Doctoral Dissertation

Understanding Interdependency Between Residential and Travel Choice Behavior in the Context of a Developing City

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ABSTRACT

While urbanization and motorization can have positive economic effects, they have also brought numerous negative externalities such as air pollution, traffic congestion and overuse of energy. To mitigate such negative influences, it is important to understand the interdependence between urbanization and motorization, particularly in cities in developing countries. From the perspective of demand side, such interdependence can be partially explained as the interdependence between people's residential and travel choices. Therefore, understanding the link between people's residential and travel choice may give insights into urbanization and motorization. In the transportation field, researchers have long been interested in how to influence people's residential and travel choices towards more environmentally-friendly choice behavior through land use and transport policies. Generally, people's choice behavior is affected by not only objective factors (e.g. land use patterns and level of transport services) but also subjective factors (e.g. attitudes, learning experience and expectations). To show the true influences of land use on people's residential and travel choices, such subjective factors should also be taken into account. Taking such subjective factors into account, this study aims to depict several possible interdependencies between residential and travel choices in the context of developing countries. Generally, people in developing countries face more internal constraints (e.g. income) and external constraints (e.g. housing and transport supply) in the context of residential and travel choice than people in developed countries. However, the change in socio-economic conditions, housing and transport supply in developing countries is fast. In the context of developing countries, it is hypothesized that:

- People's self-selection regarding residential and travel choices may vary across different income groups (i.e. target groups) because different income groups may face different internal and external constraints. Additionally, self-selection effects

may vary over time due to the change in: i) people's life situation and attitudes, and ii) external constraints (i.e. housing and transport supply).

- People's choice behavior may be not only back-ward looking but also forward-looking.

In this study, hence, we focus on two main parts: i) self-selection effects and ii) the influences of future expectation and state dependence. The current study consists of 7 chapters with the following contents. Chapter 1 contains the background, research motivation, research objectives and questions, and outline of the thesis.

Chapter 2 reviews existing studies regarding self-selection, state dependence and future expectations in the field of travel behavior. Several aspects related to methodology, behavioral viewpoints, new approaches and the context of this study will be described, followed by information on the surveys and data used. The study draws on two sources of data relating to people's residential and travel choice. First, a large-scale household interview survey was conducted in Hanoi in 2005 by the Japan International Cooperation Agency (JICA, 2007). Secondly, a small-scale household interview survey was carried out in Hanoi in 2011 by Hiroshima University Transportation Engineering Laboratory (HITEL) in close cooperation with Hanoi University of Transport and Communications (UTC). Information regarding the survey design, study area, data collection procedure, and descriptive statistics of data are described in this chapter.

Chapter 3 examines the existence of self-selection across different groups of workers. Generally speaking, knowledge-intensive workers are medium-and-high income, while labor-intensive-workers are low income. Coinciding with economic growth in developing countries, there may be a shift in the structure of the labor market from the dominance of labor-intensive workers to the dominance of knowledge-intensive workers, leading to changes in their transport-land use systems. Here, it is assumed that labor-

intensive workers may be less able to self-select because they face more economic constraints. In other words, the influences of self-selection may vary across different groups of workers. Focusing on commuting for work purposes, integrated models of residential location, work location and commuting mode for both groups of labor-intensive and knowledge-intensive workers are developed. The interdependencies between these three choices are captured by using common random terms in utility functions. Notably, such common random terms may include individual- or household-specific unobserved factors (e.g. lifestyle and attitudes) that impact people's sensitivity to both location and travel choices. In a sense, common random terms may partially control for self-selection effects. These models are empirically tested with the large-scale data collected in Hanoi in 2005. As a result, the statistical significance of multiple self-selection effects caused by unobserved factors is confirmed, suggesting that the joint estimation of the above three choices is a useful approach. Moreover, the analysis shows that self-selection effects caused by unobserved factors seem to be more influential in knowledge-intensive workers' choices, while socio-demographic factors seem to be more influential in labor-intensive workers' choices. As for land use attributes, different types of households, and labor-intensive and knowledge-intensive workers, show different responses to different types of land use in location choices, especially for the work location choice. Effects of land use diversity and population density on the commuting mode choice are mixed. Additionally, the geographic centralization of knowledge-intensive employment and decentralization of labor-intensive employment are captured. These findings may be useful for city planners in Hanoi in designing land use patterns in the future.

Following Chapter 3, Chapter 4 investigates the dynamics of self-selection effects by assuming that people's life situation and attitudes will vary over time. Additionally, external constraints may be reduced over time due to economic growth and improvements

in housing and transport supply. In Hanoi, urbanization and motorization in the 1990s and 2000s were characterized by urban fringe development and the rapid growth of motorcycle ownership. This phenomenon may be partially explained as outcomes of household urban fringe and motorcycle ownership choice. Hence, this chapter first examines the relationship between motorcycle ownership and urban fringe choice. It then builds a joint analysis of car ownership and urban fringe choice. As in Chapter 3, this chapter uses common random terms that partially control for self-selection effects due to household-specific unobserved factors. Furthermore, the dynamic self-selection is controlled for by parameterizing the variance of common random terms as a function of time. The proposed models are then empirically tested with the small-scale data collected in Hanoi in 2011. The results showed that the parameter of "time" variable is statistically significant. This implies that unobserved self-selection effects have varied over time. In other words, the interdependence between urban fringe development and motorcycle ownership has been strengthened. Adding to this, the joint model of urban fringe choice and car ownership choice was tested. The estimated parameter of "time" variables is also negatively statistically significant, indicating that the interdependence between urban fringe development and car ownership has been decreasing.

To understand the influences of state dependence and future expectations, Chapter 5 describes the development of a combined Revealed Preference-Future Expectation Pair Combinatorial Logit model based on people's residential location choice behavior. The influences of state dependence are captured by adding dummies of current choices in the utility functions of future choices. In contrast, the influences of future expectations are captured by adding dummies of future choices in the utility functions of current choices. The proposed model is empirically tested with large-scale data collected in Hanoi in 2005, and it is statistically confirmed that current choices and expectations about future choices

mutually influence each other. Specifically, it is found that 26%-55% of the total variance of current residence utility can be explained by expectations about future choices, and 56-99% of future expectations can be captured by current choices. These findings suggest that future expectations cannot be ignored in the analysis of residential location choice behavior.

To further confirm the influences of state dependence and future expectations, Chapter 6 analyzed small-scale data using the life-course survey conducted in Hanoi in 2011. First, a data mining approach is applied to analyze mobilities in residential location and vehicle ownership. As a result, it was found that the most important predictor of residential mobility in the target year is the residential mobility made in the next five years. Regarding motorcycle ownership mobility, the most influential factors are household structure, and employment and education biographies in the target year, followed by household structure biography, employment and education biography, and motorcycle ownership biography in the next five years. All these findings suggest the importance of future expectations in explaining residential and motorcycle ownership over the life course in the context of developing countries. Notably, car ownership is only influenced by motorcycle ownership in the past, but not by other mobility biographies.

The present study ends with Chapter 7. In this final chapter, conclusions, policy implications and limitations to the research are presented, as well as some suggestions for future research.

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Chapter 1 Introduction

1.1. Background

In recent years, Asia has become a driver of world economic growth (Kaplinsky and Messner, 2008). Coinciding with this, there has been rapid urbanization and motorization in the region. It is projected that about 60% of Asia's residents will live in urban areas in 2030 (Asian Development Bank, 2012). Additionally, the main feature of motorization in Asia is the sharp increase in motorcycle and car ownership (Tuan, 2011). On the one hand, this increase in motorization may contribute to economic growth and improve people's mobility. On the other hand, it has several negative effects such as traffic congestion, traffic accidents, greater energy consumption and environmental pollution.

Generally speaking, urbanization and motorization may result from decisions made on both the supply side and the demand side. On the supply side, the decision- makers are entrepreneurs, employers, investors, and policy makers. Basically, the important decisions for the supply side are related to firm location and investments in housing and transport supply, such as the construction of new high-rise apartments and roads. Regarding the demand side, the decision-makers are households and individuals who make residential and travel choices such as housing type, housing location, travel mode, vehicle ownership and so on.

Practically speaking, it is very difficult to collect data on the supply side's decision-making, especially dynamic data. It is easier to collect data for the demand side's decision-making, especially dynamic data. Additionally, understanding the demand side's decision-making is important in city planning and policy-making. Therefore, the objective of this study is to understand how households and individuals on the demand side make decisions.

Many studies have shown that urbanization and motorization are interdependent and influence each other. For example, urban sprawl and the growth in car ownership often go hand in hand (Guerra, 2015). From the perspective of the demand side, this phenomenon can be explained as the interdependence between residential and travel choices. In particular, people who live far away from their main destinations such as workplaces or schools may be more likely to use more cars for daily travel. On the other hand, when cars are commonly used for daily travel, people may prefer residential locations far away from their main destinations. Understanding the interdependence between people's residential and travel choices may give some insights into the interdependence between urbanization and motorization. Hence, the focus of this study is on residential and travel choices.

As mentioned above, in many developing cities in Asia, rapid urbanization and motorization may lead to some unintended consequences such as environmental pollution and uncontrolled urban development. However, the processes of urbanization and motorization are difficult to avoid, especially in developing countries where economic growth is moving forward. The critical question is therefore how to mitigate the negative aspects of urbanization and motorization?

