Public Transport System for Reducing CO_2 Emission and Traffic Congestion in Ho Chi Minh City

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Abstract: Urban development in developing city is a complex system, which brought both negative and positive impacts on social life. Ho Chi Minh City (HCMC) is located in south of Viet Nam and plays a vital role in its development. During the last decade, HCMC has enjoyed high rate of economic growth, changing society of city enormously. In contrast, there are negative impacts, like urban sprawl, traffic congestion, deterioration of air quality and living environment, which are now becoming the bottleneck of city development. To mitigate negative impacts especially from transportation system during economic development, HCMC decided to develop public transport system in which mass rapid transit (MRT) is a key. This study presents quantitative methodology which employed system dynamic approach base on cause-and-effect analysis for simulate population and economic development on congestion level calculation, and active-structure-intensity-fuel (ASIF) philosophy on CO_2 emission calculation. This study comprises business-as-usual scenario and MRT scenario. The differences between two scenarios are without or with MRT project and percentage of predicted modal share in the future. Moreover, the effectiveness of MRT operation in terms of carrying passengers in the future will be analysed to capture all uncertain circumstances of MRT project. Data using for this quantitative analysis were mainly borrowed from existing research and statistical data of HCMC from year 2002 to year 2009. The results of this quantitative analysis showed that, MRT scenario generated positive impacts on CO_2 emission reduction around 900,000 tons of CO_2 per year in 2025 and 1.1 million in 2035 in case MRT operates with 100 percent capacity. On the other hand, congestion level of city reduced around 26% in 2025 and 22% in 2035 in terms of MRT scenario. This study suggests that, HCMC should establish MRT and enhance share of public transport system by increasing accessibility, widening bus networks and controlling population growth.

Key Words : *Mass rapid transit, Economic growth, population, CO_2 emission, Traffic congestion level.*

1. INTRODUCTION

Ho Chi Minh City is the largest city in the south of Viet Nam in terms of economic condition and population density. The land area is around 2,095 km^2 including about 500 km^2 urbanize area[1)]. The most signification contribution of Ho Chi Minh City to Viet Nam is economic growth with the high GDP of around 17.8 billion USD and GDP per capita of 2.300 USD in 2009.

Like other developing cities in Asian region, Ho Chi Minh City is developing with high rate of urbanization, motorization and rapid land use change in the surrounding area. According to official statistics, city population increased steadily from 4.7 million in 1995 to more than 7.2 million in 2009.

Transportation system in HCMC is different from other large cities in Asian regions. People are highly dependent on motorcycle and not so much on public transport. In other cities at the same range of economic status -public transport share accounted to around 50 to 60 percent of urban trips while walking and bicycle riding, as well as using private automobiles and motorcycles is roughly 20 to 30 percent.

Conversely, in HCMC from 1996 to 2002, bicycle riding decreased drastically from 32 % to 13.6% whilst private motorcycle jumped up from 64% to 79%, while bus accounted for only 2%[2].

HCMC and other Vietnamese cities were dependent highly on motorcycle. Most of Vietnamese laborers have more than one job and have to pick up or drop off their children in school. Thus, motorcycle is the best alternative for a flexible and door to door service. There was an improvement in HCMC people's economic condition, as indicated by a sharp increase in motorcycle registration from 1.5 million in 2000 to 4.1 million in in 2009. The fast increase of motorcycle volume in HCMC caused overloaded of current road network, which had no significant improvement due to difficulties on capital investment and land acquisition. In the city, occurrence of traffic congestion usually happens twice a day and normally last more than 30 minutes. Moreover, this traffic congestion has negative impact especially -on travel time (normally double when travel from East to West and North to South of city during pick hours) -deterioration of air quality -and economic loss of around 2-3 percent[2]. There were roughly 100 people died every month in traffic accident, which occurred mostly in rural areas where speed limits are higher and presence of weak of traffic signals. There were more than 62% of NOx and 98.5% VOCs originated from traffic sources which has serious effects on human health[3].

