A study on motorcycle-based motorization and traffic flow in Hanoi city: toward urban air quality management

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Abstract

Rapid motorcycle-based motorization due to the economic growth presents severe environmental issues in Hanoi city, Vietnam. This paper discusses the required policies and scientific research needed to move towards urban air quality management in Hanoi. The effect of the taxation system, the demand shift from motorcycle to bus, and signal systems that are easily implemented in the short term on the urban air quality are analyzed. The motorcycle taxation system has little effect on the regulation of the growth of ownership. Improvement of the bus service level does not lead to a great increase of bus share. The signal system cannot make the traffic flow more environmentfriendly. Therefore, the measures for decreasing emission factors by technological approaches such as inspection systems and attachment of a catalyst should be implemented urgently as well as the improvement of the signal system in Hanoi.

Keywords: motorcycle penetration, modal shift, motorcycle traffic flow, air quality management.

1 Introduction

Motorization has gradually been going on in last two decades in developing countries, especially in Asian countries. Urban areas, especially mega-cities in this region have suffered from the serious air pollution problem accompanied with the motorization. We consider that this problem can be explained by the following two major reasons.

Firstly, many second-hand automobiles and motorcycles that already operated in many years have been imported from developed countries, and have



used again in this region. Most developing countries did not introduce any legal system to inspect and maintain the engine quality. Besides, the legal frameworks and technological systems to introduce the environment-friendly fuel that contains little sulphur and lead are still in insufficient level. These situations result in higher level of vehicle emission factors such as particle matters (PM), sulphur oxides (SO_x), and so on.



Figure 1: Population and motorcycle ownership growth in Hanoi (source: Hanoi Statistical Yearbook 1999 & 2000, Hanoi Traffic Police Department).

Secondary, most mega-cities in this region have insufficient road network as well as mass transit network to cope with rapid increase of travel demand due to the economic growth. Therefore, widely distributed heavy traffic congestion occurs in whole urban area. Frequent accelerations and decelerations by each vehicle in relation to low speed traffic due to traffic congestion result in higher emission level.

This article discusses the required policies and scientific researches toward urban air quality management in Hanoi city, Vietnam. After the Doi Moi policy that started in 1986 and introduced the market economy system, motorization by motorcycle started. The rapid growth of motorcycle penetration was supported by the economic growth and the introduction of motorcycle made in non-communist countries such as Japan. Fig.1 shows the relationship between population and motorcycle ownership from 1990 to 2002 in Hanoi. The growth rate of ownership exceeds that of population and is more than 20% in last few years and traffic congestion problem have become serious gradually due to insufficient road network and traffic operation systems. These result in the progress of air pollution. The Asian Development Bank reported that concentration of several pollutants exceeds the air quality standards from the observation at main intersections in Hanoi and Ho Chi Min city [1].

The motorization by automobile will be expected in next decade due to the successive economic growth. On the other hands, motorcycle will still be the



major private transport mode in central district of Hanoi for at least one or two decades due to insufficient road network and lack of parking spaces. Guiding appropriate motorcycle penetration and use, and implementing appropriate traffic control are the key issues to make urban air quality better one. These two issues are dealt in this article.

The policies for mitigating air pollution by motorcycle source in Hanoi are discussed in Section 2. We classify the factors affecting the air pollution and required policies into four categories, technology, penetration, use and operation. The effect of motorcycle taxation system as a penetration control measure on the motorcycle ownership is discussed in Section 3. The effect of bus service improvement on modal shift from motorcycle to bus is discussed in Section 4. The effect of traffic signal system on the improvement of traffic flow is analyzed in Section 5. The conclusions are described in Section 6.

2 Policies for mitigating air pollution from motorcycle source

2.1 Emission factors

The air pollution level is the result by aggregating discharged emission gases from all automobiles and motorcycles in the streets. This is because emission factor of each vehicle and motorcycle is the most important and fundamental variable to access the air pollution level.

The emission factor is expressed by total grams of discharged gas per 1 km run. It is measured by driving cycle that consists of four vehicle movement patterns, acceleration, constant speed, deceleration and stop, and represents the typical automobile movement on the real road network. The chassis dynamometer is used to measure the emission factor precisely. However, it is unrealistic to measure the emission unit of all automobile and motorcycles using this system. The remote sensing technology from roadside using remote sensing device (RSD) is developed in the United States to improve measuring condition recently. The RSD can detect the emission factor of several pollutants simultaneously, and have high potential to make a research more precise and more efficient [2].

