Doctoral Dissertation

Context dependencies of travel behavior: A case study on motorcycle in Hanoi

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ABSTRACT

One of specific characteristics of Hanoi city is the motorcycles. This private mode is the preferred choice of the citizens including all socio-segments and level of incomes. The main reasons may come from their convenient and high flexibility in usage: they could provide a higher mobility in relative short distances and frequent trips and motorcycles often travel faster than automobiles. However, the rapid increasing of motorcycle ownership (until September 2009, the number of motorcycle in Hanoi had reached 3.6 million units) and usage has been leading to various transportation problems mainly related to traffic jam, traffic accident as well as air pollution. Thus, a matter of great urgency is how to use motorcycle in a way that maximizes its merits and overcome its demerits. In other words, we have to consider how to satisfy people's travel need by providing convenient transport modes while at the same time ensuring convenient, traffic safety, clean environment, and other social demands.

To deal with the complicated duplicity of motorcycle usage issues as presented above, the adequate understanding of travel behavior pattern is certainly needed. However, we still have many behavioral phenomena which have not adequately addressed yet, mainly due to the data limitation. Thus, we try to deepen our knowledge on the motorcycle users' travel behavior by discovering the pre-conditions of their decision making or also known as context dependencies. Base on their most specific characteristics, we categorized all attributes factors into 3 different contexts including household context, spatial context and temporal context.

In fact, the Hanoi authorities had been setting up various barriers to prevent the increasing number of motorcycle (i.e., taxes, registering regulations, etc) but in fact, the number of motorcycle had been increasing with very high rate: about 10%-12% annually. It seems that, those supply-side oriented acts not delivered the expected purposes. Therefore, in this study,

we apply a new approach which has opposite viewpoint, from demand-side, called A-S-I approach (Avoid/Reduce, Shift/Maintain and Improve). The approach tries to find the ways mainly: to avoid/reduce motorcycle's travel demands, to shift from motorcycle to current bus system and to improve public modes by introducing new transit mode, the Light Rail Transit system (LRT). These achievements could reach a suitable motorcycle utilization (i.e., in a way that maximizes its merits and overcome its demerits), contribute significantly in greenhouse gas (GHG) emission and energy consumption reductions, less congestion, with the final objective to create more livable city for Hanoi.

The study is described in 8 chapters with the following contents. The over view of current situation, problem statement, research objective and scopes and outline of the dissertation are presented in Chapter I.

Chapter II presents literature review which relevant to the fields of the study. First, the concept of context dependencies and the definition of three contexts which shall be used in the study are introduced. Second, the A-S-I approach is described with its original purposes as well as some suitable revising for Hanoi situation. Third, the review on modal shift studies which focus on shifting from motorized-private modes to non-motorized and public modes is provided. Then, in the conclusion of this chapter, the present research is positioned.

Chapter III introduces the data sources, survey design and initial findings. There are total three data sources which collected in different times including the Hanoi Person Trip survey data in 2005, the one week household travel survey in 2010 and the Stated Preference (SP) survey data in 2005.

Applying the A-S-I approach, the main body of the dissertation which contains comprehensive analyses is divided into 3 parts: the Chapter IV and V represent for the Avoid/Reduce part, the Chapter VI represents for the Shift part and the Chapter VII represents for the Improve part.

The first Avoid/Reduce part is the combination of two chapters, IV and V, in which, chapter IV focuses on motorcycle usage and ownership in household context while chapter V focus on motorcycle usage in spatial context. The findings of two chapters may give us some ideas from demand side view point to avoid or reduce the need to travel by motorcycle. Thus, in chapter IV, with Hanoi Person Trip survey data, we first analyzed the mode choice behavior of pupils base on their daily school trips. By applying a multinomial logit model, we found a significant of elementary school's pupils is motorcycle-dependent (they were picked up/dropped off by their parent of other family members) with the main reason that their school's location are out of their residential neighborhood. We then examined the relation between motorcycle ownership and mobility level with taking into account the different in household composition (i.e., whether child existence or not) by using the one week household travel survey data. An endogenous switching model was developed to check the existence of child effects in the relation between motorcycle ownership and the number of trips. The results reveal that motorcycle may have a smaller effect on the number of trips and those who want to generate the higher number of trips may self select to own him/herself a motorcycle. In addition, those who have child are less affected by motorcycle ownership compared to those who don't have child.

To continue the Avoid/Reduce part, the Chapter V analyzes motorcycle usage in spatial context by using the Hanoi Person Trip survey data with 3 parts. The first part focused on how residential land use patterns affect on modal choice behavior. Total 59,569 home-based non-work trips were selected for the analysis, the findings could bring a clearer view on the relationship between household location, travel purposes and motorcycle dependency levels. The second part tried to measure the land use impacts on motorcycle choice. Applying a multi-level binary logit model, we found that the land use impacts on non-mandatory trips (9.17%) is higher than that of commuting trips (4.92%) and Origin-Destination impacts (i.e., land use impacts of total spaces created by combining Origin and Destination zones which an motorcycle user travel in) are much larger than Residential neighborhood impacts (i.e., land use impacts of his household location's surrounding). To explore the motorcycle trip frequency in different residential location spaces, in the third part, we analyzed total 44,107 trips made by motorcycle. We found that individuals with their household location in Central Business District (CBD) have higher tendency to use motorcycle.

The findings in both chapters IV and V revealed the motorcycle's travel demand as well as factors related were almost belong to household and spatial contexts. Thus, to prevent the increasing motorcycle ownership as well as motorcycle usage, policy makers and urban planners should focus on how to avoid/reduce travel demand from people rather than to prevent motorcycle ownership (i.e., creating a better neighborhood environment for walking or cycling for children from their home to their elementary school, neighborhood design to reduce home-based shopping/leisure trips, etc).

Chapter VI is the second part of the dissertation's body (as Shift in A-S-I approach) which explored modal shift behavior which could usually observe in temporal context (i.e., when and in which conditions motorcycle owners may shift to use bus and non-motorcycle owners may shift to use motorcycle for their travel). To do this we use the one week household travel survey and apply two different multilevel binary logit models. Results shown that: 1) Non-motorcycle owners may use other's motorcycle in some cases: for short distances (i.e., less than 5 km), for *related to work* or *personal need* purposes, in the evening time and accompany with other people, especially with their family member. 2) Motorcycle owners may shift to use buses in some cases: for long travel distances (i.e., more than 5 km), in the day time, travelling alone and in bad weather (i.e., rainy day). The findings suggest for policy makers that: to encourage motorcycle owners shift to buses, those who have long commuting trip are the most potential; to prevent the motorcycle usage propensity from non-motorcycle owners, neighborhood designing to satisfy personal need (i.e., shopping/leisure purposes) is very important as well as improving buses' service density and operation in off-pick hours.

Chapter VII represented the last part (as Improve in A-S-I approach). This chapter attempted to capture the people's travel mode choice in the future, which may also considered as Temporal context, by considering the changes in both travel and socio-economic environments, when the LRT system is introduced. We used the SP survey data set and applied a combined RP/SP model (Nested Logit Model) to estimate. Based on the model estimation results, simple simulation analyses were conducted by setting up in different hypothetical scenarios on levels of income and services in the future. The findings suggest policy makers that the improving public modes' level of service is the key strategy in modal shifting from private modes users. At the end of this chapter, further discussion on how to encourage people to use public modes (i.e., by optimizing of transport infrastructure, integrating modes, designing system, etc) is provided.

Chapter VIII is the conclusion of this study. We first make a summary of all findings from previous parts then a general conclusion was provided: to achieve more livable environment for a motorcycle dependent city like Hanoi, we may apply A-S-I approach which entails three main avenues: to Avoid school trip by motorcycle and to Reduce travel demand of motorcycle users; to Shift from motorcycle to public modes, and to Improve public transportation system by building up new public mass transit system. Next, we confirm that the *spatial context* is the most involved context in applying A-S-I approach. Concretely speaking, the role of neighborhood design for avoiding travel demand and encouraging modal shift to more environmental friendly modes is very important. For more detail, we then give a brief discussion on motivators as well as barriers in applying A-S-I process. Finally, the priority policies and future researches are given.

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CHAPTER I

Introduction

1.1 Overview of current situation

1.1.1 The role of motorcycle in daily life

When society develops, demand for personal and commercial transport also rises. The means of transport must respond to increasing demand in all aspects of quantity, quality, and modal diversification. Each transport means has its merits and demerits. The problem is to select and combine each transport means in a way that maximizes merits and overcome demerits, under the specific natural, economic, and social conditions of our country in this particular development stage. We must satisfy people's travel need by providing convenient transport modes while at the same time ensuring traffic safety, clean environment, and other social demands.

During the period 1995-2005, the Vietnamese economy continued to operate under the market mechanism with socialist orientation, achieving relatively high growth of 8% or higher in consecutive years. As a result, the speed of urbanization as well as demand for trips and commercial transport also increased. Since public transport systems are currently underdeveloped, people tend to possess personal means of transport such as motorcycles and automobiles to satisfy their travel demand.

According to the report of the National Traffic Safety Committee and the Traffic Police Road and Railroad Department, motorcycles and automobiles have long been the two principal means of transport in Vietnam in terms of absolute volume as well as contribution to cargo transport in the whole country, especially in urban areas and economically developed areas. Between them, motorcycles are by far the dominant means of transport. At the end of 2005, Vietnam had 16,1million registered motorcycles and 0,9 million registered automobiles in use. Compared with the year 1990, this is an increase of 5.8 times for motorcycles and 3.6 times for automobiles. The use of both transport means rose very rapidly, especially motorcycles.

The studies of Hanoi urban planning by the Ministry of Transport and JICA (Japan International Cooperation Agency) confirmed that motorcycle was the dominant transportation mode in Hanoi which covered 62.7% of travel needs while the modal share of public transportation (only buses available) was quite small at 8.4% (ALMEC report 2007). Apparently, the motorcycle is the preferred choice of urban population, providing personal mobility in relatively short distances and frequent trips, under the condition that land use for transport is about 7.0% of total urban land use, public transport is underdeveloped, cars are beyond the reach of the general public at the current income level, and motorcycles often travel faster than automobiles. Many people also use motorcycles to make living.

1.1.2 Motorcycle usage and its related issues

Motorcycle is a popular vehicle in Vietnam across all ages, genders and occupations. It is used not only for delivering commercial goods but also for virtually all personal purposes, for example, commuting, shopping, dating, visiting friends, shuttling children to and from school, and even for sheer fun. The motorcycle excels in personal flexibility, allowing the rider to make door-to-door trips at any time without waiting, walking or transfer. It is also efficient in space use, occupying about one-fourth of space on road and in parking in comparison with a car when motorcycles are dominant, and about one-half of space of a car in mixed traffic.

The annual report of Vietnam Register in 2009 revealed that the total number of motorcycle in Hanoi has reached 3.9 million units (Vnmedia) (Figure 1.1). It was estimated that motorcycle took more than 80.0% of motorized transport but this individual transport mean served for only about 70.0% of citizens. Thus, motorcycles are also participating in various transportation problems and three most serious are listed below:

- Traffic jam: there are total 124 places where the traffic jam occurs regularly in Hanoi city area. Scientist estimated the traffic jam costs about 27 billion VND (about 1.3 million USD) loss per day (Baomoi.com).

- Air pollution: Hanoi became one of the most polluted cities in Asia with about 70.0% of pollution sources generated from transport activities. Private vehicles especially motorcycle with the annual increasing rate from 12.0% to 15.0% are main participation in generating SO_2, NOx. Air pollution costs Hanoi citizens about 4.6 billion VND (about 0.22 million USD) loss per day (Nhandan.com.vn).

- Accident: motorcycle involved about 74.0% in total of 1000 traffic accidents in 2011 which caused 749 died and 443 injured, according to the report of Hanoi traffic police bureau (Vnexpress.net).

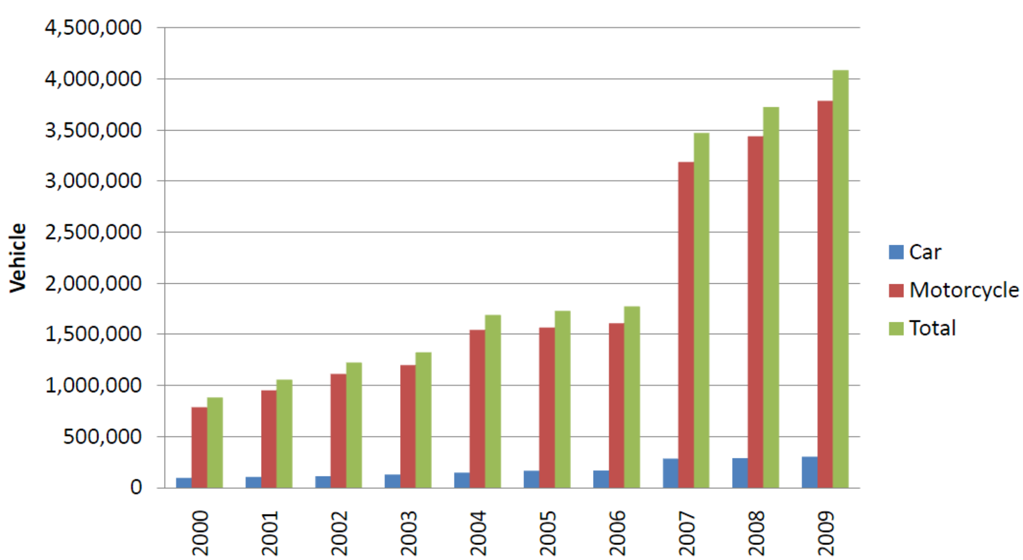

Figure 1.1 Vehicles in Hanoi 2000 – 2009 (Hanoi traffic police bureau)

1.1.3 Urban development trend

Since August 2008, the Vietnamese government decided to expand Hanoi to the Western side of the current city, increased the area from 921 km^2 to 3,300 km^2 to meet the development demand. In Hanoi master planning, the population is estimated about 10 million by 2030. The city was planned as a polycentric city (Figure 1.2) which includes the main center (current Central Business District) connected with 5 satellite urban areas and number of small towns within from 5 km to 30 km by ring roads and centripetal routes system (Perkins et al. 2009).

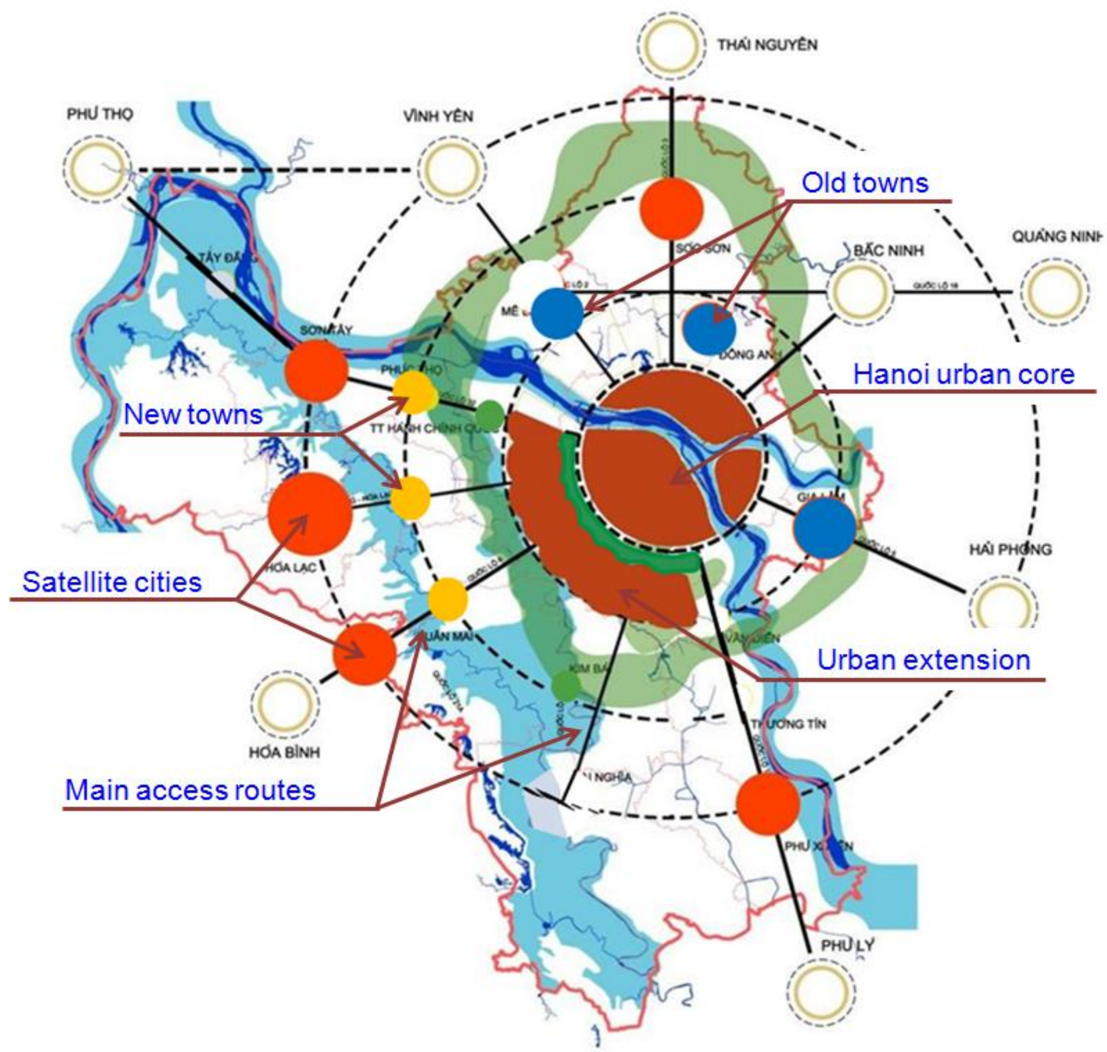

Figure 1.2 Hanoi master planning in 2030 (Perkins et al. 2009)

According to the transportation planning, to deal with the various problems caused by huge number of motorcycle, Hanoi authorities shall build up several kind of urban mass rapid transit (UMRT) including subway, light rail transit, mono rail and bus rapid transit system together with improving level of service of current bus system. These public modes are proposed to serve about 30-40% of citizens travel demand for reducing the motorcycle share to 40-45% in 2030.

1.2 Problem statement

Rapid increase of motorcycle ownership and usage has been one of the central transportation issues in Hanoi, while motorcycle is absolutely essential to fulfill people's travel needs. This implies that diversified standpoints or contradictory combination of views might be required to find out how to use motorcycle in a way that maximizes its merits and overcome its demerits. To reach these achievements, we try to find some solutions by analyzing motorcycle usage in specific contexts such as household, spatial and temporal contexts. Also with the view point from demand-side, we apply the A-S-I approach (Avoid/Reduce, Shift/Maintain and Improve) to find the ways mainly: to avoid/reduce motorcycle's travel demands and to encourage motorcycle users shift to non-motorized and public modes. These achievements could contribute significantly in greenhouse gas (GHG) emission and energy consumption reductions, less congestion, with the final objective to create more livable city for Hanoi.

In fact, there are many behavioral phenomena which have not adequately addressed yet, mainly due to the data limitation. One of the most important phenomena that need to be explored in Hanoi might be motorcycle usage and ownership patterns. Focusing on household context, we revealed the fact that household size of Hanoi citizens are become smaller (i.e., the household composition with parents and their one or two child(ren) is increasing during time and this type of household will be dominant in the future). Thus, the child existence may considered as specific characteristics of household context which affecting household's travel behavior as well as each individuals in household on travel mode choice, vehicle ownership and trip frequency. Base on that, we first determine which age of child have strong dependent on motorcycle and second, whether child existence affected to the relationship between mobility levels and household's motorcycle ownership decision are examined. Exploring the relations between motorcycle ownership and mobility level in this situation is not only deepened the understanding of motorcycle's role in daily travel activities but also helped transportation planners, for example, to discuss how to utilize motorcycle in the context of households' usage.

As mentioned above, Hanoi has rapidly urban expanding together with increasing of population which causes changes not only in travel demand but also in travel behavior, definitely. Besides, comparing to other modes, motorcycle is very flexibility and convenient in usage when it could take any route (i.e., from narrow to wide), enter any areas (i.e., residential, commercial, industrial…) and thus motorcycle is strongly affected by spatial context in general and land use patterns in particular. Therefore, in this study, we focus on land use patterns as specific characteristics of spatial context to explore the relations between land use and motorcycle usage. Through a series of analysis on modal choice and trip frequency, these impacts of land use patterns were revealed and base on that, the discussion on how to avoid/reduce travel demand by motorcycle might become plainer.

In other aspect, as mentioned in transportation planning, Hanoi authority expected that the public transport system may reduce motorcycle usage by improving current buses system and providing new public mass transit (Light Rail Transit). Related to current bus system, in the past and event up to now, the local government had been supporting a large fuel subsidy to bus operation companies annually to promote bus usage. Although this policy encourages people to use bus, it attracts almost only low income people and students (ALMEC report 2007). Thus, the understanding of bus usage in current situation especially from motorcycle owners is very crucial for encouraging them shift to bus and other public modes in the future. However, it not easy to observe the modal shift behavior from motorcycle to bus within a conventional travel survey (in which, respondents report all yesterday trip made only). Therefore, we launched one week household travel survey in 2010 to observe the variations on modal shift and all related attributes.

On the other hand, to improve public transportation system by providing new mass transit (not yet exist) with its advantages (i.e., fast, safe, punctual, environmental friendly, etc) is expected to attract attention of people and get their preference. Nevertheless, people in Hanoi city have strong dependency on the motorcycle for their travel, thus, it's very important to forecast the impacts of future mode on peoples' travel behavior. Therefore, we launched a Stated Preference survey to examine individual responses to a series of experimentally designed choice alternatives which are described in terms of combinations of attributes with several pre-defined levels. Based on the model estimation results, some simple simulation analysis were conducted by setting up in different hypothetical scenarios by different levels of income and services in the future. The findings may help us to find out what should be done to encourage modal shifting from private modes users.

1.3 Research objective and scopes

Motivated by the various problems causing by a huge number of motorcycle in the current situation and toward a sustainable transport system in the future, the focus of this research is to conduct a comprehensive analysis of motorcycle usage in different context dependencies including household, spatial and temporal contexts. The study includes wide range of exploratory analyses between various individual socio-demographic, situational, land use characteristics to capture the motorcycle usage behavior. Considering the contextual differences that are likely to exist between developed and developing cities, this research offers rich comparisons in terms of modal choice behavior, component of mode choice variations and the impacts of land use patterns on modal choice. Most of analyses conducted in this research are empirical nature and advanced econometric modeling methodologies are applied in accomplishing the model development process. In addition to explore exhaustively the behavioral aspects of motorcycle usage, this research also reveals the advantages/disadvantages of bus usage and discuss about their possible implications on future transportation planning.

The main objectives of this research are as follows:

- Understanding motorcycle usage and ownership in household context by taking into account child existence.
- Determining how land use patterns impact on motorcycle usage.
- Exploring in what situation motorcycle owners tend to choose bus and non-motorcycle owners tend to choose motorcycle.
- Forecasting the impacts of future public mass transit on travel behavior.

1.4 Outline of the dissertation

After this introductory Chapter I, the remainder of this dissertation is organized into the following chapters (Figure 1.3).

Chapter II deals with a literature review. To provide the fundamental knowledge, it first reviews the concept of context dependencies of travel behavior and defines the three contexts will be examined in the study. Second, the A-S-I approach is described with its original purposes as well as some suitable revising to put into certain application. Third, the review on travel demand management as well as modal shift studies which focus on shifting from motorized-private modes to non-motorized and public modes is provided. Then, in the conclusion of this chapter, the present research is positioned.

Chapter III introduces the data sources, survey design and initial findings. There are total three data sources which collected in different times including the Stated Preference survey data in 2005, the Hanoi Person Trip survey data in 2005 and the one week household travel survey in 2010. The preliminary results are discussed by descriptive statistical analyses.

Chapter IV and chapter V are the first part of the main dissertation's body (as Avoid/Reduce in A-S-I approach) which focus on household context and spatial context. Concretely, in chapter IV, with Hanoi Person Trip survey data, we first analyzed the mode choice behavior of pupils base on their daily school trips. By using a multinomial logit model, we found a significant of elementary school's pupils is motorcycle-dependent (they were picked up/dropped off by their parent of other family members) with the main reason that their school's location are out of their residential neighborhood. We then examined the relation between motorcycle ownership and mobility level with taking into account the different in household composition by using the one week household travel survey data. An endogenous switching model was developed to check the existence of child effects in the relation between motorcycle ownership and the number of trips. Chapter V analyzes motorcycle usage in spatial context by using the Hanoi Person Trip survey data with three parts. The first part focused on how residential land use patterns affect on modal choice behavior. With total 59,569 home-based non-work trips were selected for the analysis, the findings could bring a clearer view on the relationship between household location, travel purposes and motorcycle dependency levels. The second part tried to measure the land use impacts on motorcycle choice by applying a multi-level binary logit model. To explore the motorcycle trip frequency in different residential location spaces, we analyzed total 44,107 trips made by motorcycle in the third part.

Chapter VI, the second part of the dissertation's body (as Shift in A-S-I approach) explores modal shift behavior which could observe in temporal context only (i.e., when and in which conditions motorcycle owners may shift to use bus and non-motorcycle owners may shift to use motorcycle for their travel). To do this we used the one week household travel survey and applied two multilevel binary logit models. Results shown that: 1) Non-motorcycle owners may use other's motorcycle in some cases: for short distances (less than 5 km), for *related to work* or *personal need* purposes, in the evening time and accompany with other people, especially with their family member 2) Motorcycle owners may shift to use buses in some cases: for long travel distances (more than 5 km), in the day time, travelling alone and in bad weather (rainy day). Base on these findings, the discussion on how to Shift from motorcycle to bus from motorcycle owners as well as how to prevent motorcycle usage propensity from non-motorcycle owners were provided.

Chapter VII represents the last part (as Improve in A-S-I approach). This chapter attempted to capture the people's travel mode choice in the future, which may also considered as Temporal context, by considering the changes in both travel and socio-economic environments, when a new Light Rail Transit (LRT) system is introduced. We used the Stated Preference survey data set and applied a combined RP/SP model (Nested Logit Model) to estimate. Based on the model estimation results, some simple simulation analysis were conducted by setting up different hypothetical scenarios which mainly based on levels of income and services in the future. The findings emphasized that the improving public modes' level of service is very important in modal shifting from private modes users. At the end of this Chapter, how to encourage people to use public modes (i.e., by optimizing of transport infrastructure, integrating modes, designing system, etc) was discussed as Improve step.

This study ends with Chapter VIII. In the last Chapter, the summary of key results was first presented, followed by methodological conclusions, implication for policy and planning as well as future studies.

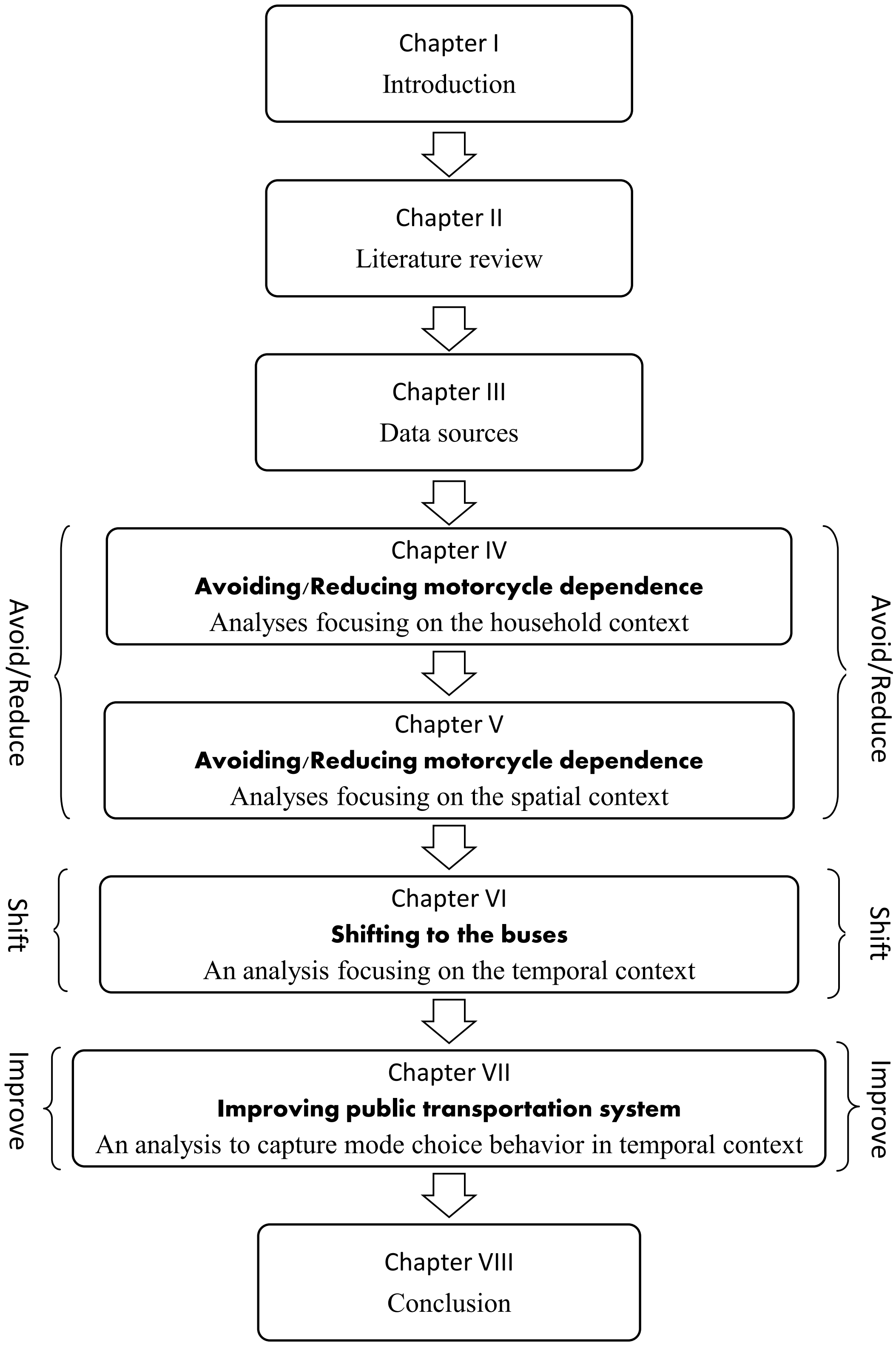

Figure 1.3 Research flow

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CHAPTER II

Literature review

2.1 Introduction

The previous Chapter has introduced various problems caused by a huge number of motorcycles in Hanoi and also addressed the fact that there are many motorcycle usage behavioral phenomena which have not adequately referred yet. Having the research problem stated, the research objectives and scopes are outlined to explore the motorcycle usage in different context dependencies. Thus, the current Chapter first discusses the literature that is relevant to the concept of context dependencies in travel behavior and defines the contexts will be applied in this study. Next, the A-S-I approach with its objective is promoting alternative mobility solutions to develop sustainable transport systems is introduced. With its focusing on the demand-side, this approach had been becoming widespread in transportation studies as well as policy implication. Then the review on travel demand management as well as modal shift studies which focus on shifting from motorized-private modes to public modes and non-motorized modes is provided. Finally, in the conclusion of this Chapter, the place of this study in literature body is positioned.

