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Analyzing Potential Impacts of Motorcycle Travel Demand Management Using an Activity-Based Travel Demand Model for Ho Chi Minh City, Vietnam

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Abstract

This paper analyses the potential impacts of motorcycle travel demand management strategies for Ho Chi Minh city, a motorcycle dominant city of Vietnam. Four scenarios on managing the use of motorcycle are analyzed using an activity-based travel demand model called FEATHERS-HCMC. The model is adapted from the FEATHERS model developed for Flanders, Belgium and based on the household travel survey in Ho Chi Minh City. The modeling framework of FEATHERS-HCMC is a combination of the heuristic rules and the econometric models. The simulation results suggest that a strong enforcement on motorcycle use would significantly reduce motorcycle trips and induce the rearrangement of location and time-of-day for daily activities. These results provide empirical evidence that shows several advantages of using activity-based travel demand models comparing to the current four-step models. FEATHERS-HCMC is a promising tool to support decision-making process for assessing sustainable transportation policies, not only for HCMC but for other regions with similar characteristics.

Keywords: activity-based travel demand model; motorcycle travel demand management; motorcycle dependence; travel demand;

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1. Background

Motorcycle is the most popular means of transport in many Asian cities due to its flexibility and reasonable costs. Although daily travels of individuals are benefited from using this mode of transport, motorcycle significantly contributes to traffic accidents, air pollution and congestion in those cities [1]. Motorcycle travel demand management (TDM) should be considered to shift motorcycle users to more sustainable modes. There have been efforts from the government to control motorcycle ownership in some Asian cities. For example, the big cities in Vietnam have imposed higher vehicle registration fees than other cities/provinces. However, this measure has not reduced the number of registered motorcycles in these cities [1]. The restriction of motorcycle registration in four central districts of Hanoi in 2003 also failed in two years after implementation. It was found to be more difficult in controlling motorcycle ownership than the restriction on its usage [1,2].

In China, the prohibition of motorcycle has been successfully implemented in many cities [3,4]. Beside the strong power of the government, the low share of motorcycle trips is considered important factor contributing to the success of this policy. This measure has also been adopted for the center of Yangon, Myanmar at early stage of motorcycle penetration since 2003. Studies on the impact of motorcycle ban policy showed that although the ban has improved local air quality and securities [3], travel cost of motorcycle users increase [5]. In the context of developing countries where most motorcycle users are at low-income level, the implementation of motorcycle TDM measures may have wide effects on the daily urban life due to the fact that transportation has an important role in urban economic development [6]. Travel demand forecasting tool, therefore, should be available to support the policy making process. Inaba and Kato [7] developed a comprehensive modeling framework to evaluate the impact of motorcycle ban policy on the change of vehicle ownership for Yangon, Myamar. Yagi et.al [8] also developed an activity-based travel demand model (ABM) to support the analysis of emission impacts under various TDM policies of Jakarta, Indonesia. Meanwhile, although urban transport is a crucial issue in Vietnam's big cities, the majority of the studies focus on investigating and evaluating motorcycle travel demand addressed mode choice behavior and its direct impact on modal shift [9,10].

At present, the urban planning process in developing countries including Vietnam mainly relies on the popular four-step models (FSM) or a sketch model which center around a mode choice model [11]. However, the time of day of the trips is not modelled in FSMs. Besides, the sequence of destination and mode choice models in which mode choice is conditional on destination choice is fixed. Without level of service variable in destination choice model and inter-connection between models, the FSMs cannot capture the change of location choice due to the change of the level of service of the transportation system. The FSMs are, therefore, limited in their capacity to evaluate synthetic effects such as travel time shift or activity location change as the results of some TDM measures [12]. Meanwhile, as TDM measures mainly target on the demand side of the transportation system, the tools to evaluate the impacts of TDM should also be more sensitive to the users' behavior than the traditional FSMs [13]. With the modeling structure which is based on behavioral mechanism, the ABMs are able to perform various transportation forecasting processes, especially TDM measures which mainly targeting on changing individuals' travel behaviors.

