Application of a macroscopic transport model in Ho Chi Minh City

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Abstract: Ho Chi Minh City (HCMC) is the largest metropolitan area in Vietnam. Thank to the economic development, urbanisation has been occurring very fast over the last few decades in this city. Transport is now an issue, like traffic congestion and air pollution. The application of simulation models to support transport planning tasks is still at early stage in Vietnam. This paper describes the process of building a model, MARS – a dynamic landuse and transport integrated simulation tool – for Ho Chi Minh City. Though socio-economic and transport data in HCMC is short, the model was calibrated and validated. Then it was used to test various scenarios based on transport masterplan of HCMC and found out that HCMC is not able to reach the defined objectives laid down by the authority.

Keywords: dynamic integrated model, sustainable development, motorcycle traffic.

1. BACKGROUND

For the past two decades, the urbanisation in Ho Chi Minh city have been happaning rapidly. Nevetheless, the development of infrastructure in general and transportation system in particular is always far behind the growth of population, leading to a heavy burden for the city. The city has officially some 7.2 million inhabitants (year 2009), nearly 8 million inhabitants 2011 though unofficial estimations are in between 10 to 12 million people and population is growing steadily at the rate of 3% per year. The city area comprises about 2095 km^2 and the land allocated for transportation is almost unchanged, approximately 7% of city area. The GDP per head in 2007 was around 2,600 US$ per capita.

Now, transport situation in Ho Chi Minh city is worsening over the time. Traffic congestion is one of six “hot” problems which the local governmnet made the priority. At present modal split for trips is 3-5% pedestrians, 1-3% cycling, around 6% public transport, 9-11% private car and the rest of more than 80% is based on motorcycles. The car motorisation rate was 60 cars per 1000 inhabitants (base year 2008) with a growth rate of 16% per annum. The motorcycle ownership is about 390 motorcycles per 1000 inhabitants with a growth rate of 8% per year (Nguyen and Doan, 2011). These are internationally seen very high growth rates compared to others such as Europe ~1% to 2% p.a., USA ~1% p.a., India and China ~7% to 8% p.a. The high motorisation in combination with low infrastructure provision lead to increasing congestion levels and a deterioration of quality of life in HCMC. The public transport system, which presently counts for only one tenth of all trips is bus based and

strongly underfinanced. Beside that the bus fleet lacks modern vehicles and, no dedicated traffic measures to speed up the bus journey times such as priority lines, prioritisation at traffic lights etc. are implemented. The individual transport is based on motorcycles since scooters are seen to be flexible, fast and affordable. Parking is allowed nearly everywhere in the city and is relatively cheap. Nowadays the increasing rate of private cars seem to disturb the motorcycle flow, so traffic rules and their enforcement become more and more necessary to ensure movement in the mixed motorcycle and car traffic in HCMC.

2. PLANNING TOOLS

A couple of transport planning studies have been made for Ho Chi Minh City. In early 2000, under the aid of JICA, a project called HOUTRANS, using Japanese STRADA transport planning package, have studied extensively the transport situation in HCMC. That is the base for developing a Masterplan for HCMC approved by the Prime Minister in 2007. Recently, a follow-up study concentrating on public transport system was made by MVA Ltd. It used Cube Voyager software helping to forecast traffic, particularly MRT system, in the year of 2015 and 2025.

Transport Master Plan (TPM) (JICA, MOT et al. 2004) of HCMC comprises 7 objectives, 35 strategies and 105 actions to overcome HCMC's transport problems. Several studies were carried out to support the Transport Masterplan development as mentioned above. Nevertheless, due to time/cost and data constraints, Ho Chi Minh City authorities do not have an actual and calibrated transport model available. Although several political documents exist, where transport related objectives and targets were listed, for example "Preparing the HCMC City Metro Rail System" (MVA Asia Limited, SYSTRA et al. 2010), no formal quantification whether these goals could be reached at all were carried out based on model simulations.