The emission factor has been decreased gradually due to the technological progress. As to motorcycle, a four-stroke engine that never requires lubricant and is more environment-friendly was introduced and emission factor was decreased. It is remarkable that the share of four-stroke engine exceeds 90% in Vietnam [1]. On the other hands, this increases as age of automobile or motorcycle increase, and in case engine maintenance and petrol quality is poor. Zachariadis proposes the macroscopic methodology to analyze the motor vehicle emission considering the aging and technological substitution, however numerical examination is not yet conducted [3].

The number of researches dealing the emission factor of motorcycle is limited except in Taiwan. Tzeng and Chen develop the motorcycle driving cycle in Taipei city by field observation, reflecting the motorcycle characteristics of high average acceleration and deceleration, frequent change between



acceleration and deceleration, and low travel speed [4]. They also compare the emission factors of two-stroke engine with those of four-stroke engine, and those by European cycle with those by proposed cycle though the experimental measurement of 45 motorcycles. Chen *et al* continue the investigation of motorcycle emission factors based on proposed driving cycles [5]. Tsai *et al* estimate the emission factors of new and in-use motorcycle using European driving cycle [6]. The difference of emission factors by five patterns of motorcycle movement is also examined. However, the standard deviations of several pollutant emission factors are very large in these studies.





2.2 General classification of factors affecting air pollution

Fig. 2 explains the relationship among the factors that affect the air pollution status. Air pollution problem is recognized in case the concentration of focused pollutant is at higher level. The pollutant concentration is the result of the aggregation of discharged emission gases from automobiles and motorcycles as already described. Therefore, it is important to know the factors that directly affect the level of emission factors.

The progress and the improvement of the vehicle related technologies are the most fundamental determinants to reduce the emission factors. These technologies include the development of environment-friendly engine and catalyst, the improvement of fuel quality, and so on.



The consideration of the vehicle penetration status is inevitable to assess the potential of air pollution. The total number of vehicles registered is the largest determinant to the total discharged emission gases, of course. Not only total volume but also the composition of vehicle type and age are also important. Vehicle with large engine capacity and aging vehicle make the emission factors larger. The sort of fuel affects the pollutant to be focused.

category	policy	objective		
technology	environmental regulation	introducing low emission motorcycle		
		promoting attachment of calalyst		
		improving fuel quality		
	inspection system	maintaining engine quality		
	police enforcement	maintaining engine quality		
penetration	environmental regulation	promoting aging motorcycle retirement		
		introducing quality standard for second-hand motorcycle		
	motorcycle registration system	regulating appropriate penetration growth		
	motorcycle taxation system	regulating appropriate penetration growth		
		upgrading level-of-service of road network		
		promoting low emission motorcycle penetration		
	land use control	decreasing trips and distance traveled by motorcycle		
use	fuel taxation system	decreasing trips and distance traveled by motorcycle		
		upgrading level-of-service of road network		
	land use control	decreasing trips and distance traveled by motorcycle		
	promotion of public transport	decreasing trips and distance traveled by motorcycle		
operation	traffic control system	increasing average travel speed		
		decreasing acceleration and deceleration frequency		
	road network extension	increasing average travel speed		

 Table 1:
 Possible policies for mitigating air pollution.

The vehicle use status is the third factor. The total discharged emission gases decrease if the total distance travelled decreases because the unit of the emission factor is g/km as already explained. They also decrease if the number of trips by vehicle decreases (e.g. shift to public transport). The urban structure may be the determinant because it closely relates to the vehicle use.

The vehicle operation is also important factor. The emission factors are the function of travel speed, and they decrease if average travel speed increases. The traffic control system may be the determinant to increase average travel speed.

This study highlights the measures for motorcycle penetration control, demand shift to bus service and motorcycle operation control as the key factors for mitigating the air pollution in Hanoi.

2.3 Possible policy set in Hanoi

Consequently, the policies for mitigating air pollution from motorcycle source listed in Table 1 are classified into four categories corresponding to the factors in Fig. 2.