To this end, the objective of this study is to introduce the ABM model developed for Ho Chi Minh City (HCMC), a motorcycle dependent city of Vietnam and its application on analyzing the impacts of some motorcycle TDM measures. The results provide empirical evidences that shows several advantages offer by ABMs in evaluating various TDM measures than existing FSMs. The remainder of the paper consists of four parts. The first part presents the methodology with descriptions of the study area and the ABM developed for HCMC. The second part describes the proposed TDM measures. The analysis results are presented in the third part and the last part concludes the paper.

2. Methodology

2.1. Study area

The study area of HCMC with total area of 2,061 km2 and 8,99 million inhabitants (in 2019) is divided into 317 wards of 24 districts. The 24 districts are groups as three types: center business districts (CBD), newly developed districts (NDD) and rural districts (RA) (Fig. 1). The CBD including 13 districts is home to more than 50% population, characterized with high-rise buildings, shopping malls, historical places, high quality hospitals and education centers, etc. Six districts of NDD are newly established districts (less than 25 years) with high urbanization rate. The rest area covering more than 75% total area of HCMC is the rural districts.

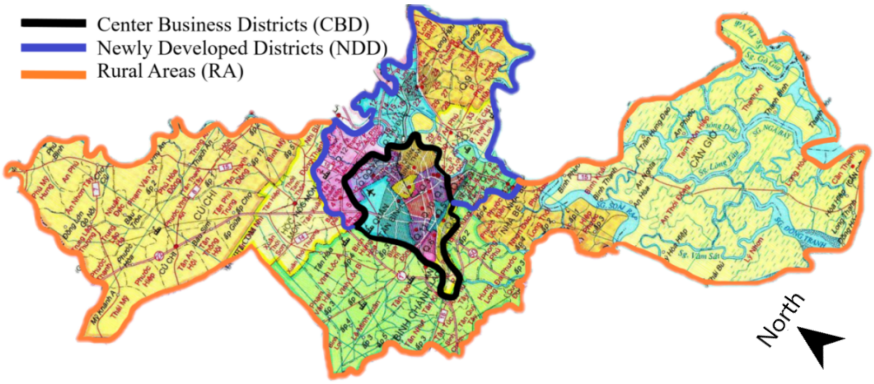

Fig. 1. Study Area of Ho Chi Minh City

According to the most recent large-scale travel survey: "Data Collection Survey on Railways in Major Cities in Vietnam" (METROS) funded by the Japan International Cooperation Agency (JICA) in 2013, the road transport of HCMC relies on private vehicle, especially motorcycle which trips share more than 75% of total trips. The public transport system accounts for less than 7% of the total trips. It was estimated by the HCMC transport authority that there were approximately 356,429 cars and 6,071,701 motorcycles in use in 2019 (HCMC Department of Transport). Automobile ownership has increased by 20% annually in recent years with approximately 6.7% of car owning households in 2019 (HCMC Census 2019). The city transport authority has put significant effort into increasing public transport ridership through subsidy programs, expanding the bus network, and constructing new transit systems. On the other hand, motorcycle ban measure is also under consideration.