2. PROBLEM STATEMENTS AND OBJECTIVES

It is clear that while HCMC city is achieving high economic growth it is not free from negative impacts such as traffic congestion, air pollution, and to some extent, economic losses due to increase on travel time. HCMC authorities expected that MRT system will ease that negative impact as well as contribute to stainable development of the city

Currently, there were still no studies on quantifying CO_2 emissions and the percentage of congestion level, which are likely to be reduced by establishing MRT system. To fill the gaps of other studies on transportation in HCMC, the main objective of this research is to quantify effects of developing public transport system, which can be categorized in two goals as follows i) Quantify reduction of CO_2 emission under various scenarios of public transport system development ii) Quantify congestion level of HCMC under various scenarios of public transport system development.

3. METHODOLOGY

This research applied quantitative methodology, in which system dynamic approach combine with Active-Structure-Intensity-Fuel (ASIF) philosophy.

SD is a computer-based simulation modeling methodology developed at the Massachusetts Institute of Technology (MIT) in the 1950s as a tool for managers to analyze complex problems. Its philosophy and methodology were developed by Jay W. Forrester since 1961 and was first introduced for the simulation of the urban system[4]. It is an evaluation tool in environmental studies, energy system, industrial system and environmental impact assessment. The SD approach is usually used in evaluating the performance of regional development[5], analyzing the relation between transport and land use[6] and estimating the environmental influence of industrial garden[7]. Besides, SD now is widely used for evaluating the effects of low-carbon urban system[8] and testing the various alternative public transport development scenarios on motorization and mobility in developing countries[9]. Jifeng et al (2008) [10] used system dynamic model to evaluate effects of policy on vehicle ownership in urban development of GDP, population and number of vehicles.. Generally, SD approach is more useful than other approaches when applied in evaluating developing trends of long-term dynamic behaviors because of its feedback structures and functional capacity under various parameters and initial inputs[11]. Therefore, SD is considered as one of the most appropriate tools for data processing and simulation of results, which is important for decision-makers in formulating policies

Mathematically, the basic structure of a formal system dynamics computer simulation model is a system of coupled, nonlinear, first-order differential (or integral) equations,

$$\mathrm{d}x(t)/\mathrm{d}t=\mathrm{f}(x,p) \tag{1}$$

Where x is a vector of levels (stocks or state variables), p is a set of parameters, and f is a nonlinear vector-valued function. Simulation of such systems is easily accomplished by partitioning simulated time into discrete intervals of length dt and stepping the system through time one dt at a time. Each state variable is computed from its previous value and its net rate of change $x'(t)$: $x(t) = x(t\text{-d}t) + \mathrm{d}t * x'(t\text{-d}t)$. The conceptual tools of system dynamic are feedback loop, stock and flow.

ASIF philosophy connects activities (passenger and freight travel) with structure (share by mode and vehicle type), with intensity (fuel efficiency), and with fuel type (see equation below) [12].

$$G = A * S_i * I_i * F_{ij} \tag{2}$$

Where G is the carbon emissions from the particular transport sector, A is total travel or freight activity (in passenger- or ton-kilometers), S is a vector of the modal shares, I is the modal energy intensity, and F_{ij} represents the sum of each of the fuels j in mode i.

Tables below shows steps for calculation CO_2 emission and traffic congestion level

Table 1: Step for calculating CO2 emission

I	Macroeconomic assumption by 2015, 2025 and 2035 (GDP and Population)	
II	Total travel demand	
III	Without MRT scenario (Business-as-usual scenario)	With MRT project
	1. Modal share (Motorcycle, car and conventional bus). 2. Emission factor of gasoline and diesel. 3. Average trip length by each mode. 4. Average occupancy of motorcycle, car and bus. 5. Fuel economy of motorcycle, car and bus. 6. Technology improvement factor	1. Modal share (Motorcycle, car, conventional bus **and MRT**). 2. Emission factor of gasoline and diesel. Average trip length by each mode. 3. Average trip length by each mode. 4. Average occupancy of motorcycle, car and bus. 5. Fuel economy of motorcycle, car and bus. 6. Technology improvement factor 7. Total length of MRT construction. 8. Emission factor of 01 kilometer of MRT construction in HCMC. 9. Emission factor of 01 MRT user.
IV	CO_2 emission from urban transportation.	