Therefore it was decided in Megacities Project to set up a strategic land use transport interaction model to be able to quantify the impacts of different transport strategies mentioned to be implemented in the HCMC TPM. The model chosen was the dynamic land use and transport model MARS (Metropolitan Activity Relocation Simulator) developed by TU Vienna(Pfaffenbichler 2003; Emberger and Ibesich 2006; Jaensirisak, Emberger et al. 2006; Mayerthaler, Haller et al. 2009; Pfaffenbichler, Emberger et al. 2010; Emberger 2012). MARS is a dynamic Land Use and Transport Integrated model. The basic underlying hypothesis of MARS is that settlements and activities within them are self organising systems. MARS is based on the principles of systems dynamics (Sterman 2000) and synergetics(Haken 1983). The development of MARS started some 15 years ago partly funded by a series of EU-research projects. The present version of MARS is implemented in Vensim®, a System Dynamics programming environment.

MARS is capable of analysing policy combinations at the city/regional level and assessing their impacts over a 30 year planning period. MARS model consists of a transport and land use element and can be divided into a series of sub models as the following and as shown in Figure 1.

- Scenario input module
- Policy input module
- Transport model
- Commuting trips sub model

- Other trips sub model
- Land use model
- Housing development sub model
- Housing relocation sub model
- Workplace development and relocation sub model
- Fleet composition and Emission model
- Evaluation and Assessment module
- Output representation modules (AniMap, Vensim graphs, Venapp)

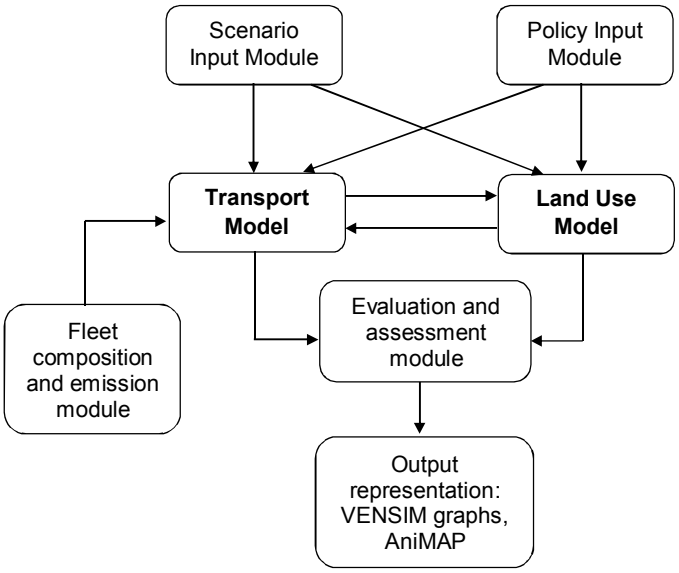

Figure 1: Basic structure of the MARS sub-models

The aim is to make the MARS model quick and easy to use whilst being easily understood by decision-makers rather than being a black box. MARS was therefore built using the System Dynamics approach, basing the model on causal loop diagrams and evidence from Austria in the first instance. The model is now being used in many EU research projects and models exist for 18[1] cities and 1 country (Austria) around the world.

3. DATA ISSUES

To be able to set up a complex land use transport interaction model like MARS a series of input data are needed. These input data can be classified in three different groups:

1. Indicators to describe HCMC regarding its socio-demographic and socio-economic status quo and future development
2. Indicators to describe the existing transport infrastructure and spatial land use within HCMC

[1] Gateshead, Leeds, Edinburgh (GBR), Oslo, Trondheim (NOR), Helsinki (FIN), Vienna , Salzburg , Eisenstadt , Austria (AUT), Madrid (ESP), Stockholm (SWE), Ho Chi Minh City, Hanoi (VIN), Chiang Mai (THA), UbonRatchantani (THA), Washington DC (USA), Porto Alegre (BRA), Bari (ITA).

3. Indicators regarding the present mobility behavior of HCMC citizens to calibrate MARS

Socio-demographic and socio-economic data
This set of indicators comprise beside others the number of people living in a certain zone (in our case we divided HCMC in 24 zones), the number of jobs for different sectors (industrial/service) in a zone, the average household size and income per zone, the average rental cost for housing, the car and motorcycle ownership rate, etc. Additionally we estimated the corresponding growth rates, e.g. for population growth, for car ownership growth, for motorcycle growth, and so on. These data were obtained from official available statistics.

