41(5), pp. 367–381.
13. TRB, 2007. *Metropolitan Travel Forecasting: Current Practice and Future Direction.*
14. Wegener, M., 2004. Overview of land use transport models. in *Handbook of Transport Geography and Spatial Systems*. Ed. P. Stopher, D.A. Hensher, K.J. Button, K.E. Haynes, Emerald Group Publishing.
15. Wegener, M., 2013. The future of mobility in cities: Challenges for urban modelling. *Transport Policy*, 29, pp. 275-282.