In the transportation field, researchers have long been interested in how to mitigate such negative effects by studying how policies regarding transport and land use influence households' and individuals' residential and travel choices. For example, Broaddus et al. (2009) proposed a set of measures in which land use planning is a key measure for travel demand management due to its long-term effects on people's travel. Other studies have found that mixed land use patterns or pedestrian-friendly neighborhoods may encourage people to drive less and use more environmental-friendly modes such as walking and

cycling (Cervero, 2002; Ewing et al., 2004; Mitra et al., 2010; Mitra and Buliung, 2012). Hence, land use becomes a key factor in policy debate (Zhang, 2004).

In summary, this study focuses on the interdependence between residential and travel choice and analyzes the role of land use in people's choices.

1.2 Research Motivation

In the field of travel behavior research, the mutual influences of residential and travel choice may be caused due to both objective and subjective factors. Regarding subjective factors, the interdependence between residential and travel choice can be explained in several ways. First, residential self-selection has emerged as a possible link between residential location and travel choices. Residential self-selection is defined as "a tendency of people to choose locations based on their travel abilities, needs and preferences" (Litman, 2011). However, the influence of residential location on travel behavior may be overestimated if residential self-selection regarding travel attitudes or neighborhood preferences are not controlled for (Handy et al., 2005). In other words, travel behavior may be influenced by physical conditions of residential location as well as travel-related attitudes or neighborhood-related attitudes. For example, people residing in transit-oriented neighborhoods may ride transit more and drive cars less than those living in less transit-oriented neighborhoods. However, people with strong preferences for riding transit may prefer living in a transit-oriented neighborhood and use transit more. Or people with environment-friendly lifestyles are likely to choose a transit-oriented neighborhood, so they can walk and ride transit more.

Secondly, the concept of backward-looking behavior may be used for explaining the interdependence between residential and travel choices. This concept refers to the causal link between past choice and current choice (also called state dependence). For instance, for people who have a history of travelling by walking and cycling in the past,

this past travel mode may affect their current choice of residence in a walkable neighborhood. Additionally, their current residence in a walkable neighborhood may reinforce their walking and cycling in the future.

Third, the concept of forward-looking behavior also can be used for investigating the interdependence between residential and travel choices. This concept refers to the causal link between current choices and future choices or goals (also called future expectation). For example, people are likely to reside in car-oriented neighborhoods at the current time if their future travel choice is a car.

Dealing with such interdependence between residential and travel choice, recently, there are two remarkably new approaches. The first one is spatial mobility approach in which Scheiner (2014) emphasized the influences of life situation, self-selection (i.e. preferences for travel and location) and state dependence in explaining the interdependence between residential and travel choices. Adding to this argument, Zhang (2014) proposed life-oriented approach to re-examine the interdependence between residential location and travel choices. Zhang noted the role of life choices, state dependence as well as future expectations.

Location and travel choices is "a result of people's resources, needs and wishes, as modified by the constraints and opportunities given by the structural conditions of society" (Næss, 2009a). In other words, the decision-making process of location and travel choices is a mix of constraints and attitudes. In the context of residential and travel choices, constraints basically refer to the following conditions: i) decision-makers' socio-economic situation (e.g. income and job), and ii) market conditions such as housing and transport supply. Additionally, attitudes refer to people's liking, thinking or feeling about residential or travel alternatives. Generally speaking people's decision-making in residential and travel choice in developing countries are likely to face more constraints. With respect to

people's constraints (i.e. internal constraints), the majority of people in developing countries are low income, while the majority of people in developed countries are medium and high income. With respect to market constraints (i.e. external constraints), housing and transport supply in developing countries has more limitations. For example, citizens in developed countries may have several travel options by public transport such as bus, subway and monorail. On the other hand, public transport systems are less developed in developing country cities. For example, there is only a bus system now in Hanoi or Ho Chi Minh in Vietnam. In addition, most people in developing countries are in low- or medium-income groups. However, such constraints may be reduced in the future because economic growth, housing and transport supply are moving forward. Under such circumstances, the afore-mentioned link between residential and travel choices (i.e. self-selection, state dependence and future expectation) needs to be reconsidered.

In this study, two key hypotheses regarding people's choices in developing are included:

- First, people's self-selection regarding residential and travel choices may vary across different income groups (i.e. target groups) because different income groups may face different internal and external constraints. Additionally, self-selection effects may vary over time due to the changes in: i) people's life situation and attitudes and ii) external constraints (i.e. housing and transport supply). .
- Second, people's choice behavior may be not only backward-looking but also forward-looking, because economic growth, housing and transport supply are expanding.

As for the first hypothesis, self-selection in the context of residential and travel choice is induced by two sources: i) socio-demographic characteristics and ii) attitudes

regarding neighborhood and travel (Mokhtarian and Cao, 2008). Generally, attitude-induced self-selection refers to people's liking, feeling or thinking regarding travel and neighborhood alternatives such as travel mode, vehicle ownerships and residential location. In the context of developed countries, people may be more able to rely on their attitudes in their residential and travel choices because they face less internal and external constraints. In other words, attitude-induced self-selection may be more involved in people's residential and travel choices in developed-country cities. In that sense, the degree of attitude-induced self-selection may be significantly large. In such circumstances, it is really important to control for the influences of attitude-induced self-selection when transport and land use policies are evaluated. In contrast, the degree of attitude-induced self-selection in the context of developing countries may be small because people may face more internal and external constraints. However, constraints may be reduced in the future, leading to a change in self-selection over time.

Here it should be emphasized that the influences of land use in developed countries in the future may be predicted even if only self-selection effects are captured in current time, because there is stability in socio-economic conditions at the macro level. In other words, the influences of self-selection regarding residential and travel choice may be stable in the context of developed countries. In developing countries, however, it may not be possible to predict the influences of land use on residential and travel choices if only self-selection effects at the current time are taken into account. While car ownership rates in developed countries are reaching saturation levels, motorization trends in developing countries keep rising due to economic growth and rising income levels (Robert Cervero, 2013). At the same time, advanced transit modes are increasingly being introduced and operated in developing countries, implying that people in developing countries may have more options for travel in the near future. Currently, they may prefer motorcycles but car

and transit may be more preferred in the near future. In other words, people's self-selection regarding specific modes may go up and down over time. In this study, we do not intend to figure out whether or not people are influenced more by socio-demographic characteristics or attitudes. The current study emphasizes that self-selection may vary over time in the context of developing countries. It is important to control for the dynamics of self-selection in understanding and modeling residential and travel choice.

As for the second assumption, our concern is that the majority of existing studies only consider state dependence, which refers to influences of past choices on current choices. It may be true that people rely on their past decisions to make current decisions. However, the ignorance of future expectations on current decisions may lead to overestimation, especially in developing countries where economic growth, housing and transport supply are changing rapidly. Under such circumstances, the future outcomes may be involved in people's current decisions. Departing from existing studies, this study examines the influences of future expectations as well as state dependence on people's choices in the context of developing countries.

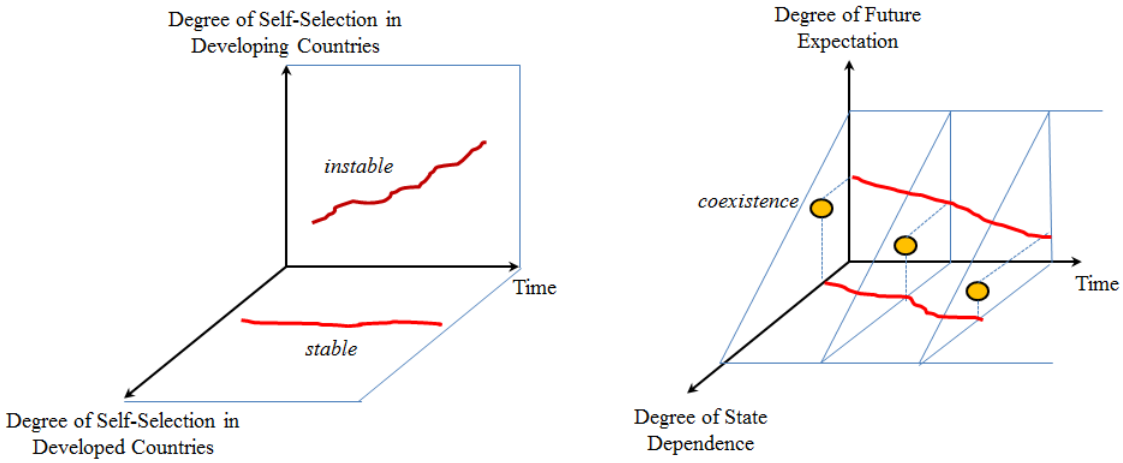


Figure 1.1: An illustration of key hypotheses

The two above-mentioned hypotheses are illustrated in Figure 1. Specifically, the first hypothesis of self-selection is shown in Figure 1.1a in which horizontal axis represents

time and the others represent degree of self-selection in the context of developed or developing countries. As discussed above, it is assumed that the influence of self-selection on residential and travel choice in the context of developed countries is stable over time due to the stability in socio-economic conditions at the macro level. In the context of developing countries, however, such influence is instable over time due to the fast changes in the socio-economic environment at the macro level. In other words, self-selection may vary over time.