2.2 Context dependencies of travel behavior

The context dependence is usually referred to the pre-conditions of decision making, however, there is no unified and widely used general definition. Early works of Kahneman et al. (1991) and Tversky and Kahneman (1991) argued that choice behavior is dependent on existing conditions or reference points and empirically confirmed that change of reference points might lead to preference reversal. Oppewal and Timmermans (1991) grouped the context into choice sets and background which refers to circumstantial factors such as trip purposes in mode choice and tax level in housing choice. Tversky and Simonson (1993) distinguished the context into background context as the previous choice results and local context as the choice set. More recently, Zhang et al. (2004) re-classified these pre-conditions into 3 categories: 1) *alternative-specific context*, 2) *individual-specific context* and 3) *circumstantial context*. The *alternative-specific context* includes the number (or the availability) of alternatives with their attributes and the correlated structure of attributes. The *individual-specific context* refers to the individual's choice history, household or workplace attributes and the cognitive existing conditions. And the *circumstantial context* includes all situational factors or background which defined by Oppewal and Timmermans.

Focusing on motorcycle, the dominant mode in Hanoi city, the "context dependencies" terminology used in this study indicates the condition or circumstantial factors that are relevant to motorcycle usage behavior and the differences between contexts are their most specific characteristics. Concretely speaking, we grouped all related attribute factors into 3 contexts including: *household context*, *temporal context* and *spatial context*.

- The *household context* respects to household attributes (i.e., household income, household size/structure, child existence, vehicle ownerships, etc.) and individual attributes (i.e., gender, age, employment status, education level, mobility tool ownerships, etc).

- The *spatial context* includes factors related to surrounding environments of household location, origin and destination including population/employment/facilities density, land use patterns, mix-use index, etc. In addition, the trip distances between an origin and a destination are also considered as factors of spatial context.

- The *temporal context* refers to factors which is day-to-day influent to individual's fluctuant mode choice behavior including time/trip attributes (i.e., day of week, departure/waiting/travel time, travel cost, punctuality, etc.) and situational attributes (i.e., accompany, traffic/weather conditions, travel purposes, etc).

2.3 Avoid – Shift – Improve (A-S-I) approach

The traditional approach applied to deal with increased transport demand has been the provision of additional road space by means of new and expansive road infrastructure. However, this supply-side oriented approach has not delivered the expected benefits. Induced traffic has been created and roads continue to produce excessive levels of congestion, GHG emission and other externalities. For this reason, the traditional approach in the current years is considered ineffective and old school. Therefore, a new approach to tackling current transport problems is required.

Based on the above statement, in the 1990s, the German national Government commissioned a governmental advisory body through a state legislature that introduced the idea of "*vermeiden, verbessern, verlagern.*" When translated into English, this is "avoid, shift, improve". Inspired by the principles of sustainability, this alternative approach focuses on the demand side, as opposed to the conventional approach. The new approach, known as A-S-I (from Avoid/Reduce, Shift/

Maintain, Improve), seeks to achieve significant GHG emission reductions, reduced energy consumption, less congestion, with the final objective to create more livable cities. The objective of the A-S-I approach is to promote alternative mobility solutions and to develop sustainable transport systems.

<u>The Avoid- Shift- Improve approach entails three main avenues:</u>

- Avoid/Reduce: The "avoid" refers to the need to improve the efficiency of the transport system. Through integrated land-use planning and transport demand management the need to travel and the trip length may be reduced.

- Shift: instruments seek to improve trip efficiency. A modal shift from the most energy consuming urban transport mode (i.e. cars) towards more environmentally friendly modes is highly desirable. In particular, the shift towards the following alternative modes:

Non-motorized transport (NMT): walking and cycling. They present the most environmentally friendly options.

Public transport (PT): bus, rail, etc. Although PT also generates emissions, lower specific energy consumption per km and higher occupancy levels imply that the CO_2 emissions per passenger-km are lower compared to cars.

- Improve: focuses on vehicle and fuel efficiency as well as on the optimization of transport infrastructure. It pursues to improve the energy efficiency of transport modes and related vehicle technology. Furthermore, the potential of alternative energy use is acknowledged.

Table 2.3.1: Comparison between original idea and applying in the study

	A-S-I original idea	A-S-I applying in the study
Objective	Travel demand in general	Motorcycle usage in particular
Avoid/Reduce	- The need to travel - The trip length	- The need to travel by motorcycle - The motorcycle trip length
Shift (from most energy consuming mode to)	- Non-motorized modes: walk, bicycle - Public modes: bus, rail, etc	Current bus system
Improve	- Vehicle and fuel efficiency - Optimization of transport infrastructure	Future Light Rail Transit

As described above, the original idea of A-S-I approach is to deal with the increasing travel demand in general while the objective of our study just to deal with the increasing motorcycle usage in particular. Therefore, considering the specific characteristics of transportation system as well as socio-economic conditions in Hanoi, to apply A-S-I approach, some targets' details of each stage are modified (see Table 2.3.1) as follow:

- Avoid/Reduce: the need to travel by motorcycle as well as the motorcycle trip length.

- Shift: from motorcycle to current bus system (since Hanoi public transportation system has only bus).

- Improve: the public transportation system by providing new Light Rail Transit (how the new public mode influences to citizens' commuting mode choice, especially motorcycle users).

2.4 Modal shift studies

2.4.1 From personal motorized vehicle to non-motorized modes

Non-motorized travel (mostly known as Walking and Bicycling) is often overlooked and undervalued. Many conventional travel surveys indicate that only a few percent of total travel is by non-motorized modes, which implies that it is unimportant, and improving non-motorized conditions can do little to solve transport problems. But such surveys tend to undercount non-motorized travel because they ignore short trips, non-work travel, children travel, recreational travel, and non-motorized links. In fact, non-motorized modes are important components of the transportation system. They are resource-efficient travel modes (i.e., they consume minimal road and parking space, impose minimal costs on consumers and the environment), providing access (i.e., access to essential services, education, employment, and social activities as well as public transit), transportation choice, healthy exercise, creating more livable communities and supporting efficient land use (i.e., new urbanism, location efficient development, transit oriented development).

With their advantages, as a matter of course, there are various studies focusing on measuring non-motorized travel demand by answer the question that: how much people would use non-motorized modes under various circumstances. A number of specific factors can affect demand for non-motorized transport in a particular situation (Schwartz, et al. 1999; Moudon 2001; Dill and Carr 2003; Schneider, Patten and Toole 2005; Raford and Ragland 2006; McDonald, et al. 2007; Krizek, et al. 2007; Pike 2011; Leather et al. 2011). These factors may include: attractions, trip distance, demographics, land use patterns, travel conditions, topography and climate, community attitudes and time and geographic scope.

However, the studies focusing on shifts from personal motorized vehicle to non-motorized modes are not ample and mainly from automobile. It was reported that, when automobile travel is reduced in response to disincentives such as increased vehicle fees or vehicle restrictions, a significant portion (typically from 10% to 50%) of reduced trips shift to non-motorized modes: shorter trips (i.e., less than three miles) shift to non-motorized modes, and longer trips shift to combined transit and non-motorized trips. A study in United Kingdom on how to reduce short trip (i.e., less than 8kms) by car found that respondents could shift 31% of these trips to bus, 31% to walking, and 7% to bicycle (Mackett 2001). In Canada, after fuel prices increased about 15% in 2001, a Federal Competition Bureau survey observed that about a quarter of motorists shifted some automobile travel to other modes, of which 46% took transit, 36% walked, 24% cycled, and 20% shared car rides. On the other hand, the effects of pedestrian and bicycling improvements and encouragement programs have some effects: from 5 to 10% of urban automobile trips can reasonably be shifted to non-motorized transport (Mackett 2000; Cairns et al. 2004).

2.4.2 From personal motorized vehicle to public modes

Studies on personal motorized vehicle shift to public modes mainly focused on car in developed countries. There are various reasons for choosing the car as one's mode of transportation over public transport and other alternatives including speed, time, cost, flexibility, safety, comfort and even symbolic reasons (Jakobsson 2004; Steg 2005; Gatersleben 2007). Car use, with all its advantages, leads to many car users developing, in the long-term, the habit of choosing the car as their mode of transport. A number of repeated occasions of choosing the car lead to habitual behaviour in which the car is chosen without other possible options being considered (Fujii and Gärling, 2005).

Focusing on factors which influence the intentions of the single-occupant commuters to switch to buses, various studies found that: for bus, convenience is the most important variable associated with the intention to shift (Tischer and Dobson 1979); “Improving public transport” is most likely to attract them out of their cars (Mackett 2003); travel time and travel cost of busway system are the main variables to develop utility functions (Alvinsyah et al 2005). On the other hand, to encourage car users’ shift to public transport (i.e., bus, train), travel time, walking distance to public transport stations and subsidized fare are most important factors (Nurddin et al 2007). Exploring the citizens’ perceptions of the bus, condition attributes including fare, convenience, and frequency have a significant influence on public-transport-mode choice (Gebeyehu and Takano 2007). From supply-side’s view point, the public transport system must appear attractive, not only to its present users, but also to prospective users who currently use their cars. To appear attractive, it must not be too expensive and must have timetables and routes that allow users to travel in an efficient manner. One measure that can be used to force commuters out of their cars is higher car-use costs; however, car-use costs may need to be substantially higher than the cost of using public transport in order to be effective (Eriksson 2009).

In developing world, especially the South East Asia countries, where motorcycle is dominant in modal share, however, it does seem not easy to find a study focusing on modal shift from motorcycle to public transport. However, there is a study in Malaysia to identify the factors that motorcyclists might change their travel mode to a safer alternative; namely, bus travel (Ibrahim et al 2006). Results show that reduction of total travel time for the bus mode is the most important element to attract motorcyclists towards public transport.

2.5 Summary

Dealing with various transportation problems caused by a huge number of motorcycles while still ensuring convenient, traffic safety, clean environment, and other social demands, is very difficult task. At present, almost studies on motorcycle in developing countries mainly focusing on ownership, safety and traffic flow control while studies focus on motorcycle usage are very limited. In addition, the experience from developed countries on this field is quite empty because their transportation systems (with cars or public modes as dominant modes) are so different with developing countries. This study is therefore an attempt to fulfill this need. Concretely speaking, we try to reveal suitable solutions by discovering the motorcycle usage in different contexts with the view point of demand-side by applying A-S-I approach. To do that, we not only utilized the experiences from developed countries on modal shift (i.e., from car to non-motorized modes and public modes) but also carefully considered the specific characteristics of motorcycle as well as the Hanoi city traffic conditions.

The findings of this research may deepen the knowledge of the motorcycle usage, reveals motorcycle travel demand as well as offers rich comparisons modal shift between car and motorcycle.

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CHAPTER III

Data sources

3.1 Hanoi Person Trip survey data 2005

3.1.1 Outline of the survey

The Household Interview Survey, also known as the Person Trip Survey, is conducted in 2005 to obtain basic data to be utilized in comprehensive urban and transportation master plan for The Comprehensive Urban Development Programme in Hanoi Capital City (HAIDEP) study. This work was created by the ALMEC Corporation through financing from Japanese International Cooperation Agency (JICA) for the government of Hanoi. The targeted survey area is composed of Hanoi City (14 districts, 921 km^2) and adjoining area, Ha Dong, Dan Phuong, and Hoai Duc District in Ha Tay Province, and Me Linh and Phuc Yen in Vinh Phuc Province (5 districts, 450 km^2). The 301 zones, including 228 zones in Hanoi and 73 zones in adjoining area are covered. The number of sampled households is estimated to be 2.2% of total households. However, the sample in the ancient quarter area as well as some communes in Hoan Kiem District, is set to 5.0% (about 1,000 households) in order to analyze their characteristics in depth and since this area is considered as one of the most important areas to focus. At the end, 20,020 households are selected as sample for the field survey.

3.1.2 Preliminary results

Demography

Population of Hanoi City is rapidly increasing and its annual increase rate is more than 3.0%. In 2003, the population exceeded three million. Population density is also high, which is already over 200 persons/ha in urban area. Most crowded areas are found in Hoan Kiem and Hai Ba

Trung Districts with density marking from 800 to 1,000 persons/ha. Population densities in urban fringes are not so high at present, but their growth rates are quite high. The rate reaches more than 6% in average, and some communes, represented by Tay Ho, Thanh Xuan and Cau Giay Districts, show annual growth of more than 10%.

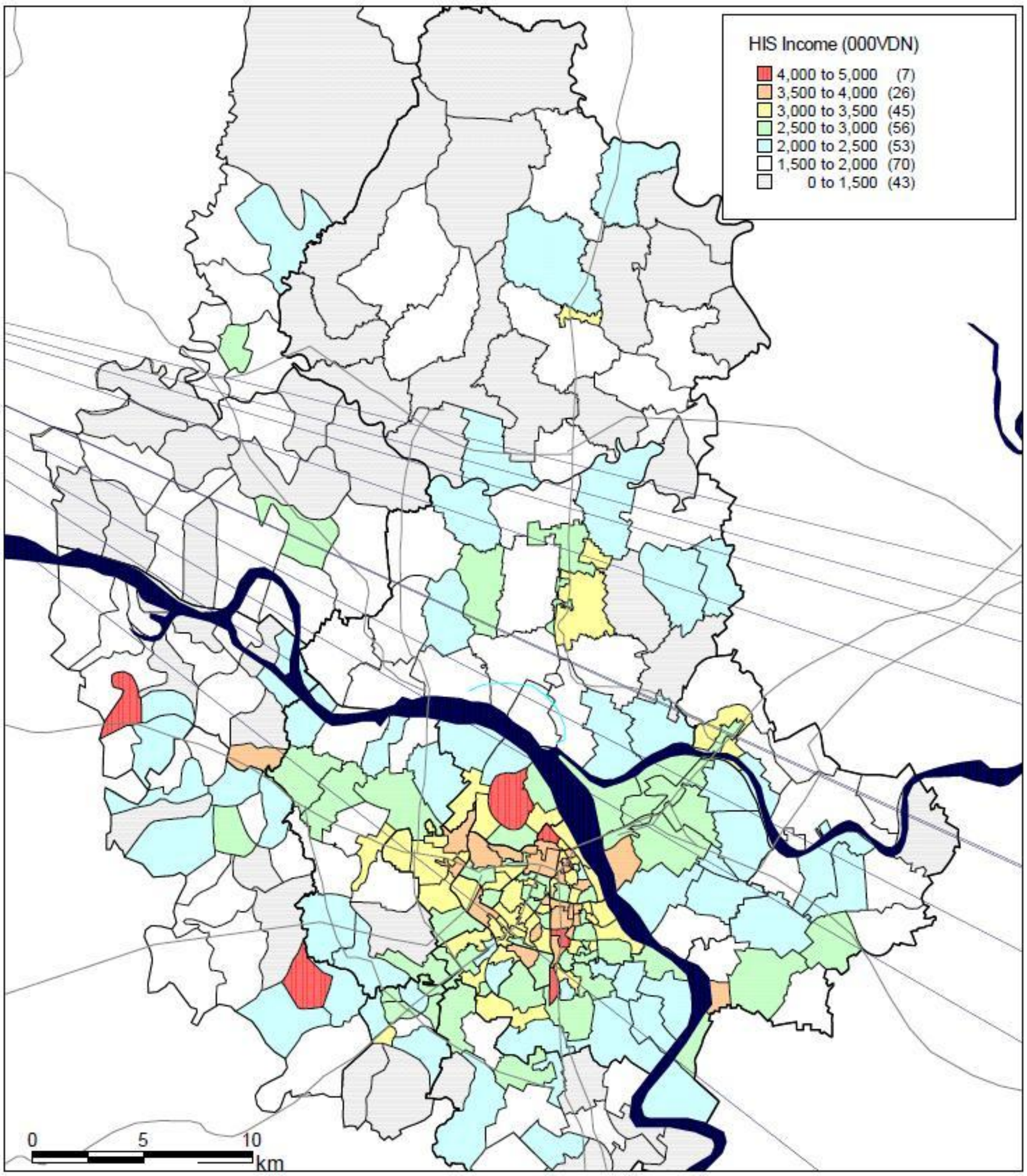


Figure 3.1.1 Average household incomes (HAIDEP)

Household income

The average income is higher for households living in urban area. The average in Hanoi is 2.7 million Vietnam Dong (VND) /month.

Vehicle ownership

In Hanoi City, 85.0% of households own at least one motorcycle and 45.0% own more than two motorcycles. This ratio is higher in urban area; particularly more than 50.0% of households in urban center and urban fringe area have more than two motorcycles. Ownership of motorcycles is also relevantly high in the rural area; most of the households have at least one motorcycle by 76.2%. The ratio of households which own car(s) is still very low, 1.8% in Hanoi and 0.7% in adjoining districts.

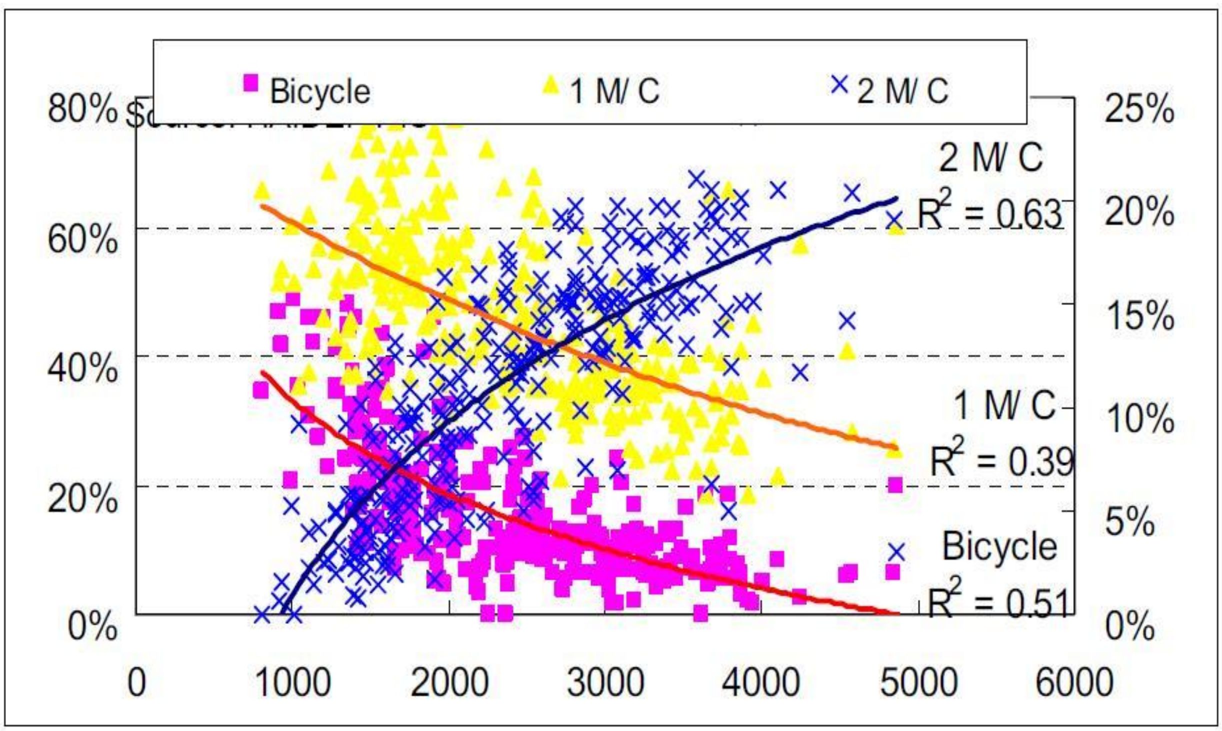


Figure 3.1.2 Household income and vehicles ownership (HAIDEP)

In terms of the relationship between household income and vehicle ownership (cars, motorcycles, and bicycles), the Figure 3.1.2 shows that as income increases, the ownership rate of bicycle decreases (negative correlations), yet as income increases the ownership rate of multi-vehicles, including motorcycles and cars, increases (positive correlations).

Traffic congestion and traffic safety

About 72.0% residents said that the traffic condition became more convenient compared to 5 years ago. On the other hand, 62.7% of them have claimed traffic congestion is significant especially in the urban areas. People consider that this is largely from the increase of motorcycles, slow road development, and driving attitudes. Residents living in urban areas also tend to complain about traffic safety, especially on issues of motorcycle and cross roads. Additionally, there are many complains on driving manner of motorcycles in the city. There are no significant differences between urban and rural areas in the number of serious accidents, but there are more non-serious accidents in urban area compared to the adjoining districts. Households in Dong Da and Thanh Xuan Districts have higher concern about traffic congestion and safety as well as experience on traffic accidents.

Public transport

Only 13.7% of interviewed people use bus at least once a week, and this ratio increases in the urban areas. Most of the respondents (95.0%) consider that bus services need to be expanded, regardless to their current use of bus service. Future public transport which residents are hoping to have is the urban railway systems, such as underground and Light Rail Transit (LRT). Passengers of bus service answered satisfactory at all items asked. Among items asked, bus fare is the one that satisfies users the highest. On the other hand, there are opinions that bus stops are inaccessible and their location should be improved.

3.2 One week household travel survey data 2010

3.2.1 Introduction

The household multi-day travel survey which was launched from December 2010 in Hanoi is an ambitious approach to observe and analyze the structure as well as the determinants of temporal aspects in individual travel behavior for not only deepening the knowledge of motorcycle dependency but also encouraging the usage of public transportation. Thus, the following sampling strategy is used for this survey; 1) finding a person who use buses, and 2) asking them to see if their household members, who are over 15 years old (it is assumed that these people can manage their own activity-travel behavior), would join the survey. Most of the respondents were recruited at main bus stations, thus, the residential location of the respondents were spread out throughout in Hanoi city. As a second step, a surveyor came to their household to interview each member for collecting information related to household/individual attributes and to guide them to fill all their trips made during one week in a trip diary. Information collected would be grouped in to three categories as follow:

- Household attributes: number of household, child existence, vehicle owned, total income, residential facilities characteristics, etc.
- Individual attributes: age, gender, occupation, education level, commuting distance, driving license, motorcycle for own use, bus monthly ticket, etc.
- Trip attributes: trip purpose, accompanying person, travel mode, departure/arrival time, origin/destination place, traffic/weather conditions, etc.

At the end of the survey, the information of total 150 households with 449 individuals and their 6,692 trips were collected.

3.2.2 Trip diary design

Based on the well-known Mobidrive survey, the structure of trip diary was designed with some revising for suitability for Hanoi conditions (Figure 3.2.1). For better understanding, example activity types were given for the different activity categories offered in the diary form as show below:

◯ **Pick up / drop off somebody**

For example, to pick up or drop off people from/ at:

- Bus stop, railway station, airport
- Kindergarten, child care, school
- Doctors, hospital
- Sports field, shop

or similar

◯ **Professional business**

For example, the trip related to your work:

- Conference
- Getting data, document
- Field trip, business trip

or similar

◯ **Personal business**

For example,

- Authority, administrations
- Hairdresser, cosmetics
- Doctor, massage, optician
- Post office, letter box
- Petrol station, repair services
- Shoemaker, tailor, laundry

or similar

◯ **Leisure**

For example,

- Private meetings or visits
- Cinema, theater, concert, museum
- Restaurant, café, pub, beer garden
- Sport activities
- Trade fairs, exhibition, fairs
- Pagoda, church

or similar

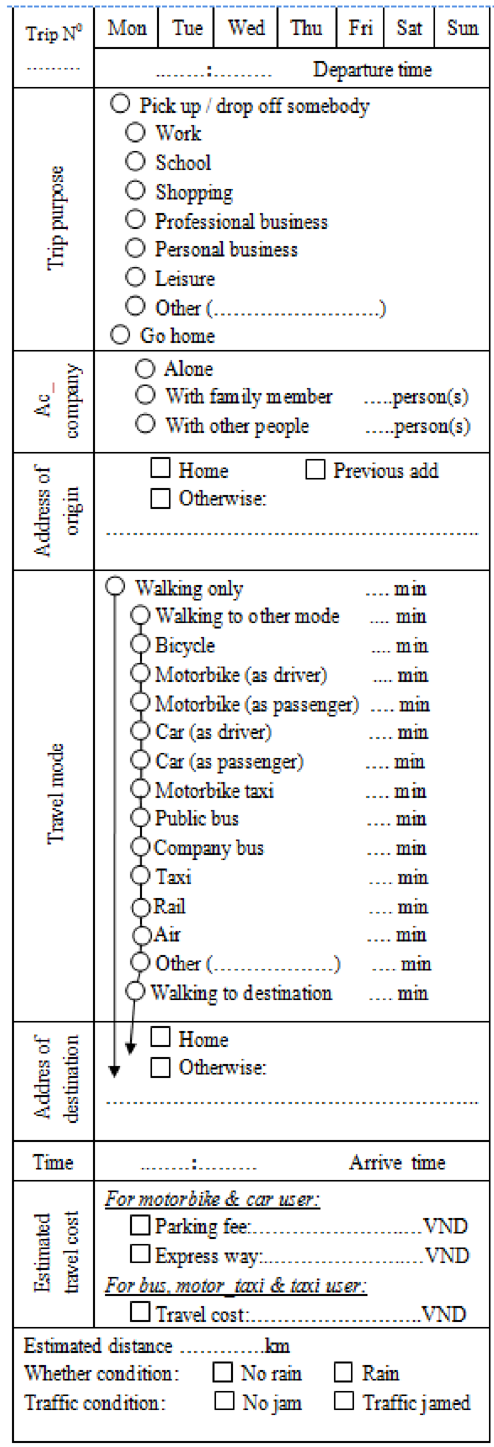


Figure 3.2.1 Example of trip record

The trip record started with day of the week, trip number on that day and departure time. To fill in, respondents selected accordant travel purpose in the list with referring to the given examples of different activity categories. Next, accompany person and address of Origin are required to fill. Travel mode with logical chain design helped respondents fill in easily; otherwise, they may referred two examples which were given in advance (Figure 3.2.2). Respondents then fill in address of Destination and arrive time. Finally, the respondents' estimation on travel cost, travel distance, whether / traffic conditions are also required to fill in the last part of the trip record.

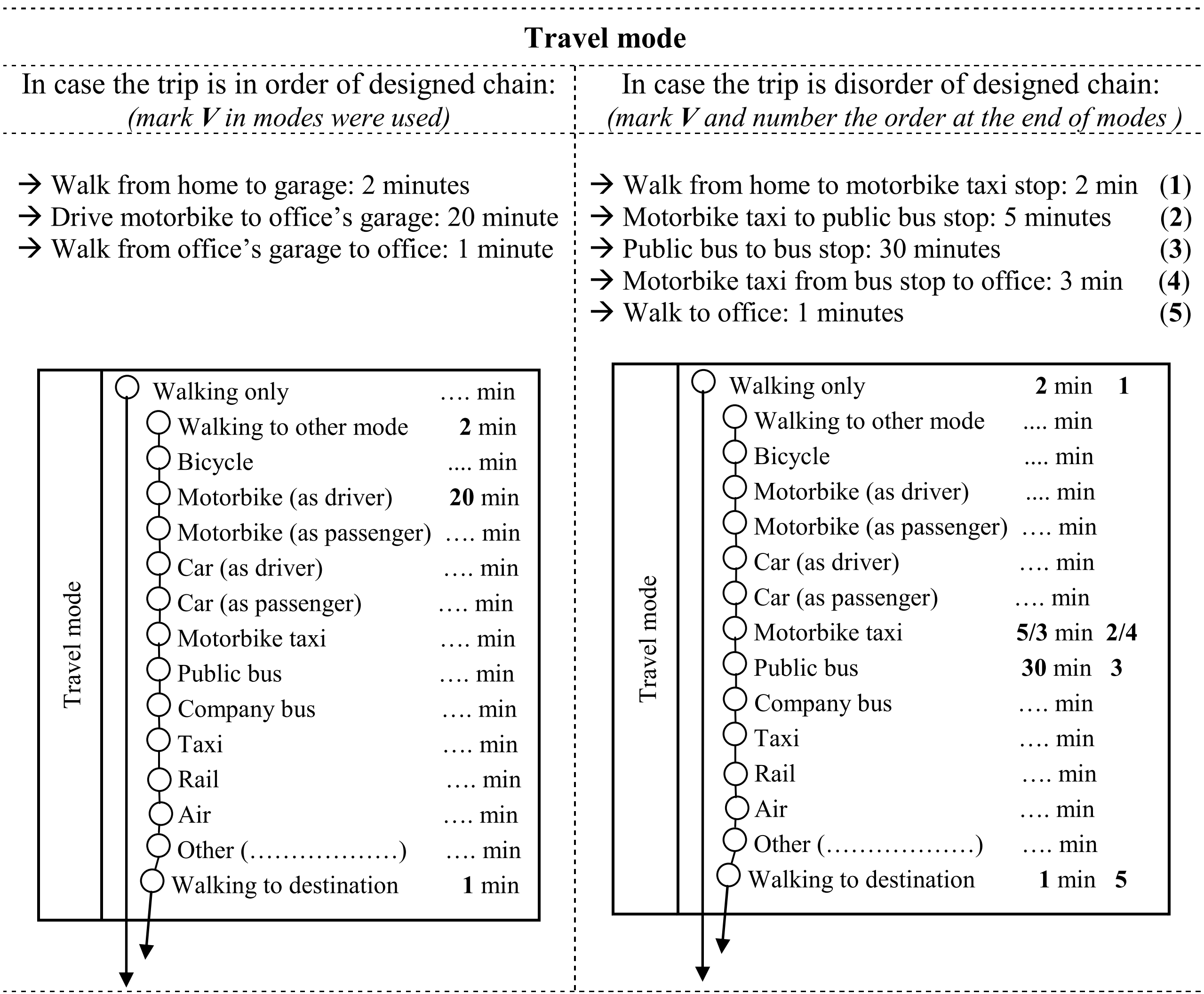


Figure 3.2.2 Examples of how to fill in travel mode

3.2.3 Preliminary results

Households' information

The information of 150 households is shown in the Figure 3.2.3. It can be confirmed that 67.4% of households are families of four or more and no one live alone. Child(ren) existence occupies 20.7 % of households. The household income distribution is quite similar with the actual income distribution in Hanoi (GSO, 2010). Motorcycle ownership is very high with total 94.7% of household have at least one motorcycle. There are 62.7% of households located within easy access bus area, around 500 meters while only 16.0% of households located far over 1 km from

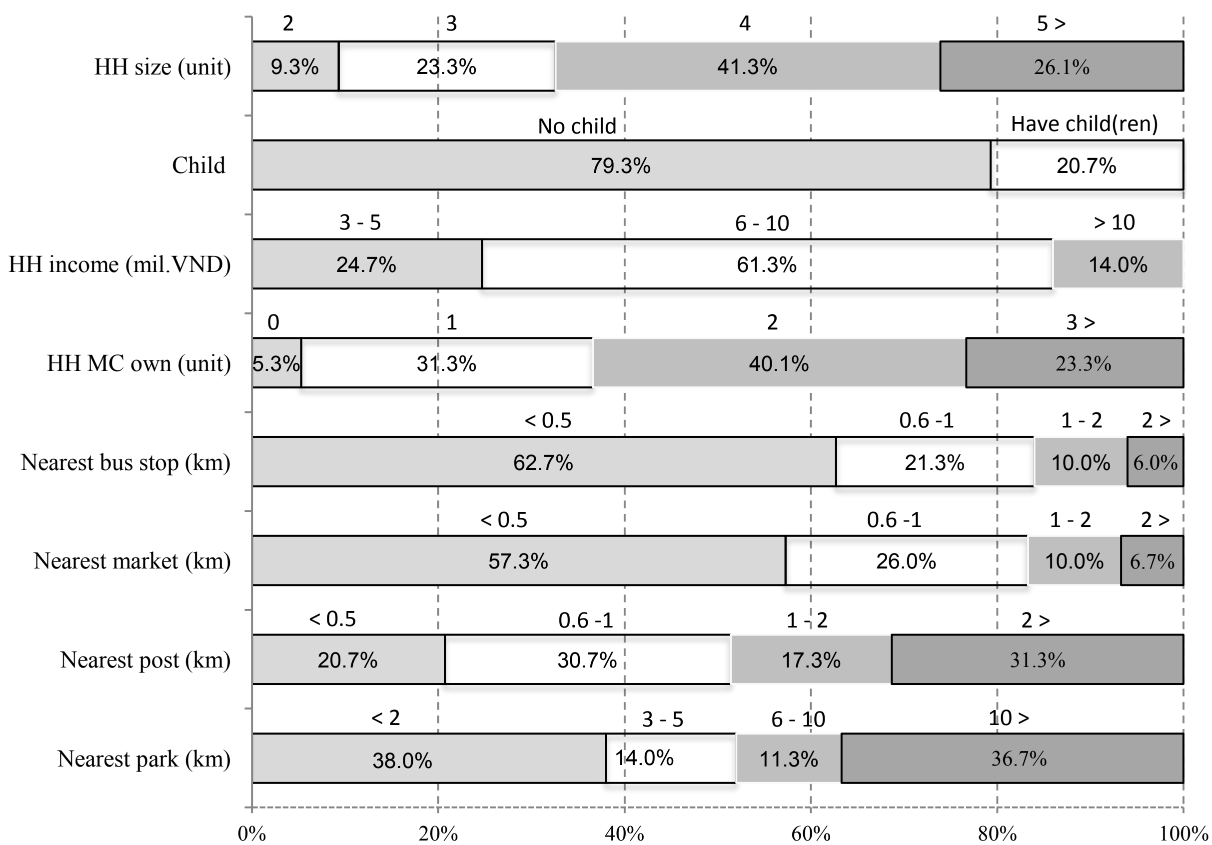


Figure 3.2.3 Households' information

nearest bus stop. Daily shopping seems very convenient for 83.3% of households located closer 1km from nearest market. About half of households may access the nearest post office within 1 km and 52.0% of households could visit a nearest park within 5 km.