Of course, technology is the most influential factor to mitigate the air pollution by decreasing the emission factor dramatically. The introduction



regulation more severe environmental regulation facilitates not only the development of low emission motorcycle and electric motorcycle but also the improvement of fuel quality. The inspection system is also important to maintain the engine quality and keep the emission factor at better level of operated motorcycle. However, it will take longer time to make these policies effective in Vietnam. Vietnam government now tries to implement the action plan including introduction of tight emission standards and inspection system to reduce vehicle emissions toward 2010 [1]. The police enforcement at roadside to punish the driver using high emission motorcycle may be effective.

Actually, motorcycle penetration control policies are the most powerful ones to mitigate the air pollution. The most indispensable policy is to eliminate the high emission motorcycle such as aging motorcycle and low quality motorcycle. The motorcycle registration system should be introduced to monitor the motorcycle ownership by household and to make the taxation system efficient. Hanoi City Government (HCG) introduced a policy to prohibit the motorcycle registration in four districts located at city center temporary in 2003, however this was not effective due to the loose registration system [7]. The introduction of the taxation system for ownership and registration is also inevitable not only to regulate the motorcycle penetration growth but also to ensure the fund for extending road network and introducing public transport services. HCG also introduced the motorcycle registration tax (about 3 to 6 % of market price) and import tax (100% of market price) in 2003 [7]. The taxation system that can promote the retirement of aging motorcycle is important because of the specific market structure in which selling price of used motorcycle made in Japan does not decrease much compared with purchasing price.

Generally speaking, it is very difficult to control the penetration unless the strong policies such as prohibition of the registration and quota system like Singapore. Therefore, to lead appropriate use of motorcycle may be the most important and effective for mitigating the air pollution. The higher tax for fuel sales will discourage the use of motorcycle. It is of course important to make motorcycle users shift to the use of public transport. HCG improved the bus service level from 2001 to encourage the modal shift from motorcycle [7].

The emission factor is sometimes expressed by the function of travel speed. It decreases if average travel speed increases and it increases if average travel speed reaches high-speed domain as commonly known. The introduction of traffic signal system at intersections is rapidly required in Hanoi. The extension of road network in advance is also important to mitigate serious traffic congestion expected after automobile penetration.

The sequence of the policies should be considered to reduce discharged emission gases. The policies to regulate the motorcycle penetration and use may keep the increase of emission at slow level in shorter terms. In addition, the improvement of traffic control system is highest priority. Therefore, we discuss on the possibility of taxation system as a motorcycle penetration control measure, the possibility of demand shift from motorcycle to bus, and the possibility of signal control system in next chapters.



Of course, the inspection facilities should be developed in these years to strengthen the inspection system. Urban structure is also significant determinant for ownership and use. The rapid sprawling of urban area has already started and been worried in Hanoi. Appropriate land use control in suburban area is persuaded in long term.



Figure 3: Annual number of purchases in the sampled households.

3 Effect of taxation system on motorcycle penetration

3.1 Household survey of motorcycle ownership

We conducted the original survey on the households' motorcycle ownership in Hanoi in September 2003 to know the historical decision making process of motorcycle transactions (purchase, dispose and replace) and their relating data (purchasing and selling price, the reason, total household income at that time, etc.) from 1990 to 2002 [7]. The data from 299 households are obtained.

Fig. 3 shows the annual number of purchases in the sampled households. The number of purchase for second and third motorcycles in household is obviously increasing in late 1990s due to the economic growth and the introduction of cheaper motorcycle made in China. The total number of transactions is 626, and 84% is for purchase. The most interesting result is that the average purchasing price of motorcycle is more than three times of annual income.

Fig. 4 shows the composition of vintage and engine capacity classified by first, second and third motorcycle in the household. The share of used motorcycle for second and third motorcycle becomes smaller than that for first motorcycle, however still exceeds 20%. In environmental viewpoint, we should pay attention that motorcycle with 100cc engine becomes popular for second and third motorcycle that was recently purchased. The motorcycle with larger engine capacity that can run faster is preferable due to the extension of urban area,



however the environmental load becomes larger on the road in downtown district with lower travel speed.