The second hypothesis of future expectation is presented in Figure 1.1b, where the horizontal axis represents time and the others represent degree of future expectation and degree of state dependence. At a given time point, there are three possible scenarios. The first scenario is that the involvement of state dependence in people's decision-making is larger than that of future expectation. The second scenario is that the involvement of state dependence is equivalent to that of future expectation. The third scenario is that the involvement of state dependence is smaller than that of future expectation. This study does not intend to compare the influence of state dependence with that of future expectation. The main point is to show the coexistence of state dependence and future expectation in people's decision-making process.

In this study, it is important to notice that the shape of the graph in Figure 1.1 is dependent on choice context. It may be linear or quadratic or fluctuating. Additionally, a general assumption is that the characteristics of developing countries are remarkably different from that of developed countries. Generally speaking, income is a key factor in people's residential and travel choice. Different income groups may show remarkable differences in residential and travel choice. There are two ways to make such a comparison. The first way is to directly compare people's choice behavior in developing countries with that in developed countries. The second way is to look at the variation of people's choice

behavior across different income groups, even only in developing countries. Due to data limitation, this dissertation does not intend to make a comparison between developing and developed countries. Instead, the second way is selected. There are two main approaches to reflecting the differences in people's residential and travel choices by income level. The first approach is directly based on income, whereby people are divided into different income groups. The second approach is indirectly based on other criteria that also reflect different income groups such as people's job categories or vehicle ownership. For example, intuitively, workers in knowledge-intensive workers often have higher salaries because their jobs require a higher level of skills and education. Hence, knowledge-intensive workers also represent medium-and-high income groups, while labor-intensive workers represent low-income groups. The other example is that car users are often high-income people, while bus users are often low-income. Coinciding with economic growth, in the context of developing countries, there may be a shift in social structure such as households by income, workers by job markets and users by vehicle types. Both these two approaches will be used in this dissertation. Depending on the specific context, either the first approach or the second approach will be selected.

In summary, the current study attempts to bridge several gaps in existing studies:

- With respect to methodology: in existing studies, there is a dominance of static modeling while dynamic modeling is less developed and applied.
- With respect to behavior: in developing countries, changes in socio-economic conditions and urbanization are rapid. However, existing studies generally ignore: i) the dynamics of self-selection, and ii) the influence of future expectations, despite the fact that people's choice behavior may also be forward-looking.

- With respect to "new approach" in travel behavior research: there is a need to extend the boundary of decision-making, as well as a need for greater efforts to model dynamic choice behaviors.
- With respect to context: at present, there is a dominance of studies on developed countries (mostly done in the United States and Europe), while in-depth studies of developing countries are rare.

1.3 Aims and Objectives

The aim of this study is to shed light on people's residential and travel choices in the context of a developing-country city (Hanoi, Vietnam).

Based on the key hypotheses presented in the Research Motivations section, there are several research questions related to people's residential and travel choices in developing countries:

1) Whether or not self-selection effects may vary across different targeted groups;
2) Whether or not self-selection may vary over time if constraints change over time;
3) Whether or not people's choice behavior is not only backward-looking but also forward-looking.

To answer these research questions, there are several specific tasks to be carried out, as follows:

i. To identify the role of land use in people's residential and travel choice when self-selection is controlled for.
ii. To control for the variation of self-selection across different targeted groups.
iii. To control for the variation of self-selection over time.

iv. To examine the influences of future expectations as well as state dependence on long-term and medium-term decisions.

1.4. Outline of the Thesis

This dissertation consists of seven chapters and appendices (see Figure 1.2). The background, research motivation, and aim and objectives for this research have been described in this chapter. The remainder of this dissertation is organized into the following chapters:

Chapter 2 gives a review of existing studies regarding self-selection, state dependence and future expectation in the field of travel behavior. Several aspects related to methodology, behavioral viewpoints, new approach and context of this study will be described in this chapter. Then, survey and data are presented. There are two sources of data which include people's residential and travel choice. First, a large-scale household interview survey was conducted in Hanoi in 2005 by the Japan International Cooperation Agency (JICA, 2007). Secondly, a small-scale household interview survey was carried out in Hanoi in 2011 by Hiroshima University Transportation Engineering Laboratory (HITEL) in close cooperation with Hanoi University of Transport and Communications (UTC). Information regarding the survey design, study area, data collection procedure, and descriptive statistics of data are described in this chapter.

Chapter 3 examines the existence of self-selection across different groups of workers. Generally speaking, knowledge-intensive workers are medium-and-high income, while labor-intensive-workers are low income. Coinciding with economic growth in developing countries, there may be a shift in the structure of the labor-market from the dominance of labor-intensive workers to the dominance of knowledge-intensive workers, leading to changes in their transport-land use systems. Here, it is assumed that labor-intensive workers may be less able to self-select because they face more economic

constraints. In other words, the influences of self-selection may vary across different groups of workers. Focusing on the context of commuting, hence, the integrated models of residential location, work location and commuting mode for both groups of labor-intensive and knowledge-intensive workers are developed. The interdependencies between three above choices are captured by using common random terms in utility functions. These models are empirically tested with the large-scale data collected in Hanoi in 2005.

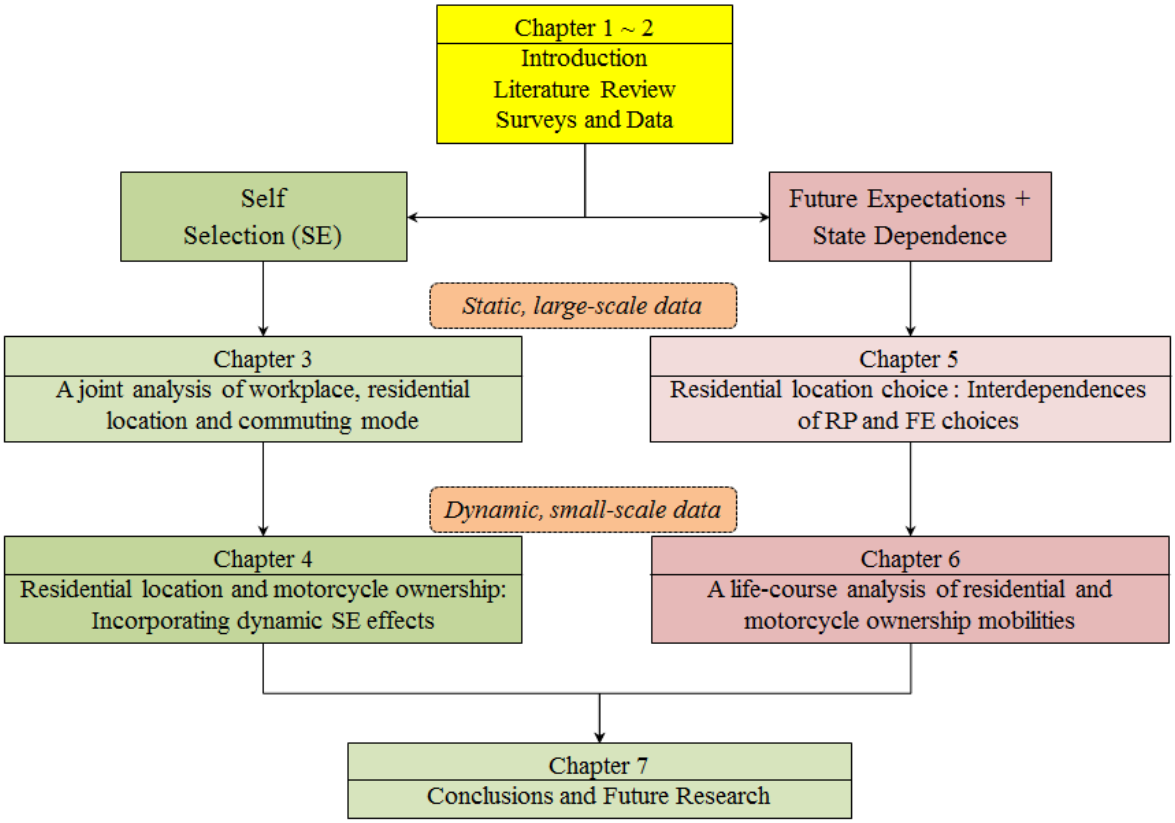


Figure 1.2: Structure of the Thesis

Following Chapter 3, Chapter 4 investigates the dynamics of self-selection by assuming that people's life situation and attitudes will vary over time. Additionally, external constraints may be reduced over time due to economic growth and improvements in housing and transport supply. In Hanoi city, urbanization and motorization in the 1990s and 2000s were characterized by urban fringe development and the rapid growth of motorcycle ownership. This phenomenon may be partially explained as outcomes of household urban fringe and motorcycle ownership choice. Hence, this chapter first

examines the interdependence between motorcycle ownership and urban fringe choice. It then builds a joint analysis of car ownership and urban fringe choice. As in Chapter 3, this chapter uses common random terms that partially control for self-selection effects due to household-specific unobserved factors. Furthermore, the dynamic self-selection is controlled for by parameterizing the variance of common random terms as a function of time. The proposed models are empirically tested with the small-scale data collected in Hanoi in 2011.