Respondents' information

It can be seen that, among 449 individuals joint the survey, the ratio of female are higher with 53.5% (Figure 3.2.4). Young people from 15 to 30 years of age are dominant with total 61.5%. Respondents' employment as worker, student and pupil are dominant with 48.7% and 46.8%, respectively. This is because of the sampling strategy employed in this study, as mentioned in the *Survey design*. That also affects on the high ratio of bus monthly ticket ownership with nearly

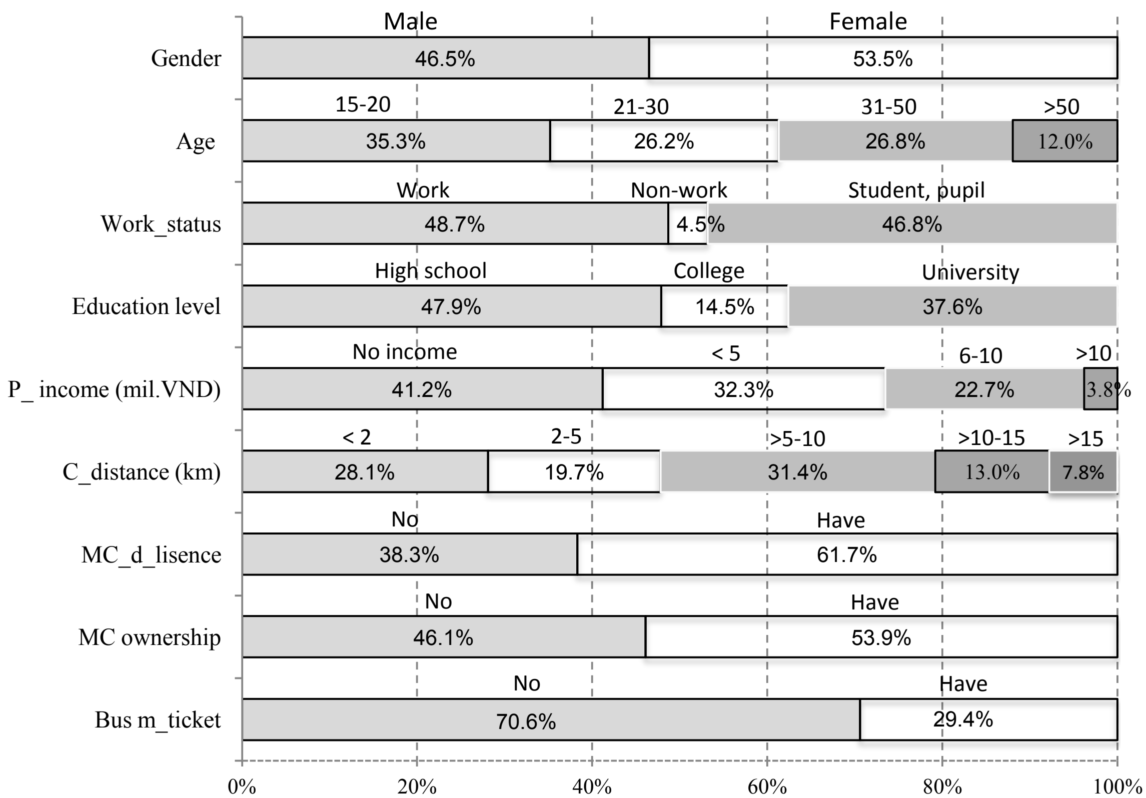


Figure 3.2.4 Respondents' information

30.0%. The personal income shows the high ratio *no income* which correlative with the ratio of those are students, pupils. The ratio of respondents with high education level (university level or above) is relatively high compared to that of the whole population of Vietnam. More than a half of respondents (52.2%) have their commuting trip distances longer than 5 km. There are total 61.7% of respondents having motorcycle driving license while the ratio of respondents who own themselves a motorcycle is smaller with 53.9%.

Trips' information

Information related to total 6,692 trips made by 449 respondents during a period of 7 days is shown in Figure 3.2.5. The number of trips made by motorcycle is highest with 46.1% while trips made by bus occupy the second high value 26.0%. Comparing to the current modal share in Hanoi, the bus share in this study is triple higher. The reason for high share of bus usage surely comes from the sampling strategy employed in this study as well as from the high ratio of respondents who are pupil and student. Commuting trips (i.e., going to work and study) occupies total 32.6%, while non-mandatory trips (i.e., shopping, leisure, and other personal purposes) take 19.6% of total trips. The rest are mainly consisting of *back home* with 39.8% of total trips.

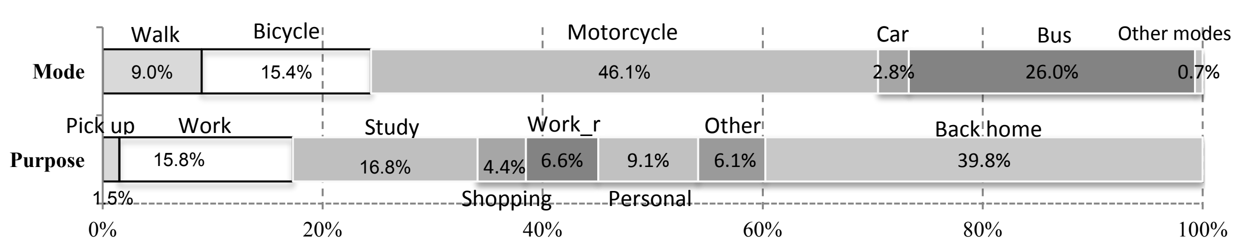


Figure 3.2.5 Travel mode choice and travel purpose information

3.3 Stated Preference (SP) survey data 2005

3.3.1 The SP technique

The SP technique is the application to obtain data on preferences and behavioral intentions to the actual market behavior. It provides an approximation based on hypothetical situations which were set up by the researcher. In SP survey, individuals are asked about what they would choose to do in one or more hypothetical situations. The main characteristics of SP approach are:

It is based on the elicitation of respondent's statements of how they would respond to different hypothetical alternatives.

Each option is represented as a package of different attributes like travel time, cost, headway, reliability and so on.

The researcher constructs these hypothetical alternatives so that the individual effect of each attribute can be estimated.

The researcher has to make sure that interviewees who are given hypothetical alternatives could understand, appear plausible and realistic, and relate their current level of experience.

The respondents state their preferences toward each option by ranking them in order of attractiveness, rating them on a scale indicating strength of preference or simply choosing the most preferred option from a pair or group of them.

The responses given by individuals are analyzed to provide quantitative measures of the relative important of each attribute.

The power of SP exercise lies in the freedom to design quasi-experiments to meet the requirements of a wide variety of research needs. This power has to be balanced by the need to ensure the responses provided by the subjects are realistic, that is as close as possible to how they would have responded had these hypothetical options actually existed in practice. The principle aim of SP techniques is to obtain observations that allow the researcher to infer respondents, valuations towards different attributes of a particular "good".

3.3.2 Outline of the survey

To deal with the transportation problems caused by a huge number of motorcycle while public transportation has only bus, Hanoi authority attempted to build up a modern LRT system. This idea was proposed in early years of new decade in which the new mode was expected to share travel demand with the current overloaded and downgrade bus system as well as to attract motorcycle users. In order to forecast the influences of new LRT system, the SP survey was launched in early 2005 with two parts:

1) Revealed Preference (RP) questions to collect information on current socio-economic and travel behaviors of respondents.

2) Stated Preference (SP) questions to examine mode choice behavior of respondents. In this part, the respondent chose their choice on alternatives such as motorcycle, car, bus or LRT in a package of different hypothetical travel attributes in travel time, travel cost, waiting time and punctuality under changing of 3 Level of Service (LOS) and 3 income levels.

There are 4 attributes (a): travel cost, travel time for all alternatives and waiting time, punctuality for public transport modes, and 3 LOS (n), determine a factorial design (n^a). Therefore, there is $3^4 = 81$ options for the number of hypothetical options need to test people choice preference in SP design method. Based on the orthogonal fractional SP design method, a total 27 profiles are set up with respect to the combinations of the assumed income and the LOS attributes with 3 levels. After excluding the unrealistic profiles, 24 profiles are used in the experiment. To reduce respondents' burden, the 24 profiles were groups into 3 balanced blocks. Each respondent received only 1 block with 8 profiles and is asked to choose the most referred alternative from the 4 predefined travel modes.

The survey area, which contains several living complexes with the population, estimated about 30,000 people, some universities with thousands of student, located along the route where a bus system operated and the LRT line will be built. Along both side of the road, many office buildings, companies, and factories are also included in survey launching. About 400 questionnaires were collected over a period of 2 months from January to March 2005.

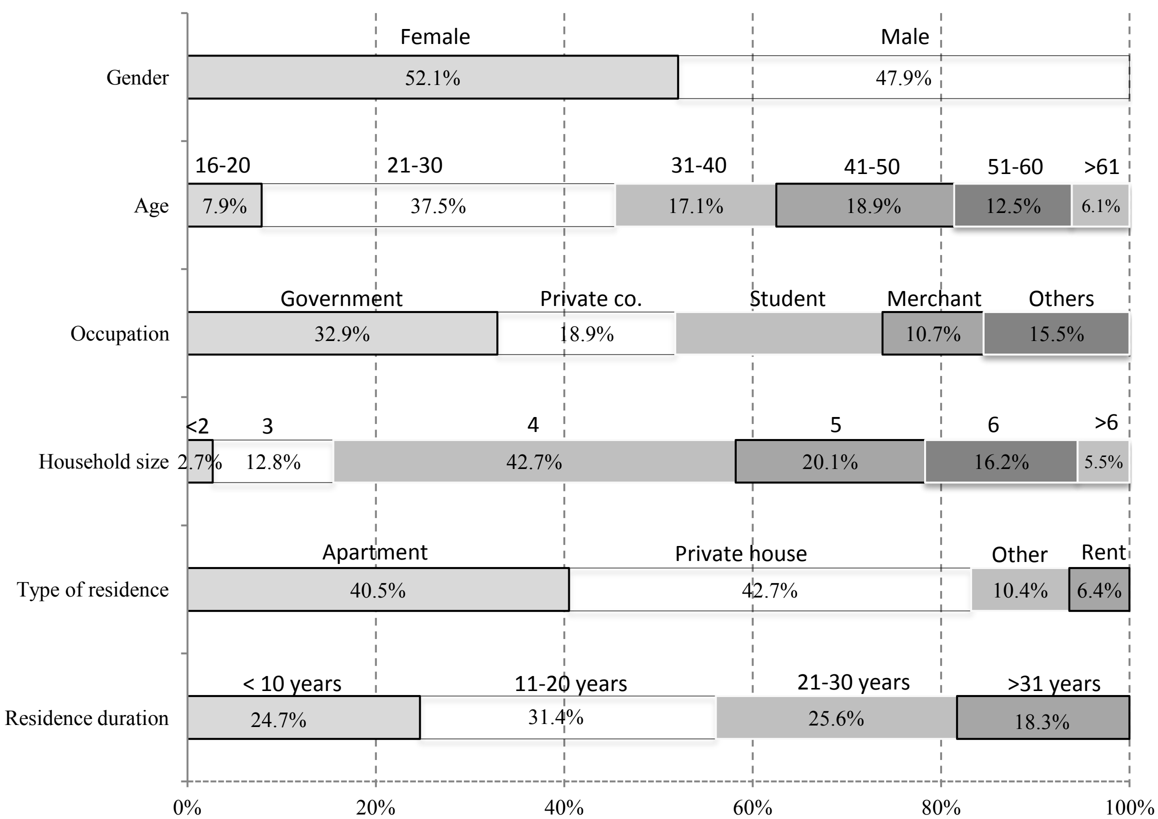
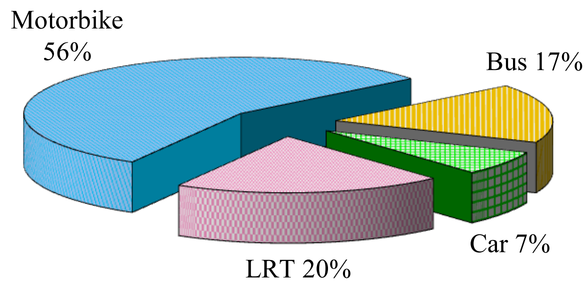
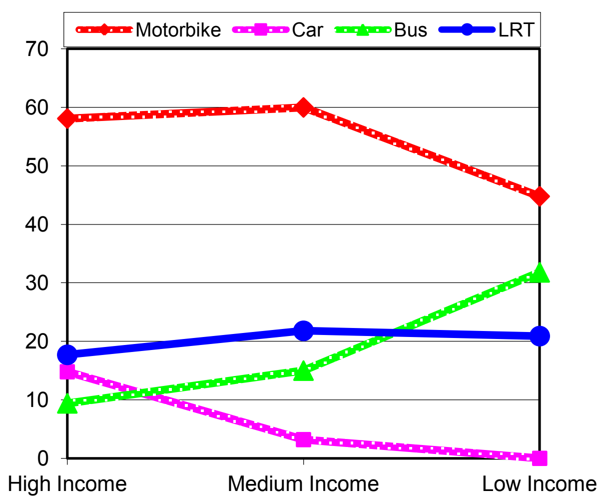


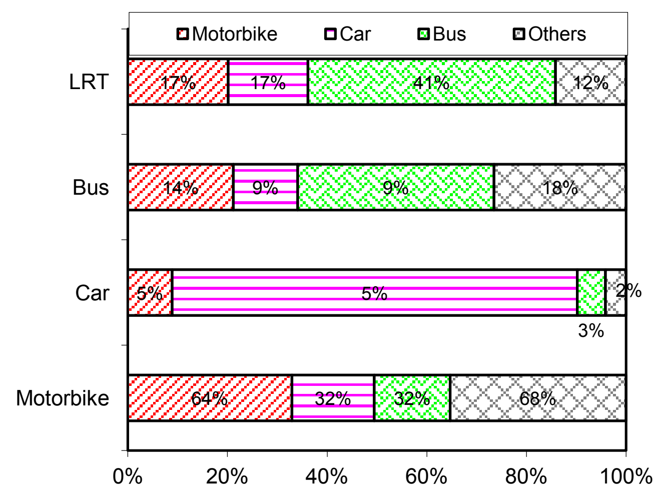
Figure 3.3.1 Respondents' information



SP choice in total



SP choice by income level



SP choice by current modes

Figure 3.3.2 Travel mode choices in SP

3.3.3 Preliminary results

Personal information of respondents shows that 52.1% of them are female and the rest 47.9% are male. Respondents from 21 to 50 years of age are dominant with total 73.5%. Employment information of respondents are as follow: work for government services are highest with 32.9%, work for private company services with 18.9%, student take 22%, merchant take 10.7% and the rest including housewives, non-employee and other. Most of families have from 3 to 6 members. There are 42.7% of respondents living in private house and those living in apartment are 40.5%.

People who had lived from 11 years to 30 years in Hanoi are total 57.0% and 24.7% of respondents which include many students have a living period in this city under 10 years (see Figure 3.3.1).

Stated preference questions help people imagine future assumed income levels with hypothetical travel attributes of each travel mode then give an answer. Through 8 questions, 20% respondents chose LRT (not yet exist), 56% chose motorcycle, 17% chose bus and 7% chose private car. As by changing higher income level, mode choice preferences for bus users are decreasing contrary to the stableness of mode choice preference for LRT. There are 17.0% of current motorcycle users, 13.0% of current car users, 41.0% of current bus users and the rest 12.0% other modes users (i.e., bicycle, taxi or *motorcycle taxi* for travel) expect their willing to shift to the LRT as new alternative for commuting trip (see Figure 3.3.2).

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CHAPTER IV

Avoiding/Reducing motorcycle dependence: Analyses focusing on the household context

This chapter is composed of 4 parts. Section 1 gives general literature review on each household context's factors which had significant impacts on travel behavior. Based on the household composition characteristics of Hanoi city, we then narrowed the scope of the study by arguing that the child(ren) factor may become the most significant impact on mode choice, trip frequency and household's motorcycle ownership decision. Section 2 identifies which ages of child have higher dependency on motorcycle base on home-based trips to study analyses of pupils from 6 to 17 years of age. Section 3 explores the impact of child(ren) existence on the relationship between trip generation and motorcycle ownership decision. The findings summary of this chapter is provided in section 4.

4.1 Introduction

4.1.1Household context and travel behavior

A large number of papers studied the impact of *household context* which included all socio-demographic variables of each individual in household on travel behavior and verified some significant relationships between travel behavior and variables such as gender, age, income, employment status, vehicle ownership, household composition, child existence, etc.

Differences in travel behavior due to gender was a significant factor in many studies with women recognized as being more likely to adopt sustainable travel behaviors compared with men in both developed and developing worlds. Best and Lanzendorf (2005) attempted to determine the gender differences in car use and travel patterns for maintenance travel. Overall the authors found that there were no significant differences in the total number of trips or distances travelled between men and women. However, the type or destination of trips did provide some gender differences. They found that women made fewer journeys to work by car and more journeys for maintenance activities such as shopping and child-care. This was also confirmed by Boarnet and Sarmiento (1998) in their study of travel behavior in southern California. Moriarty and Honnery (2005) studied urban travel in all Australian State capital cities and found that women on average travel less often and for shorter distances than men. Olaru et al (2005) studied travel behavior in the Sydney metropolitan area and found that women were more likely to travel closer to home than men particularly if they came from a non-English speaking household. Perhaps the strongest link between travel behavior and gender was found by Polk (2003, 2004) in studies of travel behavior in Sweden in 1996. Polk found a significant relationship between sustainable travel patterns and gender. Women were more willing to reduce their use of the car than men, more positive towards reducing the environmental impact of travel modes and more positive towards ecological issues. Polk concludes by stating that researchers must consider gender as a factor in attitudinal research on car use. On the other hand, in developing world, Turner and Fouracre (1995) focused on women travel behavior and revealed that, in Brazil women make only a third of work trips but half of non-work trips, and research in Kenya, women's travel is mostly local and on foot. In the studies from both Brazil and Kenya, women reported a higher transit mode share than men. Srinivasan (2006) found that in Chennai, India, men spend more time and money on travel than women, although women walk more, make more trips, and complete more shopping tours than men. Peters (2001) reviewed case studies from cities in India, Mali, Bangladesh, Turkmenistan, and Peru and concluded that women have less access than men to individual mechanized modes of transit ranging from bicycles to automobiles and that women who do have access to public transit are more dependent on it than men with similar access.

Travel behavior heterogeneity happens on different ages of people. Newbold *et al* (2005) studied the different in travel behaviors of Canadians elder people, who aged 65 years, and the younger. Their study found that elder people do make fewer daily trips than younger Canadians but this could be caused by the fact that the participants in the study were no longer employed and hence were no longer making travel-to-work journeys. Thus daily trip numbers and duration decreased significantly due to changes in employment and health status. In addition, there was a greater reliance on the car and a significant reduction in the use of public transport as the principal travel mode compared with younger Canadians. Buehler and Nobis (2010) also focused on elderly people's travel behavior by making a comparison between two countries Germany and the United States. In both countries, the elder age group had their trip rates and travel distances lower than the younger age groups, who made additional trips, such as work trips, and were generally healthier than the elderly. Elderly Germans used the automobile far less than Americans and elderly Americans used the car more often than Germans. McDonald (2005) study focused on children's travel behavior in the United Stated by using data from the 2001 National Household Travel Survey (NHTS). He found that the private vehicle was the dominant mode of transportation for youth under 18 years of age, representing over 75% of all trips. In contrast, walking constitutes only 12% of all trips for this age group; however, when the trip distance was under one-half mile, walking was the main transportation mode occupied 42 %. Obviously, the majority of youth in this age classification has no capability for driving; therefore, it is very important to provide them public transportation when distance and other factors became barriers.

Household composition and employment status were also found to be major influences on travel behavior in a number of papers. Ryley (2005) found that households with children have distinct travel behavior characteristics in Edinburgh, the capital of Scotland. These households are highly dependent on cars as the primary source of travel mode, own but don't often use cycles, and favor cycle trips predominantly for leisure rather than work journeys. Key stages within the household life cycle that impact on travel behaviors includes gaining employment, having children and retirement. Thus households consisting of students, the unemployed and part-timers without children are most likely to use non-motorized forms of transport. Conversely families consisting of retirees and high-income owners are least likely to use non-motorized forms of transport. In other study, Dieleman *et al* (2002) explored the travel behaviors of participants aged 12 years or more in Netherlands. The major findings were that families with children were more likely to use the car than one-person families.

Other two factors have strong impacts on travel behavior are income and vehicle ownership. The results reveal that household income had strong affect to poor households' automobile ownership behavior differently than they do non-poor households' behavior. Specifically, poor households convert income into automobiles at a higher rate and convert larger adult household size into automobiles at a lower rate than non-poor households.

4.1.2 The scope of this chapter

As consequence of living standard gradually improves and urban lifestyle, the household size in urban area of Hanoi is became smaller than that of rural area. The main reason may came from young people who got married and wanted to live their life independently from their original family by creating new families. The household composition with parents and their one or two child(ren) is increasing during time and this type of household will be dominant in the future. With the view point of transportation analysis, the existence of child(ren) is very important factor affecting household's travel behavior as well as each individuals in household including travel mode choice, vehicle ownership and trip frequency. Therefore, in this study, we focus on child existence in household as specific characteristics of *household context*. Base on that, we first determine which ages of child(ren) have strong dependent on motorcycle and second we try to examine whether child existence affected to the relationship between mobility levels and household's motorcycle ownership decision.

In the first part, to ensure persuasive results, we used the Hanoi Person trip survey data 2005. All trips from Home with "to study" purpose of 6 to 17 years old pupils were selected. Information of households as well as individuals was also utilized to develop a multinomial logit model to analyze their mode choice behavior. The findings may broaden our understanding on children's travel behavior for more affective related policies. However, a misjudgment on child(ren) effects on the relation between motorcycle ownership and mobility level may occurred by the existing of self-selection effects (the details will be discussed in section 4.3.3). Thus, in the second part, we used the one week household travel survey data 2010 and established an endogenous switching model to examine whether the self –selection effects exist or not. Such understanding of the relations between motorcycle ownership and mobility level could help transportation planners, for example, to discuss how to utilize motorcycle in the context of households' usage (including pick-up or drop-off their family members) in Hanoi where motorcycle is an essential component of the transport system.

4.2 Does child need motorcycle?

Walking and cycling to school have become a concern for public health and transportation planners and policy makers around the world during recent years. In a developing city like Hanoi, the streets have become hyper-congested by motorized vehicles, the pavements are utilized for household merchant as well as motorcycle parking so that children have less physical activity and more likely to be drop-off to school by motorized travel modes for their safety. Their schools become large trip generations in local areas which cause more traffic congestion on the streets especially in rush hours. Thus, the objective of this part was to identify the factors influencing the travel mode choice behavior of Hanoi's pupil traveling to school. Total 10,346 trips from home to school of pupils from 6 to 17 years of age were selected and analyzed by using a multinomial logit model. The results of the research will help planners to develop a better understanding of children's travel behavior for setting up more effective policies and programs. It can also provide researchers a comparison to show international similarities and country-specific differences in students' travel behavior.

4.2.1 Data summary

Table 4.2.1 reports modes of travel for trips to school from Hanoi Person trip survey data 2005. It can be seen that bicycle is the most preferred mode of pupils 6 – 17 years of age and it

Table 4.2.1 Travel modes for school trip

Modes	Go to school	
	Count	Percent
Walk	3856	37.3%
Bicycle	4598	44.4%
Motorcycle passenger	1577	15.2%
Bus	175	1.7%
Other	140	1.4%
Total	10346	100.0%

occupies 44.4% of modal share. The second large share is walking which represents 37.3%. Use motorcycle as passenger including by parents drop-off and by motorcycle taxi service stands third with 15.2%. The number of pupils used public transport to go to school is very small compare to other countries with only 1.7%. The smallest mode share is other modes which occupies 1.4%.

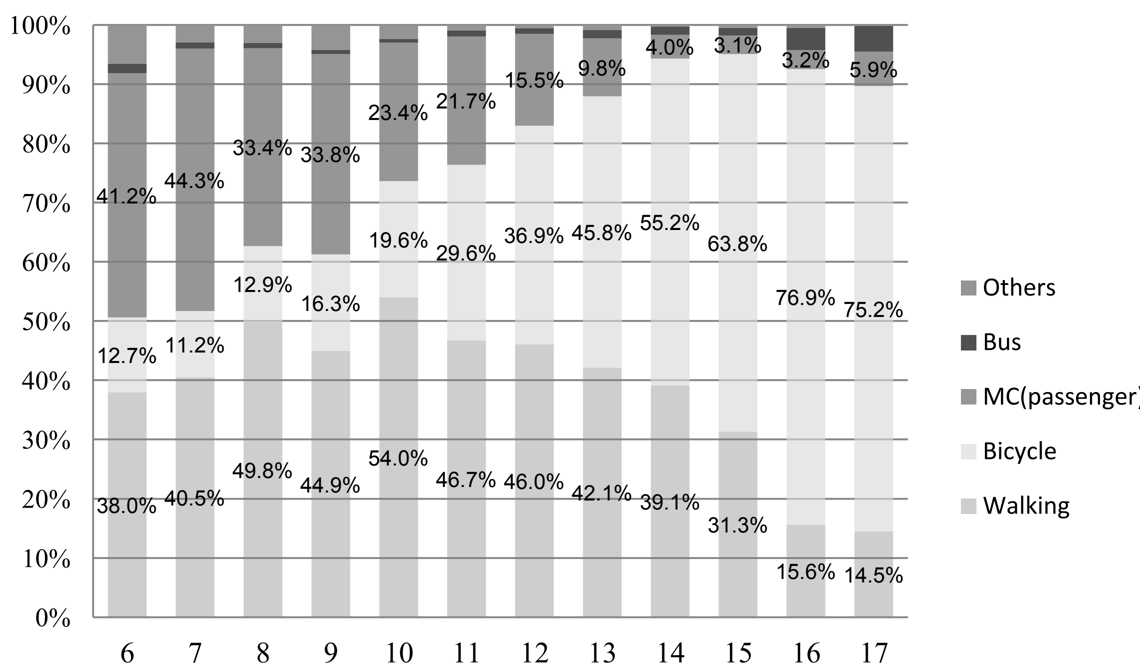

Figure 4.2.1 Modal split on school trip for pupils from 6 to 17 years of age

As can be seen from Figure 4.2.1, walking seem increases until age 10 to 54.0% then drops gradually opposite direction with increasing of age to 14.5%. On the contrary, the more growing up, the more pupils independent and could select them self for biking to school as show in increasing ratio from minimum 11.2% to maximum 76.9%. Thus, the most favorite mode for high school pupils from 15 to17 years of age is bicycle. Elementary pupils from 6 to 10 years of age have a considerable motorcycle share especially pupils from 6 to 7 years of age when they occupy more than 40%. However, the ratio starts decreasing from 8 years of age as sharing for other modes as walking and biking. The ratio of motorcycle share decreases significantly for high school pupils. Go to school by bus occupies very small share for all of ages but it could be confirmed that, the older pupils, the higher share of bus.

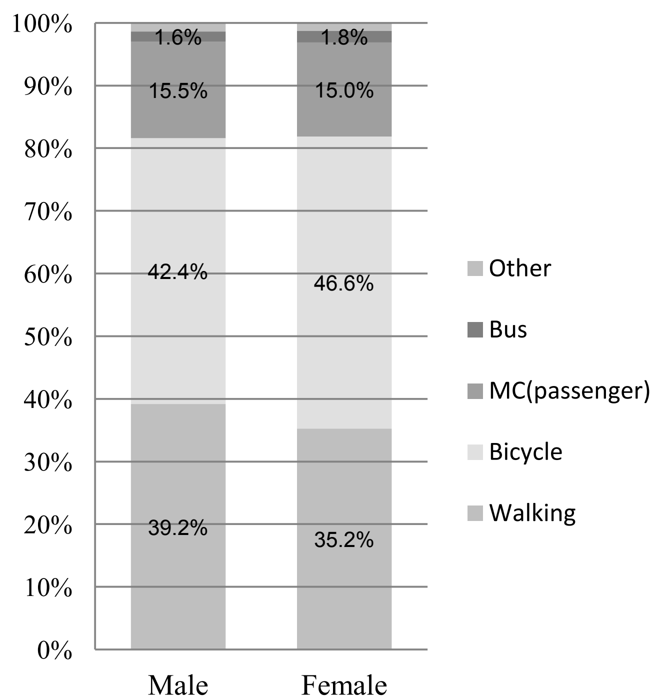

Figure 4.2.2 Modal split on school trip by gender

Figure 4.2.2 shows the modal split for trip to school for male and female pupils. Results indicate that girls are less likely to prefer walking than cycling to school: 35.2% of girls walk to school while 39.2% of boys prefer this mode and 46.6% of girls use bicycle while the ratio of boys is lesser with 42.4%. Gender seems not affect to motorcycle mode choice because the ratios of both male and female are almost equally. Bus choice and other modes choice for school trips are quite small to distinguish the different in mode choice between genders.