Transport system and land use related data
Here we collected information regarding the average link capacity for trips between the different zones separated for different means of transport (walking, cycling, motorcycle, car, public transport), the corresponding cost for the usage of each means of transport, the parking place availability and costs for each zone, public transport frequency between zones, ticket fares and so on. On the other hand we derived the availability of free land to be converted into housing or commerce areas to enable the simulation of the future development in HCMC in order of the growing population. These data stem also from official available statistics.

Indicators to describe the present transport behavior of HCMC citizens
These data comprise the modal split figures of HCMC, the average travel speeds between different zones for the different means of transport, average car and motorcycle occupancy, and other information. The main sources for this kind of information were existing studies and own data collection exercises.

In general it has to be noted that the data availability and the data accuracy and actuality is by far not satisfying. For many of the necessary input parameters expert guesses have had to be made to set up the MARS model.

One important recommendation for HCMC authorities derived from this MARS modelling exercise is that for transport modelling and future transport planning adequate data collection procedures should be implemented. This problem is not HCMC specific, also in many cities, the lack of data is one of the most critical obstacles for transport and land use planning processes.

4. MODELLING EXERCISE

In a further step the transport strategies listed in the TPM HCMC were implemented into MARS and their impacts simulated for the coming 30 year time period. These simulation results were then assessed on the one side against the do-nothing scenario and on the other side against the targets listed in the TPM HCMC and other documents.

The comparison included the indicators CO_2-emissions, modal split, km travelled, etc. Additionally MARS delivered dynamic GIS maps where the developments of population, household location, workplaces distribution etc. were shown for the 30 year simulation period.

One of the intentions in HCMC was to evaluate if the proposed objectives regarding modal split (modal split share of public transport of 22-26% in the year 2010 to 2015 and 47-50% by year 2020 – as stated in "Preparing the HCMC City Metro Rail System" (MVA Asia Limited, SYSTRA et al. 2010) could be reached with the suggested policy instruments listed in the HCMC TPM.