To understand the influences of state dependence and future expectation, Chapter 5 describes the development of a combined Revealed Preference-Future Expectation Pair Combinatorial Logit model based on people's residential location choice behavior. The influences of state dependence are captured by adding dummies of current choices in the utility functions of future choices. In contrast, the influences of future expectations are captured by adding dummies of future choices in the utility functions of current choices. The proposed model will be empirically tested with large-scale data collected in Hanoi in 2005.

To further confirm the influences of state dependence and future expectation, Chapter 6 analyzed small-scale data from a life-course survey in Hanoi in 2011. A data mining approach is applied to analyze mobilities in residential location and vehicle ownership.

The present study ends with Chapter 7. In this final chapter, conclusions and limitations to the research are presented, as well as some suggestions for future studies.

Chapter 2 Literature Review, Study Location and Data Collection

2.1. Literature Review

To understand how travel behavior is decided, people's travel choices in concert with residential choices have long been investigated in the transportation field. For better understanding of people's decision making in the context of residential and travel choice, a comprehensive literature review is required. As for behavioral aspects, the interdependencies between residential and travel choices can be explained in terms of self-selection, state dependence and future expectation. This section presents an overview of the literature on these three behavioral relationships, with a focus on research-related issues, concept/definition, methodology, new approach and challenges.

2.1.1. Self-Selection

a) Casual relationship between land use and travel behavior

The question of whether or not people's residential and travel choices are effectively modified by land use and transport policies has long been a controversial one (Olaru et al., 2011). On the one hand, city planners and researchers have believed that well-designed land use patterns or neighborhoods may encourage people to drive less and walk or cycle more. By reviewing more than 50 empirical studies regarding land use and travel choices, Ewing and Cervero (2010) identified several possible relationships between land use and different types of travel choices. First, vehicle miles traveled (VMT) is most strongly affected by measures of accessibility to destinations (e.g. job accessibility by transit or car) and secondarily to street network design (e.g. bicycle land density or intersection density). Second, the choice of walking is most associated with measures of land use diversity (e.g. entropy index) and street network design (e.g. intersection density).

Third, the choice of public transport is most affected by street network design, the measures of density (e.g. population density) and proximity to transit. On the other hand, it is important to account for self-selection when evaluating the influences of land use on travel choices (Litman, 2011). Here two emerging questions are: i) what is self-selection?; and ii) why should it be taken into account in existing studies regarding residential and travel choices?

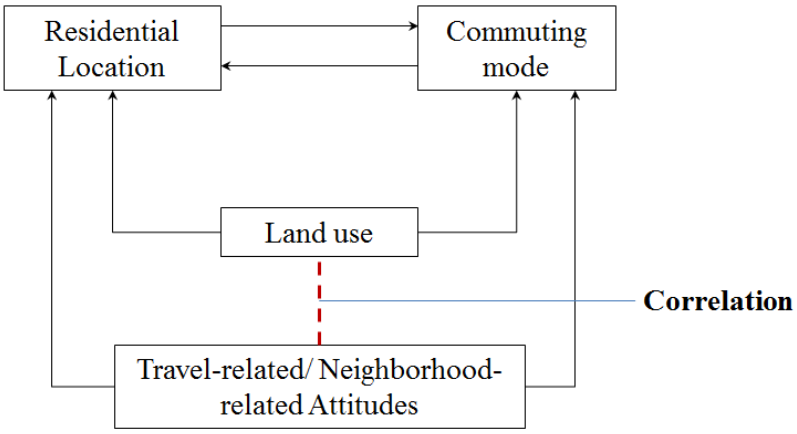


Figure 2.1: Self-selection regarding travel or neighborhood preferences

b) The definition of self-selection

As for the first question, the origin of self-selection in the context of residential location (i.e. residential self-selection) refers to "the tendency of people to choose locations based on their travel abilities, needs and preferences" (Litman, 2011; Mokhtarian and Cao, 2008). Generally, residential self-selection is induced by attitudes and socio-demographics (Mokhtarian and Cao, 2008). Following this, Van Wee (2009) extended the scope of self-selection and defined it as "the tendency of people to make choices that are relevant for travel behavior, based on their abilities, needs and preferences". In the analysis of residential and travel choices, socio-demographics are often controlled for. Hence, the main concern of existing studies is related to attitudes regarding travel and residential location (Bohte et al., 2009). In this study, self-selection regarding residential and travel

choices is re-defined as "the tendency of people to make residential and travel choices based on their abilities, needs and preferences" (see Figure 2.1). For instance, a person with a strong preference for transit may reside in a transit-oriented neighborhood and use transit more, leading to a spurious relationship between land use and travel choices.

With regard to the second question, the influence of land use on residential and travel choices may be overestimated if self-selection is ignored (Bohte et al., 2009). The goal of existing studies regarding self-selection is to ensure true influences of land use on residential and travel choices (Cao et al., 2009).

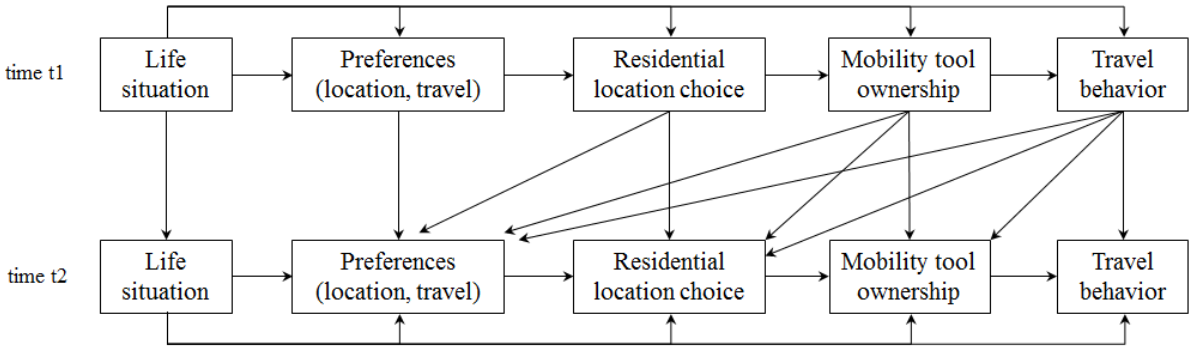


Figure 2.2: Spatial mobility

Source: Adapted from Scheiner (2014)

c) Methodologies for controlling self-selection effects

In the context of residential and travel choices, if self-selection exists, there will be three issues: 1) simultaneity, 2) omitted variables, and 3) non-random assignment. From a methodological perspective, Van Wee (2009) simplified the theory of self-selection as a problem in correlation between observed variables (i.e. variables included in model estimation) and unobserved variables (i.e. variables not included in model estimation). Specifically, Van Wee suggests that observed variables of land use are correlated with unobserved variables (such as in travel or neighborhood preferences). In a similar vein, Herick and Mokhtarian (2015) describe two aspects of the self-selection problem: i) the correlation between observed variables of land use and unobserved variables (i.e. omitted

variables), and ii) people may choose location based on their travel-related and neighborhood related attitudes (i.e. non-random assignment). Herick and Mokhtarian further clarify that these two aspects can be solved simultaneouly if attitudes are included in both models of residential and travel choices. Additionally, Paleti et al. (2013) argue that residential location and travel choices may be chosen at the same time (i.e. simultaneity) if self-selection exists. Methodologies for dealing with self-seleection have been summarized in several existing papers (Bohte et al., 2009; X. (Jason) Cao et al., 2009a; Herick and Mokhtarian, 2015; Mokhtarian and Cao, 2008). Each methodological approach to self-selection can deal with one or all of these issues (See Table 2.1). One notable approach tackling all of the above-mentioned issues is the simultaneous joint discrete choice model that was developed by (Bhat and Guo, 2007).

Table 2.1: Summary of methodologies for controlling for self-selection effects

Method	Issues		
	Simultaneity	Omitted variables	Non-random assignment
Direct questioning	✓		✓
Statistical Control	-	✓	✓
Instrumental variable models	-	✓	✓
Sample selection models	-	✓	✓
Propensity score models	-	✓	✓
Joint discrete choice models (sequential models)	-	✓	✓
Joint discrete choice models (simultaneous models)	✓	✓	✓
Cross-sectional structural equation models	-	✓	✓
Longitudinal models	-	✓	✓

Note: (✓) Applicable; (-) Not applicable

d) New approach

Studies on residential or travel-related self-selection effects have been attracting more and more attention, motivated by policy debates on whether to advocate land use and transport policies to reduce auto-dependence and increase the use of alternative means of

transport. A special issue on residential self-selection (Cao, 2014), published in the Journal of Transport and Land Use in 2014, evaluated research progress and collected major thoughts to guide the development of the self-selection research in future. In this issue, there are several notable papers. Firstly, Scheiner (2014) argued that travel behavior should be studied by explicitly linking various domains of an individual's life course, including family biography, employment biography and residential biography (see Figure 2.2). In other words, life situation should be considered when investigating residential and travel-related self-selection effects. Adding to Scheiner's argument, Zhang (2014) calls for a trans-disciplinary life-oriented approach to re-examine the self-selection issue (see Figure 2.3). Zhang argues that residential self-selection may be not just attributable to demographic characteristics and travel/residential attitudes, but also influenced by individuals' life choices in different domains, such as job, health, family life and budget, neighborhood, education and learning, and leisure and tourism. In other words, the residential and travel-related self-selection under the life-oriented approach refers to "the tendency of people to make residential and travel choices based on not only demographic characteristics and travel/residential attitudes but also life choices in different life domain".