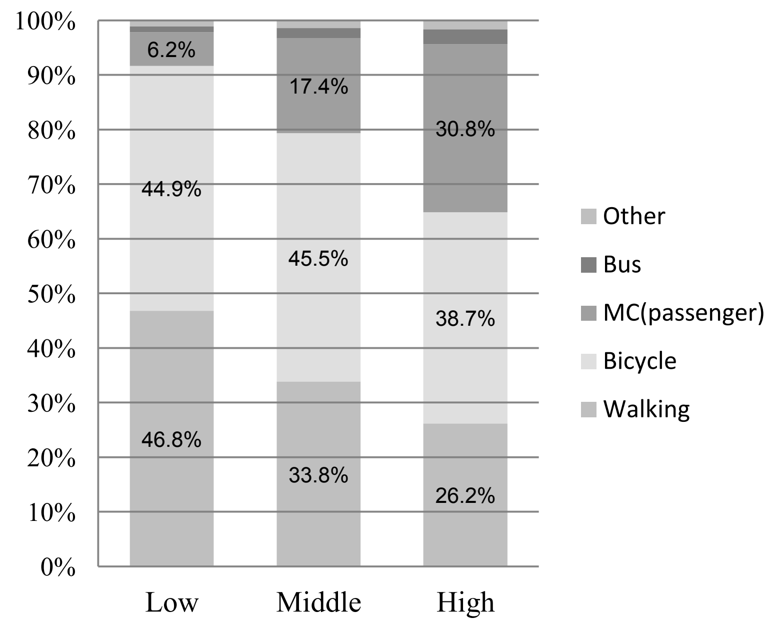

Figure 4.2.3 Modal split on school trip by levels of household income

From figure 4.2.3, the modal split for pupils with different level of household income (i.e., low, middle and high) has been shown. For pupils with low household income: 46.8% walk, 44.9% use bicycle and the percent of pupils use motorcycle to go to school is very small with 6.2%. 45.5% of pupils in medium household income use bicycle, the walking ratio is lower and use motorcycle is higher comparing to pupils with low household income: 33.8% and 17.4%. For pupils with high level of income, only 26.2% of pupils walk, 38.7% use bicycle while the ratio of using motorcycle is highest with 30.8%. It's could be seen that, household income has very significant impacts on pupils mode choice behavior, especially on the motorcycle choice.

Table 4.2.2 Multinomial logit model results for school trip modal choice behavior

Variables	Walking	Bicycle			Motorcycle passenger			Bus		
		Parameter	t_statistic		Parameter	t_statistic		Parameter	t_statistic	
Constants	-	0.840	8.500	***	-2.846	-17.480	***	-4.494	-11.548	***
School in neighborhood										
No	-	1.114	18.756	***	2.442	29.072	***	4.095	13.075	***
Yes	-	-	-		-	-		-	-	
Household income level										
Low	-	-0.090	-1.038		-1.646	-13.979	***	-0.612	-2.418	*
Medium	-	0.001	0.009		-0.589	-6.079	***	-0.324	-1.533	
High										
Grade										
Elementary (6 - 10 years of age)	-	-1.900	-26.323	***	2.683	20.478	***	-0.540	-2.235	*
Secondary (11 - 14 years of age)	-	-0.884	-15.294	***	1.179	9.233	***	-0.707	-3.834	***
High school (15-17 years of age)	-	-	-		-	-		-	-	
Gender										
Male	-	-0.196	-4.059	***	-0.094	-1.322		-0.264	-1.663	.
Female	-	-	-		-	-		-	-	
Weekday										
Yes	-	-0.072	-1.481		0.090	1.234		-0.105	-0.645	
No	-	-	-		-	-		-	-	
Log-likelihood at zero					-14342.60					
Log-likelihood at convergence					-8605.20					
Rho					0.4000					
Number of observations					10,346					

(*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

4.2.2 Model results and discussion

For travel to school by bicycle relative to walking, the school location out of neighborhood is significant meaning that, the pupils who have household's location in different community zones are more likely to cycle to school. Household monthly income levels do not significantly influence pupils' bicycle choice. The grades of pupils have significant impacts in negative way and these impacts are in the opposite direction with the grade level. In other words, the younger pupils the lesser choosing bicycle. The reason may come from the fact that, pupils as elementary school are too young to drive their bicycle from home to school. For boys relative to girls, the negative significant could be understand that girls are more likely than boys to prefer taking bicycle to walking. Temporal variable as weekday has no significant to pupil's mode choice behavior.

For travel to school by motorcycle as passenger relative to walking, the school location out of neighborhood is also significant and higher than that of travel by bicycle. The similar conclusion can be made for motorcycle choice of the pupils who have households and school's location in different community zones. Household monthly income levels have significant impacts in negative way and these impacts are in the opposite direction with the income level. In other words, pupils of higher household income levels are more likely prefer to use motorcycle to go to school. The grades of pupils have significant impacts and these impacts are reducing due to the grade levels. These could be imply that the younger pupils the higher properties to choose motorcycle to go to school. Safety issues may the main reasons for parents to drop-off their children by motorcycle, especially elementary pupils. Gender and temporal variables are not significant for travel to school by motorcycle as passenger.

For travel to school by bus relative to walking, the school location out of neighborhood is also significant but smaller than that of travel by bicycle and travel by motorcycle. It's obliviously that the pupils who live in the different community zone with their school location prefer to use vehicle to go to school rather than walking. The low household monthly income has negative significant implies that comparing to pupils from high income households, pupils from low income households have lower properties to choose bus for their school trip. In other words, older pupils, those in higher grade and those with higher household income are less likely to prefer walking to bus. Girls are more likely than boys to use bus as showed by negative significant in *male* variable. Again, temporal variable has no significant to pupil's bus choice.

In summary, the findings indicate that age, gender, family income and the school location have strong affect on pupil's mode choice behavior. The most important findings are both of child groups, from 6 to10 years of age and from 11 to 14 years of age are higher dependent on their parent's motorcycle to make school trip and the younger group the higher dependency on motorcycle. The results may contribute a great deal to better understanding of pupils' travel behavior for transportation professionals and planners.. These findings also reveal many issues related to urban planning, neighborhood design to encourage walking and cycling from home to school as well as motorcycle usage which will be further discussed at the latter past of this chapter.

4.3 Child existence and motorcycle ownership decision

4.3.1 Introduction

With the aim to understand the motorcycle ownership and usage in *household context*, this part explores whether child existence affected to the relationship between mobility level and household's motorcycle ownership decision by focusing on the coupling constraints caused by child(ren) and motorcycle ownership impact on mobility level. In a motorcycle dependent city like Hanoi, pick-up and drop-off family member(s) by motorcycle is very common phenomena, for example, drop-off child from home to their school as proved in previous part. In such case, it can be expected that owning a motorcycle may be quite important especially for those who face with strong behavioral constraints, for example, an individual who has a responsibility to drive his/her family member(s) to some places where they can meet their needs.

The behavioral constraints could be divided into three different components: capability constraints, coupling constraints, and authority constraints (Hagerstrand, 1970). In this study, we only focus on coupling constraints, which can be defined as "Where, when, and for how long, the individual has to join other individuals". Coupling constraints has been intensively discussed in the discussions of activity based approach, providing fundamental concept of group decision making (the detailed discussions can be found in, for example, Fujiwara and Zhang (2006) and Schwanen (2008)). In this empirical analysis, coupling constraints caused by child existence is investigated. The reason why this analysis focus on child effects is that pick-up and drop-off their child could be considerable coupling constraints for parents, partly caused by the lack of schools (i.e., travel distance from home to school could be longer), safety problems (i.e., pavements for pedestrian occupied by merchants activities and utilized for motorcycle parking), and poor public transport services. Such coupling constraints would limit parents' travel and activity decisions in terms of both time and space by adding additional places to be visited, which probably affect their activity space. To overcome the coupling constraints, it could be expected that higher level of mobility (i.e., owning a motorcycle) is needed for them, compared to those who do not have child(ren).

Under the above mentioned considerations, this analysis attempts to examine the relation between motorcycle ownership and the number of trips with taking into account the household composition differences, which might cause the different level of coupling constraints. In this study, child existence is considered as a household composition difference. Additionally, it is supposed that, under the condition of the same household composition, the number of trips is a kind of measure of their mobility level. In other words, it is assumed that those who can generate the higher number of trips are less affected by coupling constraints. By using one week continuous household travel diary data, the number of trips made by adults with/without children and motorcycle/non-motorcycle owners are first compared. At this stage, we simply compare the differences in their mobility levels by conducting cross tabulation analysis. After that, we recheck the obtained conclusion of the effects of motorcycle ownership on mobility level, by indentifying whether self-selection effects existing or not, which potentially lead to misjudgment on the relations (the details will be discussed in latter section). To check the existence of child effects in the relation between motorcycle ownership and the number of trips, an endogenous switching model is established. Such understanding of the relations between motorcycle ownership and mobility level could help transportation planners, for example, to discuss how to utilize motorcycle in the context of households' usage (including pick-up or drop-off of their family members) in Hanoi where motorcycle is an essential component of the transport system. This part of chapter IV is organized as follows. Section 2 shows preliminary aggregation results related to motorcycle ownership. Section 3 describes an endogenous switching regression model and its expected implications. Section 4 gives estimation results and discussions.

4.3.2 Motorcycle ownership and trip frequency

The number of trips might be dependent on whether the respondent has child(ren) or not, as well as whether the respondent has motorcycle or not. To confirm the role of motorcycle in their trip making with the consideration of child effects, all respondents are divided into 4 sub-groups: motorcycle owners with child(ren), non-motorcycle owners with child(ren), motorcycle owners without child(ren), and non-motorcycle owners without child(ren). Here, child means person who is under 15 years old. The crosstab results are show in Table 4.3.1.

Table 4.3.1 Estimation results of aggregation analysis

	With child(ren)	Without child
The number of total trips /day (including immobile days)		
Motorcycle owners	2.25	2.13
Non-motorcycle owners	2.23	2.07
n = 3143 (449 individual x 7days)		*(trips)*
The number of total trips /day (excluding immobile days)		
Motorcycle owners	3.13	2.96
Non-motorcycle owners	3.03	2.87
n = 2272 (449 individual x mobile days only)		*(trips)*

The data was firstly analyzed on total 7 days of week including immobile days. It could be seen that those who have child(ren) generate the higher number of trips for both motorcycle owners and non-motorcycle owners. The results also show that there are positive impacts of motorcycle ownership on their trip making, but the impact of motorcycle ownership is higher for those who have child(ren), implying that motorcycle ownership is more crucial for those who have child(ren) to keep their mobility level under their behavioral constraints. On the other hand, the number of trips between days of week may vary across groups. Thus, the data is then analyzed focusing on mobile days only. The results confirmed the findings in previous analysis: those who have child(ren) generate the higher number of trips. It could be understood that, the motorcycle owners without child are less influenced by coupling constraints, implying that they could decide their travel behavior based on their own needs.

Table 4.3.2 Motorcycle ownership ratio by age groups and gender

	Male	Female
16-20 years old	16.9%	9.3%
21-30 years old	77.4%	57.6%
31-50 years old	94.2%	76.4%
Over 50 years old	87.1%	45.5%

Table 4.3.3 The number of trips/day by age groups and gender

	Male	Female
16-20 years old	2.97	2.89
21-30 years old	3.14	3.09
31-50 years old	3.05	2.90
Over 50 years old	2.59	2.67

The differences in motorcycle ownership and the number of trips across age groups and gender are then examined as shown in Table 4.3.2 and Table 4.3.3. As shown in Table 4.3.2, the percentage of male’s motorcycle ownership is higher than female’s motorcycle ownership across all age groups while younger and elder females have lesser ownership. On the other hand, the aggregation results of the number of trips shown in Table 4.3.3 show that males make more trips than females (except for over 50 years old group) and stable across all age groups. Both findings may imply a possibility that motorcycle may not an important mobility tool for female in terms of trip making.

4.3.3 Development of endogenous switching regression model

Let y_i is the number of observed trips per day (in empirical analysis, the natural logarithm of the number of trips for y_i), and I_i is a dummy variable (I_i = 1 if the individual owns motorcycle; I_i = 0 otherwise). Let y_{1i} is the number of trips for motorcycle owner, and y_{2i} is the number of trips for non-motorcycle owner. Thus, the number of trips can be written as follows:

$$y_i = \begin{cases} y_{1i} & if \quad I_i = 1 \\ y_{2i} & if \quad I_i = 0 \end{cases} \tag{1}$$

$$y_{1i} = \alpha \mathrm{x}_\mathrm{i} + \varepsilon_{1i} \tag{2}$$

$$y_{2i} = \beta \mathrm{x}_\mathrm{i} + \varepsilon_{2i} \tag{3}$$

where, α and β are the vectors of unknown parameters, x_i is the vector of explanatory variables, and ε_{1i} and ε_{2i} are unobserved random components. We also assume that their motorcycle ownership behavior (i.e., whether an individual owns his/her own motorcycle) is determined by the following equations.

$$I_i^* = \gamma \mathrm{x}_\mathrm{i} + \varepsilon_{3i} \tag{4}$$

$$I_i = \begin{cases} 1 & if \quad I_i^* > 0 \\ 0 & if \quad I_i^* \le 0 \end{cases} \tag{5}$$

Here, I^*_i is the latent variable that determines their motorcycle ownership based on eq. (5), γ is the vector of unknown parameters, and ε_{3i} is an unobserved component. We further assume that ε_{1i}, ε_{2i} and ε_{3i} follow the multivariate normal distribution:

$$(\varepsilon_{1i}, \varepsilon_{2i}, \varepsilon_{3i}) \sim MVN(0, \Sigma) \tag{6}$$

$$\Sigma = \begin{bmatrix} \sigma_1^2 & 0 & \rho_{1\varepsilon}\sigma_1 \\ 0 & \sigma_2^2 & \rho_{2\varepsilon}\sigma_2 \\ \rho_{1\varepsilon}\sigma_1 & \rho_{2\varepsilon}\sigma_2 & 1 \end{bmatrix} \tag{7}$$

Since the changes in I^*_i can switch not only their motorcycle ownership decisions (eq. (5)), but also trip making decisions (eqs. (1)), and these two decisions are dependent each other through the random components, the model can be called as an endogenous switching model. The feature of the endogenous switching model can be found by checking the expected number of trips conditional on their motorcycle ownership decisions as follows:

<u>The expected number of trips (for those who own their own motorcycle)</u>

$$E(y_{1i} \mid I_i = 1) = \alpha \mathrm{x_i} + \rho_{1\varepsilon}\sigma_1 \frac{f(\gamma \mathrm{z_i})}{F(\gamma \mathrm{z_i})} \tag{8}$$

<u>The expected number of trips (for those who don't own their own motorcycle)</u>

$$E(y_{2i} \mid I_i = 0) = \beta \mathrm{x_i} - \rho_{2\varepsilon}\sigma_2 \frac{f(\gamma \mathrm{z_i})}{1 - F(\gamma \mathrm{z_i})} \tag{9}$$

where $f(\cdot)$ is a standard normal density distribution function and $F(\cdot)$ is a standard normal cumulative distribution function. The existence of self-selection effects can be tested by checking whether $\rho_{1\varepsilon}$ and $\rho_{2\varepsilon}$ are equal to zero or not. If these two correlation parameters can be seen to be equal to zero, we could say that the decisions of motorcycle ownership and trip making are independent, and vise versa. Further, the signs and magnitudes of $\rho_{1\varepsilon}$ and $\rho_{2\varepsilon}$ are also important to identify what kind of self-selection effects there are. For example, in case of $\rho_{1\varepsilon}$ >0 and $\rho_{2\varepsilon}$>0, the average number of trips of motorcycle owners is greater than αx_i, and the average number of trips of non-motorcycle owners is less than βx_i. In this case, the average number of trips of motorcycle owners is higher than that of non-motorcycle owners even when the current motorcycle users are in the situation where motorcycle is not available. Similarly, the average number of trips of non-motorcycle owners is lower than that of motorcycle owners even when the current non-motorcycle users are in the situation where motorcycle is available. These indications might imply that those who want to generate the higher number of trips self-select themselves to own motorcycle to obtain higher mobility. In this study, such self-selection effects are identified for both those who have child(ren) and who don't have child(ren). Note that there are two ways to take into account child effects: developing the model for each group and introducing the corresponding explanatory variable (i.e., whether they have child(ren) or not). The former addresses only differences in intercepts in eqs. (2)-(4) by population group, whereas the latter addresses differences in slope coefficients as well. In this study, we decide to use the former approach to reduce the number of unknown parameters, since the sample size is quite limited. Applying the latter approach with the larger sample size is an important future task to be investigated.

The unknown parameters in the above mentioned switching model can be obtained by maximizing the following log-likelihood function (see Maddala, 1983).

$$LL=\sum_i \left\{ \begin{aligned} & I_i \left[ln\left(F\left(\frac{\gamma z_i+\rho_{1\varepsilon}(y_{1i}-\alpha x_1)/\sigma_1}{\sqrt{1-\rho_{1\varepsilon}^2}} \right) \right) + ln\left(\frac{1}{\sigma_1} f\left(\frac{(y_{1i}-\alpha x_i)}{\sigma_1} \right) \right) \right] \\ & +(1-I_i)\left[ln\left(1-F\left(\frac{\gamma z_i+\rho_{2\varepsilon}(y_{2i}-\beta x_i)/\sigma_2}{\sqrt{1-\rho_{2\varepsilon}^2}} \right) \right) + ln\left(\frac{1}{\sigma_2} f\left(\frac{(y_{2i}-\beta x_i)}{\sigma_2} \right) \right) \right] \end{aligned} \right\} \quad (10)$$

4.3.4 Model estimation results and discussion

Table 4.4.1 shows estimation results of the endogenous switching model built in the previous section. The potential influential factors are putted as explanatory variables, including built environment attributes (i.e., distances to the nearest park and post office), day of week, and individual/household attributes (i.e., age, gender, household income, working status, motorcycle license, and child existence). Even insignificant explanatory variables are kept in the final model estimation, because the purpose of model development in this study is to understand their decisions on motorcycle ownership and trip making, rather than establishing a prediction model. As show in the Table, *motorcycle driving license* and *work* status show significant impacts for motorcycle ownership (i.e., when he/she has motorcycle driving license or has a work , he/she tend to own a motorcycle). *Male* and *age* are also significant; indicate that older males tend to own their own motorcycle. It is also confirmed that *household income* has significant and positive impacts on motorcycle ownership. Focusing on the regression part, the neighborhood felicities around residence location such as nearest park and post office are not significant influential factors on their trip making.

Usually, we think that, if a person had a motorcycle, the number of his/her trip might become higher than before or when he/she disposes their own motorcycle, the number of his/her trip will

Table 4.4.1 Estimation results of endogenous switching model

	choice of motorcycle ownership I_i (γx_i)			regression for motorcycle owner y_{1i} (αx_i)			regression for non-motorcycle owner y_{2i} (βx_i)		
	param	t-value		param	t-value		param	t-value	
EXPLANATORY VARIABLE									
Constant	-2.503	-20.502	***	2.133	20.569	***	0.841	11.686	***
Age	0.008	3.122	**	-0.001	-0.491		-0.002	-1.420	
Male (D)	0.358	6.041	***	0.006	0.167		-0.005	-0.143	
Household income [mil. VND]	0.053	4.673	***	-0.003	-0.412		0.019	1.543	
Work (D)	1.187	16.362	***	0.107	1.018		0.072	0.806	
Motorcycle license (D)	1.843	26.787	***	-0.098	-0.862		-0.035	-0.392	
Weekend (D)				0.002	0.100		-0.007	-0.191	
Distance to the nearest park [km]				0.004	1.515		0.005	0.447	
Distance to the nearest post office [km]				-0.008	-1.130		0.001	0.275	
Child (D)	-0.075	-0.968		0.063	1.423		0.036	0.849	
VARIANCE-COVARIANCE									
Dispersion parameter (σ_1)				1.067	64.840	***			
Dispersion parameter (σ_2)							1.055	60.021	***
Correlation parameter ($\rho_{1\varepsilon}$)				0.064	0.420				
Correlation parameter ($\rho_{2\varepsilon}$)							-0.132	-1.022	
Log-likelihood at zero	-5837.862								
Log-likelihood at convergence	-4130.112								
Rho	0.293								
Number of observation	3,143								

(*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

reduce. But, the results got from the endogenous switching model shown in Table 4.4.2 indicate somewhat different conclusions. It could be explained that motorcycle users generate the higher number of trips partly because he/she has higher needs for travel than non-motorcycle users, because both correlation parameters are positive (See the discussions made in the previous section). In other words, even in the situation when he/she is no longer own a motorcycle; he/she may still make trips by other modes to satisfy his/her needs.

Table 4.4.2 Self-selection effects on their trip-making

	$E(y_{1i} \mid I_i = 1)$	$E(y_{2i} \mid I_i = 0)$	$P(I_i = 1)$	$\rho_{1\varepsilon}\sigma_1 \frac{f(\gamma z_i)}{F(\gamma z_i)}$	$-\rho_{2\varepsilon}\sigma_2 \frac{f(\gamma z_i)}{1 - F(\gamma z_i)}$
All samples	0.951	0.943	0.539	0.042	0.092
-with child(ren)	1.005	0.968	0.480	0.052	0.081
-without child(ren)	0.937	0.936	0.554	0.039	0.095

In summary, there is a possibility that the simple aggregation results on the motorcycle impacts may be biased and motorcycle itself may have a smaller effect on the number of trips, and those who want to generate the higher number of trips may self select to own him/herself a motorcycle. Under our model system developed here, the above implications are true for both those who have child(ren) and those who don't have child(ren). But we can also confirm the differences between them. Concretely, the results shown in Table 4.4.2 indicate that there might be a larger self-selection effect for motorcycle users with child(ren) (0.052), compared to that for motorcycle users without child(ren) (0.039). The results also imply that there might be a smaller self-selection effect for non-motorcycle uses with child(ren) (0.081), compared to that for non-motorcycle uses without child(ren) (0.095). These results mean that those who have child(ren) are less affected by motorcycle ownership compared to those who don't have child(ren). The results might reflect the situation that those who have child(ren) may have more fixed schedules causing by their family members' needs.

4.4 Summary

A better understanding of motorcycle usage in *household context* is a key role for transportation planners to discuss about how to utilize motorcycle effectively, especially in the Hanoi context where the motorcycle is dominant. In fact, under the conditions of poor public transport services, motorcycle could be a powerful mobility tool, which gives them flexible decisions on their activity and travel.

In this chapter, focusing on the *household context* with coupling constraints caused by child(ren), the motorcycle impacts on mobility level which was described by the number of trips were explored. Concretely speaking, the aggregation analyses were first conducted to confirm the well-known fact that motorcycle could provide the higher mobility level. Then, an endogenous switching model was further established to confirm the existence of child effects in the relation between motorcycle ownership and the number of trips.

The empirical results indicate that, although the motorcycle can provide the higher mobility level, there is a possibility that the simple aggregation results of the motorcycle impacts on their trip making may be biased and motorcycle itself may have a smaller effect on the number of trips than expected. This result underscores that motorcycle owners generate the higher number of trips partly because he/she just has higher needs for travel than non-motorcycle owners. Thus, careful discussions about motorcycle impacts on trip generation might be needed in Hanoi context. Furthermore, the empirical results also showed that those who have child(ren) are less affected by motorcycle ownership compared to those who don't have child(ren). The higher number of fixed schedules might be one of the reasons for this, but it is certainly needed to reach a general conclusion.

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CHAPTER V

Avoiding/Reducing motorcycle dependence: Analyses focusing on the spatial context

The chapter V, with total 6 sections, analyses the motorcycle usage in the *spatial context*. In the section 1, Introduction gives general literature review on how the *spatial context* impact on travel behavior. Based on the trend of urban extension in Hanoi city and the flexible characteristics of motorcycle, we narrowed the scope of the study by arguing that within various spatial factors, the land use patterns are the most significant impact on motorcycle usage. Therefore, in the section 3, 4 and 5, we try to analyze 3 issues: the impacts of household location's land use patterns on modal choice, the amount of land use impacts on motorcycle choice and the residential location impact on motorcycle trips frequencies. Before that, section 2 gives a brief description on the data and all the explanatory variables will be used in these analyses. At the end, the section 6 summarizes the main findings of both chapter IV and V then gives some policy discussion on how to avoid/reduce motorcycle dependence as the first step of applying A-S-I approach.

5.1 Introduction

5.1.1 Spatial context and travel behavior

Studies on the relation between *spatial context* and travel behavior are also various. In other words, these studies stress the interaction between individuals and their surrounding environment which including urban form in general and residential neighborhood in particular and goes beyond the question of actual choice mainly modal choice, route choice and destination choice or activity spaces as well.

Boarnet and Crane (2001) studied the travel activities of 7,469 households in Orange County and San Diego and they found an extremely complex relationship which indicating that land use and design proposals will influence the price of travel and hence the type of trip undertaken. Cervero (2002) studied whether compact, mixed-use and pedestrian-friendly developments areas could significantly influence travel modes by using three core dimensions of the built environment, namely density, diversity and design. The study found that the density and mixture of land use was a significant influence in determining travel mode particularly in the decision to use public transport, share a car or drive alone. Higher gross densities lowered the occurrence of solo-commuting (i.e., driver-only car commuting). In addition, Cervero found that workplace destinations with a higher density of mixed land use produced a higher level of public transport use and described the impact of sidewalk ratio as the most important built environment variable to encourage commuters to take the bus. In the same time, Goudie (2002) studied the travel behaviors of 408 households in Townsville and Cairns and found that location played a large part in fuel consumption and distances travelled. Guiliano and Narayan (2003) studied the travel behaviors of United States (US) and British populations and found that the US land use patterns reinforce vehicle dependence particularly in the sprawling suburbs of the major metropolitan regions. The authors suggest that the stronger urban planning and design controls in European countries have led to a more compact and higher density urban form and hence an increased use of public transport. Soltani and Primerano (2005) focused on households' travel behavior in suburban Adelaide, Australia and found that low-density, single use, large area zoning limited the ability of participants to walk or cycle for their daily travel requirements. Proximity to local shopping and service centers and local networks encouraged a wider choice of sustainable travel modes. Conversely, the location of suburban development away from major activity centers encouraged the use of the private car and decreased the use of other travel modes. Naess (2003) and Naess and Jensen (2004) studied the influence of residential location on travel behavior in Norway and Denmark. They found that the closer the participants lived to the centre of the city, the more likely they were to walk or use a cycle to get to the facilities located there. Srinivasan and Rogers (2005) revealed the fact that participants who live in the more densely populated areas of central Chennai city are more likely to use non-motorized modes of travel (walking and cycle in particular) than those located in peripheral areas. The main reason may come from the location of employment opportunities located in central Chennai. Newman P and Kenworthy J (1989) compared 32 cities across North America, Australia, Europe and Asia and concluded that denser cities, particularly in Asia, have lower car use than sprawling cities, particularly in North America Within cities, studies from across many countries (mainly in the developed world) have shown that denser urban areas with greater mixture of land use and better public transport tend to have lower car use than less dense suburban and exurban residential areas. More recent studies using more sophisticated methodologies have generally refuted these findings: density, land use and public transport accessibility can influence travel behavior.

On the other hand, there are number of studies focused on the relation between residential neighborhood space and travel behavior by comparing travel patterns of residents in neighborhoods that support walking and those that do not support walking while matching the neighborhoods on other characteristics such as regional accessibility. These studies findings could be summarized that the share of trips that are taken by pedestrian and bicycle modes for multiple trip purposes, and the raw number of these non-motorized trips, is higher in neighborhoods defined a priori as walkable than those that are not walkable (for a review see Cervero and Gorham, 1995; Cervero and Radisch, 1995; Dill, 2004; Friedman et al., 1994; Handy et al., 2006; Handy and Clifton, 2001; Kitamura et al., 1997; Rutherford et al., 1996) but no difference in travel for recreation or leisure was detected in the 3 studies that examined this (Handy, 1992, 1996; Rodriguez et al., 2006). Consistent with the findings of Saelens et al., (2003), it seems that travel for errands is the source of overall differences in non-motorized transport for travel between high- and low-walkable neighborhoods. While studies of neo-traditional developments (NTDs are new urban areas which were proposed to develop the paradigm's ability to alter travel behavior, reduce dependence on motorized vehicles, and foster social capital among their residents) in the US indicate that residents of those neighborhoods actually make more total trips per day than residents of typical suburban developments, there is agreement that these trips are shorter and that many auto trips are substituted for walking trips (Cao, 2009; Rodriguez et al., 2006; Khattak and Rodriguez, 2005; Limanond and Niemeier, 2004). Additionally, households in NTDs make fewer external trips (Khattak and Rodriguez, 2005; Limanond and Niemeier, 2004), having a greater ability to stay within the neighborhood to purchase goods and services to meet the majority of their daily needs.

In summary, the studies on the relation between *spatial context* and modal choice behavior mainly focus on how the build environments affect non-motorized modes (i.e., walking and cycling), car or public modes (i.e., bus, rail) choices, which play the role as main modes: the higher density (more compact) or higher mix use level of land use patterns the higher properties to choose non-motorized modes as well as public modes. Otherwise, low-density, single use or large zone could encourage the use of private car.

5.1.2 The scope of this chapter

Comparing to other modes, motorcycle is very special (or flexible) mode: it may become main mode, access mode or egress mode. With its flexibility and convenient in usage, motorcycle could take any route (i.e., from narrow to wide), enter any areas (i.e., residential, commercial, industrial, etc) and thus motorcycle is strongly affected by *spatial context* in general and land use patterns in particular. Beside, rapid increasing in urbanization, especially the urban expansion to the Western side of Hanoi, had been changing the urban form as well as land use patterns from time to time. These changes have significant impacts on citizens' life style as well as travel behavior, consequently. For example, citizens with high level of income may prefer to live in central of the city with higher mix land use when other may live in new extended urban areas, which have main function for resident with poorer social facilities. These land use changes may strongly affect to motorcycle usage in the future (i.e., people live in new urban area may have higher dependency on their private motorized modes). Therefore, in this study, we focus on land use patterns as the most specific characteristic of *spatial context* to explore the relation between land use and motorcycle usage. Concretely, we try to answer these questions: How does the residential location impact on modal choice behavior? How much the land use impact on motorcycle choice? And how does the residential location impact on motorcycle trips frequencies? These answers might be very important for not only urban/transportation planners but also policy makers.

The rest of this chapter is organized as follows: The second part gives brief description on the data set (including Person Trip Survey and land use data) and all explanatory variables use for model estimation. The third part, in order to explore how land use patterns surrounding household location impact on modal choice, we select all trips made from Home to make different modal choice analyses (i.e., all home-based trips, home-based shopping trips and home-based leisure trips. For better understanding of interrelation between modes we put walking, bicycle, motorcycle and other modes (i.e., car, bus, taxi, cyclo…) in to the model. In the fourth part, we attempt to measure how much the impacts of land use on motorcycle usage by distinguishing and comparing two kinds of land use impacts, Residential neighborhood and Origin-Destination (detail discussion will be given in 5.4.1). We select all trips made by motorcycle and divide trip purposes into two groups: commuting and non-mandatory which assumed to get different impacts from land use patterns. Then, the *household attributes*, *trip attribute* and *individual socio-demographic attributes* are added in the *Halfway model* and finally the Origin-Destination and Residential neighborhood *land use attributes* are added into the *Full model* to identify what kinds of land use attributes have higher impacts on mode choice behavior. In the fifth part, applying the regression modeling, we try to get an extensive view on motorcycle usage in *spatial context* by exploring the motorcycle trip frequencies in different spatial of households' location. At the end, the findings of both chapter IV and V are summarized as well as the policy discussion are provided.

5.2 Data description and variables specifications

In this chapter, two kinds of data source are used for empirical analyses: 1) the Household Interview Survey (HIS) data (or known as Person Trip Survey data) and 2) a set of land use data for each of Traffic Analysis Zones (TAZs). These data were collected in 2005 as parts of *The comprehensive urban development programme in Hanoi capital city of the Socialist Republic of Vietnam* (ALMEC et al. 2007). The targeted survey area is composed of total 14 districts within

921 km^2 (including 228 TAZs) of Hanoi city and 5 adjoining districts of other provinces (including 73 TAZs) as shown in Figure 5.2.1 below.