3.2 Model analysis of growth rate of motorcycle penetration

We model the motorcycle purchasing behavior by dynamic discrete choice framework considering the state dependence. In the model, household decides whether to purchase a motorcycle or not annually comparing the utilities of purchasing and non-purchasing behavior. The utility is expressed by the linear function of several explanatory variables such as household size, motorcycle price, households' annual income, expected utility of motorcycle expressed by motorcycle type (simultaneous choice of vintage, brand and engine capacity) choice model. The motorcycle type choice model is also estimated by our data (in detail, see [7] and [8]).

Table 2 shows the result of the sensitivity analysis of annual growth rate of motorcycle ownership is conducted by using our model. The successive

economic growth results in the highly growth rate. We can understand easily that the total discharged emission gases will increase awfully if emission factors do not decrease dramatically and if traffic congestion becomes serious due to the insufficient development of road network. The strong policy to make motorcycle equip catalyst in the exhaust pipe is required immediately.

Year	Job increase rate (%)*	GDP/cap increase rate (%)*	Annual growth rate of ownership (%)
2005	11.0	9.2	17.0
2010	10.1	9.7	20.5
2015	9.3	9.7	23.2
2020	8.5	8.7	25.2

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*source: Ministry of Transport, Vietnam (2001)





3.3 Impact of taxation system on motorcycle penetration

We also analyze the possibility of the introduction of new taxation system for ownership in Hanoi. The effect of two taxes, raising the registration tax and annual ownership tax, on the annual growth rate of motorcycle ownership is examined by the sensitivity analysis using our model.

Fig.5 shows the result of the relationship between rate of registration tax and the annual growth rate. Surprisingly, the annual growth rate only decreases in 7% although tax equivalent to 100% of market price is imposed. The registration tax may not be effective to regulate the motorcycle penetration.

Fig. 6 shows the result of the relationship between rate of annual ownership tax and the annual growth rate. The annual growth rate only decreases in 7%

although tax equivalent to 5 million VND (the currency of Vietnam), that is one third or one fourth of average market price, is imposed. Annual ownership tax may be more effective than registration tax if household hold a motorcycle for a long time. However, we may conclude that motorcycle taxation system has a little effect to regulate the growth of motorcycle ownership.





4 Possibility of demand shift from motorcycle to bus

4.1 Questionnaire survey

We conducted the questionnaire survey on attitude toward the bus service during October of 2002 in Hanoi. The samples of totally 1,200 individuals were selected from whole Hanoi area.

We asked the evaluation of 10 service factors of bus system, driver's service, frequency, convenience, safety, punctuality, fare level, operation speed, distribution of bus stops, transferring condition and ticket vending. Each respondent is requested to reply the dissatisfaction level for service factor by 5 categories, very good, good, fair, bad and very bad. Some statistical analyses suggest that respondents complain about the total convenience of bus service. Especially, the coverage of bus network and accessibility to bus stop are the vital factors to promote the use of bus service.

4.2 Person trip survey for modelling mode choice behavior

We also conducted the person trip survey from same 1,200 samples. In the survey, respondents reply all trips generated on surveyed day with their origin and destination zone that are set in advance, purpose, departure and arrival time, mode used, and so on.





Figure 7: Change of choice probability of bus by time and cost difference.

The mathematical model that can analyze the effect of policy relating to the improvement of bus service on the mode shift from motorcycle to bus is required. Binary logit model is applied to the modal shift model in Hanoi. The utility function is expressed by the linear function of travel time, travel cost and several attributes as follows:

$$P_i^b = \frac{1}{1 + \exp V_i} \tag{1}$$

$$V_i = -0.053 \times \left(T_i^c - T_i^b\right) - 0.000222 \times \left(C_i^c - C_i^b\right) + 2.62\delta_i$$
(2)

where caption *b* expresses bus, caption *c* expresses motorcycle, *i* is individual, T_i^m is travel time (minutes) of transport mode *m* for *i*, C_i^m is travel cost (VND) of *m* for *i*, and δ_i is dummy variable for office worker and student. All parameters are statistically significant and the model fitness indices are all large enough. Unfortunately, frequency of bus service which is important policy variable is not significant because travel time data includes the waiting time at bus stop and the correlation between frequency and travel time is so high.

4.3 Impact of bus service improvement on modal shift

The modal shift model we estimate includes travel time and travel cost as explanatory variable. Therefore, we can calculate the effect of the policies that vary travel time and fare on the choice probability of bus.