In this special issue, Næss (2014) stated that the implications of attitude-based residential selection in previous studies are considerably exaggerated. In Næss's viewpoint, the causal effects of residential location on travel behavior exists even attitude-induced self-selection occurs. Reacting to Næss's opinions, Wee and Boarnet (2014) argued that residential self-selection is still an important issue due to two main points. Firstly, unfounded nihilist statements (for example, we know nothing due to residential self-selection) do not appear much in the scientific literature on this topic. Secondly, basic scientific inquiry requires additional studies, including inquiry into attitudes, moving patterns and self-selection. In a response, Næss (2014a) agreed with the two above-

mentioned main points of Van Wee and Boarnet. Additionally, Næss agreed with Van Wee and Boarnet in the following points: 1) transport-related residential self-selection is in itself a demonstration of the influence of residential location on travel behavior, 2) travel attitudes are not necessarily antecedent to choices of residential location but may themselves be influenced by residential location, 3) travel attitudes are not the most important criteria of residential preferences, and that several constraints can prevent people from realizing what they would prefer.

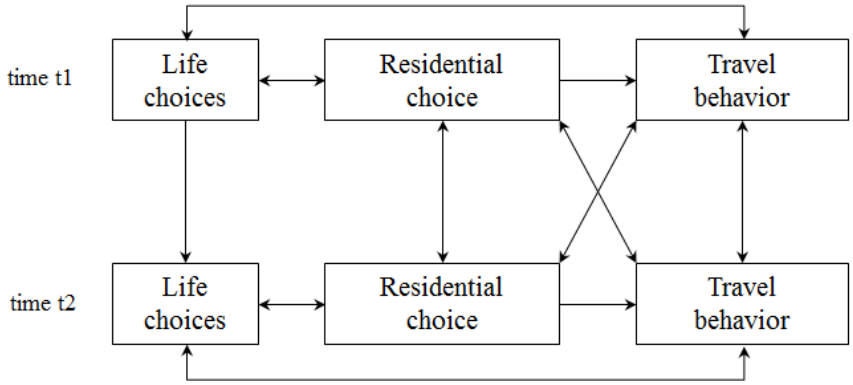


Figure 2.3: Life-oriented approach

Source: Adapted from Zhang (2014)

Chatman (2014) indicated three interrelated issues in controlling for residential self-selection in previous studies. Firstly, researchers have often failed to realize that the built environment may have different influences on travel by different groups of people. A question which emerges is whether or not such differences are directly observable (e.g. household income) or not (e.g. attitudes). Secondly, the link between built environment and travel partially consist of residential sorting based on heterogeneous preferences. Thirdly, the effectiveness of some policies on travel is dependent on the population composition of the market (i.e. the distribution of preferences in the population).

e) Studies regarding self-selection in developing countries

In the transportation field, almost all studies regarding self-selection have been conducted in European countries and the U.S., with only a few studies in developing countries. A common point of studies regarding self-selection in developing countries is that cross-sectional data was used. Additionally, these studies found that people's residential and travel choices in developing countries seem to be less affected by attitudes-induced self-selection. Specifically, Tsai (2009) hypothesized that attitudes-induced self-selection increases the probability of workers commuting by rapid rail transit. Using data from passenger surveys along the Taipei Raid Transit System, Tsai found that the influence of attitudes-induced self-selection is only partly supported. In the context of Tehran city (Iran), Masoumi (2013) hypothesized that "location decisions in Iranian cities are less oriented to transportation and more under the effect of economy". By using direct questioning method, Masoumi found that the main reason for selecting the location of residential units are related to socio-economic factors such as rise of house prices. Focusing on transit-oriented development in Bangkok city (Thailand), Sanit (2014) found only limited evidence of attitudes-induced self-selection in the relationship between the built environment and travel behavior. Furthermore, Sanit suggested two salient points for future studies. Firstly, attitudes may change over time, so longitudinal data should be employed. Secondly, the needs of different income and social groups should be taken into account.

f) Summary

In summary, there are several notable points from the existing literature regarding self-selection:

i) The dominance of static modeling, while dynamic modeling is less developed and less often applied.

ii) Life-oriented approach and mobility biography approach call for more effort to model self-selection in a dynamic way.

iii) Self-selection may vary across different social groups and over time, especially in developing countries where the changes in economic growth and urbanization are fast.

iv) The dominance of case studies in developed countries (mostly US and EU), while cases in developing countries are rare.

2.1.2. State Dependence and Future Expectation

Transport researchers and policy makers have long been interested in how to reduce motorized vehicle ownership and usage such as cars and motorcycles. In the field of travel behavior research, it is assumed that people's choice implies a new and independent maximization process based on the trade-offs of the attributes in the current situation (Cherchi and Manca, 2011). Based on this assumption, the policy-related variables (e.g. road pricing and parking restriction) traditionally are introduced in model estimation in order to investigate how those variables influence the change in people's choices. However, the formation of habits can be involved in individual behavior, leading to reluctance to change (Cantillo and Ortúzar, 2006). Hence, the ignorance of individuals' history or habits may result in overestimation or biased results of policy variables (V. Cantillo et al., 2007). In fact, existing studies regarding residential and travel choices empirically indicate the significant influences of individuals' past experience or habit (Chen et al., 2008; Ramadurai and Srinivasan, 2006; Tayyaran et al., 2003; Wu et al., 2012).

In this study, state dependence refers to individuals' history of decision-making (i.e. past decision-making). The question here is what kind of information on past decision-making must be incorporated in model estimation? From a psychological viewpoint, choices are dependent on context (Fujii and Gärling, 2003). In this sense, the context of past decision-making should be given attention. Zhang et al. (2004) group the context of

decision-making into three categories: i) alternative-specific context, ii) circumstance context, and iii) individual-specific context. The first one refers to the number of alternatives and their attributes, the correlated structure of attributes and the availability of alternatives. The second one refers to weather conditions, market conditions, and status quo of choice across a population. The third one refers to individuals' choice history, household or workplace attributes, and the cognitive status quo of the reference group. Such context of past decision-making has been given attention in existing studies regarding residential and travel choices (Chen et al., 2008; Prillwitz et al., 2007). The most typical measure of state dependence is to incorporate the dummy variables of past choice in the function of current choice (Cherchi and Manca, 2011). Additionally, both new approaches proposed by Zhang (2014) and Scheiner (2014) reinforce the influences of state dependence in research on residential and travel choices (see Figure 2.2. and 2.3).

Existing studies regarding residential and travel choices mainly consider the influences of state dependence, but the involvement of future expectations is generally ignored. In transportation research, a few studies dealing with the influence of future expectation can be found. Using a dynamic generalized extreme value (DGEV) model proposed by Swait et al. (2000), Kuwano et al. (2011) and Wang et al. (2010) investigated the influences of future expectations on travel mode choice and vehicle type choices.

Similar to state dependence, future expectation refers to people's future context of decision-making. Such future context can also be grouped into three categories: i) alternative-specific context, ii) circumstance context, and iii) individual-specific context. Here a concern is that people's current choices may be affected by their future expectations. Especially in developing countries, people currently face more constraints but economic growth, housing and transport supply are moving forward. Consequently, people's residential and travel choice behavior may be not only backward-looking but also forward-

looking. This implies the influences of both state dependence and future expectation on current residential and travel choices. In the context of developing countries, estimation results of policies regarding land use and transport may be overestimated if only state dependence is taken into account.

2.2. Study Location

The city of Hanoi, Vietnam, is selected as a case study in this empirical research. The main reasons why Hanoi was selected are: i) high ratio of housing-price-to-income and fewer travel options by public transport imply that people face more constraints in the context of residential and travel choices, and ii) economic growth, housing and transport supply are moving forward. As for the first reason, CBRE Vietnam (2013) estimated that only about 2% of households in Hanoi can afford to buy a house. There has been a big gap between housing price and annual income. In addition, normal bus is the only transit choice for residents of Hanoi to date (i.e. 2015). Basically, most residents rely on motorcycles for their daily travel. In other words, these residents face significant constraints in the context of residential and travel choices. Regarding the second reason, the gap between housing price and annual income may be shrinking year by year due to economic growth, low inflation and several intervention policies such as social housing (i.e. housing with reasonable price for low-income people) and loans with low interest. Additionally, urban railway and bus rapid transit are under construction. It is projected that two or three urban railway lines will be operated in Hanoi in 2020. These imply that residents will have more freedom in the context of residential and travel choices in the near future. Intuitively, the Hanoi context is compatible with key assumptions mentioned in the Introduction.