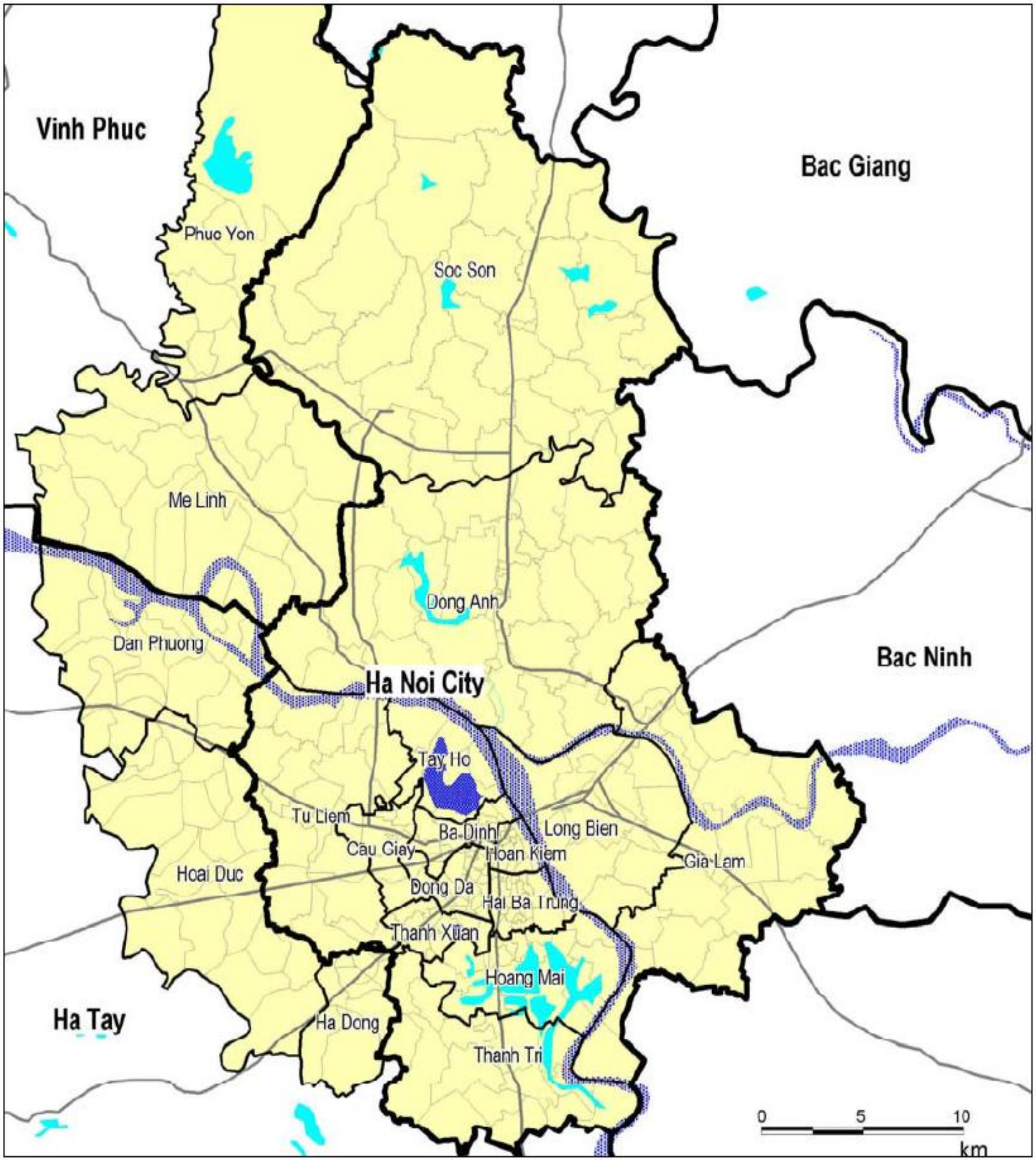

Figure 5.2.1 Areas for Household Interview Survey

The number of sampled households is decided by the population data of 2005. About 2.2% of total households in Hanoi city and adjoining districts are selected. However, the sample in the ancient quarter area as well as some communes in Hoan Kiem District, is set to 5.0% (about 1,000 households) in order to analyze their characteristics in depth and since this area is considered as one of the most important areas to focus. At the end, 20,020 households are selected as sample for the field survey. The selected information from HIS which were used in this study including:

- Household information: location, number of household member, number of vehicle, total income, residential characteristics, etc.
- Household member information: age, gender, occupation, education level, driving license, vehicle for own use, personal income, work/school address, etc.
- Daily activity information: origin/destination place, departure/arrival time, trip purpose, travel mode, etc.

The land use data base which includes detail information related to 21 different land use patterns of total 228 TAZs (as shown in Figure 5.2.2) in Hanoi city was also combined. Base on the location of each household (Residential neighborhood) and the location of each trip's origin and destination (O-D) made by respondents, the land use impacts on mode choice were analyzed. Due to the limitation of land use data base (not including 5 adjoining districts of other provinces within other 73 TAZs), only information from households which located inside Hanoi city area were selected.

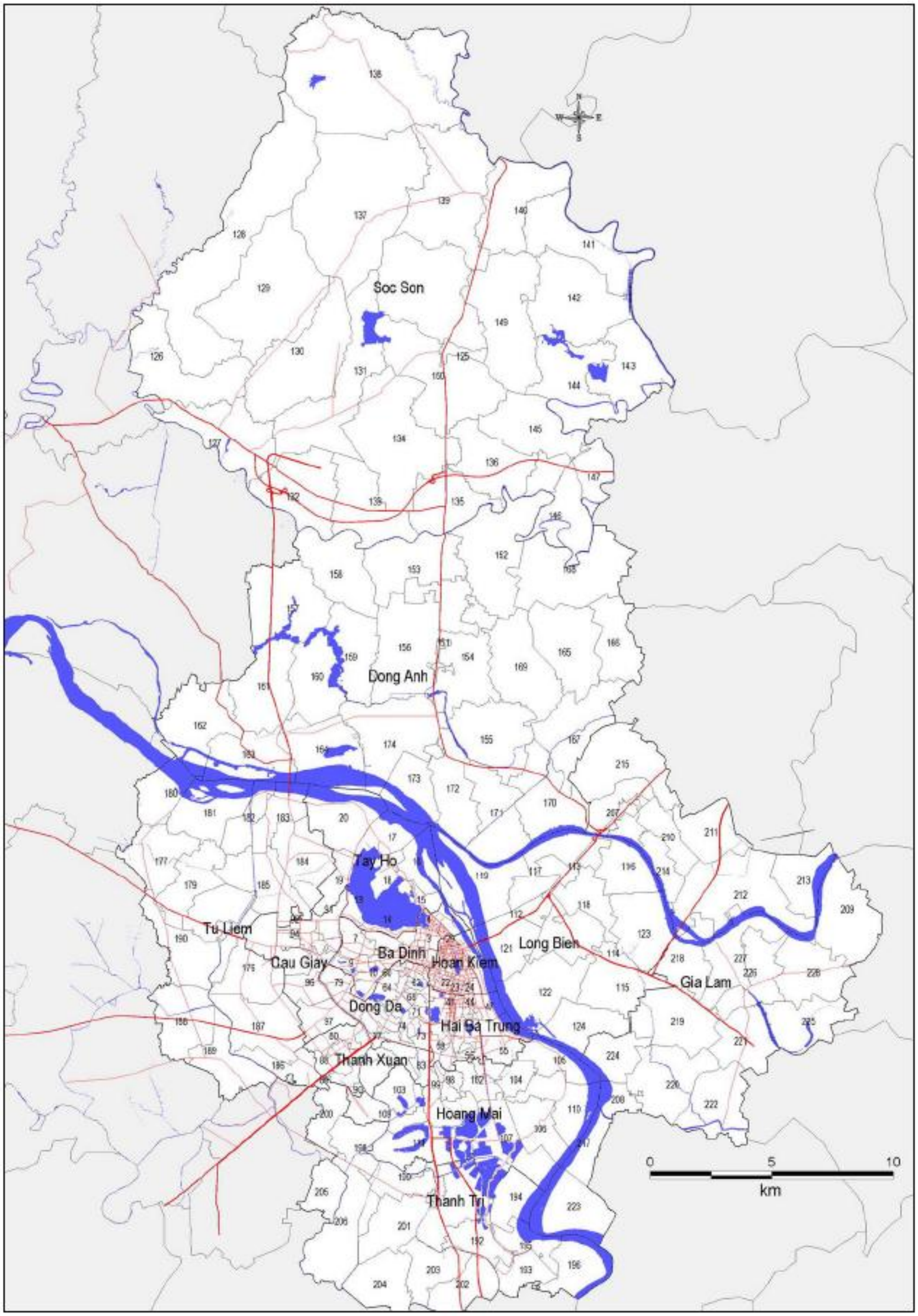

Figure 5.2.2 Total 228 Traffic Analysis Zone

Table 5.2.1 Explanatory variables use for model estimation

Explanatory variables	Definition
Household attributes	
hh_member	Number of member in household
hh_m_inc	Household monthly income (VND)
hh_mc	Number of motorcycle in household
Trip attribute	
ttime	Travel time (minute)
Individual socio-demographic attributes	
Age	Age of respondent
Male	Male (1 = yes; 0 = no)
Work	Have a work (1 = yes; 0 = no)
Student	Student (1 = yes; 0 = no)
Land use attributes	
R_density	Population density in Residential neighborhood
R_cbland	Percentage of commercial and business land in Residential neighborhood
R_ecland	Percentage of educational and cultural land in Residential neighborhood
R_prland	Percentage of park and recreational land in Residential neighborhood
R_rfland	Percentage of rice field and agricultural land in Residential neighborhood
R_tsland	Percentage of transport land in Residential neighborhood
R_urland	Percentage of urban residential land in Residential neighborhood
O-D_density	Population density in Origin-Destination
O-D_cbland	Percentage of commercial and business land in Origin-Destination
O-D_ecland	Percentage of educational and cultural land in Origin-Destination
O-D_prland	Percentage of park and recreational land in Origin-Destination
O-D_rfland	Percentage of rice field and agricultural land in Origin-Destination
O-D_tsland	Percentage of transport land in Origin-Destination
O-D_urland	Percentage of urban residential land in Origin-Destination

5.3 Residential land use patterns and mode choice behavior

This section explores the effects of residential land use patterns (or household location land use patterns) on individual mode choice decisions made by travelers in Hanoi area in 2005. It combines detailed household, individual travel behavior data with percentage of each type of land use patterns as well as population density to construct a series of multinomial logistic regression models of modal choice for a variety of non-work trip purposes. The general form of the models tested is as follows:

$$Prob[m_i/M] = f[H_i, ID_i, R_i\ ]$$

where:

m denotes the non-work travel mode chosen by traveler i from the set of possible travel modes *M*

H_i indicates the household characteristics of traveler *i*

ID_i indicates the individual characteristics of traveler *i*

R_i indicates the residential land use patterns of traveler *i*

Following logic first suggested by McFadden (1974), individual are assumed to make his/her travel decision to obtain the greatest amount of satisfaction possible within the constraints by his/her household/individual attributes, time, location and transport supply. An individual's preferences determine how the various characteristics of potential choices are evaluated in order to reach at the utility-maximizing choice. Because the interaction between these various constraints is extremely complex thus this type of decision is most often modeled in a reduce form discrete choice framework.

5.3.1 All home-based non-work trips

This analysis combines all shopping trips, study trips and social and recreational trips. Altogether, the full sample of Hanoi Person Trip Survey 2005 respondents undertook 59,569 home-based non-work trips. The estimation results are shown in Table 5.3.1.

For travel by bicycle relative to walking, three of household variables and almost all individual variables are statistically significant. Member of larger households are less likely to use bicycle while number of household bicycle are much significant impacts on bicycle choice. All age groups are shown significant and positive impacts on bicycle choice however the likelihood is highest with under 21years of age group then decreases: every about ten years of additional age reduces the likelihood of walking from 10% to 60%. For male relative to female, the positive sign could be understand that male are more likely than female to prefer bicycle for home-based non-work trips. The availability of *bicycle for own use* is definably the most positive significant to bicycle choice. Then, we could observe the significant impacts of almost residential land use attributes to bicycle choice relative to waking. The population density has negative impacts may implies that the higher population density in household location, the lesser bicycle choice (i.e., they may prefer to walk rather than use any modes). Same conclusion could be made with two other residential land use attributes: the percentage of *park and recreation land* and the percentage of *transportation and service land*. On contrary, individuals who have residential location in higher percentage of *rice field and agriculture land* (i.e., household located in rural areas) are likely to use bicycle. Moreover, the percentage of *urban residential land* are also has significant impacts on bicycle choice. In other words, individuals live in higher percentage of *urban residential land* are less likely to walk.

For travel by motorcycle relative to walking, all household and individual variables are statistically significant and have effects in the expected directions. The *household size* and the *number of household bicycle* variables have negative impacts implying that individuals in larger households with higher number of bicycle may prefer to walk or use bicycle rather than to use motorcycle. The *number of child aged below 10* is positive impacts on motorcycle choice (as proved in part two of chapter IV which examining trip to school modal choice behavior) together with *household monthly income* and the *number of household motorcycle* variables. All age groups are shown positive impacts on motorcycle choice implying the specific characteristic of motorcycle dependent city whereas motorcycle is the most preferable mode of Hanoi citizens in all range of age. Definably, the use of motorcycle decreases with ages and the most likely to use motorcycle are individuals in range from 22 to 30 years of age. *Male* is also positive and the most significant variables is *motorcycle for own use*. Related to residential land use patterns, there are only two variables significant in opposite directions: the *population density* has negative impacts and the percentage of *urban residential land* has positive impacts. These imply that the higher population density where individuals live in, the lesser motorcycle choice they made and individuals are more likely to use motorcycle when their household location in higher percentage of urban residential land.

For travel by other modes including cyclo, car, taxi, bus, etc relative to walking, three of household attributes show significant impacts. Similar with appeared in other two mode choice, bicycle and motorcycle, the *household size* variables have negative impacts while *household monthly income* and the *number of household motorcycle* variables have positive impacts. Related to individual attributes, only three first age groups show significant and positive impacts implying that individuals who aged fewer than 40 are likely to use other modes rather than walking for their non-work trip purposes. Comparing to female, male are prefer to use other modes while individuals own bicycle may less likely to use other modes for their non-work trips travel. The impacts of residential land use patterns on other modes choice could be observed through opposite impacts direction: *population density* and percentage of *rice field and agricultural land* show negative impacts while percentage of *transportation and service land* and percentage of *urban residential land* show positive impacts. These imply that for home-based non-work trips individuals live in higher population density and percentage of *rice field and agricultural land* are less likely to use other modes while those live in higher percentage of *transportation and service land* and percentage of *urban residential land* are much likely to use other modes.

5.3.2 Home-based shopping trips

The Hanoi Person Trip Survey 2005 contains about seven thousand home-based trips with the purpose of shopping. Table 5.3.2 shows the model estimation results.

For travel by bicycle relative to walking, two of household variables and all individual variables are statistically significant. Member of larger households are less likely to use bicycle while number of household bicycle are much significant impacts on bicycle choice. All age groups are shown significant and positive impacts on bicycle choice however the likelihood increase with age until 40 years old then decrease gradually. The positive sign of *male* could be understand that men are more likely than women to prefer bicycle for home-based shopping trips. The availability of *bicycle for own use* is also found to have the most positive significant to bicycle choice while the availability of *motorcycle for own use* has impacts in opposite direction. Among residential land use attributes, we could observe the significant impacts of three variables. Two of them have negative impacts: *population density* and percentage of *transportation and service land* imply that individuals live in higher population density and higher percentage of transportation and service land are less likely to use bicycle for their shopping trips. The third, percentage of *rice field and agriculture land*, has positive impacts implies those has household location in higher percentage of rice field and agriculture land are much likely to use bicycle rather than walking for shopping.

For travel by motorcycle relative to walking, only two household attributes show positive impacts while almost individual variables are statistically significant except *bicycle for own use.* The *number of child aged below 10* and the *number of household motorcycle* are positive impacts on motorcycle choice. Similar with previous analysis of all home-based non-work trips, the specific characteristic of motorcycle dependent city whereas motorcycle is the most preferable mode of Hanoi citizens in all range of age is confirmed through all age groups are shown positive impacts on motorcycle choice. Again, *male* is also positive and the most significant variables is *motorcycle for own use*. Related to residential land use patterns, there are only two variables significant in opposite directions: the percentage of *urban residential land* has negative impacts and percentage of *rice field and agriculture land* has positive impacts. These imply that the higher percentage of urban residential land where individuals live in, the lesser motorcycle choice they made and individuals are more likely to use motorcycle for shopping trips when their household location in higher percentage of rice field and agriculture land.

For travel by other modes relative to walking, none of household attributes and residential land use pattern show significant impacts. Four age groups show significant impacts implying that individuals who aged fewer than 50 are likely to use other modes rather than walking.

Table 5.3.1 Multinomial mode-choice model for all home-based non-work trips

Explanatory variables	Walking	Bicycle			Motorcycle			Other modes		
		Parameter	t_statistic		Parameter	t_statistic		Parameter	t_statistic	
Alternative specific constants	-	-3.018	-46.352	***	-3.124	-45.960	***	-3.692	-27.891	***
Household attributes										
Household size	-	-0.023	-1.956	.	-0.112	-9.442	***	-0.100	-3.941	***
Number of child aged below 10	-	0.028	0.891		0.576	18.859	***	-0.077	-1.162	
Household monthly income	-	0.008	3.068	**	0.007	3.253	**	0.016	5.239	***
Number of HH bicycle	-	0.212	14.203	***	-0.070	-4.427	***	0.056	1.648	.
Number of HH motorcycle	-	0.025	1.554		0.380	24.240	***	0.121	3.681	***
Individual attributes										
Under 21 years of age	-	1.572	40.618	***	1.508	33.442	***	0.893	11.768	***
22-30 years of age	-	0.872	15.761	***	2.071	41.168	***	1.246	13.141	***
31-40 years of age	-	0.775	14.061	***	1.747	33.586	***	0.718	6.213	***
41-50 years of age	-	0.389	8.375	***	1.154	24.641	***	-0.039	-0.346	
51-60 years of age	-	0.141	3.126	**	0.424	8.705	***	-0.062	-0.635	
Male	-	0.088	3.315	**	0.471	17.625	***	0.599	11.007	***
Bicycle for own use	-	2.322	76.841	***	-0.239	-6.759	***	-0.369	-5.329	***
Motorcycle for own use	-	-0.056	-1.135		2.117	63.607	***	-0.134	-1.680	
Residential land use attributes										
Population density	-	-0.001	-11.708	***	-0.001	-6.445	***	-0.002	-7.619	***
Commercial and business land	-	0.258	0.513		0.316	0.736		1.481	1.839	.
Park and recreation land	-	-1.377	-3.314	**	-0.414	-1.146		-1.214	-1.544	
Rice and agricultural land	-	0.304	4.523	***	0.043	0.565		-0.623	-3.433	**
Transportation and services land	-	-0.591	-2.062	*	0.453	1.764	.	3.145	6.671	***
Urban residential land	-	0.516	5.689	***	0.785	8.820	***	1.493	8.366	***
Log-likelihood at zero					-82580.17					
Log-likelihood at convergence					-49418.55					
Rho					0.4016					
Number of observations					59,569					

(.) significant at the 90% level, (*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

Table 5.3.2 Multinomial mode-choice model for all home-based shopping trips

Explanatory variables	Walking	Bicycle			Motorcycle			Other modes		
		Parameter	t_statistic		Parameter	t_statistic		Parameter	t_statistic	
Alternative specific constants	-	-2.685	-15.055	***	-3.678	-16.789	***	-4.852	-7.810	***
Household attributes										
Household size	-	-0.099	-2.835	**	-0.041	-1.067		-0.085	-0.688	
Number of child aged below 10	-	-0.013	-0.118		0.388	3.505	***	0.215	0.602	
Household monthly income	-	0.005	0.774		0.010	1.673		0.016	1.166	
Number of HH bicycle	-	0.387	8.612	***	0.006	0.122		-0.116	-0.657	
Number of HH motorcycle	-	0.056	1.252		0.238	5.004	***	0.030	0.194	
Individual attributes										
Under 21 years of age	-	1.203	5.749	***	2.438	10.526	***	1.902	3.468	***
22-30 years of age	-	1.058	6.873	***	2.459	14.388	***	1.725	3.893	***
31-40 years of age	-	1.048	7.883	***	2.262	13.863	***	1.323	3.025	**
41-50 years of age	-	0.733	6.597	***	1.663	10.923	***	0.951	2.419	*
51-60 years of age	-	0.451	4.228	***	0.920	5.955	***	0.354	0.899	
Male	-	1.018	8.180	***	1.920	17.566	***	1.855	6.212	***
Bicycle for own use	-	1.808	20.752	***	-0.091	-0.898		-0.235	-0.734	
Motorcycle for own use	-	-0.377	-2.725	*	1.823	19.074	***	0.037	0.113	
Residential land use attributes										
Population density	-	-0.001	-3.764	***	0.000	-0.378		-0.001	-0.876	
Commercial and business land	-	-0.618	-0.422		-1.466	-1.013		-0.279	-0.069	
Park and recreation land	-	-0.435	-0.384		-0.180	-0.145		0.157	0.043	
Rice and agricultural land	-	1.064	5.145	***	0.840	3.347	**	-0.730	-0.728	
Transportation and services land	-	-1.704	-2.051	*	-0.792	-0.984		0.431	0.190	
Urban residential land	-	-0.173	-0.709		-0.506	-1.846	.	0.916	1.125	
Log-likelihood at zero					-9878.73					
Log-likelihood at convergence					-5147.59					
Rho					0.4789					
Number of observations					7,126					

(.) significant at the 90% level, (*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

Table 5.3.3 Multinomial mode-choice model for all home-based leisure trips

Explanatory variables	Walking	Bicycle			Motorcycle			Other modes		
		Parameter	t_statistic		Parameter	t_statistic		Parameter	t_statistic	
Alternative specific constants	-	-3.131	-8.348	***	-3.549	-12.650	***	-3.359	-6.305	***
Household attributes										
Household size	-	0.049	0.671		0.002	0.038		-0.026	-0.215	
Number of child aged below 10	-	0.277	1.230		0.173	1.057		-0.553	-1.207	
Household monthly income	-	-0.055	-1.182		-0.020	-1.999	.	0.011	0.787	
Number of HH bicycle	-	-0.026	-0.291		-0.117	-1.635		0.104	0.710	
Number of HH motorcycle	-	-0.155	-1.591		0.131	2.175	*	-0.007	-0.045	
Individual attributes										
Under 21 years of age	-	1.254	5.116	***	2.646	12.407	***	1.032	2.257	*
22-30 years of age	-	0.737	2.061	*	2.823	15.580	***	0.949	1.990	.
31-40 years of age	-	0.321	0.832		2.258	11.484	***	0.364	0.580	
41-50 years of age	-	-0.448	-1.586		1.022	6.281	***	-0.464	-1.027	
51-60 years of age	-	-0.537	-2.712	*	0.506	3.302	**	-0.292	-0.974	
Male	-	0.757	4.658	***	0.251	2.059	*	-0.181	-0.731	
Bicycle for own use	-	2.070	11.031	***	-0.141	-0.860		-0.196	-0.688	
Motorcycle for own use	-	-0.154	-0.634		1.629	11.322	***	-0.252	-0.752	
Residential land use attributes										
Population density	-	-0.002	-4.195	***	-0.001	-3.113	**	-0.003	-4.326	***
Commercial and business land	-	1.704	0.730		1.161	0.743		4.038	1.328	
Park and recreation land	-	-2.217	-1.237		-5.830	-3.678	***	-4.211	-1.277	
Rice and agricultural land	-	0.300	0.696		0.508	1.319		-1.652	-1.524	
Transportation and services land	-	-5.760	-3.638	***	-2.797	-2.936	**	-1.160	-0.548	
Urban residential land	-	1.285	2.742	**	1.601	4.353	***	2.633	3.460	***
Log-likelihood at zero					-5674.10					
Log-likelihood at convergence					-2387.05					
Rho					0.5793					
Number of observations					4,093					

(.) significant at the 90% level, (*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

5.3.3 Home-based leisure trips

The Person Trip Survey 2005 dataset contains about four thousand home-based leisure trips including go out to eat, joy riding, social/recreational purposes. Results of the model are shown in Table 5.3.3.

For travel by bicycle relative to walking, none of household variables show significant impact implies that bicycle choice for home-based leisure trips are not affected by any household attributes. Related to individual attributes, two first age groups are shown positive impacts while the fifth age group is shown negative impacts. These imply that individuals aged below 30 are likely to use bicycle for home-based leisure trips when individuals aged in range from 51 to 60 are less likely to use bicycle. Inevitably, *male* and *bicycle for own use* are also shown positive impacts. Then, we could observe the significant impacts of three residential land use attributes to bicycle choice relative to waking. The *population density* and the percentage of *transportation and service land* has negative impacts may imply that individuals who live in the higher population density and the higher percentage of transportation and service land (i.e., CBD of Hanoi) the lesser bicycle choice for their leisure trips. On contrary, individuals who have residential location in higher percentage of *urban residential land* are likely to choose bicycle.

For travel by motorcycle relative to walking, only one household attribute is shown positive impacts. On contrary, almost individual attributes are statistically significant. One more time we could observe all age groups have positive impacts on motorcycle choice as well *as motorcycle for own use* which can be implied that motorcycle is very crucial mode for leisure trips purposes for all range of individuals' age. Related to residential land use patterns, three of land use attributes show negative impacts including *population density*, percentage of *park and recreation* *land* and percentage of *transportation and service land* while only one have positive impacts to motorcycle choice is percentage of *urban residential land*.

For travel by other modes including cyclo, car, taxi, bus, etc relative to walking, none of household attributes show significant impacts. Related to individual attributes, the first two age groups show significant and positive impacts implying that individuals who aged fewer than 30 are likely to use other modes rather than walking for their leisure trip purposes. There are two residential land use attributes show significant impact but in opposite direction: *population density* with negative impacts and percentage of *urban residential land* with positive impacts. These imply that individuals live in higher population density are less likely to use other modes while who live in higher percentage of urban residential land are likely to use other modes for their leisure trips purposes.

In summary, the residential land use patterns show their significant impacts on modal choice behavior, evidentially. However, the amounts of these impacts depend on travel mode as well as travel purpose. Focusing on how residential land use patterns impact on motorcycle choice, we may give some conclusions as follow: the population density has negative impacts on motorcycle choice in almost home-based non-work trips implying that individuals living in higher population density area, their home-based non-work trips have lesser depending on motorcycle. Percentage of urban residential land has positive impacts with almost home-based non-work trips except shopping trip implying individual live in higher percentage of urban residential land prefer walking for shopping rather than use their motorcycle. The similar mode choice behavior could be observed from home-based leisure trips of individuals who living in higher percentage of park and recreational land. On contrary, individuals living in higher percentage of rice field and agricultural land have higher dependency on motorcycle for their home-based shopping.

5.4 Measuring the impacts of land use

5.4.1 Distinguishing different types of land use impacts

A huge number of studies on the relations between land use and mode choice behavior have been conducted. An individual makes a trip from a certain origin to destination, and thus the mode choice may be affected by the land use characteristics across origin and destination which determines travel time and other level-of-service attributes. On the other hand, it can also be expected that residential neighborhood characteristics affect mode choice decisions. For example, people who live in urban area may be difficult to have parking space for their car, and under such conditions car ownership and usage may be restricted. Thus, there would be two different types of studies on land use impacts: Origin-Destination land use impacts and Residential neighborhood land use impacts.

In fact, in addition to the impacts of level-of-service attributes on mode choice decisions, there are a number of empirical evidences on Residential neighborhood land use impacts. For example, it was empirically confirmed that higher population density leads lower car ownership and better transit service (Kitamura et al. 1997). Joyce et al. (2003) also confirmed that car use is facilitated in less-densely populated areas, whereas public transport is a more practical and economic alternative in more densely populated areas. Cervero (1996) found that the residential density has strong impacts on commuting mode choice: people living in low residential density areas tend to commute by car. Badoe and Miller (2000) showed that traditional neighborhood design schemes have a strong impact on auto ownership and use. By analyzing data from the Dutch National Travel Survey 1998, Schwanen et al. (2001) confirmed that deconcentration of urban land uses encourages driving and discourages the use of public transport as well as cycling and walking.

After reviewing a large number of studies, Ewing and Cervero (2001) concluded that mode choice is one of the most sensitive travel behavior aspects with respect to Residential neighborhood land use characteristics.

The differences between Origin-Destination land use impacts and Residential neighborhood land use impacts might correspond to the conceptual differences between trip-based mode choice model and chain-based mode choice model: trip-based mode choice model basically deals with the impacts of level-of-service, while chain-based mode choice model deals with interdependencies of mode choice decisions across trips made within a single trip chain, where it can be expected that the land use characteristics of initial location in the trip chain (mostly residential location) may have a higher impacts on mode choice behavior by considering temporal sequences of trips. Thus, distinguishing these two land use impacts is certainly important to determine the mode choice modeling framework. Nevertheless, at the best of our knowledge, there is no comparative study to examine which land use information has higher impacts on mode choice behavior. Though identifying those impacts may bring many implications not only for academic but also for practical aspects: if Residential neighborhood land use characteristics have higher impacts on mode choice behavior, urban planner may have to focus on neighborhood designs for example to promote public transport use. Furthermore, in such case, a typical assumption of traditional trip-based analysis, in which trips are assumed to be independent, may not be accepted, because trips made by individuals who live in the same residential area are dependent each other.

To compare which type of land use has higher impacts on people's mode choice decisions, we first re-classified Residential neighborhood and O-D located on 228 TAZs into 14 administrative units (district levels). And then only inter-zones trips (i.e., O and D are different) are used for our analysis. The maximum number of O-D pairs is 91 (= {14 origins x 14 destinations}-14 same O-D / 2). As for explanatory variables, 7 land use variables are used: residential density, percentage of commercial and business land, percentage of education and cultural land, percentage of park and recreational land, percentage of rice field and agricultural land, percentage of transportation land and percentage of urban residential land.

After doing the above data cleaning, 40,792 inter-zone trips made by 16,622 individuals from 8,573 households were selected. Preliminary aggregation analyses show that:

1) 62.3% of households were families with three and four household members, and 28.1% were families with five or more household members;

2) Households with low income (less than 3 million Vietnam Dong (VND)) occupied 58.4%, 28.6% were in medium income group (from 3 to 5 million VND), and the rest 13 % were high income households (total income from 5 million VND);

3) 91.8% households owned at least one motorcycle;

4) 55% of respondents are male;

5) 52.6% of respondents were workers, pupils and students are 25.6% and the rest 21.8% are retired, non-work or jobless people.

The differences in modal shares across trip purposes are examined as shown in Table 5.4.1. Travel modes are divided into three categories include *motorcycle*, *other motorized modes* i.e., car, truck, buses, taxi, motorcycle taxi and rail train and *non- motorized modes* i.e., walk and bicycle. Trip purposes are also divided into two categories, i.e., *commuting* and *non-mandatory* (i.e., shopping, leisure, personal needs, etc.). From the table, we can confirm that motorcycle is a dominant travel mode for both trip purposes, indicating that people's mobility in Hanoi is highly dependent on motorcycle.

Table 5.4.1 The percentage of trips by modes and trip purposes

	Commuting (n)	Non-mandatory (n)
By motorcycle	71.4% (9475)	59.6% (3164)
By other motorized modes	12.5% (1702)	11.9% (632)
By non-motorized modes	16.1% (2197)	28.5% (1515)
Total	100.0% (13644)	100.0% (5311)

5.4.2 Applying multi-level binary logit model

Assumed land use impacts structure

In existing studies, it has been confirmed that travel time and travel cost are important influential factors on the mode choice decisions, meaning that Origin-Destination land use patterns have been dealt with. On the other hand, the impacts of Residential neighborhood land use on mode choice decisions have also been recognized. For example, higher population densities lead shorter trip distance and more public modes and non-motorized modes use, and it might be better to employ Residential neighborhood land use if our purpose is to identify household accessibility impacts. In fact, it is usually difficult to capture all land use impacts (due to the limitation of land use information) so that many of them would remain as unobserved factors.