Table 2: Steps for calculating traffic congestion level

I	Macroeconomic assumption by 2015, 2025 and 2035 (GDP and Population)	
II	Total travel demand in pick hour (number of urban trips)	
III	Without MRT scenario (Business-as-usual scenario)	With MRT project
	1. Modal share (Motorcycle, car and conventional bus). 2. PCE per vehicle (Motorcycle, car and conventional bus) 3. Average occupancy	1. Modal share (Motorcycle, car, conventional bus **and MRT**). 2. PCE per vehicle (Motorcycle, car, conventional bus and MRT) 3. Average occupancy
IV	Total passenger cars equivalent (PCE) demand in pick hour	
V	Total PCE supplied by urban road network	
VI	Traffic congestion level	

Traffic congestion level is the results of interaction between transport demand and transport supply. The main steps to calculate traffic congestion associated with two transport scenarios are shown on table below

This quantitative analysis consists of a lot of variables and 02 sub models of economic and population leading to a more complicated calculation. To simplify calculation and data control procedure, Powersim Studio software was used.

4. SCENARIOS SETTING

The first scenario, Business As Usual (BAU) adopted the current trend of urban transport. In this alternative, it was indicated that the public transport system in HCMC would be served by the conventional bus system. The local authority regarded bus system as the main public transportation with the assumptions that the share of public transport will keep increasing in the future. It was also assumed that, car ownership would increase steadily due to escalation of income to some extent that motorcycle riders will use the car instead. Walking and biking were also expected to decrease continually. Bicycle, on the other hand will be phased out in the city center in year 2015 and 2025.

The second scenario is the MRT scenario wherein the implementation of mass rapid transit (MRT) in HCMC was considered. In 2007, the prime minister of Viet Nam approved the transportation master plan for HCMC up to 2025 when in fact, the MRT system was included. Table below summarizes modal share used as input for model calculation.

Table 3: Modal share (%) of vehicles of two transportation scenarios

			BAU scenario		**MRT scenario**	
	2002	**2007**	**2015**	**2025**	**2015**	**2025**
Bus	2.1	3.6	16	22	25	35
Car	1.6	4.8	17	29	15	18
Motorcycle	79	89.3	67	49	58	38
Bicycle	17.3	2.3	0	0	0	0
Rail	0	0	0	0	2	9

Source: Modified from Houstran (2004) [2] and ADB (2007)[13].

5. MODEL VALIDATION

To validate the proposed model, outputs for the years 2007, 2008 and 2009 were calculated using series of data from year 2002 to year 2006. It is insignificant to validate proposed model using limited points and short period time series. However, it is difficult to collect valid data. The output value of population and GDP were compared with population and GDP were compared with reported data to determine possible errors (see **Table 4**)

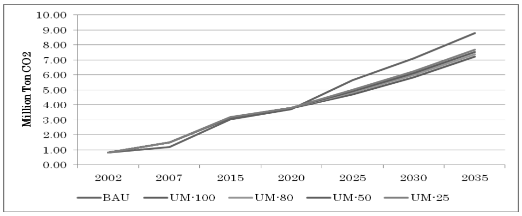
Table 4: Comparison of model outputs with reported data

		Model output	Reported data	Error
2007	Population (million)	6.3	6.4	-0.92%
	GDP (billion USD)	14.2	14.7	-3.93%
2008	Population (million)	6.5	6.7	-2.16%
	GDP (billion USD)	16.3	16.3	-0.43%
2009	Population (million)	6.7	7.2	-7.28%
	GDP (billion USD)	18.7	17.8	4.40%

According to the results, the errors of population and GDP in year 2007 and 2008 are all less than 5%. Therefore, it is effective to simulate the proposed model.