2.2.1. Urbanization in Hanoi city

Hanoi is the capital city, and is located in the north of Vietnam (see Figure 2.4a). Before the expansion of its administrative boundary, Hanoi city was divided into four districts in the urban core, four districts in the urban fringe and four districts in the suburban area, with a total area of about 921 km2 (JICA, 2007). In 2008, the Prime Minister decided to expand the administrative boundary of Hanoi city towards the west. As a result, the whole of the old Ha Tay province was incorporated into the city capital of Hanoi. Hanoi now has 10 inner districts, 1 town at urban grade 3 and 20 townships at urban grade 5[1]. Inner districts are mainly concentrated in the South of Red River (Vietnam Ministry of Construction, 2009). Coinciding with fast economic growth, urbanization of the city capital is occurring at a high rate (Pham and Yamaguchi, 2011). Specifically, GDP per capita in Hanoi city gradually increased four-fold from 522 US$ in 2003 to 2009 US$ in 2011 (see Figure 2.5). In addition, Hanoi has been able to absorb a large number of migrants during the last 10 years, perhaps because of the expansion of employment opportunities, leading to the gradual increase in the population of Hanoi (World Bank, 2011). As a result, population density increased by roughly 500 persons per square kilometer from 2003 to 2011 (see Figure 2.6). Basically, urbanization is concentrated in old Hanoi. By using remote sensing and spatial metrics, Pham and Yamaguchi (2011) indicated that the urban growth of Hanoi from 1975 to 2003 has spread from the urban core to the outskirts of the city, mainly to the west of the Red River (see Figure 2.4b). In old Hanoi, population density increased by 1000 persons per square kilometer between 2003 and 2011. The population density of old Hanoi in 2011 is approximately twice as large as that of new Hanoi, 4,241 persons/sq.km compared to 2,407 persons/sq.km, respectively.

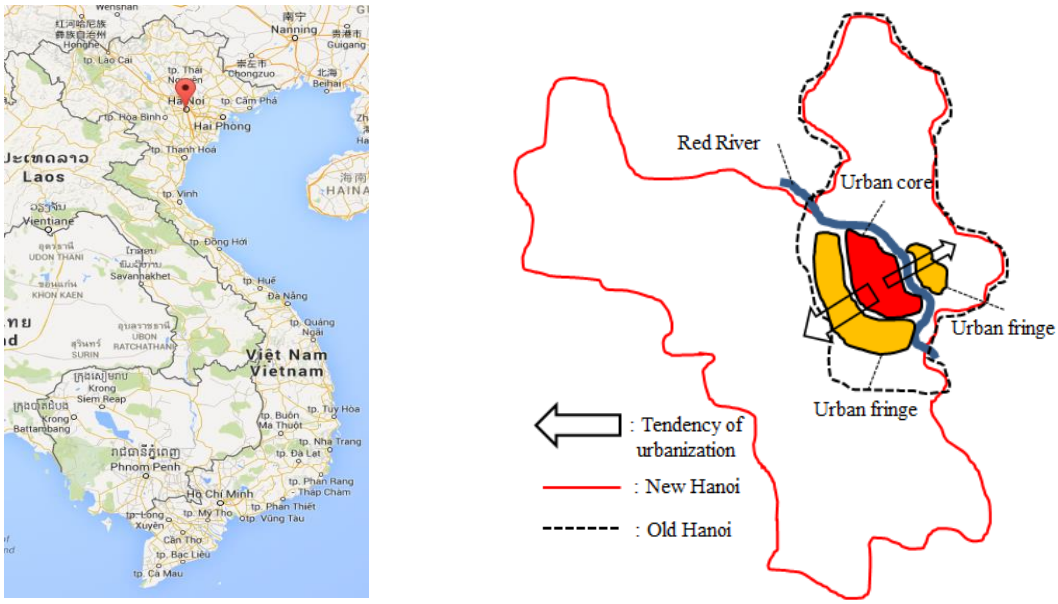
[1] Based on several criteria (e.g., population size and density), cities in Vietnam have been classified into six grades (The National Government of Vietnam, 2009).

2.2.2. Motorization in Hanoi city

Due to rapid economic growth, motorcycle and car ownership are rapidly increasing in Hanoi city. There was a sharp growth in the motorcycle ownership rate (vehicles/1000 persons) from 2005 to 2011 (see Figure 2.7). Additionally, the car ownership rate (vehicles/1000 persons) gradually increased in the same period. In 2011, the rate of motorcycle ownership climbed to 423 vehicles per thousand persons while that of car ownership was only 66 vehicles per thousand persons. The rate of car ownership in Hanoi city is low due to two reasons. The first one is that household annual income is still relatively low. The second one is high taxes and fees on car ownership and usage. As a result, motorcycles are the dominant travel mode in Hanoi. There is a big gap in vehicle ownership between old Hanoi and new Hanoi. With respect to motorcycle ownership, the rate of old Hanoi in 2007 is two-times as large as that of new Hanoi, 584 (vehicles/1000 persons) versus 299 (vehicles/1000 persons), respectively. With respect to car ownership, the rate of old Hanoi was 62 vehicles per thousand persons in 2007, while that of new Hanoi was only 36. Generally, vehicle ownership is strongly affected by GDP per capita (Dargay and Gately, 1999; Dargay, 2001; Tuan, 2011). The gap in vehicle ownership between old Hanoi and new Hanoi is understandable due to the big gap in GDP per capita (see Figure 2.5). In 2006, for example, GDP per capita in old Hanoi is 1329 US dollar while that in new Hanoi was only 897 US dollar.

In summary, motorization in Hanoi in period 2000-2011 was characterized by a sharp growth of motorcycle ownership and a modest increase in car ownership. At the same time, urbanization mainly occurred in urban fringe areas. Intuitively, there is a link between motorcycle ownership and urban development in fringe areas. Regarding the link between urban structure, transport and mobility, the World Bank (2011) warned that the

high population densities and sparse road networks of Hanoi are simply incompatible with adoption of private cars as a major means of transport.



(a) (b)

Figure 2.4: The location and tendency of urbanization

Source: Adapted from Google Map

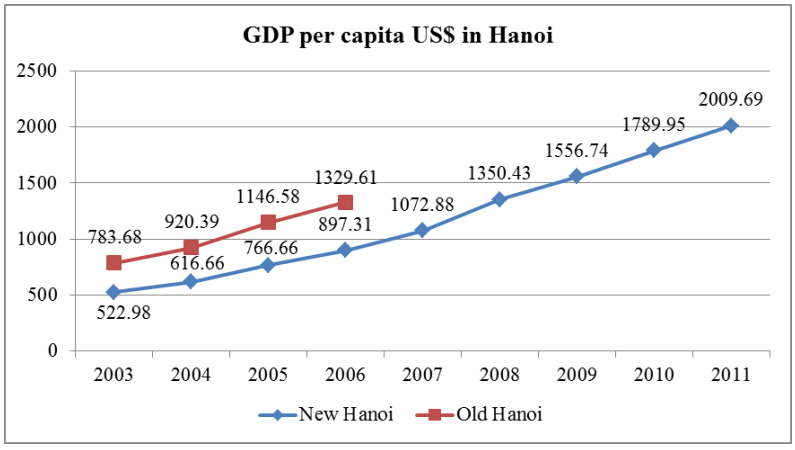


Figure 2.5: GDP per capita in Hanoi city

Source: (Hanoi Statistical Office, 2007, 2011, 2012)

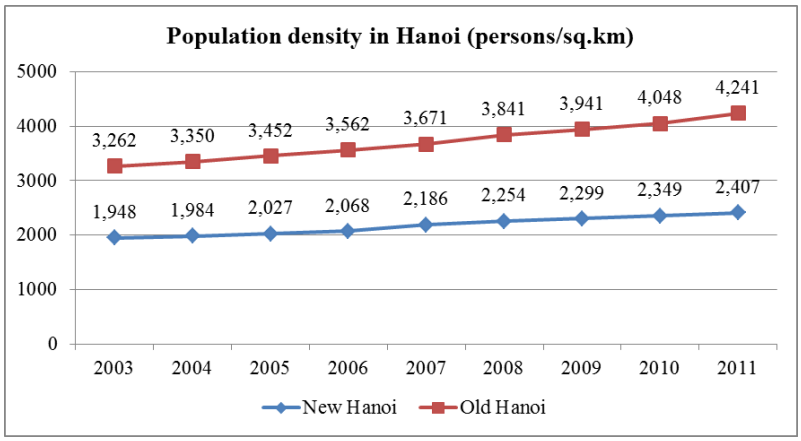
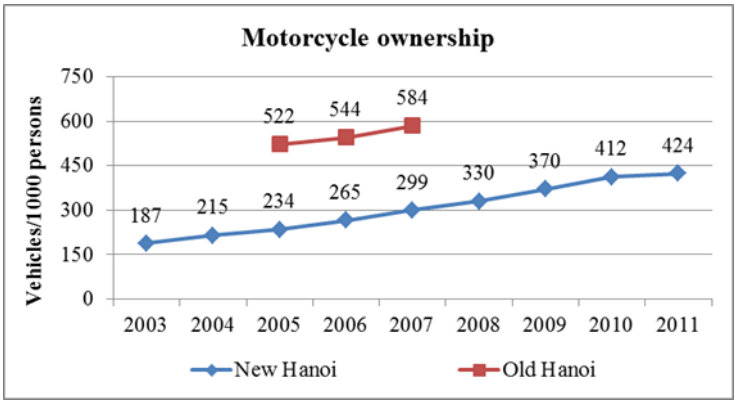


Figure 2.6: Population density in Hanoi city

Source: (Hanoi Statistical Office, 2007, 2011, 2012)

(a)



(b)

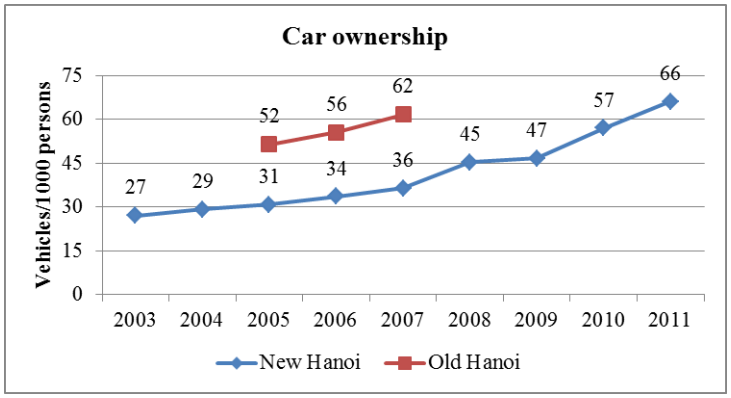


Figure 2.7: Vehicle ownership in Hanoi city

Source: Hanoi Road and Railway Traffic Police Department

2.3. Data

In travel behavior research, the influential factors in people's residential and travel choices are classified into three categories: i) decision-maker-specific factors, ii)

situational factors, and iii) alternative-specific factors (Zhang et al., 2004). To observe each type of influential factor, several data collection methods have been used in existing studies.