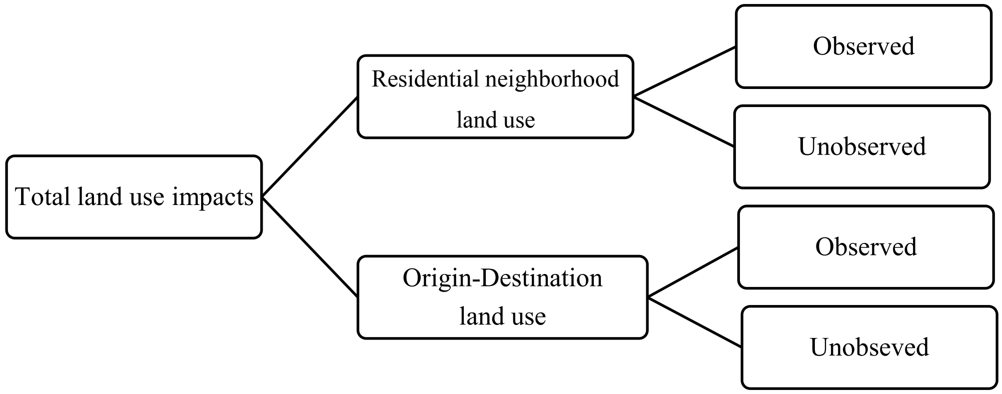

Figure 5.4.1 The impacts structure assumed in this study

To deal with these complex land use impacts, a multilevel modeling technique (Hox et al. 1995 and Kreft et al. 1998) is used in this study. This method treats hierarchical and/or cross-classified variation structure, and in this study we attempt to decompose total land use impacts on motorcycle choice into two components, i.e., Residential neighborhood and Origin-Destination impacts with regard to both observed (non-random) and unobserved (random) effects as shown in Fig 5.4.1.

The multi-level binary logit model

Consider the situation that an individual i (i = 1, 2,…, I) who lives in Residential neighborhood r (r = 1, 2,…, R), travels in the space Origin-Destination pair (od = 1,2,…, OD), chooses alternative j, his utility function could be written as:

$$U_{jirod} = \beta_0 + \beta_j x_{jirod} + \gamma_{jr} + \gamma_{jod} + \varepsilon_{jirod} \quad (1)$$

where x_{jirod} indicates a set of explanatory variables including both individual/household attributes and situational/contextual factors. Let β_j be a coefficient vector associated with x_{jirod}.

Let γ_{jr} and γ_{jod} be introduced to capture unobserved impacts of Residential neighborhood and Origin-Destination land use and both of them are assumed to be normally distributed with means zero and variance σ_r^2 and σ_{od}^2, respectively. Let ε_{jirod} be an unobserved component which follow a logistic distribution with a variance of $\pi^2/3$ (the scale parameter is fixed as one, since the utility is unitless). Based on the above mentioned definition, the probability choosing motorcycle P_{id}^{mc} can be written as follows:

$$P_{jirod}^{mc} = \exp\,(U_{jirod})/\{\exp(U_{jirod}) + 1\} \tag{2}$$

The impacts properties of utility difference

Here we shall mention a way to describe land use impacts in the above-mentioned model. Usually, other researchers have often focused only on observed impacts which can be directly connected to policy discussions. This study follows a somewhat different approach (Chikaraishi et al. 2011). That is, all land use impacts are first treated as unobserved impacts in order to determine what kinds of land use impacts really exist. Using the tilde symbol "~" to represent model estimation results without any explanatory variables (called the *Null model*), the total variance of the utility can be calculated as follows:

$$Var(\widetilde{U}_{jirod}) = \ \tilde{\sigma}_r^2 + \tilde{\sigma}_{od}^2 + \ {}^2/3 \tag{3}$$

In the next step, we shall introduce a several set of explanatory variable to provide reasons for the land use impacts measured in the *Null model*. Using the hat symbol "^" to represent model estimation results with explanatory variables, the total variance of utility can be calculated as follows:

$$Var(\widehat{U}_{jirod}) = Var(\,\beta_j x_{jirod}) + \hat{\sigma}_r^2 + \hat{\sigma}_{od}^2 + \ {}^2/3 \tag{4}$$

Our purpose here is to evaluate what types and how many of the land use impacts can be captured by introducing explanatory variables. To do this, we compare the variation components in Eq. (3) against those in Eq. (4). Here, although the absolute expected value of $Var(\widehat{U}_{jirod})$ may change depending on the size of the unobserved component, the component ratio for each impact can be compared between the different models as long as the existence of the same "true" utility can be expected (see Chikaraishi et al. 2011). This comparison shows which types and how many of the land use impacts can or cannot be captured by introducing a certain set of explanatory variables, as follows:

- For observed Residential land use impacts (%):

$$[\tilde{\sigma}_r^2 / Var(\widetilde{U}_{jirod}) - \hat{\sigma}_r^2 / Var(\widehat{U}_{jirod})] * 100 \quad (5)$$

- For unobserved (or remaining) Residential land use impacts (%):

$$[\hat{\sigma}_r^2 / Var(\widehat{U}_{jirod})] * 100 \quad (6)$$

- For observed Origin-Destination land use impacts (%):

$$[\tilde{\sigma}_{od}^2 / Var(\widetilde{U}_{jirod}) - \hat{\sigma}_{od}^2 / Var(\widehat{U}_{jirod})] * 100 \quad (7)$$

- For unobserved (or remaining) Origin-Destination land use impacts (%):

$$[\hat{\sigma}_{od}^2 / Var(\widehat{U}_{jirod})] * 100 \quad (8)$$

5.4.3 Model estimation results

In this section, we shall first report the estimation results of the multilevel binary logit model in *Null model* to detect the ratio of two kinds of land use impacts. Explanatory variables are then introduced in a sequential manner with *household attributes*, *trip attribute* and *individual socio-demographic attributes* in what we called here as the *Halfway model* (all explanatory variables are defined in Table 6.2). We then add a set of *land use attributes* in the *Full model.* The reasons for taking this procedure are not only to provide the land use impacts in greater details, but also to identify the degree of impacts of the *land use attributes* on the model performance. We develop two different models of motorcycle choice for *non-mandatory trips* and *commuting trips*, respectively.

Before explaining model estimation results, to confirm whether introducing Residential neighborhood and Origin-Destination land use random components lead considerable model improvement or not, we made chi-square tests between different models as follow:

* For commuting trips purposes:

-2 x $[LL_{R+OD} - LL_R]$ = -2 x [-7986 – (-8131)] = -290

-2 x $[LL_{R+OD} - LL_{OD}]$ = -2 x [-7986 – (-8004)] = -36

* For non-mandatory trips purposes:

-2 x $[LL_{R+OD} - LL_R]$ = -2 x [-3467 – (-3562)] = -190

-2 x $[LL_{R+OD} - LL_{OD}]$ = -2 x [-3467 – (-3480)] = -26

where LL_{R+OD} is the final log-likelihood of *Null* model, LL_R is the final log-likelihood of *Null* model without the random component γ_{jod}, and LL_{OD} is the final log-likelihood of *Null* model without the random component γ_{jr}. The results indicate that both land use types have a impact with significant level at P<0.01, implying that introducing Residential neighborhood and Origin-Destination land use random components lead significant model improvements.

The estimation results are shown in Table 5.4.1. Here, it can be confirmed that the goodness-of-fit of the model (i.e., final log likelihood) improves as more explanatory variables are added in a sequential manner. Concretely speaking, for commuting trip purposes, an increase of about 1893 points in the goodness-of-fit of the *Halfway model* can be observed compared to that of the *Null model*, which is actually caused by introducing *household attributes, trip attribute* and *individual socio-demographic* attributes. Moreover, the goodness-of-fit of the *Full model* shows an increase of around 41 points from that of the *Halfway model*. In other words, introducing *land use attributes* lightly improves the performance of the model. This implies that land use attributes have certain impacts on motorcycle choice. Such impacts of land use are also confirmed for *non-mandatory trips*: the goodness-of-fit of the model increases sequentially from 614 to 15 points.

Looking at the details of the estimation results, it can be found that there are no unexpected or unexplainable values in both *commuting trips* and *non-mandatory trips* analysis. Firstly, focusing on *household attributes*, the *number of household member* shows a significant and negative impact on motorcycle choice. These may imply that the higher number of household member the lesser dependent on motorcycle i.e., they may prefer higher capacity mode as a private car. Due to the rapid economy grow in recent years, the price of a motorcycle is no longer too expensive compare to a household income. Thus, the *household monthly income* shows no impact on motorcycle choice as a consequence. Additionally, the higher *number of motorcycle* owned by household surely will lead to higher motorcycle choice.

Secondly, the trip attribute with only *travel time* shows its significant and negative sign as

Table 5.4.2 Estimation results

Variable	Commuting trips						Non_mandatory trips					
	Null model		Halfway model		Full model		Null model		Halfway model		Full model	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Constant	0.681	7 ***	1.806	8.689***	-0.370	-0.775	0.594	6.211***	2.817	11.896***	0.442	0.665
Household attributes												
hh_member	---	---	-0.252	-12.133 **	-0.255	-12.273 ***	---	---	-0.219	-7.279 ***	-0.222	-7.370 ***
hh_m_inc	---	---	0.001	0.147	0.001	0.293	---	---	0.000	-0.078	-0.001	-0.113
hh_mc	---	---	0.905	31.533 ***	0.908	31.585 ***	---	---	0.609	15.708 ***	0.617	15.862 ***
Trip attribute												
ttime			-0.045	-24.168**	-0.044	-23.463***			-0.018	-7.451***	-0.018	-7.306***
Individual socio-demographic attributes												
Age	---	---	-0.003	-1.203	-0.003	-1.124	---	---	-0.050	-18.594 ***	-0.050	-18.511 ***
Male			0.470	10.134 ***	0.474	10.197 ***			0.864	12.647 ***	0.868	12.696 ***
Work	---	---	0.459	4.689 ***	0.465	4.750 ***	---	---	0.507	5.819 ***	0.495	5.662 ***
Student	---	---	-1.301	-11.934 **	-1.300	-11.926 ***	---	---	-0.611	-4.886***	-0.614	-4.921 ***
Land use attributes												
R_density	---	---	---	---	-0.001	-2.684 **	---	---	---	---	0.000	-0.082
R_cbland	---	---	---	---	3.510	1.644	---	---	---	---	-0.806	-0.204
R_ecland	---	---	---	---	-1.462	-0.893	---	---	---	---	3.578	1.298
R_prland	---	---	---	---	-0.908	-0.429	---	---	---	---	11.200	2.822 **
R_rfland	---	---	---	---	0.155	2.498 *	---	---	---	---	0.128	1.461
R_tsland	---	---	---	---	-0.633	-0.713	---	---	---	---	-0.716	-0.630
R_urland	---	---	---	---	-0.429	-1.955 .	---	---	---	---	-0.237	-0.659
O-D_density	---	---	---	---	0.002	0.922	---	---	---	---	0.003	1.072
O-D_cbland	---	---	---	---	17.910	1.551	---	---	---	---	1.756	0.124
O-D_ecland	---	---	---	---	-55.440	-3.649 ***	---	---	---	---	-43.580	-2.294 *
O-D_prland	---	---	---	---	-20.980	-1.594	---	---	---	---	-35.200	-2.209 *
O-D_rfland	---	---	---	---	5.217	4.320 ***	---	---	---	---	3.442	2.073 *
O-D_tsland	---	---	---	---	11.990	1.200	---	---	---	---	32.180	2.655 **
O-D_urland	---	---	---	---	8.279	5.511 ***	---	---	---	---	2.324	1.149
Residential land use impacts	0.049		0.115		0.000		0.052		0.066		0.013	
Origin-Destination land use impacts	0.409		0.318		0.189		0.229		0.368		0.236	
Log-likelihood at zero	-9457.3		-9457.3		-9457.3		-3681.3		-3681.3		-3681.3	
Log-likelihood at convergence	-7986		-6093		-6052		-3467		-2853		-2838	
Rho	0.156		0.356		0.360		0.058		0.225		0.229	
Number of observation			13,644						5,311			

(.) significant at the 90% level, (*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

expected implies that the longer travel time the higher probability of not using motorcycle.

Thirdly, the *individual socio-demographic* attributes with *male* and *work* show positive and significant impacts. These imply that male and those who have a certain work are higher depending on motorcycle than female and those who do not have a work. The *student* shows negative sign may implies the fact that almost pupils and students in Hanoi use other modes for their daily travelling such as walk, bicycle or bus. The *age* attribute shows negative sign in both travel purpose categories but significant in *non-mandatory trips* only. These results may imply that for *non-mandatory trips* the higher age of respondents may lead to the higher propensity of not choosing motorcycle while this would not happen in *commuting trips* purposes.

Lastly, we could observe the significant impacts of several land use attributes in both Residential neighborhood and Origin-Destination. As confirmed the findings of Cervero (1996), both of *population density* and *urban residential land use* percentage in Residential neighborhood have significant impacts on commuting trip mode choice. However, the negative sign may implies that the higher density of population or residential land use the lesser depending on motorcycle. On the other hand, the *rice field and agricultural land use* attribute has significant and positive sign in both travel purpose categories not only in Residential neighborhood but also Origin-Destination implies that people living and travelling in high percentage of agricultural land (i.e., in suburban of Hanoi city) may have higher dependency on motorcycle. On the contrary, the significant and negative sign could be seen in both travel purposes categories from the *educational and cultural land use* and from *park and recreational land use* attributes in Origin-Destination. These may imply that the higher percentage of the *educational and cultural land use* or *park and recreational land use* the higher non-motorcycle usage. Moreover, the *transport land use* attribute in Origin-Destination shows significant and positive in *non-mandatory trips* purposes. This could imply that in *non-mandatory trips* purposes, the higher percentage of *transport land use* in Origin-Destination may lead to higher dependent on motorcycle. The only one land use attribute which shows no impacts on motorcycle choice is the *commercial and business land use* percentage.

To evaluate the variation properties of utility difference, we use the variation decomposition technique mentioned in Eq. (5 to 8). The results are shown in Table 5.4.2.

Table 5.4.3 The ratio of land use impacts

	Commuting trips	Non-mandatory trips
Residential neighborhood	0.07 %	0.09 %
Observed impacts	*0.07 %*	*0.07 %*
Unobserved impacts	*0.00 %*	*0.02 %*
Origin-Destination	4.85 %	9.08 %
Observed impacts	*3.35 %*	*3.75 %*
Unobserved impacts	*1.50 %*	*5.33 %*
Total	4.92%	9.17%

It is clearly that the land use impacts from Residential neighborhood on motorcycle choice are very small compared to those impacts from Origin-Destination: about 1.42% in *commuting trips* and 0.98% in *non-mandatory trips* (calculated by dividing 0.07 by 4.92 and 0.09 by 9.17). Moreover, the *non-mandatory trips* have higher Origin-Destination land use impacts compared to *commuting trips* while the impacts of introduced land use attributes are much higher in *commuting trips*: about 70% (calculated by dividing 3.35 by 4.85) of Origin-Destination land use impacts in commuting trips can be captured while only 41% (calculated by dividing 3.75 by

9.08) of them is explained in *non-mandatory trips*. In other words, the introduced land use attributes could not explain 59% of Origin-Destination land use impacts in *non-mandatory trips*, indicating that other land use attributes may need to be further explored.

In summary, there are several important findings from the study. First, the *land use attributes* have certain impacts on motorcycle choice. Concretely speaking, for *commuting trip* purposes the total land use impacts are 4.92% while in *non-mandatory trip* purposes those are higher with 9.17%. Second, the results shown that land use impacts from Origin-Destination on motorcycle choice are much larger comparing to those impacts from Residential neighborhood. This finding may strengthen the traditional trip based analysis in which trips are assumed to be independent and land use in Origin-Destination are often considered as influential factors. Third, it's more challenging to capture the Origin-Destination land use impacts in *non-mandatory trips* than in *commuting trips*. Finally, the impacts of land use on motorcycle choice are different depending on each type of land use attribute and travel purposes: *population density* and *urban residential land use percentage* in Residential neighborhood have significant and negative impacts in *commuting trips*; *rice field and agriculture land use percentage* in both Residential neighborhood and Origin-Destination have significant and positive impacts in both travel purpose categorizes; *educational and cultural land use percentage* and *park and recreational land use percentage* in Origin-Destination also have significant but negative impacts in both travel purpose categorizes; and *transport land use percentage* in Origin-Destination has significant and positive impacts in *non-mandatory trips* only.

5.5 Trip frequency in different residential location

Table 5.5.1 presents the estimation results of trips frequencies by regression model. There are total 44,107 trips made by motorcycle of 15,419 individuals who belong to 9,239 households used in the analysis. First, the *household size* has strong impacts but negative to motorcycle trips frequency. This may indicates the situation that, the larger household size the lower number of motorcycle trips made by household members. In that case there are some possible situations: household with larger size may choose a higher capacity mode such as car for travel or choose other modes such as walking, cycling or bus. Next, the *number of child ages below 10* is positively associated with motorcycle trip rates imply that those who live in households with more child(s) (under10 year olds) tend more to use motorcycle for travel. For example, as was found in 4.2, parent drop-off their child to school is very common phenomena due to safety and lack of neighborhood schools. Older child(s), over 10 years old, may go to school by themselves by walking and cycling because they are more physically and mentally mature. Last, *household monthly income* was found to have no effect on trip frequencies by motorcycles, indicating the situation that, motorcycles are dominant in modal share in Hanoi and become very common mode for all level of household income. This result also confirms the findings related to household income in previous parts.

Among individual attributes, the nonlinear effect of age was found. All of age groups have positive effects to motorcycle trip frequencies but in different amount. Individuals in first three groups whose aged in range of 22-50 are increasing to use motorcycle gradually while those belonging group from 51-60 years of age are starting to reduce motorcycle usage and those over 60 years of age are likely less to drive motorcycle.

Table 5.5.1 Regression of motorcycle trips frequency

Explanatory variables	Parameter	t_statistic	
Constant	2.378	32.028	***
Standard deviation	1.376	175.608	***
Household attributes			
Household size	-0.071	-8.001	***
Number of child aged below 10	0.412	12.810	***
Household monthly income	0.002	0.949	
Individual attributes			
22-30 years of age	0.150	3.141	**
31-40 years of age	0.276	5.485	***
41-50 years of age	0.390	7.717	***
51-60 years of age	0.222	3.933	***
>60 years of age	0.139	2.035	*
Male	0.047	1.957	*
Motorcycle driving license	0.181	4.329	***
Motorcycle for own use	0.276	7.162	***
Residential spatial attributes			
CBD	0.084	2.149	*
Non_CBD	0.057	1.436	
Rural	-0.096	-2.094	*
Log-likelihood at zero	-60429.84		
Log-likelihood at convergence	-26795.33		
Rho	0.5566		
Number of observations	15,419		

(*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

By gender, male group is positively associated with motorcycle trip frequencies indicating that this group has higher dependency on motorcycle comparing to female group. Both *motorcycle driving license* and *motorcycle for own use* variables are found to have positive impacts on motorcycle trip frequencies, implying that those own mobility tools (i.e., driving license and motorcycle) are more likely to use motorcycle for their travelling.

The spatial residential attributes was found to have some impacts on motorcycle trip frequencies. Concretely speaking, individuals with their household located in CBD, Central Business District, have higher tendency to use motorcycle (as shown by significant and positive impacts of *CBD* attribute). On contrary, the negative impacts of *rural* attribute may indicate that individuals with their household located in rural areas may have tendency to use other modes rather than use motorcycle.

5.6 Summary and policy discussion

As the first step in applying A-S-I approach, chapter IV and chapter V attempted to explore the source of motorcycle travel demand. Focusing on household and *spatial context*s we made travel behavior analyses with the viewpoint from demand side and base on these findings, we may propose some concrete and effective policies to avoid/reduce motorcycle usage.

In the *household context*, we first analyzed school trip of child and found that:

- Both of child groups, from 6-10 years of age and from 11-14 years of age are high dependent on their parent's motorcycle to make a trip from home to school and the younger group the higher dependency on motorcycle.

- The school location out of neighborhood is significant with travel to school by motorcycle as passenger.

These findings guide the policy implication for avoiding school trip by motorcycle: the elementary school location planning must be carefully considered. In other words, when urban planners locate elementary school, they better to give high priority in finding a suitable service radius for maximization the number of children those would commute by walking or cycling. As a matter of course, to encourage children go to school by walking or cycling, the environment for that are very important. In fact, it seems not easy to deal with these issues when almost pavements in Hanoi city are occupied by motorcycle parking and household merchant activities. However, toward a lesser motorcycle dependence society and livable city goals, urban design for better environment for walking and cycling must be considered adequately.

We then explored whether child existence affected to the relationship between mobility level and household's motorcycle ownership decision and the findings were:

- Motorcycle owners generate the higher number of trips partly because he/she just has higher needs for travel than non-motorcycle owners.

- The child existence has some impacts on increasing of travel demand; however, those who have child are less affected by motorcycle ownership compared to those who do not have child (see discussion in 4.3.4).

In the conventional way to deal with the increasing number of motorcycle, the authorities try to prevent the ownership by various taxes and regulations. However, even the price of motorcycle become very high and it's difficult to register a motorcycle, the number of motorcycle in Hanoi city still increasing fast around 10% - 12% annually. The reason of failing to prevent ownership may reveal from our findings above: motorcycle itself may have a smaller effect on the number of trips. The matters here are from the user him/her self. Because, if he/she has higher travel demand, he/she may equip him/her self a motorcycle to satisfy his/her travel need. Thus, to prevent the increasing number of motorcycle, it better to focus on how to reduce travel demand from people rather than preventing motorcycle ownership.

In the *spatial context*, our analyses shown that the land use patterns have certain impacts on motorcycle usage. The findings are various upon land use patterns and travel purposes; however, we may summarize them as follow:

- Individuals living in higher population/residential density areas, their home-based non-work trips have lesser depending on motorcycle.

- Individuals living in lesser population/residential density areas (i.e., suburban areas with higher *percentage of rice field and agricultural land*) have higher dependency on motorcycle.

- The land use impacts on *non-mandatory trip* purposes are higher than those on *commuting trip* purposes (i.e., commuting trips usually have fixed Origin – Destination while *non-mandatory trip* do not have).

- The land use impacts from Origin-Destination on motorcycle choice are much larger comparing to those impacts from Residential neighborhood or in other words, land use impacts from space which motorcycle users travel within are larger theses land use impacts from their residential neighborhood.

Base on the main findings above, the role of urban design to reduce travel demand from motorcycle owners is consolidated. Concretely speaking, the neighborhood design to reduce/shorten home-based shopping/leisure trips is very important especially for those live in lower population/residential density areas. In case of Hanoi city's situation, there are various new residential quarters located in suburban and rural areas where as lack of services as well as social facilities. As a consequence, people living there have no choice to travel to CBD areas for their need. Therefore, the neighborhood design to bring services and social facilities for these new residential quarters should be well considered. That also brings concrete tasks for policy makers to manage a suitable population/residential density rate as well as to prevent urban sprawl toward compact new urban areas.

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CHAPTER VI

Shifting to the buses: An analysis focusing on the temporal context

6.1 Introduction

6.1.1 Temporal context and travel behavior

As we could image, individuals' travel behaviors are not stable and changing from day to day and time to time. For example, an office man use bicycle to commute but in a bad weather day, he/she may change to bus or taxi. This complexity in *temporal context* is outcome of both habitual behavior and variability which may be described as random as well as systematic deviations from the behavioral regularity. For three decades, there were many studies had focused those aspects and factors affecting behavioral patterns. There are some findings but the most important may include habits in behavior, equilibrium of behavior, dynamics and variability.

The first important aspect, as mentioned in Goodwin, Kitamura and Meurs (1990) study, is the re-use of behavioral segments or sequences of solutions in similar decision situations. In other words, an approved behavioral pattern with known travel costs (travel time or other affecting factors) which has satisfied similar needs in the past is re-used or re-applied. The motivation behind this re-application is to avoid costs (or any disadvantages) for the new decision. In individuals' travelling, this becomes obvious for the minimization or even avoidance of information acquisition to get efficiently from an Origin to a Destination. To the best of our knowledge, there are several studies dealing with day-to-day variations in mode choice over a continuous period of time. Ramadurai and Srinivasan (2006) used a mixed logit model to estimate within-day variability of mode choice with data from a consecutive two-day travel diary. Interestingly, they found an inherent rigidity or inertia, indicating individuals are highly likely to choose a mode they have previously chosen. The inertial effect here is particularly strong for bike and walk modes. Chikaraishi et al. (2011) confirmed that mode choice behavior showed smaller day-to-day variations (compared to other behavioral aspects), meaning that individuals tend to use same mode over time. Cherchi and Cirillo (2008, 2009) studied the effect of repeated tours and investigate the intrinsic day-to-day variability in the individual preferences for mode choices. They found that individual tastes for time and cost are fairly stable but there is a significant systematic and random heterogeneity around these mean values and in the preferences for the different alternatives. They also confirmed that there would be a strong inertia effect in mode choice behavior, and the sequence of mode choice made is influenced by the duration of the activity and the weekly structure of the activities.

The second aspect as behavioral equilibrium is achieved if all details which determine travel behavior have remained constant over a sufficiently long period of time and the behavior has been adjusted to the environmental factors completely (Goodwin, Kitamura and Meurs, 1990). Such an environmental factor is for example the household composition which structures daily activity patterns and travel demand. Behavioral equilibrium is a long-term phenomenon which has to be distinguished from random or unexpected short-term adjustments of behavior which do not have a systematic character. It should be noted here that complete behavioral equilibrium over time is hardly ever observable. Most of the environmental factors are themselves subject of permanent change (i.e., seasonal rhythms, current political developments, etc.). Even substantially stable determinants of travel such as household related details such as home location, lifecycle and occupation status cannot be defined as entirely constant. They change over longer periods with notable implications for the individual mobility. Behavioral equilibrium therefore remains a theoretical construct – at least from a long-term perspective.

For the third important aspect, the dynamics of behavior describes the systematic adaptation of decisions to changing circumstances and to the situation_context of travel, for example mode, departure, destination or route choice (Kitamura, 1988). Those involve including short-term reactions of travelers to traffic conditions (e.g. congestion, bad weather) and long-term of behavior influencing variables such as working hours, household composition or the changing of workplace. Although some of the structural characteristics in the travelers' life occur in periodic intervals (e.g. change of work place), the term rhythm is here only used to describe the periodicity of behavior at the daily, weekly or monthly level. The development of rhythms of travel behavior is a reaction of the traveler towards the dynamic and social environment or in other words, fundamental socio-economic alterations in life foster the development of habitual behavior and rhythms. For instance, the day-to-day dynamics of travel behavior was explored by Mahmassani and colleagues when they analyzed the departure time choice, trip chaining and route choice of morning and evening commuting trips (Hatcher and Mahmassani, 1992; Mahmassani, 1997; Mahmassani, Hatcher and Caplice, 1997). They found that the propensities of changing route choice are stronger than departure time choice. Besides, the variability of travel behavior can be discussed from two perspectives: First, the behavior of two persons almost always differs due to differences in their socio-economic background or attitudes. This aspect of variability is often defined as *inter-individual variation* (Pas, 1987) and may be described as the deviation of the individual behavior from the socio-economic group that individual belongs to. In contrast to that, the behavior of an individual or a household varies considerably if they are observed over periods of time. For example, one may have different route choice due to time of a day and that variability is defined as *intra- individual variation*. Both categories of variability have a systematic component - which is explainable or predictable by e.g. personal characteristics - and a remaining random component. Predictable as well as random elements of variability are inherent in models of human behavior and have implications for the reliability or explanatory power of the models. Various studies focused on variability of travel behavior and they shown the significant sharing of intra-individual variations. Early works of Pas (1983, 1988) found that about 50% of the total variations in trip-making could be attributed to intra-individual variations. Pendyala (1999) confirmed the high percentage of variability for travel time, travel distance, trip frequency and departure and arrival time. Susilo and Kitamura (1999) explored day-to-day variation in an individual's action space and concluded that unobserved intra-individual variations may explain about 85% of the total variation of discretionary activities. Kitamura et al. (2006) and Chikaraishi et al. (2009) examined departure time choice and found that depending on the activity type, the intra-individual variations may occupy 35-85% of the total variations.

6.1.2 The scope of this chapter

As mentioned in Chapter I, motorcycle is the dominant mode in Hanoi city and motorcycle owners are usually captive users who have high tendency to use their motorcycle for all travel purposes event in short distances. However, in the one week household travel survey data 2010, all trips during one week of each individual were recorded; we found that some motorcycle owners used bus and some non-motorcycle used motorcycle. These variability of travel mode choice are quite interesting and finding the reasons behind (i.e., in which situation these behavior happen) will be very important work to help us not only encouraging motorcycle owners to shift to public modes (because Hanoi city will have Light Rail Transit, monorail and Bus Rapid Transit systems in the future) but also preventing non-motorcycle owners to use motorcycle as well as understanding advantages/disadvantages of each mode. Therefore, in this chapter, we focus on the day-to-day variations of mode choice behavior as a particular trait of *temporal context*: non-motorcycle owners' motorcycle choice and motorcycle owners' bus choice behavior. In our analysis, both of behaviors are examined with same explanatory variables. The reason for this is to check the differences/ similarities of influential factors on mode choice decisions between motorcycle owners and non-motorcycle owners groups: for example, there is a possibility that both of groups may tend to use bus in long travel distance or when they travel with others, while there is also a possibility that some factors may have different impacts on mode choice decisions between them.

This chapter is organized as follows. Section 2 describes the data and the variables used in this analysis. Section 3 presents briefly the methodology and the applying a multilevel binary logit model. Section 4 gives estimation results and discussions. The summary of this chapter and the policy discussion on how to Shift (as second step in applying A-S-I approach) are provided in the last section.

6.2 Data description and variables specifications

Through 451 respondents' trip diaries, it could be found that there are 65 non-motorcycle owners used motorcycle and 55 motorcycle owners used bus. All these respondents' information shall be analyzed in details as follow.

6.2.1 Motorcycle owners used bus information

There are total 242 respondents are motorcycle owner in which 55 of them (who belong to 47 households) used bus at least one time during the observation period. The Figure 6.2.1 below shows their information.