Fig. 7 shows the result of sensitivity analysis that explains the change of choice probability of bus by the time and cost differences with motorcycle.

When both cost and time differences are zero, the choice probability of bus is about 6%. When the travel time of bus service is 30 min shorter than that of motorcycle and the travel cost of bus service is 5,000 VND cheaper that of



motorcycle, the choice probability of bus service exceeds 50%, however this situation is unrealistic. According to our data obtained, the average time difference between bus and motorcycle is 26 min, and the average cost difference is 833 VND, the choice probability of bus service is only 3 %.

The sensitivity analysis suggests that Hanoi people are likely to choose motorcycle for their trips. Any policy to improve the competitiveness of bus service such as frequent service, smooth operation and fare reduction is not very effective to increase the modal share of bus. It is not feasible to reduce the emissions dramatically by improving the service level of bus. However, if the usefulness of bus service is well recognized by Hanoi people, we can make the modal shift model more sensitive.



Figure 8: Motorcycle traffic flow at unsignalized intersection in Hanoi.

5 Effect of signal system on motorcycle traffic flow

5.1 Survey on motorcycle traffic flow at intersection

In Hanoi, many of intersection are not signalized yet. In addition, there is no specific rule of driving manner at intersection. Therefore, traffic flow becomes chaotic as seen in Fig. 8. At signalized intersection, conflict between straight flow and left turn flow occurs frequently because simple signal system with only two phases is introduced.

We conducted the survey on motorcycle traffic flow at signalized and unsignalized intersection in Hanoi in September 2004. The time-space data of focused motorcycle is obtained using the image processing technology from videotaped traffic flow images, and is smoothed by filtering technique. Travel speed, acceleration and angular velocity of 100 motorcycles are coded in every one-sixth second from the time entering intersection to the time exiting intersection at both intersections.







5.2 Basic traffic flow characteristics

We should treat the motorcycle traffic flow as two-dimensional movement. However, there is no theory to explain this movement yet.

We hypothesize the existence of personal space to explain the twodimensional motorcycle movement. The personal space is the domain which every driver wants to secure for safe and comfortable driving. This becomes larger if travel speed increases. It is assumed that driver tries to change his speed or direction when personal space dramatically decreases or increases. However, we have much difficulty in determining the domain from observed data in general. Therefore, we substitute the occupancy for the personal space in this study in the assumption that the differentiation of personal space is same as that of occupancy. The occupancy is calculated by the Voronoi tessellation.

Fig. 9 shows the typical case of relationship between acceleration and occupancy change rate for some motorcycle running straightforward. Motorcycle accelerates as occupancy change rate increases and decelerates as it decreases. The occupancy will change largely and frequently in chaotic traffic flow at unsignalized intersection, and frequent acceleration and deceleration that increase the total volume of pollutants occur.

Fig. 10 shows the traffic flow status at signalized intersection. The lines express the path of motorcycle. The path is not straight and meandering in many cases. We can observe typically that several left-turn motorcycles form a group and a group enters into the straightforward traffic flow forcibly. The meandering of straightforward traffic flow and serious conflict are caused by this behavior. These phenomena result in the decrease of travel speed and increase of distance travelled at intersection.

5.3 Comparison of traffic flow indices between signalized and unsignalized intersection

The important indices in traffic flow analysis for evaluating the environmental load are frequency of acceleration and deceleration, travel speed, distance



travelled. Therefore, we compare the difference of these indices between signalized and unsignalized intersection.



Figure 10: Motorcycle traffic flow at signalised intersection in Hanoi.



Figure 11: Distribution of speed group at both intersections.

Fig. 11 shows the distribution of travel speed group at signalized and unsignalized intersection. The share of speed less than 3 m/s exceeds 70% at unsignalized intersection. Although the average speed at signalized intersection is much larger than that at unsignalized intersection, it is still at lower level than expected. The share of speed less than 3 m/s still exceeds 40% at signalized intersection. Appropriate phase setting of signal system (e.g. left-turn specific phase) should be introduced to avoid unnecessary braking by straightforward motorcycle flow.

Fig. 12 shows the distribution of acceleration group at signalized and unsignalized intersection. More than 25% of observation cases are decelerating

behavior at unsignalized intersection. The difference of the distribution between signalized and unsignalized intersection is not significant. The change of signal phase setting is of course effective to decrease the share of deceleration.