As for decision-maker-specific factors, firstly, the common approach to data collection is household or individual interview survey by face-to-face, phone-based, mailbox-based, email-based and web-based methods. In developed countries, the phone-based, mailbox-based, email-based and web-based are prevalently used because of time and money constraints. However, such kinds of survey have several limitations such as a high non-response rate and omitted information (Stopher and Greaves, 2007). In the context of developing countries, people seem to be less willing to participate in a survey. Hence, face-to-face interview is often selected when survey location is in a developing country. The decision-maker-specific factors will be recorded by using a questionnaire in which respondents are asked to self-report information that are relevant for household and individual attributes such as household income, number of children, age, sex, education, employment and so on.

With respect to situational factors, people's residential and travel choices are affected by the existing state of housing and transport supply, economy, society, technology, politics and so forth. Situational factors can partially be observed by asking respondents to self-report their feelings or perceptions. Additionally, the data related to situational factors can be provided by numerous sources such as statistical yearbooks or private and public organizations.

Generally speaking, alternative-specific factors can be partially investigated by paper-based household interview survey. In addition, the data related to alternative-specific factors can be partially observed by GPS-based and GIS-based survey or other computer-aided software.

In summary, the household interview survey has been a prevalent way to collect data in research regarding residential and travel choices. In this study, hence, data collected from a household interview survey will be used. We first used a large-scale household interview survey conducted by JICA. However, such cross-sectional data cannot be used in dealing with the change in people's residential and travel choices over time, especially in developing countries where socio-economic conditions, housing and transport supply evolves rapidly. In this case, longitudinal data should be collected. Therefore, a small-scale household interview survey was also conducted.

2.3.1. Large-Scale Household Interview Survey (Static Data)

The Comprehensive Urban Development Program (HAIDEP) was done in Hanoi city in 2007 by JICA. In this HAIDEP, the transport master plan is one of the key components. To develop a transport master plan, it is necessary to identify people's travel patterns in Hanoi city. Hence, a face-to-face Household Interview Survey (HIS) was conducted by JICA in 2005. The targeted area of this survey consisted of old Hanoi city (14 districts) and adjoining areas (JICA, 2007). In transport planning, large-scale household interview surveys are often carried out and sample sizes are often as big as 1-3% of the population (Stopher and Greaves, 2007). In HIS, 20,020 households were selected as final sample for this survey, accounting for 2.23% of Hanoi's population.

The questionnaire used in HIS is composed of five parts (see Appendix 1). The first part is related to household information, while household member information is in the second part. In the third part, respondents were asked to report their daily activity information. People's opinions regarding transport environment were collected in the fourth part. People's satisfaction and perceptions regarding living conditions were included in the fifth part. Based on such information, people's residential and travel choices can be picked up, such as motorcycle ownership and housing location.

2.3.2. Small-scale Household Interview Survey (Dynamic Data)

Based on a brief summary of urbanization and motorization in Hanoi city in Section 2.2, there are two remarkable points: i) the spread of urbanization from the urban core area to the outskirts of the city, especially towards the west of the Red River (Pham and Yamaguchi, 2011), and ii) the fast increase in motorcycle ownership and the gradual growth of car ownership. Such urban growth and the dominance of motorcycles may be interdependent. Because urban core areas were mainly developed before 1975, the increases in motorized vehicle ownership and urbanization in urban fringe and suburban areas seem to be occurring at the same time. Hung (2006) indicated that Hanoi was a typical motorcycle dependent city in which urban activities are highly concentrated in the city center. From the perspective of the demand side, this can be explained by the interdependence between people's residential and travel choices. On the one hand, if people have motorcycles they may prefer to live in urban fringe areas which are closer to the urban core. On the other hand, if they have cars they may prefer to live in suburban areas which are further away from the urban core. To capture the change in such interdependencies, a face-to-face household interview survey with 300-household samples was carried out in Hanoi in 2011. The targeted survey area is composed of 6 locations in urban fringe and suburban areas (see Figure 2.8).

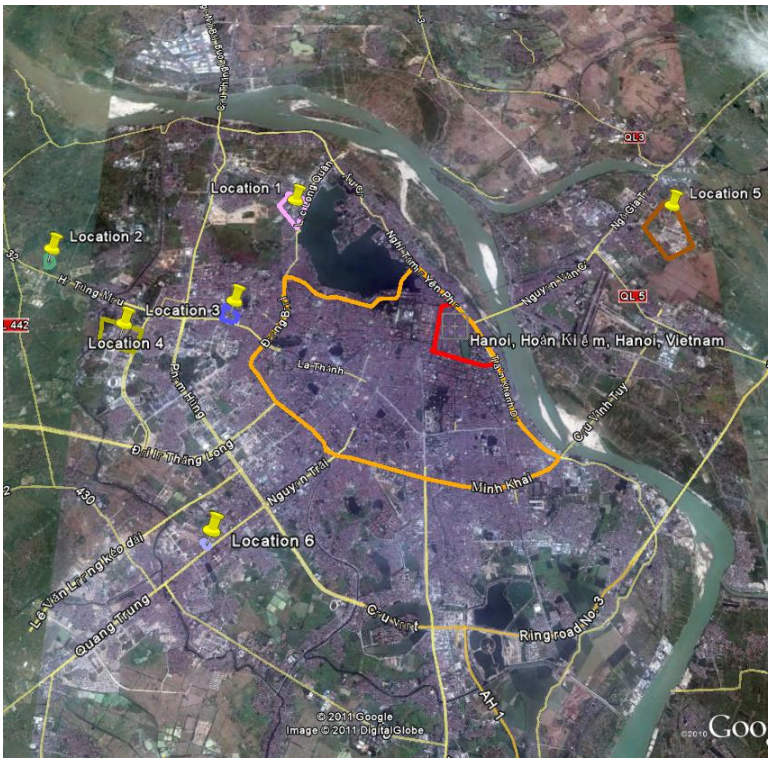


Figure 2.8: Survey locations in Hanoi in 2011

Source: Adapted from Google Earth

The questionnaire used in this survey consists of five parts (see Appendix 2). Respondents were asked to report household member information in the first part. The second part consists of a retrospective survey regarding residential location, household composition, employment, and vehicle ownership from 1991 to 2011. Travel behavior of each household member was collected in the third part. People's travel attitudes and life satisfaction are included in the fourth part. People' neighborhood perceptions are located in the fifth part.

Chapter 3 A Joint Analysis of Residential Location, Work Location and Commuting Mode Choices in Hanoi, Vietnam

3.1. Introduction

Traffic congestion and its resulting issues (for example, waste of energy and emission of air pollutants) caused by commuting traffic are a major concern of transport policy makers. If people could live close to their workplaces and commute by environmentally-friendly travel modes, the impacts of commuting traffic may be largely mitigated. In the early stages of urbanization in developing-country cities, it can be said that most people lived very close to their daily destinations and traveled less by motorized vehicles (Robert Cervero, 2013). The increase of income and the resulting growth of car ownership have significantly improved people's quality of life. As people became more affluent and enjoyed basic economic and political rights, more people have been able to enjoy the benefits (privacy, mobility, and choice, etc.) once reserved for wealthier people (Bruegmann, 2005,p.109). At the same time, cities have grown bigger and bigger in both size of population and area of urbanized space, especially those in developing countries. From the perspective of the demand side, this phenomenon can be explained as the outcome of people's residential and travel choices. While it is a challenge to slow down the rate of urbanization and motorization in these cities, it is possible to consider ways to manage it better. One such way is to encourage people to live closer to their workplaces and commute by environmentally-friendly travel modes.

Due to economic growth and improvements in housing and transport supply, people living in developing country cities have more options for their residential location and travel mode than in the past. People may therefore be choosing not to live closer to their workplaces and/or to commute by environmentally-friendly travel modes because such

choices do not meet their preferences. Unfortunately, little is currently known about people's preferences regarding residential location, work location, and commuting mode in developing-country cities, which are targeted in this study. Coinciding with economic growth, there may be a shift in the structure of the labor market, from labor-intensive sectors (e.g. workers in agriculture, forestry and fishery) to knowledge-intensive sectors (e.g., financial and banking services, scientific and technological activities). This may lead to changes in land use and transport systems.