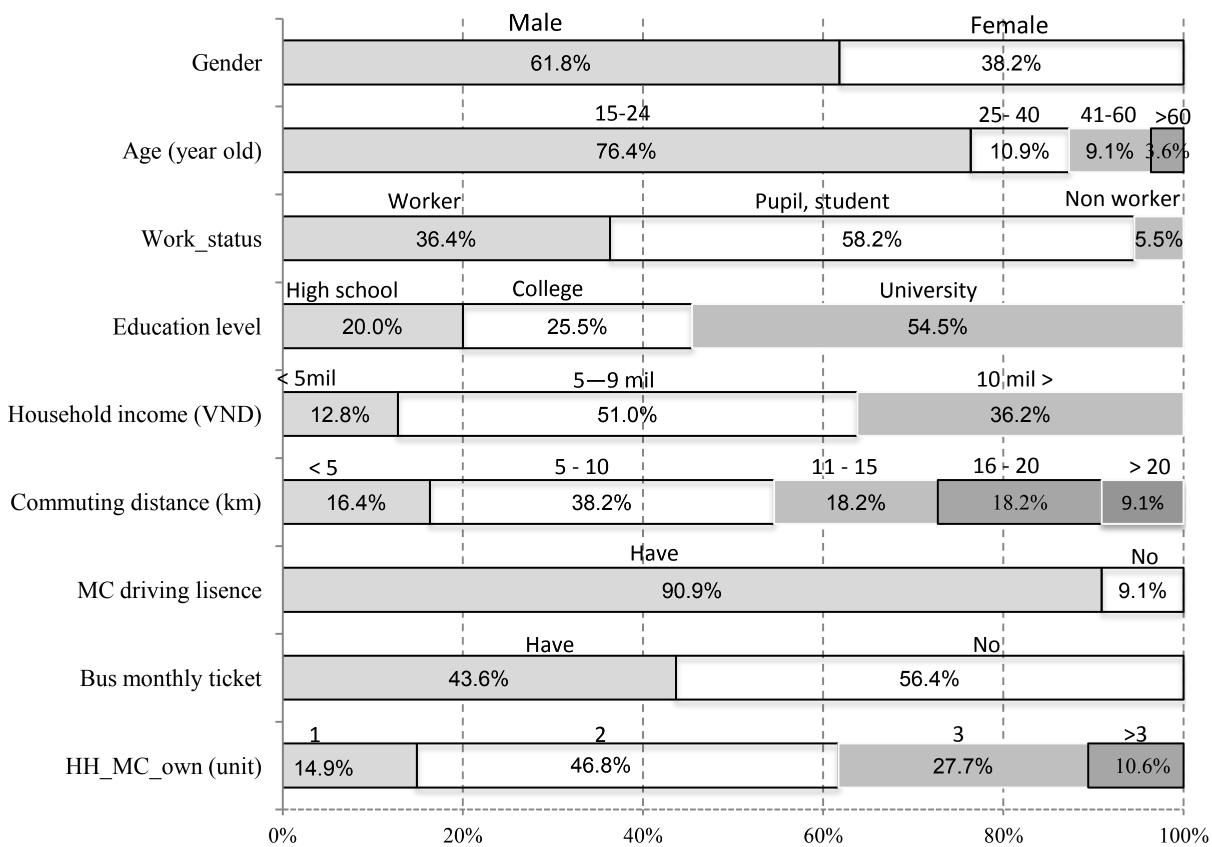

Figure 6.2.1 Motorcycle owners used bus's information

From the Figure 6.2.1, it can be confirmed that, among 55 motorcycle owners who used bus during the one-week survey period, 61.8% of them are male. Young people from 15 to 24 years of age are dominant with total 76.4%. The dominant respondents are workers and students. This is because of the sampling strategy employed in this study, as mentioned in the *Survey design*. That also affects on the high ratio of bus monthly ticket ownership with 43.6%. The household income distribution is quite similar with the actual income distribution in Hanoi (GSO, 2010). The ratio of respondents with a high education level (i.e., university level or above) is relatively high compared to that of the whole population of Vietnam. Nearly 85% of these respondents' commuting trip distances are longer than 5 km. The last bar in the figure show the household motorcycle ownership (HH_MC_own) in which around 85% of households have at least 2 motorcycles.

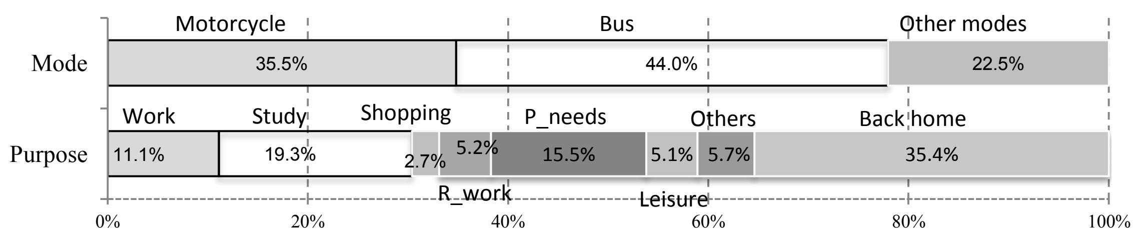

Figure 6.2.2 Motorcycle owners used bus's trip information

Figure 6.2.2 shows some basic information related to total 859 trips made by 55 respondents during the period of 7 days. The number of trips using bus is the highest with 44.0%, and then the trips using motorcycle show the second high value with 35.5%. The reason for high share of bus usage surely come from 58.2% respondents are pupil and student. Commuting trips, i.e., going to work and study, occupied total 30.4%, while non-mandatory trips, which include shopping, leisure, and personal needs, took 23.3% of total trips. The rest are mainly consisting of *back home* and all other purposes trips.

6.2.2 Non- motorcycle owners used motorcycle information

There are total 209 non-motorcycle owners and 65 of them were found to use motorcycle (as driver) at least one time during observation period. That may reflects the high propensity to use motorcycle in the context of motorcycle dependence city in which people may use any motorcycle when it available such as borrowing from family member or their friend. The figure 6.2.3 below shows us some information of these 65 people.

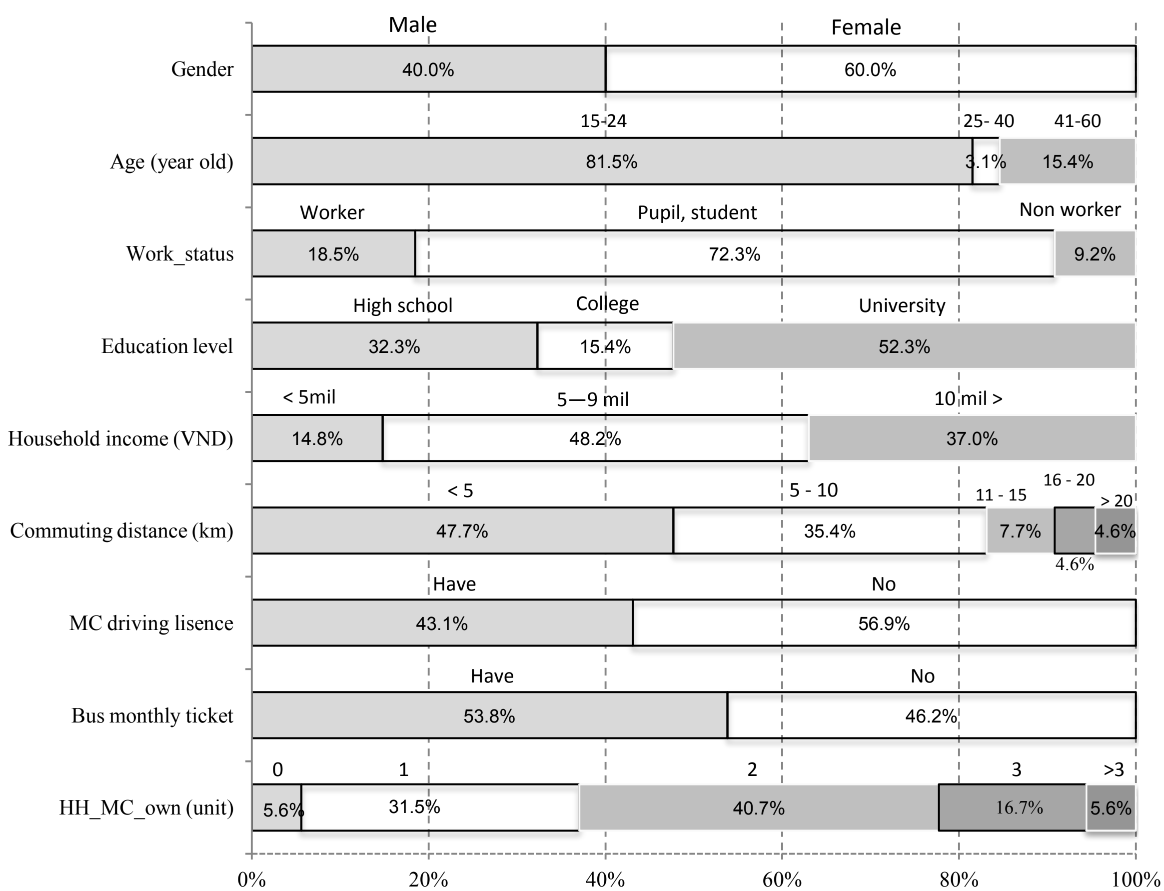

Figure 6.2.3 Non-motorcycle owners used motorcycle's information

Female occupied 60% and young people from 15 to 24 years of age are the main part when they occupied 81.5% of 65 non-motorcycle users used motorcycle. Pupil, student and worker respondents are dominant with total 90.8% and the rest 9.2% are non-workers. The ratio of respondents who have *university level or above* are highest with 52.3%, the second are *high school* with 32.3% and lowest are *college* level with 15.4%. The high percentage of *pupil, student* and *high school* education level are relatively with the high ratio of people who have no motorcycle driving license (56.9%) and those who own bus monthly ticket (53.8%). Household income and household motorcycle ownership show no much different with previous analysis on motorcycle owners used bus but the difference in commuting distance. Concretely, their commuting distance which is shorter than 5 km is highest occupy with 47.7%.

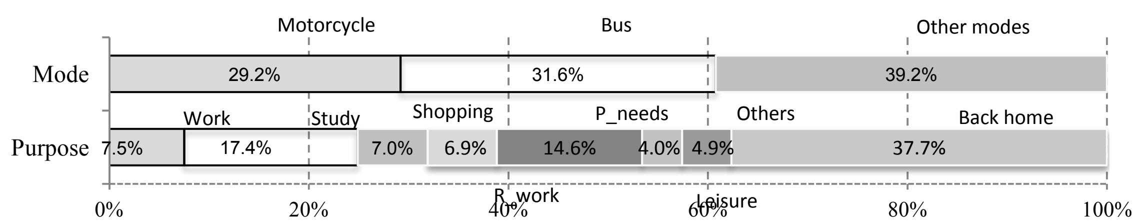

Figure 6.2.4 Non-motorcycle owners used motorcycle's trip information

During a continuous 7 days, 65 non-motorcycle owners used motorcycle made total 996 trips. As shown in Figure 6.2.4, we could observe a considerable trips made by motorcycle with 29.2%. Other modes except bus and motorcycle are highest occupy with 39.2%. Commuting trip purposes ratio is a little bit smaller than non-mandatory trip purposes in turn with 24.9% and 25.6%; other purposes took nearly half of total trips.

Table 6.2.1 Explanatory variables used for models estimation

Explanatory variables	Definition
	Mobility tools
HH_MC	Number of motorcycle in household
MC_license	Motorcycle driving license (1 = yes; 0 = no)
B_ ticket	Bus monthly ticket (1 = yes; 0 = no)
	Individual socio-demographic attributes
Male	Male (1 = yes; 0 = no)
Age 24	15 – 24 years of age (1 = yes; 0 = no)
Age 25 - 40	25 – 40 years of age (1 = yes; 0 = no)
Age 41 - 60	41 – 60 years of age (1 = yes; 0 = no)
Work	Have a work (1 = yes; 0 = no)
Student, pupil	Student or pupil (1 = yes; 0 = no)
Edu_uni_ level	University level or above (1 = yes; 0 = no)
HH_income	Household income (in VND)
	Situational attributes
Acc_HH	Accompany with household member (1 = yes; 0 = no)
Acc_OT	Accompany with other people (1 = yes; 0 = no)
Complexity of tour	Number of stop during Home to Home tour
DT_Morn	Departure time in morning from 5AM to 9:59AM
DT_Noon	Departure time in noon from 10AM to 13:59PM
DT_Aft	Departure time in afternoon from 14PM to 18PM
D 5- 10	Dummy for travel distance (1 = 5km to 10 km, 0 = otherwise)
D 11- 15	Dummy for travel distance (1=10km to 15 km, 0 = otherwise)
D 16	Dummy for travel distance (1 = 15km or over, 0 = otherwise)
Weekdays	Weekdays (1 = yes; 0 = no)
Rain	Rain (1 = yes; 0 = no)
Traffic jam	Traffic jam (1 = yes; 0 = no)
Work	Go to work (1 = yes; 0 = no)
Study	Go to study (1 = yes; 0 = no)
Shopping	Shopping (1 = yes; 0 = no)
Related to work	Related to work (1 = yes; 0 = no)
Personal needs	Personal needs (1 = yes; 0 = no)
Leisure	Leisure (1 = yes; 0 = no)

6.2.3 Variables specifications

All explanatory variables in this analysis were classified into three sets including *mobility tools, individual socio-economic attributes* and *situational attributes* and their definition are shows in Table 6.2.1. The *mobility tools* includes the availabilities of alternatives, the *individual socio-economic attributes* refers to the individual's attributes and the *situational attributes* contains attributes in terms of travel party, departure time, travel distance, travel purposes, etc. These explanatory variables shall be used in both mode choice models to check the differences/similarities of influential factors on mode choice decisions between motorcycle owners and non-motorcycle owners as already mentioned in *Introduction*.

6.3 Applying a multi-level binary logit model

As we could imagine, the sources of mode choice variations do not only differ in macro levels (i.e. household, zone) but also vary within micro levels (i.e. individual) and their interaction is following hierarchical or cross-classification structures. To deal with these complex variation patterns, the multilevel modeling may be one of the best approaches (Hox et al. 1995 and Kreft et al. 1998). This method treats hierarchical and cross-classification structures as unobserved heterogeneities and allow for decomposition of total variation into the variations from various sources. In this study, the total variations of modes choice behavior were decomposed into two variation components that include inter-individual and intra-individual variations with regard to both observed (non-random) and unobserved (random) effects as shows in Fig 6.3.1 in next page.

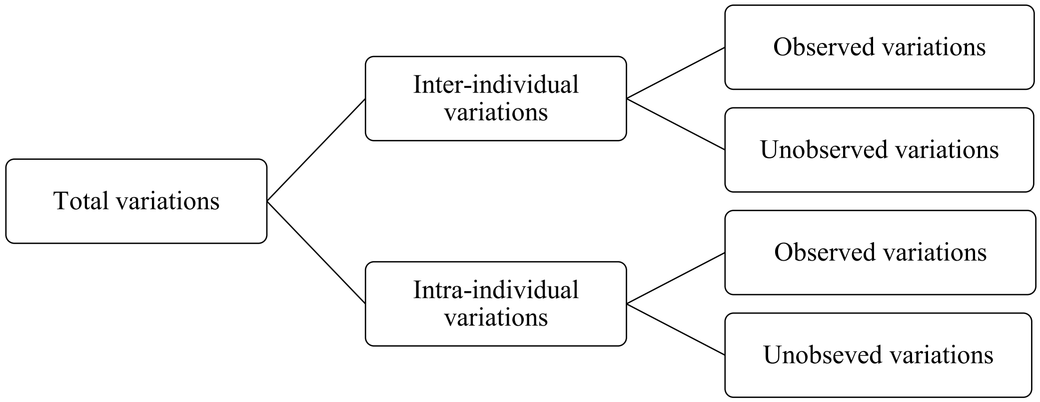

Figure 6.3.1 The assumed variation structure

In this study, two binary logit models is developed in the context of transportation mode choice behavior (i.e., whether they choose bus/motorcycle or not). Consider the situation that an individual *i* chooses an alternative *d*, his utility function could be written as:

$$U_{id} = \beta_0 + \beta\, \mathrm{x}_{\mathrm{id}} + \varepsilon_{id} \quad (1)$$

where β_0 is constant, x_{id} indicates a set of explanatory variables including individual/household attributes, situational/contextual factors and travel purposes. β' is a coefficient vector associated with x_{id} . Let γ_i be an unobserved component at individual level which represents inter-individual variations. Here, γ_i is assumed to be normally distributed with mean zero and variance σ_i^2 , let ε_{id} be a unobserved component at situational level which reflect intra-individual variations. Here, ε_{id} is assumed to follow a logistic distribution with a variance of $\pi^2/3$ (the scale parameter is fixed as one, since the utility is unitless). Based on the above mentioned definition, the probability choosing bus or motorcycle (MC) $P_{id}^{bus/MC}$ can be written as follows:

$$P_{id}^{bus/MC} = \exp\,(U_{id})/\{\exp(U_{id}) + 1\} \quad (2)$$

To describe behavioral variations, this analysis employed the approach which developed by Chikaraishi et al (2011), in which, all behavioral variations are first treated as unobserved variations in order to determine what kinds of variations really exist. Using the tilde symbol "~" to represent the model estimation results without any explanatory variables (called the *Null model*), the total variance of the utility can be calculated as follows:

$$Var(\tilde{U}_{id}) = \tilde{\sigma}_i^{\,2} + \pi^2/3 \qquad (3)$$

In the next step, explanatory variables shall be introduced to provide reasons for the behavioral variations measured in the *Null model*. Using the hat symbol "^" to represent model estimation results with explanatory variables, the total variance of the utility can be calculated as follows:

$$Var(\hat{U}_{id}) = Var(\beta' x_{id}) + \hat{\sigma}_i^{\,2} + \pi^2/3 \qquad (4)$$

The introducing explanatory variables could put behavioral variations into observed variations while the rest remain unobserved variations. The purpose here is to evaluate what types and how many of the variations can be captured by introducing explanatory variables. To do this, we compare the variation components in Eq. (3) against those in Eq. (4). Here, although the absolute expected value of $Var(\hat{U}_{id})$ may change depending on how many intra-individual variations can be captured by introducing explanatory variables, the component ratio for each variation can be compared between the different models as long as the existence of the same "true" utility can be expected. This is because the scale of $Var(\hat{U}_{id})$ is strictly defined by the rest of the unobserved intra-individual variations, and also because the other fixed and random parameters are automatically rescaled. Thus, we can compare the component ratio for each variation between Eq. (3) and Eq. (4). This comparison shows which types and how many of the variations can or cannot be captured by introducing certain explanatory variables, as follows:

- For observed inter-individual variations (%):

~ (~) - ^ ⌢ 100 (5)

- For unobserved (or remaining) inter-individual variation (%):

^ ⌢ (6)

- For observed intra-individual variations (%):

- (~)- - ⌢ (7)

- For unobserved (or remaining) intra-individual variations (%):

- ⌢ (8)

The variation properties derived from Eqs. (5) to (8) could evaluate the model's performance more precisely for each type of variation. Based on the ratio of them, we shall try to reduce the remaining of variations as much as possible for a better result. In other words, this could bring many implications for not only model improvement but also for data collection.

6.4 Model estimation results

In this section, the estimation results of two different multilevel binary logit models in *Null model* to detect the ratio of inter-individual variation from total variations are reported. The first is non-motorcycle owners' mode choice model which examined whether they chose motorcycle or not to explore the potential disadvantages of bus usage. The second is motorcycle owners' mode choice model to explore the potential advantages of bus usage through their bus choice.

Explanatory variables are then introduced in a sequential manner with the *mobility tools* and the *individual socio-demographic attributes* in what so called here as the *Halfway model*. The *situational attributes* are then added in the *Full model*. The reasons for taking this procedure are not only to provide the behavioral variation information in greater details, but also to identify each attribute set's impacts on the model performance.

The estimation results are shown in Table 6.4.1. Here, it can be affirmed that the goodness-of-fit of the model (i.e., final log likelihood) improves as more attribute sets are added in a sequential manner. Concretely speaking, for non-motorcycle owners' motorcycle choice, an increase of about 1.7 points increase in the goodness-of-fit of the *Halfway model* can be observed compared to that of the *Null model*, which is actually caused by putting *mobility tools* and *individual socio-demographic attributes*. Moreover, the goodness-of-fit of the *Full model* shows an increase of about 51 points from that of the *Halfway model*. It could be said that putting *situational attributes* significantly improves the performance of the model. This also means the non-motorcycle owner's motorcycle choice behavior depending much on *situational attributes*. Such situation is also confirmed in the motorcycle owners' bus choice behavior: the goodness-of-fit of the model increases sequentially from 3.8 to 115.8.

Then, the impacts of each attribute set on modes choice behavior are estimated. It could be seen that the *mobility tools* and the *individual socio-demographic attributes* have no significant impact on both groups' modes choice. These imply that the non-motorcycle owners' motorcycle choice and the motorcycle owners' bus choice are not depending on any alternatives, *gender*, *ages*, social components, *education levels* or *household incomes*. On the other hand, it could be observed the *situational attributes* has strong impacts on their modes choice through several significant attributes but in contrariety ways. Concretely, the *accompany with household member*

Table 6.4.1 Estimation results

Variable	Non_motorcycle owners' motorcycle choice						Motorcycle owners' bus choice					
	Null model		Halfway model		Full model		Null model		Halfway model		Full model	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Constant	-1.012	-5.273 ***	-1.651	-1.911 .	-2.131	-2.053 *	-0.064	-0.323	-0.472	-0.352	-3.419	-2.308 *
Mobility tools												
HH_MC	---	---	0.004	0.013	0.061	0.206	---	---	0.028	0.095	-0.131	-0.432
MC_license	---	---	0.606	1.323	0.754	1.457	---	---	-0.589	-0.835	-0.209	-0.287
B_ticket	---	---	0.075	0.176	0.122	0.253	---	---	0.068	0.151	0.366	0.787
Individual socio-demographic attributes												
Male	---	---	-0.206	-0.456	-0.201	-0.395	---	---	0.124	0.308	0.072	0.173
Age 24	---	---	0.232	0.189	0.256	0.193	---	---	0.278	0.219	0.302	0.228
Age 25 - 40	---	---	-0.613	-0.465	-0.946	-0.639	---	---	0.263	0.176	0.995	0.636
Age 41 - 60	---	---	0.561	0.653	1.112	1.141	---	---	-0.719	-0.478	0.206	0.131
Work	---	---	0.183	0.245	0.097	0.115	---	---	-0.154	-0.151	-1.416	-1.330
Student	---	---	0.633	0.818	1.229	1.406	---	---	0.234	0.264	-0.143	-0.155
Edu_uni_ level	---	---	-0.285	-0.572	-0.303	-0.542	---	---	-0.341	-0.827	-0.198	-0.465
HH_income	---	---	0.001	0.015	-0.009	-0.086	---	---	0.086	0.855	0.167	1.569
Situational attributes												
Acc_HH	---	---	---	---	1.662	5.322 ***	---	---	---	---	-1.663	-3.530***
Acc_OT	---	---	---	---	0.754	2.664 **	---	---	---	---	-0.633	-2.484 *
Complexity of tour	---	---	---	---	-0.161	-1.809 .	---	---	---	---	-0.109	-1.357
DT_Morn	---	---	---	---	-1.079	-3.183 **	---	---	---	---	1.050	2.829 **
DT_Noon	---	---	---	---	-0.822	-2.696 **	---	---	---	---	0.651	1.950 .
DT_Aft	---	---	---	---	-0.419	-1.444	---	---	---	---	0.838	2.564 *
D 5-10	---	---	---	---	-0.348	-1.457	---	---	---	---	1.738	6.082 ***
D 11-15	---	---	---	---	-0.667	-1.877 .	---	---	---	---	3.246	8.853 ***
D 16>	---	---	---	---	-0.807	-1.813 .	---	---	---	---	3.447	9.874 ***
Weekdays	---	---	---	---	-0.075	-0.308	---	---	---	---	0.152	0.543
Rain	---	---	---	---	0.567	1.358	---	---	---	---	0.753	2.069 *
Traffic jam	---	---	---	---	0.141	0.41	---	---	---	---	0.106	0.284
Work	---	---	---	---	0.666	1.547	---	---	---	---	0.076	0.177
Study	---	---	---	---	0.031	0.09	---	---	---	---	0.321	1.033
Shopping	---	---	---	---	0.410	0.987	---	---	---	---	-0.534	-0.699
Related to work	---	---	---	---	1.638	3.931 ***	---	---	---	---	0.555	1.262
Personal need	---	---	---	---	1.265	4.173 ***	---	---	---	---	-0.467	-1.447
Leisure	---	---	---	---	0.169	0.342	---	---	---	---	0.120	0.271
Inter_individual variations	1.915		1.783		2.279		1.769		1.431		1.345	
Log-likelihood at zero	-1436.92		-1436.92		-1436.92		-1239.28		-1239.28		-1239.28	
Log-likelihood at convergence	-514.1		-512.4		-461.4		-523.9		-520.1		- 404.3	
Rho	0.642		0.643		0.679		0.577		0.580		0.674	
Number of observation			996						859			

(.) significant at the 90% level, (*)significant at the 95% level, (**)significant at the 99% level, (***) significant at the 99,9% level

and the *accompany with other people* have positive impacts on non-motorcycle owners' motorcycle choice but they have negative impacts on motorcycle owners' bus choice; these imply that motorcycle owners tend to choose bus when they travel alone while non-motorcycle owners tend to use motorcycle when their trip have the participation of other people as their friend, colleague or especially their household member.

Next, the departure times are significant and positive in bus choice but negative in motorcycle choice may illustrate the situation that motorcycle owners may choose bus when their departure time in daytime while non-motorcycle owners, on the contrary, have propensity to use motorcycle in evening time.

Then, the advantages of bus usage for motorcycle owners could be reveal evidentially through the significant impacts from travel distance category: the longer travel distances the higher bus choice properties from motorcycle owners. On the other hand, the travel distances category has negative impacts on motorcycle choice: non-motorcycle owners have lesser preference to use motorcycle for their travel distances over 5km. In other words, it could be said that non-motorcycle may have higher preference to use other's motorcycle for their short distance trips (less than 5km). Another advantage of bus could be revealed form the significant impact of weather condition attribute. It may imply that motorcycle owners have high propensity to use bus in rainy days.

Finally, all the travel purposes attributes show no impact on bus choice but two of them have strong impacts on motorcycle choice. These imply the situation that non-motorcycle owners may have higher preference to choose a motorcycle when their trips are for *related to work* or *personal need* purposes. Combining with the propensity to use motorcycle in evening time as mentioned above these could reveal the disadvantages or constraints in operation time and service density of current bus system in which non-motorcycle owners may use bus in fix schedule like commuting trips such as go to work or go to study and in day time only, otherwise, they have to borrow other's motorcycle to travel.

So far, the above estimation has mainly focused on observed behavioral variations without mention of unobserved variations. To evaluate the variation properties of utility difference, we use the variation decomposition technique mentioned from Eq. (3) to Eq. (8). The results are shows in Table 6.4.2.

Table 6.4.2 The ratio of variations

	Non-motorcycle owners' motorcycle choice	Motorcycle owners' bus choice
Inter-individual variation	36.79 %	34.97 %
Observed inter-individual variation	*14.62 %*	*15.96 %*
Unobserved inter-individual variation	*22.17 %*	*19.01 %*
Intra-individual variation	63.21 %	65.03 %
Observed intra-individual variation	*31.20 %*	*18.53%*
Unobserved intra-individual variation	*32.01 %*	*46.50 %*
Total	100%	100%

It is confirmed that the modes choice behavior of both groups depend much on intra-individual variation. The introducing three set of explanatory variables could explain certain variations: for non-motorcycle owners' motorcycle choice, about 40% of inter-individual variation (calculated by dividing 14.62 by 36.79) and 49% of intra-individual variation (calculated by dividing 31.20 by 63.21); for motorcycle owners' bus choice, about 45.6% of inter-individual variation and 28.5% of intra-individual variation can be captured. In other words, there are still remaining variations: 60% of inter-individual variation and 51% of intra-individual variation in motorcycle choice of non-motorcycle owners; 54.4% of inter-individual variation and 71.5% of intra-individual variation in bus choice of motorcycle owners need to be further explored. To do that, we may not only apply different setting for the variations structure i.e., adding more variations like household, spatial variations and even the co-variation which may exist between them but also collect more information related to household/individual attributes and especially situational attributes such as household/origin/destination location and land use, day of week, weather condition, etc.

6.5 Summary and policy discussion

At this second step in applying A-S-I approach, this chapter attempts to answer the question: how to Shift. Focusing on particular modal choice behaviors which were observed in *temporal context*, we try to explore in what conditions motorcycle owners used bus and non-motorcycle owners used motorcycle. In this analysis, the one-week travel diary data from 55 motorcycle owners and 65 non-motorcycle owners were used and two different multilevel binary logit models were developed. The estimation results could deepen our understanding in the differences/similarities of influential factors on mode choices decision between motorcycle owners and non-motorcycle owners.

Our analysis has shown that only the *situational attributes* has strong impacts in contrary ways on both groups' mode choice behavior. Concretely, non-motorcycle owners may have higher preference to use other's motorcycle when their travelling are in some cases: for short distance (i.e., less than 5km), for *related to work* or *personal need* purposes, in the evening time and accompany with other people, especially with their family member. On the other hand, motorcycle owners may shift to use buses in some cases: for long travel distances (i.e., more than 5km), in the day time, travelling alone or in bad weather (i.e., rainy day). These modes choice behavior also revealed the buses' advantages in long travel distances and in bad weather condition while the disadvantages may come from operation time (i.e., less frequency in off-pick hours) and service density (i.e., mostly in main routes only).

Base on the findings above, we may have some actions to encourage modal shift from motorcycle to bus. In the situation that Hanoi city was planned to become a *polycentric* city which includes the main center (i.e., current CDB) connected with 5 satellite urban areas and number of small towns (as nodes) within from 5 km to 30 km by ring roads and centripetal routes system (Perkins et al. 2009). In the very near future, people who have to commute long distance between *nodes* may have high tendency to shift from their motorcycle to current bus system of other public modes in the future (which may include several kinds of mass transit system i.e., light rail transit, metro). Policy makers should first focus on encouraging these people to increase motorcycle access usage and decrease motorcycle usage as main mode, for example, motorcycle parking space in main public modes stations/stops on the routes connect from rural, suburban to CBD should be carefully consider to plan. On the other hand, to prevent the motorcycle usage propensity from non-motorcycle owners, neighborhood designing to satisfy personal need (i.e., shopping/leisure purposes) is very important as well as improving public modes' service density and operation in off-pick hours.

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CHAPTER VII

Improving public transportation system: An analysis to capture future mode choice behavior in temporal context

7.1 Introduction

Rapid growing in economy in recent years had significant changing urban form by urbanization's expanding from time to times. Many new living quarters with high-rise apartments had been building in sub-urban and rural areas surrounding Hanoi city. It does seem not difficult to recognize that the number of trip (i.e., commuting trips) between those areas and centre of Hanoi will rapidly increase. In the situation that public transportation has only bus, which is taking the huge travel demand with low level of services; citizens in Hanoi have not much choice to prefer private modes such as motorbike and car. However the overuse of private modes is also generating many problems such as traffic jam, accidents as well as damaging the air environment. Improved public transport services, as the last step in applying A-S-I approach, by providing a new modern mode, which has a mass transit capacity and environmental friendly, is expected to relieve those problems.

Since 2005, the Ministry of Transportation proposed a Light Rail Transit system planning which including 8 lines for Hanoi city, in which, the feasibility study on the line number 2 was finished. This line is combined by elevated light rail and metro crosses through Dong Da, Thanh Xuan and Ha Dong Districts and connects transport clue Hanoi Station to residential quarters, organizations, commercial centers, industrial areas, Hanoi Music College, Industrial Arts

University, National University, Foreign Languages University, Hanoi Architectural University, etc with total 14.83 km length and 14 stations. In the situation when public transport is lacking in both capacity and quality, the introduction of a new transit system with its advantages is expected to attract attention of people and get their preference. However, people in Hanoi city have long time dependent on motorcycle for their travel, thus, it's very important to forecast the impacts of future mode on peoples' travel behavior. Therefore, this chapter attempts to estimate people's future travel mode choice behavior under changes in travel and socio-economic environments, in case of introducing a Light Rail Transit system in Hanoi city: how people choose their modes and which factors influence their choices are also analyzed.

To capture individual's preferences for not yet existing alternatives, the Stated Preference (SP) approach has proven to be successful mainly in the context of developed countries. This approach examines individual responses to a series of experimentally designed choice alternatives which are described in terms of combinations of attributes with several pre-defined levels. Referring to the considerable size of the discrete choice models with SP-RP combined data, a Nested Logit model which collects similar modes under a nest without considering the data source is applied.

7.2 Analysis of future mode choice behavior

7.2.1 Model structure

In the study, we have used econometric model structures based on Multinomial Logit Model (MNL) and Nested Logit Model to estimate the commute trip mode choice in Hanoi city.