2.2. FEATHERS – HCMC: an Activity-based Travel demand model for HCMC

FEATHERS-HCMC is an ABM model developed for HCMC under the collaboration project between the Transportation Research Institute (IMOB) of Hasselt University, Belgium and the Vietnamese-German Transportation Research Centre (VGTRC) of Vietnamese-German University, Vietnam. Its operation is based on a modular framework inherited from FEATHERS (Forecasting Evolutionary Activity – Travel of Household and their Environmental RepercurssionS) which was developed for Flanders, Belgium [14]. The processing sequence of the microsimulation composes of three levels: day pattern, tour level and stop level (Fig. 2). At the day pattern level, the number of work episodes, other types of activities with specific sequences are chosen. The number of home-base (HB) tours are also determined. For each tour in the scheduled obtained from day pattern level, the models at tour levels predict the attributes of the primary activity in tours, including activity duration, activity starting time of day (ToD), main mode of the tour and location of the primary activity. The stop level models predict similar attributes for intermediate stops in each tour. Although FEATHERS-HCMC adopts the modeling system from the original model, its behavioral models and modeling framework were re-estimated due to the differences in social-economics and transportation system between HCMC and Flanders. This section summarizes the model system.

FEATHERS-HCMC were estimated from the 2013 household travel survey in HCMC (METROS). One-day travel diaries of nearly 47,000 individuals of 16,288 households were collected. The scheduling process of the model described in Fig. 2 is a combination of heuristic rules and discrete choice models. The discrete choice model (DCMs) components bordered with blue dash lines in Fig. 2 (a) are series of multinomial and nested logit models. At this stage of the model development, only choice of ToD, mode and location at both tour level and stop level are designed with DCMs. In the hierarchies of these models, the lower models are conditional on the upper models. They also transfer information to the upper models through log-sum values. In FEATHERS-HCMC, the joint choice of mode and activity starting time was modelled for home-based work tours (HBW), home-based education (HBS) tours and stop level as illustrated in Fig. 2 (b). With the consideration of high intrazonal trip rate observed in METROS, the hierarchy developed for HBO tours is different (Fig. 2 (c)) with the two modeling structures for the joint choice of time and mode for intrazonal tours and the nested structure of time, mode and location choice for interzonal tours. The simulation outcomes for the base year of the model showed a good match with observation in METROS (Table 1).

Table 1. Simulated resutls by FEATHER-HCMC and METROS in base year 2013 (in percentage)

Location & Mode	CBD	NDD	RA	Walk	Bicycle	Motorcycle	Car	Bus
Simulated	52.22	28.98	18.79	21.95	6.27	64.98	0.87	5.93
METROS	58.34	25.41	16.25	21.56	7.50	67.37	0.41	3.17

Time of day	00:00 to 06:30	06:31 to 08:59	09:00 to 10:59	11:00 to 13:59	14:00 to 15:59	16:00 to 18:59	19:00 to 24:00
Simulated	7.65	38.42	9.46	12.01	5.55	13.58	13.32
METROS	16.08	23.15	6.10	11.99	3.13	24.79	14.76