6. RESULTS AND DISCUSSION

Firstly, BAU scenario should be tested using modal share input data for calculation. Secondly, BAU scenario modal share should be replaced by MRT scenario. On one hand, only people who are using buses and other intermediate public transportations can shift to use MRT system. On the other hand, MRT passengers can still use their own vehicles or other mode of public transportation. To capture all these circumstances, effectiveness of MRT operation should be tested by using the efficiency factor of 100%, 80%, 50% or 25%



- BAU: Business as Usual scenario.
- UM-100: MRT scenario with assumption that MRT operate with 100 percent capacity.
- UM-80: MRT scenario with assumption that MRT operate with 80 percent capacity.
- UM-50: MRT scenario with assumption that MRT operate with 50 percent capacity.
- UM-25: MRT scenario with assumption that MRT operate with 25 percent capacity.

Figure 1: CO_2 Emissions under various scenarios

Figure 1 showed results of CO_2 emission under various scenarios.From 2007 to 2015, the first stage of MRT construction, CO_2 emissions of BAU scenarios was lower than MRT scenario even MRT operate with 100 percent capacity. However, from year 2020 to 2035, trend of CO_2 emission started to change. BAU scenario generated more CO_2 emission than MRT scenario even MRT operates with only 25 percent of capacity. The quantities of how much CO_2 saved under various scenarios are shown on **Figure 2** and **Figure 3**.

From year 2007 to 2020, MRT scenario generated negative impact on CO_2 emission compare with BAU scenario. In this period of time, construction of MRT have no significant impact on CO_2 reduction, and to some extent, it also generates more than 250,000 ton CO_2 per year. In contrast, in 2025, MRT scenario have positive impact on CO_2 reduction in a long-term perspective, Considering the effectiveness of MRT operation, say MRT system operates 100% capacity, MRT scenario can save around 900,000 ton CO2 per year or nearly 15% reduction. For the 25% operation capacity, it is estimated to save more or less 500,000 tons per year or nearly 10% reduction. Assuming the average CDM carbon price of $US10 per ton, the reduced emission can be valued at $US9 million per year (100% capacity) and $US 5 million (25% capacity). If time and fuel saving are included, monetary benefits from MRT system will be higher.

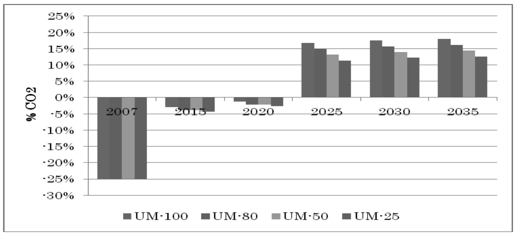


Figure 2: CO_2 (%) saved under various scenarios

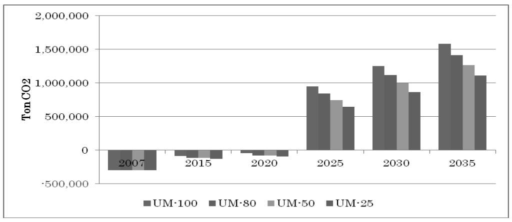


Figure 3: Quantities of CO_2 emission saved under various scenarios

Figure 4 shows detail of CO_2 emission comparative values of HCMC and other Asia citites like

Bangkok, Manila, Jakarta and Ha Noi. By 2030, MRT expansion in Bangkok and Manila could enhance CO_2 saving of both cities. Bangkok could save 1.2 million tones of CO_2 emission and Manila could save 1.5 million tons of CO_2. Besides that, HCMC, Ha Noi and Jakarta would achieve CO_2 emission reduction after 2025. If HCMC desires to catch up with CO_2 emission saving as in the cases of Bangkok or Manila, the importance of finishing the whole system on time in 2025, as mentioned in approve Master Plan, the government should take serious actions and political will.