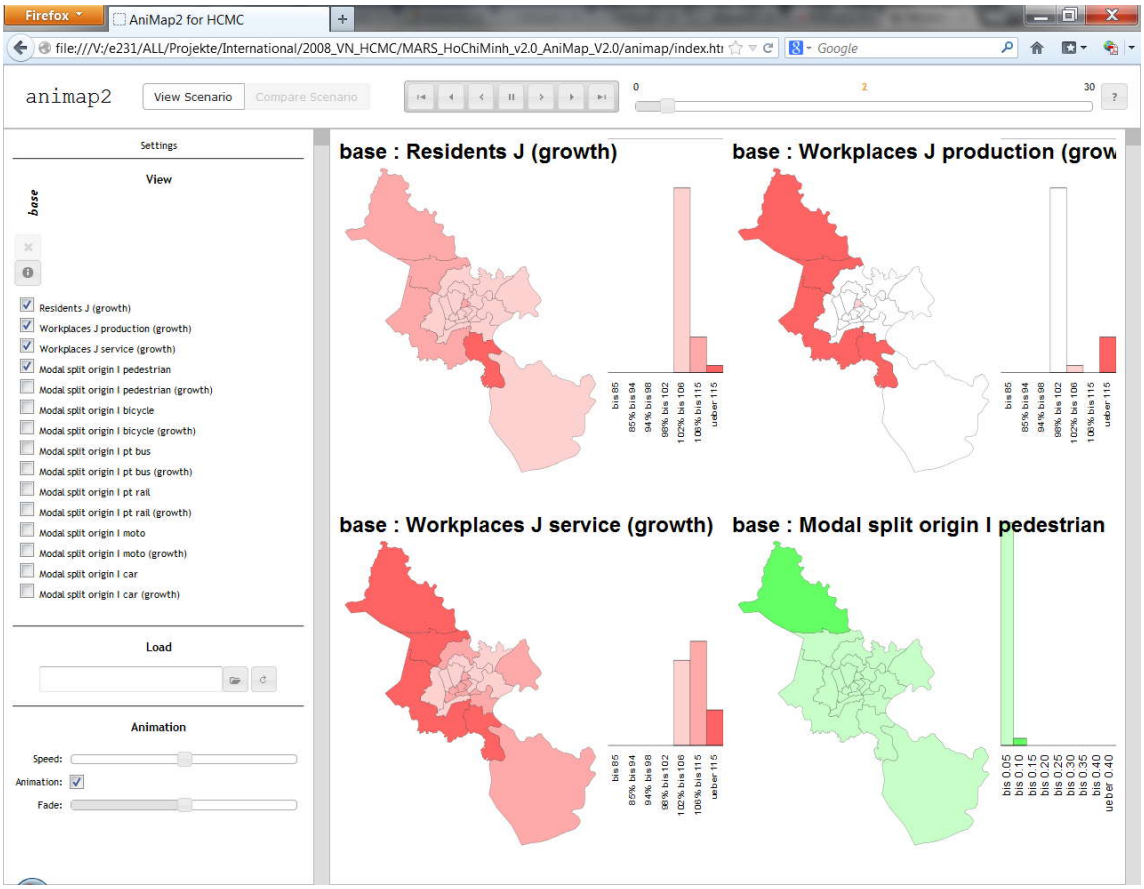

Figure 2: Dynamic GIS presetation of residents, workplaces and modal split

In detail, the following 6 scenarios were simulated to check whether the transport objectives regarding modal split and CO_2 can be reached with the measures suggested in the TPM or not. The scenarios were

1. Business as Usual – base run
2. TPM HCMC scenario Policy rail 2015
3. TPM HCMC scenario Policy rail_2015+parking fees
4. TPM HCMC scenario Policy rail_2015+ parking places reduction -20%
5. TPM HCMC scenario Policy rail_2015+ parking places reduction -40%
6. TPM HCMC scenario Policy rail_2015+BRT inner districts

Business As Usual scenario (BAU)

This scenario forms the base run scenario for all the growth rates such as population growth, car ownership growth, motorcycle ownership growth, work place development etc. They were implemented in MARS and the model was calibrated to existing modal split figures, trip distances and travel speeds. The results of this scenario can be interpreted in a way, that it

represents the development over time in HCMC in the case that no major transport policy instruments/improvements would be implemented in the next 30 years.

Policy rail_2015
With this scenario we wanted to simulate the impacts of implementing a very rail friendly policy strategy: We assumed that in 2015 all in the Transport master Plan (TPM) (Japan International Cooperation Agency (JICA), Ministry of Transport et al. 2004) and in the report "Preparing the Ho Chi Minh City metro rail System project" (MVA Asia Limited, SYSTRA et al. 2010) are fully implemented. With this scenario we test if the modal share distribution of 25% in the year 2010, and 50% by year 2020 public transport can be reached as assumed in these documents (see page 2-3, section 2.4 of (MVA Asia Limited, SYSTRA et al. 2010).

Policy rail_2015+parking fees
As it could be expected the solely implementation of an major improvement of a rail based public transport system in HCMC is not sufficient to reach the very ambitious goals of 50 % public transport usage in 2020 in HCMC. Therefore we decided to simulate a scenario where we test additionally to the above mentioned rail friendly scenario a policy where we introduce a 100% parking fees increase for short term and long term parking in the inner districts (1-12).

Policy rail_2015+ parking places reduction -20%
In this scenario we test the effects of implementation of the public transport rail network in combination with a reduction of parking places of -20%.

Policy rail_2015+ parking places reduction -40%
In this scenario we further decrease the parking place supply by – 40%.

Policy rail_2015+BRT inner districts
In this scenario we tested the effects of a BRT (Bus Rapid Transport System) system in the inner districts in combination with the implementation of the rail based public transport system. This scenario can be interpreted as the maxim possible public transport scenario in HCMC.