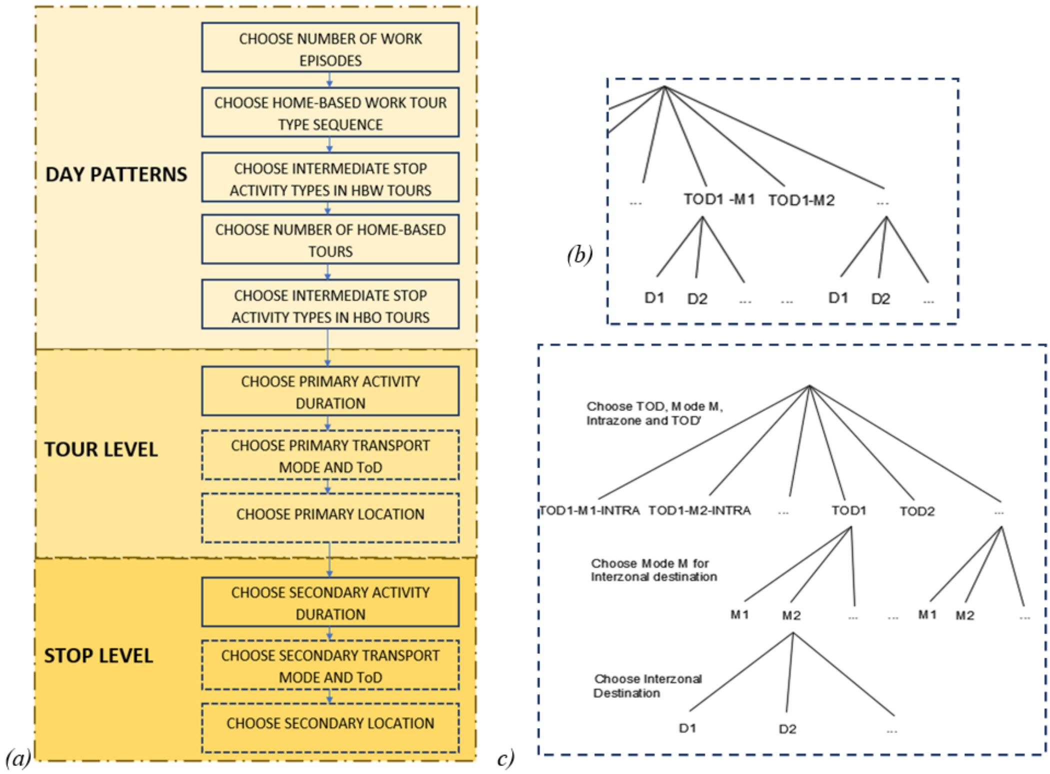

Fig. 2. HCMC–FEATHERS modelling framework (a); DCM structure in HBW/HBS tours & Stop level (b); DCM structure in HBO tours (c)

3. Scenario development

There are ongoing discussions and researches to search for effective measures to address the issues of motorcycles in Vietnam and other motorcycle-based cities [1–3]. In literature, motorcycle TDM measures can be broadly summarized as: 1) controlling motorcycle ownership; 2) controlling motorcycle use and 3) managing motorcycle parking space [2]. Case studies in the Asian cities suggest that it is more difficult to control motorcycle ownership than to restrict its usage [1–3]. To manage motorcycle use, increasing trip cost/time of motorcycle trips and promoting public transport are among the main measures to discourage the users from using motorcycle and shift to public bus [2,16]. Road pricing policies which have proved to be a promising tool to reduce private mode use in the developed economics, has not been implemented in any of the motorcycle dominant cities. Because this policy is argued to bring unequal mobility opportunities between low- and high-income road users [2], especially for the developing countries where most of motorcycle users belong to the low- and medium-income class.

During the development of our proposed models, travel cost was omitted. The models with general travel time variable had better goodness of fit. This is also an issue in the models developed for Jakarta, Indonesia [17] and Xi'an, China [18] due to the fact that the people mainly use the cheap transport modes and/or the cost information in the travel surveys was poorly reported [17,19]. In addition, since the level of service matrices of travel times and travel costs for all transport modes were not available except for those of public bus, travel costs and travel times of other transport modes are distance-based values. Therefore, travel costs and travel times are collineated. Therefore, this analysis mainly focuses on the measures targeted at changing travel times of available transport modes.

Studies have found that motorcycle users have less intention to switch to public transport. Only promoting public transport would not be sufficient to reduce motorcycle dependency [9,20,21]. The improvement of public transport service quality combining with incremental level of motorcycle use restriction is suggested to be promising strategy to reduce motorcycle dependency [20]. More specifically, this study analyses the impacts of three measures: 1) Promote public transport by extending the service to all areas in the city, providing bus exclusive lanes and improving the accessibility to public transport, etc. consequently reducing 40% total travel time by public bus; 2) Restrict the use of motorcycles through parking policies and/or providing specific routes for motorcycle drivers which result in substantial increase of motorcycle travel time; and 3) Prohibit motorcycle use in central areas. The scenarios are designed as the combination of these measures. The main assumptions on the level of service inputs for the simulation of FEATHERS – HCMC are presented in Table 2.