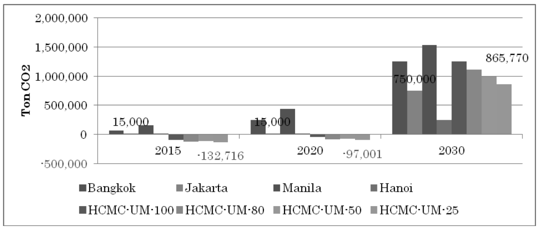


Figure 4: Comparative results of CO_2 saving by implementing MRT system in Asia cities

Another issue of HCMC is serious congestion on road network. Proposed model also calculated congestion level of the city under various scenarios. Calculation results are shown on **Figure 5**.

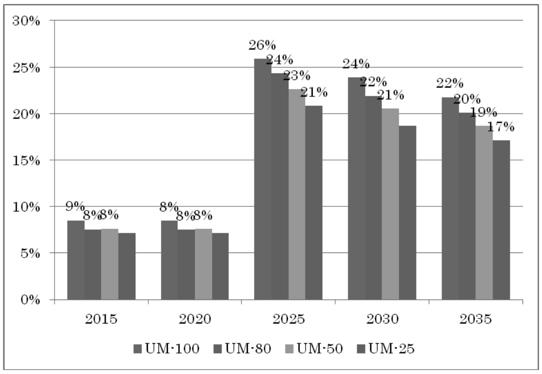


Figure 5: Congestion level reduction (%)

When MRT system starts to operate in 2015, traffic congestion decreases steadily because 9% of urban trips will be transported by MRT. MRT have exclusive right-of-way. Therefore, it would not add to the number of vehicle travelling on urban road system. In 2025, when whole MRT system will be completed, high level of reduction of traffic congestion reduction is expected. But in the succeeding years, if modal share of MRT still keep constant at 21% , traffic congestion reduction level would be lower than expected. It can be explained by the increase of travel demands and economic growth resulting to possible increase of private vehicle ownership. Aside from the reduction of traffic congestion level in the city, MRT system could also boost economic condition of the city due to other indirect values the system can provide such as time saving, reduction of fuel consumption, among others. From year 2035 onwards, the benefits of GDP become clearer and the city is expected to save around 5 billion US$ per year if MRT system operates in full capacity**.**

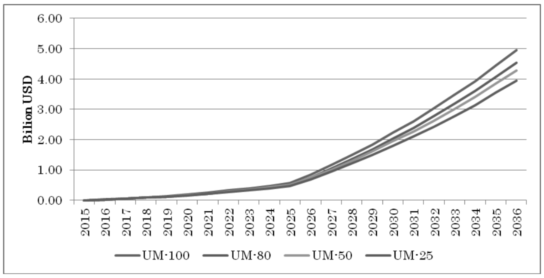


Figure 6: GDP saved under various scenarios.

7. CONCLUSION AND LIMITATION

Investment on MRT system will generate negative effect on CO_2 emission compare with BAU in short term, but positive effect on CO_2 emissions, in long term perspective. In 2035, 1.5 million ton CO_2 (18 percent reduction) will be saved in case of MRT operate 100% capacity, and 1.1 million ton CO_2 (11 percent reduction) will be saved in case of MRT operate 25% capacity.

Cities implemented MRT earlier and continue to expand their system will result in to higher CO_2 emission reduction (Bangkok and Manila cases).

Implementation of MRT system will be able to ease traffic congestion, 26 and 21 percent reduction in 2025 with 100% and 25% MRT capacity. Reduction of congestion level enhance economic of HCMC, GDP will be benefit 5 billion USD in 2035

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