5. RESULT INTERPRETATION

Figure 3 shows the results of the modal split data for all tested scenarios for the years 2007, 2015 and at the end of the simulation time for the year 2025. The first 6 bars of this figure (block 1) show the modal split distribution for the base year 2007. Since all scenarios start with the same assumptions no differences occur.

The first bar (2015 - BAU) of the block 2 of bars shows the development of the modal split in the "Business As Usual" scenario (2015 - BAU). As it can be seen the mode share for bikes will go up (compared to bar 1 /block of bars 1). The reason for that is that because of the increase of motorized transport demand on one hand caused by population growth and on the other hand by the growth in motorization levels the travel speed for motorized transport will decrease significantly, whereas for bikes the travel speed will be stay constant (model assumption) and therefore cyclists gain relative travel speed advantages compared to the user of motorized transport. This results in higher mode shares for cycling.

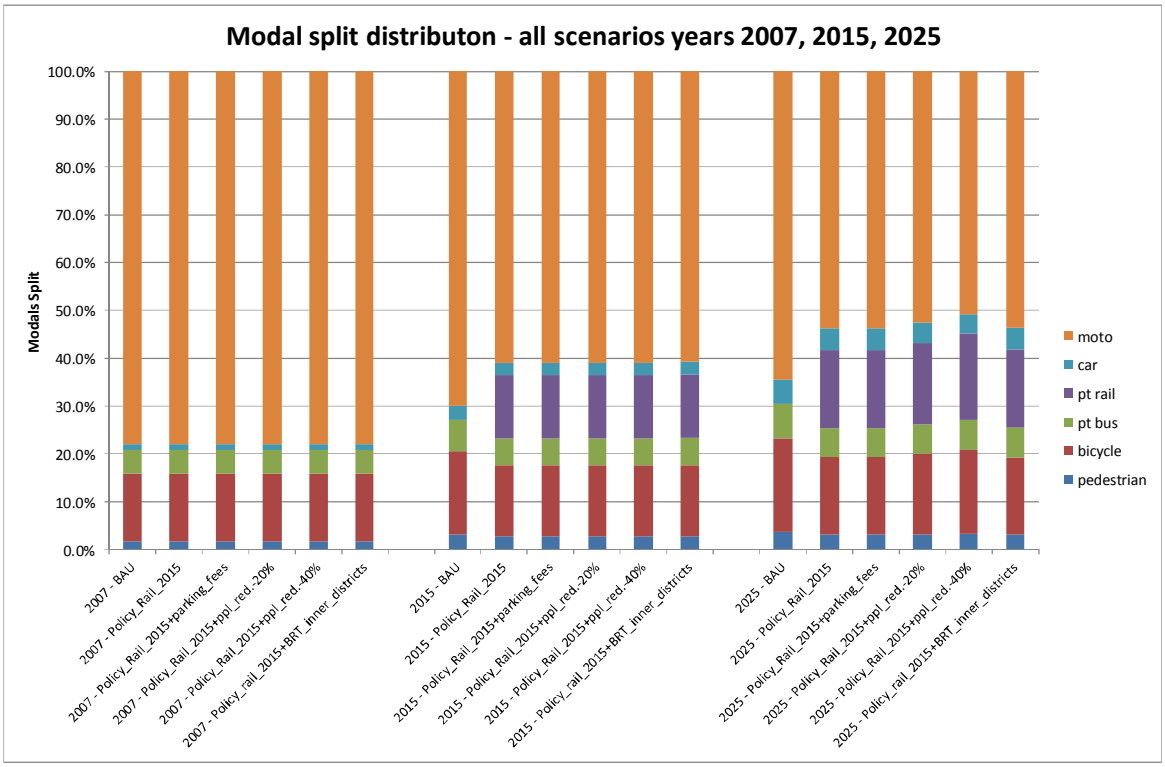

Figure 3: Modal split distribution – all scenarios years 2007, 2015, 2025

In all other scenarios depicted in the second block of bars, the rail system is assumed to be available, and this results in a significant shift from motorcycle users to the public transport system. Remarkable is also the increase of car use in all scenarios – the share increases from 1,2% in the year 2008 to nearly 3% in the year 2015.