Table 2. Level of services in designed scenarios

Scenario		Level of service input
BAU	Business As Usual scenario	Level of services of private and public network do not change;
SCEN1	Improve Bus Network	Expand bus network; improve accessibility to public transport; provide exclusive bus corridors in order to reduce 40% total time traveling by public bus.
SCEN2	Restrict motorcycle parking during morning and evening peak hours in the CBD and Improved Bus Network	In addition to the improvement of public bus, regulation on motorcycle parking will also be implemented. Total travel time by motorcycle is assumed to be 60 mins longer than current during the peak hours (6:30 to 9:00AM; and 4:00PM to 7:00 PM) for all trips with origin and/or destination in CBD.
SCEN3	Motorcycle Ban in the CBD and Improved Bus Network	In addition to the improvement of public bus, motorcycle ban policy will be implemented. Travel times of motorcycles for all the trips with origin and/or destination in CBD are set to missing value.

In addition, the model requires sociodemographic and land use inputs for the predicted year. The following assumptions for the 2025 travel demand forecast are adopted:

- Synthetic population 2025 calculated using the Iterative Proportional Fitting (IPF) procedure, with:
  - The marginal data were projected from the two most recent censuses (2009 and 2019); METROS was used as seed data
  - As there is no projection data on the socioeconomic development and vehicle ownership of HCMC, income level was obtained by a simple projection from the base year. The vehicle ownership models were developed

using METROS data. It was estimated that there are 13.7% households owning cars and 95% households owning motorcycles by 2025.
- No change in land use data at zonal level (317 zones defined by HCMC administrative boundaries)

The impacts of TDM measures will be analyzed using indicators such as activity type, modal split, trip starting time and location at aggregate level. The analysis of designed scenarios is presented in the next section.

4. Scenario analysis

Four scenarios were simulated in FEATHERS – HCMC modeling framework. The main outputs are i) full day schedules of the population in a structure text file; and ii) trip matrices for different transport mode by hours in structure text files. It should be noted that the simulation for a city of more than 9 million inhabitants as HCMC is a heavy calculation. Therefore, the simulations were performed with 10% of the synthetic population. Indicators extracted from the predicted schedules of four scenarios are summarized in Table 3. At the current stage of model development, there is no upward connection from tour level to daily pattern level. The activity participation almost does not change across scenarios.

Table 3. Policy impact comparisons

	BAU		SCEN1	SCEN2	SCEN3
Trip start time	Number of trips	Share (%)	Change (%)	Change (%)	Change (%)
00:00 to 06:30	256,844	7.47	0.11	2.10	-0.03
06:31 to 08:59	1,275,255	37.09	0.03	-2.85	-0.02
09:00 to 10:59	325,049	9.45	-0.09	0.06	0.21
11:00 to 13:59	420,439	12.23	-0.35	-0.01	0.15
14:00 to 15:59	200,215	5.82	0.05	0.46	0.31
16:00 to 18:59	470,943	13.70	0.10	-0.75	-0.18
19:00 to 24:00	489,347	14.23	0.16	0.99	-0.45
Trip mode	Number of trips	Share (%)	Change (%)	Change (%)	Change (%)
Walk	609,672	17.73	-0.17	1.93	16.91
Bicycle	176,087	5.12	1.67	2.49	6.48
Motorcycle	2,380,774	69.25	-4.44	-9.07	-32.86
Car	109,057	3.17	0.60	0.95	2.09
Public bus	162,502	4.73	2.33	3.69	7.38
Trip destination	Number of trips	Share (%)	Change (%)	Change (%)	Change (%)
Center Business Districts (CBD)	1,545,523	44.95	-0.06	-2.13	-3.52
Newly Developed Districts (NDD)	1,104,689	32.13	0.04	1.48	2.48
Rural Districts (RA)	787,880	22.92	0.02	0.65	1.03

4.1. Scenario 1

The efforts to improve public transport system in SCEN1 increase 2.33% trips by public bus, 1.67% trips by bicycle and reduce 4.44% trips by motorcycle. The change in temporal and spatial pattern of daily trips is marginal. Although positive impact on modal splits is achieved, the expected share of public transport is only 7.06% which is significantly low for a 9 million population city.