Figure 12: Distribution of acceleration group at both intersections.

We also check the increase of distance travelled by the meandered movement. Average increase of distance travelled at signalized intersection is 0.61 (m), while that at unsignalized intersection is 1.5 (m). Therefore, total distance travelled is expected to increase 5% at unsignalized, 2% at signalized intersection. The specific traffic control system and driving manner in which motorcycle never meander may be required to decrease total distance travelled at intersection completely.

6 Conclusions

In this paper, we discuss the required policies and scientific researches aiming at the consideration of appropriate urban air quality management in Hanoi. The effect of taxation system, demand shift from motorcycle to bus, and signal system that are easily implemented in short term on the urban air quality is analyzed.

Firstly, the policies for mitigating air pollution by motorcycle source in Hanoi are discussed. We classify the factors affecting the air pollution and required policies into four categories, technology, penetration, use and operation. We point out that the possibility of taxation system as a motorcycle penetration control measure, the possibility of demand shift from motorcycle to bus, and the possibility of signal control system are pursued in shorter term.

Secondary, the effect of motorcycle taxation system as a penetration control measure on the motorcycle ownership is discussed by conducting an original household survey. We understand that the penetration share of used motorcycle



still exceeds 20% for second and third motorcycle in the household, and that of larger engine capacity increases recently. Judging from the sensitivity analysis using the analytical model of households' annual motorcycle transaction choice, we conclude that motorcycle taxation system has a little effect to regulate the growth of motorcycle ownership.

Thirdly, the effect of bus service improvement on modal shift from motorcycle to bus is discussed by conducting an original questionnaire and person trip surveys. The coverage of bus network and accessibility to bus stop are the vital factors to promote the use of bus service. We conclude that any policy to improve the competitiveness of bus service such as frequent service, smooth operation and fare reduction is not very effective to increase the modal share of bus judging from the sensitivity analysis using the analytical model of trip makers' mode choice behavior.

Fourthly, the effect of traffic signal system on the improvement of traffic flow is analyzed by conducting a field observation at signalized and unsignalized intersection and comparing the characteristics of traffic flow of both intersections. We observe that group of left-turn motorcycles enters into the straightforward traffic flow forcibly and results in meandering of straightforward traffic flow even at signalized intersection. We conclude that it is very difficult to make traffic flow smoother only by introducing a signal system with two phases at intersection by checking some indices of traffic flow characteristic.

Consequently, it is almost unexpected to decrease the total discharged emission gases and to improve air quality by implementing the policies and measures we focus in Hanoi. However, it is expected that appropriate phase setting of signal system may avoid unnecessary braking at intersection. In addition, the measures for decreasing emission factors by technological approaches such as inspection system and attachment of catalyst should be implemented urgently.

References

- [1] The Asian Development Bank, Integrated Action Plan to Reduce Vehicle Emissions in Viet Nam, RETA 5937, 2002.
- [2] Mazzoleni, C. et al, Correlation between automotive CO, HC, NO and PM emission factors from on-road remote sensing: implications for inspection and maintenance programs, Transportation Research Part D, **9**, pp.477 496, 2004.
- [3] Zachariadis, T., Ntziachristos, L. & Samaras, Z., The effect of age and technological change on motor vehicle emissions, Transportation Research Part D, **6**, pp.221 227, 2001.
- [4] Tzeng, G. & Chen, J., Developing a Taipei motorcycle driving cycle for emissions and fuel economy, Transportation Research Part D, **3(1)**, pp.19 27, 1998.
- [5] Chen, K. S. et al, Motorcycle emissions and fuel consumption in urban and rural driving conditions, The Science and Total Environment, **312**, pp.113 122, 2003.



- [6] Tsai, J. et al, Air pollutant emission factors from new and in-use motorcycles, Atmospheric Environment, **34**, pp.4747-4754, 2000.
- [7] Vu, T. A., A Study on Household Motorcycle Ownership Behavior in Hanoi City, Master thesis in Department of Civil Engineering, The University of Tokyo, September 2004.
- [8] Vu, T. A. and Shimizu, T., Modeling of household motorcycle ownership behavior in Hanoi city, Submitted to Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, 2005.