The final block (block 3) of bars shows the simulation results for the year 2025. In the BAU scenario the modal of public transport users is about 7%, only 2 % higher as in the year 2008. Still more than 64% of all trips are made with motorcycles (78% in the year 2008), and the car share is around 5,1% (which is still very low compared to other countries/cities but it is nearly 5 times higher than in the year 2008!). Interesting is here, that although all metro and rail lines are fully in operation and no road capacity increase was implemented the modal split share of public transport (bus and rail together) is in the "best" case around 24,5 % (18% rail share and 6,5% bus share in the Policy_rail_2015+ppl_red.-40% scenario).

Further remarkable is that the scenario with the strongest restrictions for car use (40% park place reduction) is not strong enough to reach the in the TPM and "Preparing the Ho Chi Minh City Metro Rail report" mentioned mode shares of 47 – 50 % for public transport. One has to bear in mind that in the tested scenarios no road capacity increase was implemented, so it seems therefore very unlikely that HCMC can meet its objectives regarding modal split shares of public transport.

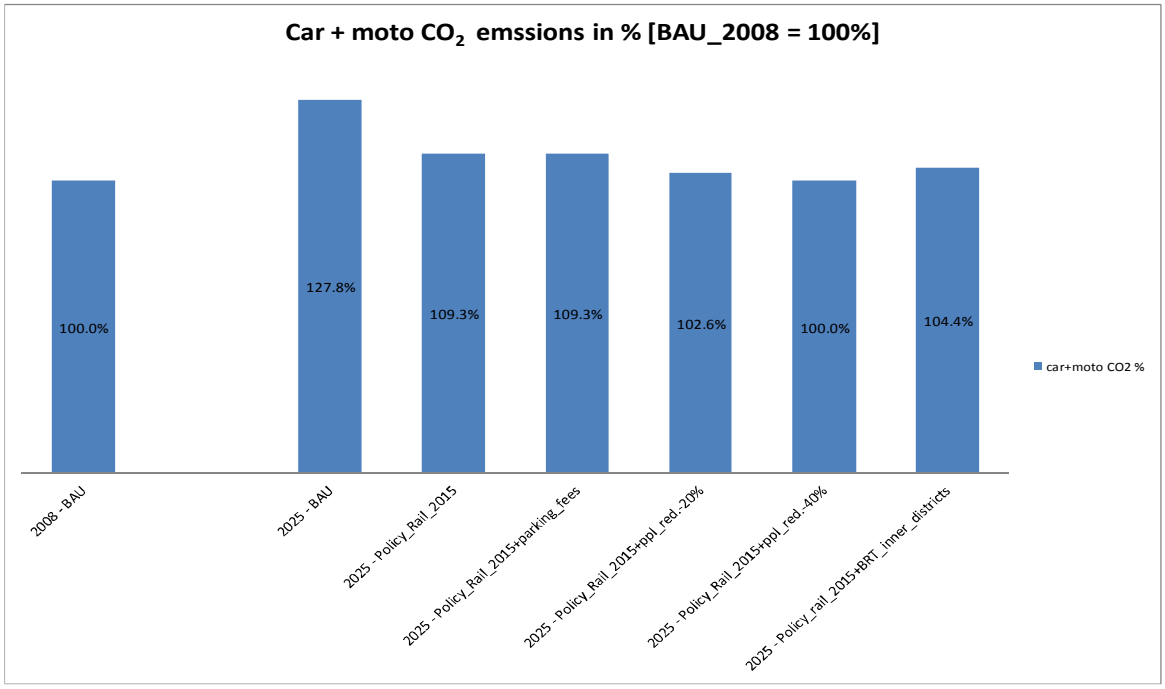

Figure 4: Car + moto CO2 emissions in % [BAU_2008 =100%]

Figure 4 shows the system wide CO2 emission development of the tested scenarios. As it can be seen in the BAU scenario the CO_2 emissions in HCMC will go up by about 30% compared to today's level. From the viewpoint of CO_2 emissions savings the very car restrictive scenario "policy_Rail_2015_+ppl_red.-40%" delivers the best result. In this scenario the total CO_2 emissions can be frozen to today's level. But also the other tested scenarios are very effective in keeping the CO_2 emissions at an acceptable level compared to the BAU scenario.