4.2. Scenario 2

In SCEN2, combining with the improvement of public transport, additional measures are considered in order to increase the total travel time of motorcycle to and from zones in the CBD, such as: eliminating on-street parking or re-allocating parking lots to CBD boundary. As an intermediate intervention prior to prohibit motorcycle use in CBD, this strategy is expected to dampened down the motorcycle use during peak hours and then shift to public transport. The direct effects on modal split and temporal distribution are observed. The strategy contributes to a reduction of 9.07% motorcycle trips. The main alternate modes are public bus, bicycle and walk with the number of trips increased up to 3.69%, 2.49% and 1.93%, respectively. Regarding trip starting time, the most significant change was found in the trips started during morning peak with a reduction of 2.85%. This reduction is compensated by the increasing trips starting before 6:30 AM. As positioned at the bottom level of the modeling structure, destination choice model contains the level of service variables. Therefore, this model is the most sensitive to the changes in level of services designed in SCEN2. The restriction of motorcycle use in the CBD leads to a reduction of 2.13% trips the CBD.

4.3. Scenario 3

In SCEN3, the motorcycle ban is assumed to be implemented in the CBD by 2025. This scenario significantly reduces the number of motorcycle trips by 32.86%. The share of bus trips increases by 7.38%. The prohibition of motorcycle also increases 2.09% trips by cars. If car ownership is not well controlled, higher car ownership would induce higher car use [7,22]. Since the CBD is the center of most urban opportunities in HCMC, individuals residing the CBD tend to localize their activities when motorcycle is banned. In the case of intrazonal trips, the share of walking trips was the second largest after motorcycle trips [15]. As a result, there is a substantial increase of walking trips by nearly 17%. In addition, the number of trips to the CBD reduces 3.52%. There is no change in trip starting time because there is no temporal constraint designed for this scenario.

In general, although the magnitudes of indicators across scenarios might be arguable, the results from the analysis show reasonable tendency of travel demand changes, i.e., the higher enforcement on motorcycle use, the higher reduction in motorcycle trips. More importantly, the activity-based travel demand modeling approach can capture synthetic effects due to TDM measures. Those are the changes in travel time choice and relocation of trip destinations which could not be captured in available FSMs.

5. Conclusion

The objective of this study is to demonstrate an application on analyzing the potential impacts of motorcycle TDM of an ABM developed for HCMC, a motorcycle dependent city of Vietnam, the FEATHERS-HCMC model. Firstly, the modeling framework of FEATHERS-HCMC was introduced with distinct features from its original model due to the differences on transportation system, cultural and economic settings. Second, the impacts of TDM measures aiming at reducing the dependence on motorcycle of daily travel were analysed using FEATHERS-HCMC. The first scenario focusing on improving public transport services in order to make it a more attractive alternative to motorcycle. However, the simulation results did not show considerable changes of motorcycle travel demand. More enforcement on motorcycle use in SCEN2 and SCEN3 results in significant decrease in motorcycle trips. The changes in trip destination and starting time were also captured in these scenarios. These results demonstrate the advantages of ABMs comparing to FSMs in their capacity to evaluate wider ranges of transport policies.

As this is the first study adopting an ABM approach to analyse the impacts of motorcycle TDMs for a developing country, limitations are unavoidable. First, the microdata collected in the cross-sectional travel survey in 2013 is not able to capture the rapid growth in economics and social changes of the cities. Therefore, additional data is required to update the model. Second, the incorporation of travel cost to the current model is worth to be investigated in order to analyse the impacts of pricing policies. The missing of the upward linkage from tour to daily pattern level limits the capacity of FEATHERS-HCMC capturing further social effects of the TDM measures.

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