Regarding the choice set, SP data has LRT trip mode in addition to Motorbike, Car and Bus, which are available in RP data. The data first estimated by MNL using samples with RP data only and SP data only. The choice probability that an individual q chooses option j can be written as:

$$P_{jq} = \frac{\exp(V_{jq})}{\sum_{i \in C} \exp(V_{iq})} = \frac{\exp(\theta^T X_{jq_q})}{\sum_{i \in C} \{\exp(\theta^T X_{jq})\}} \tag{1}$$

where V is an observable utility component; θ^T is a vector of parameters to be estimated; X_{jq} is a vector of explanatory variables and C is the choice set.

Secondly, a Nested Logit Model suggested by Ben-Akiva and Morikawa estimated the combination of RP/SP data sources. The model is used to correct SP reported biases by introducing RP information. Define the utility functions and for both RP and SP data as follows:

$$U_{jq}^{RP} = \theta X_{jq}^{RP} + \alpha Y_{jq}^{RP} + \varepsilon_{jq}^{RP} \tag{2}$$

$$U_{jq}^{SP} = \theta X_{jq}^{SP} + \phi Z_{jq}^{SP} + \varepsilon_{jq}^{SP} \tag{3}$$

where j and q indicate alternatives and decision makers, X_{jq}^{RP} and X_{jq}^{SP} are common variables for all travel modes, Y_{jq}^{RP} and Z_{jq}^{SP} are the alternative specific attributes, ε_{jq}^{RP} and ε_{jq}^{SP} are error terms, and θ, α , ϕ are the parameters to be estimated. The RP/SP combined model requires that SP utility function U_{jq}^{SP} has a different variance σ_{SP}^2 of error term ε_{jq}^{SP} from the one σ_{RP}^2 in RP utility function as follows:

$$\sigma_{SP}^2 = \mu^2 \sigma_{RP}^2 \tag{4}$$

where μ is an unknown scale parameter. Assuming that both error terms σ_{SP}^2 and σ_{RP}^2 follow an independent Gumbel distribution with zero mean, the choice probabilities can be obtained as follows:

$$P_{jq}^{RP} = \frac{\exp(\theta X_{jq}^{RP} + \alpha Y_{jq}^{RP})}{\sum_i \exp(\theta X_{iq}^{RP} + \alpha Y_{iq}^{RP})} \tag{5}$$

$$P_{jq}^{SP} = \frac{\exp[\mu(\theta X_{jq}^{SP} + \phi Z_{jq}^{SP})]}{\sum_i \exp[\mu(\theta X_{iq}^{SP} + \phi Z_{iq}^{SP})]} \tag{6}$$

The logarithm likelihood function is used to estimate the parameters base on maximum likelihood method:

$$L(\theta,\mu,\alpha,\phi) = \ln\left\{\left[\prod_j \prod_q \left(P_{jq}^{RP}\right)^{\delta_{jq}^{RP}}\right] * \left[\prod_j \prod_q \left(P_{jq}^{SP}\right)^{\delta_{jq}^{SP}}\right]\right\} \tag{7}$$

where δ_{jq}^{RP} , δ_{jq}^{SP} are dummy variables. If individual q chooses alternative j in RP or SP data then δ_{jq}^{RP} or δ_{jq}^{SP} is equal to 1, other wise 0.

7.2.2 Model estimations

The first estimation procedure was carried out for the RP data source alone with the MNL model. According to the results (Table 7.2.1), it is validated that the motorbike is the usual commute trip mode. Among the rest of the estimated parameter values, travel time variable only gets a positive parameter value unexpectedly. This might indicate that time is not conceived part of the cost, that might be specific to the context associated with developing countries condition.

The second estimation attempt is conducted by using SP data source. The results of the model show that all of the alternatives are favored with respect to bus alternative. The highest difference is estimated for the motorbike, which can be interpreted as the persistence of motorbike inclined behavior even in different contexts devised under hypothetical conditions. The estimation results for waiting time reveal positive surprisingly.

Through the separate estimations of RP data and SP data, we could recognize that the attributes and variables contained within the RP data sets are likely to be ill conditioned (i.e. be invariant), parameter estimates obtained from models estimated from RP data are likely to be biased. On the other hand, the attributes of SP data sets are likely to be of good condition and hence the associated parameter estimates from models estimated from such data are likely to be unbiased. Nevertheless, the Alternative Specific Constant (ASC) estimated from SP data likely to be behaviorally meaningless while those obtained from RP data sources are likely substantive behavioral value. So that, combine both SP and RP data sources in to a model shall allow to exploit the strengths of both data sources while discarding the weakness displayed by each (see Hensher *et al.* (2005), pp. 580-581).

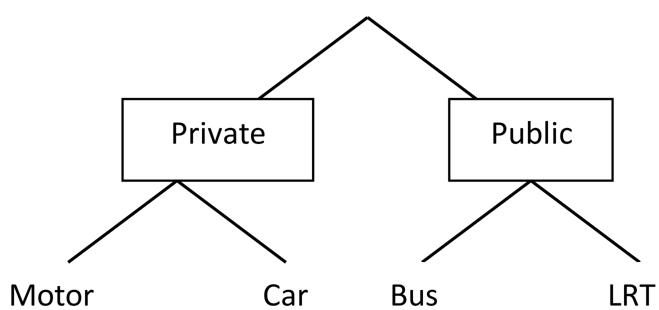

Figure 7.2.1 Tree structure of nested logit model under similar alternatives

Table 7.2.1 Estimation results of RP data, SP data and RP/SP combine sources

Variables	RP			SP			RP/SP		
	Parameters	t-statistic		Parameters	t-statistic		Parameters	t-statistic	
ASC-Motorcycle	1.6	4.31	***	2.03	10.05	***	1.59	6.98	***
ASC-Car	-0.8	-2.96	**	0.54	1.8	.	0.63	1.86	.
ASC-LRT				0.19	2.21	*	0.22	2.75	**
Travel cost / hh_income	-0.05	-5.92	***	-0.32	-9.94	***	-0.18	-6.54	***
Travel time	0.01	6.34	***	-0.03	-5.92	***	-0.02	-4.62	***
Waiting time	-0.26	-4.85	***	0.03	4.27	***	0.02	2.83	**
Punctuality 1: absolute time for late arrival				0.02	1.79	.	0.01	0.76	
Punctuality 2: expected late arrival per run				-0.01	-0.38		-0.01	-0.22	
Scale parameter for private transport alternatives							1.54	4.34	***
Scale parameter for public transport alternatives							1.18	1.77	.
Log-likelihood at zero	-194.43			-2967.19			-5695.20		
Log-likelihood at convergence	-167.11			-2847.87			-3079.22		
Rho	0.141			0.040			0.459		
Number of observations	328			2624			2952		

As indicated by Hensher *et al.* (2005), pp. 590-592, here, we combine the two data sources by establishing nests for similar alternatives: private transportation and public transit (Figure 7.2.1). With this procedure, the scale parameter becomes estimable as the true sources of scale differences in error terms are controlled by organizing the alternatives under similar sets of alternatives instead of data sources.

All of modes include Motorbike, Car and LRT attract a significant patronage compared to Bus by positive estimated parameters like them presented in estimation by using SP data source alone with the MNL model. The variable derived by dividing the cost by household income and the travel time variable had negative sign as expected. Surprisingly, waiting time for public transit modes, again, does not have a negative sign. It can be interpreted that, almost the respondents were private user who not familiar with using public modes, so that they might not consider carefully about waiting time when answer the SP questions. That is might also characteristic of a developing city based on private modes transport.

7.3 Future mode choice by simulation method

To capture people's travel mode choice behavior in the future, the simulation analysis was conducted to examine the influence of future income and LOS on the modal shift. The choice probability on travel mode is estimated based on the RP/SP parameters. Considering the present situation and next 10 years in Hanoi city, the LOS and travel attributes are re-setup by the hypothetical assumptions as show in Table 7.2.2.

Table 7.2.2 Assumption of Level of Service and travel attributes

Modes	Income (VND)	LOS	Travel cost (VND)	Travel time (minute)	Waiting time (minute)	Delay time (minute)	Frequency of delay (minute)
Motorbike	10,000,000	High	6,000	15			
	1,000,000	Low	10,000	40			
Car	10,000,000	High	20,000	20			
	1,000,000	Low	40,000	45			
Bus	10,000,000	High	3,000	25	5	20	10
	1,000,000	Low	5,000	45	20	15	3
LRT	10,000,000	High	5,000	10	5	10	10
	1,000,000	Low	10,000	30	20	10	3

Income level is difficult to ask people so here assumed the minimum people's income is 1,000,000 VND per month for the low-income level in the current time and maximum expected people's income is 10,000,000 VND per month for the high-income level in the next 10 years. Two levels of LOS and travel attributes for four travel modes were setup by the hypothetical assumption for the future improvement of private and public transport services under consideration of reliable and possible travel time and waiting time.

Table 7.2.3 Definition of scenarios

Modes	Base line	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Motorbike	Low LOS	**High LOS**	Low LOS	Low LOS	Low LOS	**High LOS**
Car	Low LOS	Low LOS	**High LOS**	Low LOS	Low LOS	**High LOS**
Bus	Low LOS	Low LOS	Low LOS	**High LOS**	Low LOS	**High LOS**
LRT	Low LOS	Low LOS	Low LOS	Low LOS	**High LOS**	**High LOS**

Policy analysis can be estimated by putting all modes in hypothetical scenarios. The estimation will be firstly made under Low level of Income. In base line, all modes were put in low LOS to find out how users choose their mode and this base line will compare to other scenarios. Next, the priority in LOS for each mode was put in turn on each scenario (Table 7.2.3).

Scenario 1: If LOS of motorbike will be improved in the future, example, there is an urban express way will be introduced or enough space and convenient for parking motorbike, which will occur in mode choice probability for each travel mode? For capturing of changing mode choice probability, travel attributes are setup by changing high LOS for motorbike only, other modes are low LOS. The results in Figure 5 shown that, when LOS of motorbike improved, the

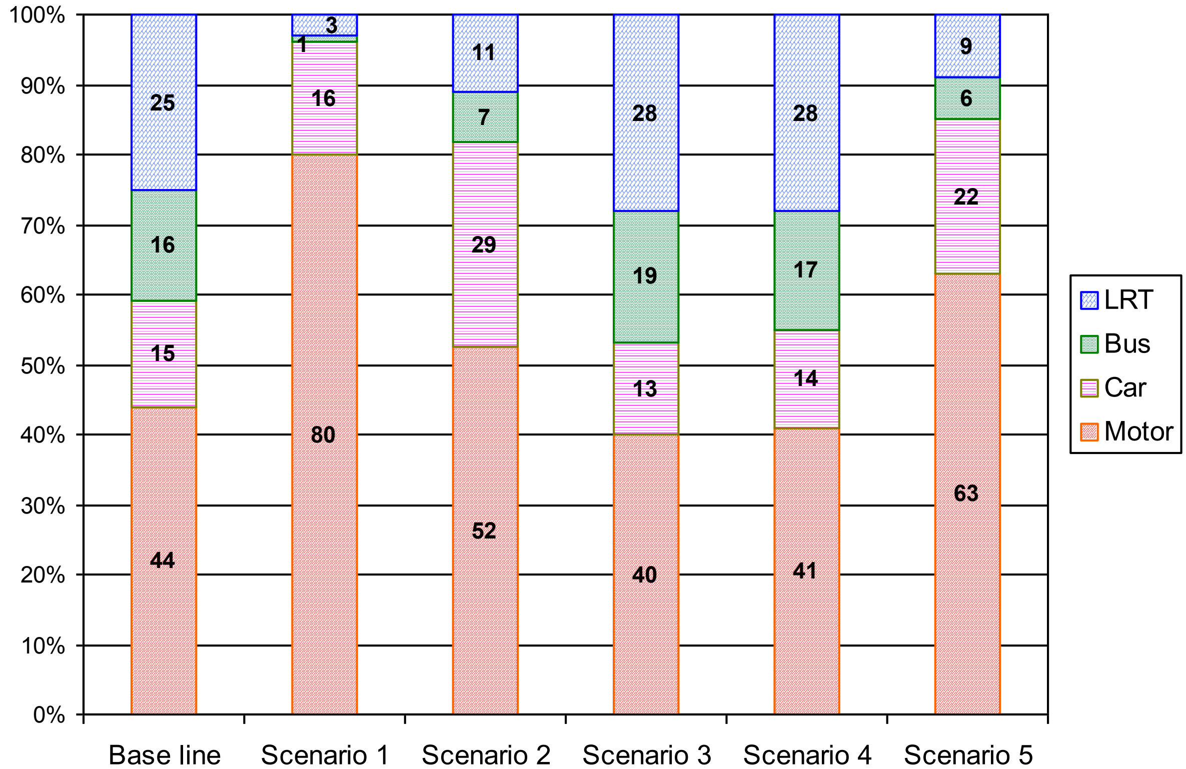

Figure 7.3.1 Mode choice probability in simulation method

number of motorbike users is increasing very large from 44% to 80%. Beside, the number of car users is also increasing. Contrarily, number of bus users is decreasing from 16% to 1% and number of LRT users is decreasing from 25% to 3%.

Scenario 2: Assuming the LOS of car will be improved in the future, example, there is an urban express way will be introduced or enough space and convenient for parking car. Travel attributes are setup by changing high LOS for car and low LOS for other modes. The results shown that, when LOS of car improved, the number of car users is increasing from 15% to 29%, the number of motorbike users is also increasing from 44% to 52% but number of bus users is decreasing from 16% to 7% and number of LRT users is decreasing from 25% to 11%.

Scenario 3: If LOS of bus will be improved in the future, example, there is an bus rapid transit system which could reduce travel time and make convenient for people use will be introduced which will occur in mode choice probability for each travel mode? In this case, travel attributes are setup by changing high LOS for bus and low LOS for other modes. The results shown that, when LOS of bus improved, the number of bus users is increasing from 16% to 19%. Beside, the number of LRT users is also increasing from 25% to 28%. Contrarily, number of car users is decreasing from 15% to 13% and number of motorbike users is decreasing from 44% to 40%.

Scenario 4: If LOS of LRT will be improved in the future, when whole the LRT system complete and put in to use effectively with reducing travel time and making convenient for people use, which will occur in mode choice probability for each travel mode? In this case, travel attributes are setup by changing high LOS for LRT and low LOS for other modes. According to the results, when LOS of LRT improved, the number of LRT users is increasing from 25% to 28%. On the other hand, the number of bus users is also increasing from 16% to 17%. Otherwise, number of car users is decreasing from 15% to 14% and number of motorbike users is decreasing from 44% to 41%.

Scenario 5: If income also private and public transport LOS will be improved in the future, example, there is an urban expressway, a bus rapid transit system and LRT system will be introduced at the same time in 2015. In this case, travel attributes are setup by changing high LOS for all modes. Therefore, the number of private transport is increasing with number of car users is increasing from 15% to 22% and number of motorbike users is increasing from 44% to 63%. Number of public transport will reduce with number of LRT users is decreasing from 25% to 9% and number of bus users is decreasing from 16% to 6%.

7.4 Summary and policy discussion

The SP survey inquired and analyzed people's travel mode preferences for the new LRT system, which was expected as a better public transport service to improve transport system in Hanoi city, under changes in travel and socio-economic. The LRT will be an additional choice and according to the survey results, the LRT got a positive interest from people.

It is very important to forecast people's travel mode choice preferences in developing countries. Because contrary to widely applying to many fields in developed countries, the SP survey method is not much applying in developing countries which have many different from people, culture, living condition to socio-economic environment. In this study, it is found that most of people prefer to use private transport means such as motorbike and car for commuting in Hanoi city. That also reflects the inconvenience by low LOS of using current public transport system.

RP and SP combined is an effective method to express complex travel behavior and to forecast travel demand for new transport services. In this study, the Nested Logit model is developed under similar alternatives considering levels of income and LOS in future. The model estimation results ensure that the commuting trip mode choice depends on both income level and LOS of transport systems. Value of parameters for travel time and cost/income are smaller than waiting time and punctuality at all three levels of income. That can be explained that, people need a better LOS in public transport services. The longer waiting time and lower punctuality will lead to the higher private mode choice probability. Therefore, improving LOS of public transport should be urgent action to deal with increasing of number of private transport and its related issues in Hanoi city.

Base on the findings above, at this last step in applying A-S-I approach, we could discuss on how to Improve for encouraging modal shift from motorcycle to public modes. We may distinguish public modes into two types including future modes (i.e., LRT, subway, bus rapid transit, etc) and the current existing bus system for policy implications.

For future modes:

Effective and logical system design: future modes to transport large numbers of people at high frequency and grade separation from other traffic. Rapid transit systems are typically located either in underground tunnels or on elevated viaducts above street level. Outside urban centers, rapid transit lines may run on grade separated ground level tracks.

High integrating with other public modes: Rapid transit system typically integrated with other public transport system such as buses, trams or commuter rail and often operated by the same public transport authorities.

For current bus system:

Effective system design: for minimizing average travel time and access time, maximizing ridership and optimizing asset utilization. For example, according to a preliminary statistics of TRANSERCO (Hanoi Transportation Company) there are about 38% of current bus users need to travel more than 500m to access the bus stop. These numbers shall be higher in the near future due to rapid increasing in urban extension. The bus system design must consider how to reduce access time, especially in new urban and suburban areas

Applying high technology in operation and management bus system: All bus vehicles will be integrated GPS devices, GSM antenna for better updating their location and operation state in every minute. All system operation can be supervised through web server including buses' operation state, traffic condition, traffic jam warning… Led light integrated inside/outside bus and in shelter bus stop could held bus users easier in identifying bus route, bus stop, managing their waiting/traveling time

Friendly bus stop designing: There are total about 1,700 bus stops in which only about 400 bus stops have shelter. It means the bus users of 76.5% bus stops need to wait for the bus in the rain or hot whether without a cover roof. Making bus stops become comfortable as well as providing useful travelling information are very important to attract people to use bus.

Implementing environmentally friendly fuel: With a considerable number of buses, about 1,300 vehicles, the applying high standard on air emission (i.e., Euro 3 standard) is very important to protect environment. For long-term, we should study to apply cleaner fuel i.e., CNG (Compressed natural gas) and LPG (Liquified Petroleum Gas) for all bus vehicles as well as to form up a complete supply system for these types of fuel.

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CHAPTER VIII

Conclusion

8.1 Summary of key results

The increasing of motorcycle ownership and usage had been leading to various transportation problems while motorcycle is a powerful mobility tool to fulfill people travel demand. This implies the diversified standpoints or contradictory combination of views are required for better understanding of current motorcycle usage. The findings may very useful for urban planners, policy makers to propose concrete strategies for avoiding/reducing motorcycle usage travel demand, encouraging modal shift to public modes usage as well as effectively utilizing motorcycle in very near future. Toward a sustainable transportation system for Hanoi, the purpose of this dissertation is to explore and deepen the understanding of motorcycle usage in different contexts. Three types of context are examined: household context, spatial context and temporal context. Each chapter's findings are summarized below:

- *Chapter IV: Avoiding/Reducing motorcycle dependence: Analyses focusing on the household context*

Focusing on the household context, this chapter was composed by two main parts: the first part used the Hanoi Person trip survey data 2005 to determine which ages of child have strong dependent on motorcycle while the second part examined whether child existence affected to the relationship between mobility level and household's motorcycle ownership decision by using the one week household travel survey data 2010.

In the first part, all home-based trips for "to study" purpose of pupils from 6 to 17 years of age were selected for analysis by multinomial logit model. The results indicated that:

1) Age, gender, family income and the location of schools have strong affect on pupil's mode choice behavior.

2) Both of child groups, from 6-10 years of age and from 11-14 years of age are high dependent on their parent's motorcycle to make a trip from home to school and the younger age the higher dependency on motorcycle.

In the second part, the aggregation analyses were first conducted to confirm the well-known fact that motorcycle could provide the higher mobility. Then, an endogenous switching model was further established to confirm the existence of child effects in the relation between motorcycle ownership and the number of trips. The results indicated that:

1) Motorcycle owner generate the higher number of trips partly because he/she just has higher needs for travel than non-motorcycle owners.

2) Those have child are less affected by motorcycle ownership compared to those don't have child.

- *Chapter V: Avoiding/Reducing motorcycle dependence: Analyses focusing on the spatial context*

This chapter employed the Hanoi Person trip survey data 2005 and land use data to explore the motorcycle choice in spatial context by answer three questions: How residential location impact on modal choice behavior? How much the land use impact on motorcycle choice? And how residential location impact on motorcycle trips frequencies?

In the first part, to examine how residential land use attributes affect modal choice behavior, we selected all home-based non-work trips for analyzing by a multinomial logit model. Analysis were divided into three different parts which depending on trip purpose: all home-based non-work trips, home-based shopping trip and home-based leisure trips. Focusing on motorcycle choice, there are some findings as follow:

1) The population density has negative impacts on motorcycle choice in almost home-based non-work trip purposes except for shopping trips.

2) The percentage of urban residential land has positive impacts motorcycle choice in in almost home-based non-work trips purposes except for shopping trips.

3) The percentage of rice field and agricultural land has positive impacts on motorcycle choice in home-based shopping trips.

4) The percentage of park and recreational land has negative impacts on motorcycle choice in home-based leisure trips.

In the second part, we distinguished and evaluated two kinds of land use impacts: Residential neighborhood and Origin-Destination. A multilevel binary logit model was applied to analyze. The conclusions of this part are as follow:

1) Origin-Destination land use impacts are much larger comparing to those impacts from Residential neighborhood.

2) Land use impacts on non-mandatory trip purposes (i.e., shopping, leisure, personal need, etc) are higher than on commuting trip purposes (i.e., go to work, go to study).

3) Depending on travel purposes, land use patterns have different impacts on motorcycle choice behavior:

- For non-mandatory trip purposes: the Origin-Destination's *transport land use percentage* has significant and positive impacts.

- For commuting trip purposes: the Residential neighborhood's *population density* and *urban residential land use percentage* have significant and negative impacts.

- For both categorize of trip purposes: *rice field and agriculture land use percentage* in both Residential neighborhood and Origin-Destination have significant and positive impacts; *educational and cultural land use percentage* and *park and recreational land use percentage* in Origin-Destination also have significant but negative impacts.

In the third part, we select all trips made by motorcycle and analyze them by regression model to identify which part of city has higher motorcycle trip frequencies as well as the impacts of household and individual attributes. The finding could be listed as follow:

1) Individuals with their household located in CBD, have higher tendency to use motorcycle while those with their household located in rural areas may have tendency to use other modes.
2) All individuals' age are shown positive impacts with motorcycle usage however this dependency are different by age (i.e., from 22-50 increasing gradually but from 51 starting to reduce).
3) Male are higher dependency on motorcycle.

- *Chapter VI: Shifting to the buses: An analysis focusing on the temporal context*

In this chapter, the variations of modes choice in temporal context are explored: in what condition, motorcycle owners tend to use bus and non-motorcycle owners tend to use motorcycle as well as their observed / unobserved variations. To capture the variation in modes choice behavior, two multilevel binary logit models were developed and same explanatory variables were used. Based on the estimation results of the models, conclusions can be summarized as follow:

1) Non-motorcycle owners have higher preference to use other's motorcycle when their travelling are in some cases: for short distances (i.e., less than 5km), for *related to work* or *personal need* purposes, in the evening time and accompany with other people, especially with their family member.

2) Motorcycle owners may shift to use buses in some cases: for long travel distances (i.e., more than 5km), in the day time, travelling alone and in bad weather (i.e., rainy day).

- *Chapter VII: Improving public transportation system: An analysis to capture future mode choice behavior in temporal context*

This chapter employs the Stated Preference survey data which launched in 2005 in Hanoi. The survey attempted to estimate the people's travel mode choice in the future, by considering the changes in both travel and socio-economic environments, when a new LRT system is introduced. The findings can be summarized as follow:

1) The LRT has high preference from current bus user.

2) Commuting mode choices are highly depend on both income level and LOS of transport systems.

3) The longer waiting time and the lower punctuality will lead to the higher private modes choice probability.

8.2 Methodological conclusions

To deal with various problems caused by the huge number of motorcycles, Hanoi authorities had been setting up various barriers to prevent the increasing number of motorcycle. Those supply-side oriented acts however not delivered the expected purposes: the number of motorcycle has been increasing and continuing to produce excessive levels of congestion, accident and GHG emissions. Therefore, applying A-S-I approach from demand-side viewpoint together with exploring motorcycle users' travel behavior in different contexts are expected to find out some concrete solutions dealing with the complicated duplicity of motorcycle usage issues. From the key results, we could realize clearly the relation between contexts and each step of A-S-I approach, as shown in Table 8.1.1 below.

Table 8.2.1The relation between contexts and the A-S-I approach

	Avoid/Reduce	Shift	Improve
Household context	○		○
Spatial context	○	○	○
Temporal context		○	○

In Avoiding/Reducing the motorcycle dependence step, our findings mainly related to the combination between *household context* and *spatial context* while the involvements of temporal context seem not significant. Concretely speaking, we found the travel demand by motorcycle were generated in *household context* (i.e., the higher travel need from motorcycle owners, the school trip of elementary pupils) and in *spatial context* (i.e., those live in rural area have higher dependency on motorcycle for their shopping trips, those live in higher population density have lesser dependency on motorcycle, etc).

In the second step, focusing on the shift mode behavior from motorcycle to bus, we found the context involvement mainly from *temporal context* and *spatial context*. Clearly that, motorcycle owner shift to use bus behavior depending much on situational attributes which could be captured in *temporal context* as well as the a certain travel distances in *spatial context*. *Household context* with household/individual's attributes show no significant.

In the last step, the public transportation system is improved by providing Light Rail Transit mode, the simulation results show us the involvement of attributes which are belong to all three contexts. Concretely speaking, we found the LRT's preference of respondents were generated in *household context* (i.e., travel cost/household income), *spatial context* (i.e., those use LRT as commuting mode from Home to work place/school) and *temporal context* (i.e., under hypothesis of income, LOS, waiting time and punctuality in the future).

8.3 Implications for policy and planning

In this section, some remarks will be made concerning the potential policy and planning implications of this work. To do this, we classified all significant attributes into two main categories including motivators and barriers which in accordance with different contexts and each step of A-S-I approach as shown in Table 8.3.1

In Avoiding/Reducing the motorcycle dependence step, analyses' results shown that the motivators are female and high density (i.e., female has lesser motorcycle dependence comparing to male and that behavior also observed from those are living in the higher density of population/ residence) while the barriers come from *household context* (i.e., motorcycle ownership and child

Table 8.3.1Motivators and barriers in each step of A-S-I approach

	Motivators			Barriers		
	Household context	Spatial context	Temporal context	Household context	Spatial context	Temporal context
Avoid/Reduce	- Female	- High density		- Motorcycle ownership - Child existance	- School out of neighborhood - Low density	
Shift		- Long distances	- Day time - Weekdays - Bad weather - Commuting - Travel alone		- Short distances	- Night time - Weekend - Personal purposes - Accompany
Improve	- High income	- Long distances	- Commuting - LOS	- Travel cost	- Short distances	- Personal purposes - Travel time

existence) and *spatial context* (i.e., elementary school out of neighborhood and low density of population/residence). To deal with these barriers, it seem not easy to provide some policies for *household context*, because, a household with several individuals has its own fundamental travel needs. However, policy makers may improve the *spatial context* by:

- Elementary school's location planning strategies with suitable radius services for maximizing the number of pupils who could commute by walking or cycling.
- Neighborhood designing to bring services and social facilities especially for lower population density areas to reduce trip's length, motorcycle dependency rate as well as encourage people to use non-motorized modes.

In Shifting to the buses step, focusing on motivators including *spatial context* and *temporal context* attributes, we found that the motorcycle owners who have long distance commuting are the most potential shifting to buses. Thus, base on these we may apply some policy implication to encourage modal shift. For *temporal context*, the situational attributes are flexible and changeable due to time, thus, it seem very difficult to provide some policy on that except to improve LOS by guarantee for better operation time schedule and punctuality of bus system. However, we may have some further act upon *spatial context*, for example, neighborhood planning/designing for easy, fast and safe access to bus stops by non-motorized modes or providing convenient motorcycle parking around main bus stops for encouraging the use of motorcycle as access mode.

In Improving public transportation system by new mode LRT, the motivators and barriers of respondent's preference are belong to all three contexts. In fact, it seems difficult to create some policies to encourage LRT usage base on those attributes. However, depending on each context, we may suggest policies to reach achievements such as:

- For *spatial context*: effective and logical system design or high integrating design with other public modes.
- For *household context*: subsidy should be provided from local government to reduce travel cost.
- For *temporal context*: LOS should be improved through reducing travel time, waiting time as well as ensuring the high punctuality.

8.4 Future studies

Here, the limitations of this study are first mentioned and some relevant suggestions are recommended in respect to three aspects: data collection, methodology and application.

1) Data collection aspect

To explore the motorcycle usage in household context and temporal context, the study used the household multi-day travel survey data which including total 150 households and 449 individuals. The main limitation of this data set may come from small sample size and the sampling strategy which was used: 1) finding a person who use buses, and 2) asking them to see if their household members would join the survey. Even it's possible to make analysis since this study focused on the variations in travel behavior which were observed in a certain time, it's still need to confirm that whether the same conclusion can be made when more randomized and larger samples are applied.

To explore the motorcycle usage in spatial context, this study employed two kinds of data: Personal Trip Survey and Traffic Analysis Zones' land use data. The former contains total 40,792 inter-zones trip by motorcycle which spread whole over the city from 16,622 individuals is very useful and may represent for general situation. While the latter contains only the percentage of land use patterns seems a considerable limitation to access the spatial context's impacts on motorcycle usage. Further studies should collect more information (i.e., employment density, land-use mix, urban form index, etc) related not only the build environment around Residential neighborhood as well as around Origin – Destination but also on the route connected between Origin and Destination.

2) Methodology aspect

The purpose of exploring context dependencies of travel behavior is to address various behavioral phenomena which we have not adequate understanding yet; especially the motorcycle usage/ownership in a specific situation likes a motorcycle dependence city. By that way, our study revealed some important findings to deal with the complicated duplicity of motorcycle usage. However, our works just focused on the most representative characteristics of each context (i.e., child existence in *household context*, land use patterns in *spatial context* and variability in *temporal context*). There is still exist various significant attributes in each context as well as the interrelation between them which may have strong impacts on individuals' travel behavior need to be further explored.

To deal with the problems created by a huge number of motorcycles, the conventional way from supply-side (i.e., preventing motorcycle ownership by various taxes and regulations) had shown ineffective. In our study, we apply the A-S-I approach to find some suitable solutions from opposite viewpoint to deal with the complicated duplicity of motorcycle usage issues. Although this approach may offer environmental co-benefits (i.e., avoiding GHG emissions from motorcycle usage by reducing transport demand has the positive side-effect of improving air quality and reducing noise levels) but it seem cannot bring cost-effective.

From the modeling aspect, our study also confirmed the reason why multilevel modeling is one of the best approaches to deal with the complicated phenomena related to the variation of travel behavior. However, in this study, the variations/impacts structure applied in chapter V and VI just focus on the main parts. Applying different setting in the variations / impacts structure, for example adding more variations such as household, spatial variations or co-variations between them as well as adding travel route, build environment impacts would be an important task for providing the behavioral variations/ impacts information in greater details.

3) Application aspect

With the aim to deepen the understanding of motorcycle usage in different contexts for avoiding/reducing motorcycle travel demand and shifting to non-motorized/public modes, the findings of this study are very useful for policy makers as well as transportation/urban planner. However, these are the interrelation between contexts and steps of approach which may become motivator or barrier for avoiding/reducing motorcycle travel demand as well as shifting to other modes. For example, the child existence in a household (i.e., increasing travel demand) may not only motivator to own a motorcycle for higher mobility level but also barrier for parent shifting to public modes. Such understanding on complicated duplicity of attributes is very important to be further explored in future works.