In very brief the simulations showed that HCMC is by no way in the position to reach its self-defined objectives laid down in its policy documents by implementing the policy measures as defined in the scenarios. The growth rates in population, the increase in household income, the related increase in car and motorcycle motorisation, the car friendly environment (e.g. tax reductions of car purchase), and the resulting urban sprawl will increase the transport problems of HCMC in the future significantly.

The conventional approach of "predict and provide", i.e. to build more roads and highway to meet the growth of vehicles as a first step and the improvement of public transport facilities as a second step, has, as can be seen in all cities around the world, never led to an environmental friendly, efficient and sustainable transport system. The HCMC case, as the simulations have shown, will there be no exception.

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REFERENCES

Emberger, G. (2012). Internal Report - Megacity Research Project TP. How Chi Minh, Integrative Urban and Environmental Planning Framework Adaptation to Global Climate Change: *AF 1 WP 5 Urban Transport - MARS modelling exercise HCMC* Institute of Transportation - Center for Transport Planning and Traffic Engineering University of Technology Vienna.

Emberger, G. and N. Ibesich (2006). "MARS in Asia - How a model can help and influence decision makers." *11th International Conference on Urban Planning & Regional Development in the Information Society*, reviewed.

Georget, J. (2009). Ho Chi Minh City -Transport modeling in a rapid growth environment - Cube Voyager Model MVA.

Jaensirisak, S., G. Emberger, et al. (2006). Application of the Metropolitan Activity Relocation Simulator (MARS). Model in Decision Making Process for Sustainable Development. *Technology and Innovation for Sustainable Development Conference* - TISD, Khon Kean, Thailand.

Japan International Cooperation Agency (JICA), S. R. o. V. M. Ministry of Transport, et al. (2004). The Study on Urban Transport Master Plan and Feasibility Study in Ho Chi Minh Metropolitan Area. HOUTRANS. Ho Chi Minh City.

JICA, MOT, et al. (2004). The Study on Urban Transport Master Plan and Feasibility Study in Ho Chi Minh Metropolitan Area - HOUTRANS. Hanoi, Japan International Cooperation Agency (JICA), Ministry of Transport, Socialist Republic of Vietnam (MOT) and Ho Chi Minh City People's Committee (HCMC-PC).

Mayerthaler, A., R. Haller, et al. (2009). Modelling land-use and transport at a national scale - the MARS Austria model. *49th European Congress of the Regional Science Assosiation International* - Territorial Cohesion of Europe and Integrative Planning. Lodz/PL.

MVA Asia Limited, SYSTRA, et al. (2010). Socialist Republic of Viet Nam: Preparing the Ho Chi Minh City Metro Rail System Project. Ho Chi Minh City, Ho Chi Minh City People's Committee (HCMC PC)Management Authority for Urban Railways (MAUR): 169.

Nguyen Anh Dung and W. Ross (2008). "Sustainable Urban Transportation Development: Prioritizing Bus Rapid Transit (BRT) in Ho Chi Minh City." *Environment and Natural Resources Journal* Vol.6, No.2.

Nguyen H and Doan D, An Outlook for Ho Chi Minh City public Transportation, *The Second International Conference of Thai Society for Transportation and Traffic Studies*, 2011

Pfaffenbichler, P. (2003). The strategic, dynamic and integrated urban land use and transport model MARS (Metropolitan Activity Relocation Simulator) - Development, testing and application. *Institute for Transport Planning and Traffic Engineering*. Vienna, Vienna University of Technology: 274.

Pfaffenbichler, P. C., G. Emberger, et al. (2010). "A system dynamics approach to land use transport interaction modelling: the strategic model MARS and its application." *System Dynamics Review 26(3)*.

Sterman, J. D. (2000). *Business Dynamics - Systems Thinking and Modeling for a Complex World*, McGraw-Hill Higher Education.