In the context of commuting, people working in different job markets may have different preferences over their choice of residential location, work location and commuting mode. Choice behavior is usually influenced by not only objective factors (e.g. land use patterns in the residential location and workplace choices, and levels of travel services in the commuting choice), but also subjective factors (e.g. attitude, liking or taste). If people like walking, they may choose to reside in an area with a better walking environment. Due to such a self-selection effect, the choice of residential location and that of daily travel mode may not be independent of each other. Recently, the self-selection effect has emerged as an important issue in the transportation field because it may create a spurious relationship between land use and transport. Therefore, researchers have tried to depict the true effect of land use variables on location choices and travel behavior by controlling for the self-selection effects. The main concern of existing literature is in attitude-induced self-selection, basically including attitudes regarding location and travel (Cao et al., 2009a; Mokhtarian & Cao, 2008). Such attitudes can be measured by directly asking people to report them. If such attitude data are not available, one has to reflect them in the choice modeling process by improving the structure of error terms. Additionally, existing studies on self-selection effects have mainly focused on the relationship between residential and travel behavior. In the context of commuting, a few studies consider self-

selection with respect to work location, especially in developing-country cities where there may be a big shift in the structure of labor market in the future.

Motivated by the aforementioned issues, the objective of this study is two-fold. First, this study clarifies the interdependencies between residential location, work location and commuting mode choices in the context of Hanoi. Second, this study examines the role of land use attributes in the three choices for workers in two types of sectors, labor-intensive and knowledge-intensive. To this end, a joint choice model is built by explicitly reflecting the influence of multiple self-selection effects.

The remainder of this paper first provides a literature review, followed by a description of the joint choice model. Next, data used in this study are briefly explained. After that, the joint choice model is estimated and effects of self-selection and land use attributes are examined. Finally, this study concludes with a discussion about the limitations of this study.

3.2. Literature Review

In the field of transportation research, the joint analysis of residential location choice and commuting mode has been done. For instance, Lerman (1976) made an initial attempt to deal with households' joint choices of residential location, housing type, auto ownership and mode to work by grouping them as a mobility bundle, and then estimating the bundle choice based on a multinomial logit model, where correlations among different choices were ignored. Similarly, Pinjari et al. (2011) estimated a joint model of residential location, auto ownership, bicycle ownership, and commute tour mode choice decision, but used a mixed logit model, which incorporates self-selection effects, endogeneity effects, correlated error terms, and unobserved heterogeneity.

In the context of commuting, whether or not work location should be jointly modeled with residential location and commute mode has long been a controversial topic.

A majority of existing studies have treated the work location as an exogenous variable to explain the residential location and commuting mode choice; however, such treatment has been questioned by some researchers. For example, Waddell (1993) estimated a nested logit model of workplace and residential choice and empirically confirmed that the assumption of exogenous workplace choice in residential location does not hold. Waddell et al. (2007) further developed a latent segmentation model of joint choice of workplace and residential location by incorporating the influence of both unobserved heterogeneity and heterogeneous choice sequence. As argued by Wang and Chai (2009), "commuting is an outcome of not only location decisions regarding to work and residence, but also decisions about transport modes". Vega and Reynolds-Feighan (2009) built a cross-nested logit model to jointly represent the choice of residential location and travel-to-work mode, where job location was given and a residential choice set was defined based on the road distance to workplace. Additionally, "co-location hypothesis" argues that "people can make rational choices of work location and residential location according to market rules" (Zhao et al., 2011).

As for self-selection issues, Van Wee hypothesized that people might self-select with respect to work locations. For instance, a car lover might dislike a workplace in a downtown location with poor car access (Van Wee, 2009). In a special issue on residential self-selection (Cao, 2014), published in the Journal of Transport and Land Use in 2014, Scheiner (2014) and Zhang (2014) argue that travel behavior should be studied by explicitly linking not only residential location choice but also other life domains/life choices where work location is involved. Supported by the above literature, work location is treated as a dependent variable in this study. In other words, it is assumed that an individual can choose his/her work location.

It is expected that various behavioral aspects related to residence, work, and commuting behavior are interdependent. One such interdependence may involve the issue of residential self-selection, defined as "the tendency of people to choose location based on their travel abilities, needs and preferences" (Litman, 2011; Mokhtarian and Cao, 2008). By extending the scope of self-selection, Van Wee (2009) re-defines self-selection as "the tendency of people to make choices that are relevant for travel behavior, based on their abilities, needs and preferences". In the context of commuting, we define self-selection as "the tendency of people to make residential location, work location and commuting mode choices based on their abilities, needs and preferences". Generally, the self-selection is induced by socio-demographics and attitudes (Mokhtarian and Cao, 2008).

In existing literature on self-selection, the joint-equation modeling framework has been widely used (Bhat and Guo, 2007; Biying et al., 2012; Pinjari et al., 2008; Pinjari, Pendyala et al., 2007) due to two main reasons. Firstly, from the behavioral viewpoint, if self-selection exists, the choices of residential location and commuting mode may be made jointly as a bundle (Paleti et al., 2013). In the context of commuting, this assumption can be extended if self-selection regarding work location is taken into account. In other words, the alternatives of residential location, work location and commute mode may be simultaneously established. This is different from a sequential decision process in which residential location is first chosen and self-selection effects are ignored (Paleti et al., 2013). Secondly, from a methodological viewpoint, the self-selection issue may consist of two aspects: omitted variables and non-random assignment (Herick and Mokhtarian, 2015). The former refers to the correlation between observed variables of land use and unobserved variables of attitudes (or lifestyles). The latter refers to the concern that residents have not been randomly assigned to be in a certain neighborhood. Herick and Mokhtarian further emphasize that "resolving one problem should resolve the other". This

can be done if attitudes are included as explanatory variables in equations of both travel and neighborhood choices. If attitudes are not observed, a feasible way is to incorporate common unobserved terms in both equations of residential location and travel behavior. It is noted that attitudes-related information are not included in data used in this study. To control for self-selection effects induced by socio-demographics and other unobserved factors (e.g., attitudes) in the context of commuting, hence, this study uses a joint-equation modeling framework in which common unobserved terms are included.

Studies regarding residential self-selection effects have been attracting more and more attention, motivated by policy debates about whether to advocate land use and transportation policies to reduce auto dependence and increase the use of alternative means of transport. However, North American studies have dominated the self-selection literature, although European scholars also contribute (Cao, 2014). In the context of developed countries, the majority of existing studies found significant influences of self-selection. By reviewing 38 empirical studies mostly conducted in United States, for example, Cao et al. (2009b) summarized the existence of self-selection effects in 25 studies. One hypothesis is that people in developed countries are more able to self-select in their decisions because they face less constraints than those in developing countries (for example, income, housing and transport supply). In other words, people in developed countries are likely to rely on their travel attitudes and lifestyle preferences when choosing residential location and travel behaviors. In developing countries, however, people are less able to choose residential location and travel behavior because they face more constraints. Accordingly, if this hypothesis is true, then it is likely that if economic conditions in developing countries improve, leading to higher incomes, and the housing supply and transport systems expand, then current constraints on people's choices in developing country cities will decline.

Taking this idea further, we can observe that in general, a greater proportion of the urban population of developed countries works in knowledge-intensive sectors compared to labor-intensive sectors, while the inverse is true of the urban population in developing country cities. Additionally, the average income of knowledge-intensive workers is higher than those working in labor-intensive sectors. Hence, a major assumption is that labor-intensive workers are less likely to self-select because they face more constraints. Coinciding with economic growth, however, a shift in the structure of labor market from labor-intensive sectors to knowledge-intensive sectors may occur in developing countries. This may result in big changes in the land use-transportation system. In the context of commuting, such phenomenon can be explained as changes in residential location, work location and commuting mode choices.

To the best of the author's knowledge, there is little known about the self-selection effects across different job markets, even in developed countries. The goal of studies related to self-selection is to identify the true relationship between land use and travel behavior (Cao et al., 2009b). Hence, understanding the influences of self-selection in different job markets could provide some useful insights in designing land use-transportation systems, especially in developing countries where the structure of the labor market is likely to change in the future. Taking Hanoi City, Vietnam as a new example, the present study aims to capture the interdependencies among three choices: work location, residential location, and commuting mode, as well as to compare the influence of self-selection among groups of labor-intensive and knowledge-intensive workers.

3.3. Joint Choice Modelling

The basic idea of the model developed here is similar to Pinjari et al. (2011) and Paleti et al. (2013). Random components were added into multinomial discrete choice formulations to represent interdependencies between residential location, work location,

and commuting mode choices. Let n ($n=1, 2, \ldots, N$), i ($i=1, 2, \ldots, I$), w ($w=1, 2, \ldots, W$), and m ($m=1, 2, \ldots, M$) represent decision-maker, residential location, work location, and commuting mode, respectively. The utility function for each choice is defined as follows:

Residential location choice:

$$u_{1ni} = \beta_{1i} x_{1ni} + \sum_w \pi_{niw} + \sum_m \omega_{nim} + \varepsilon_{1ni} \quad (1)$$

Work location choice:

$$u_{2nw} = \beta_{2w} x_{2nw} + \sum_i \pm \pi_{niw} + \sum_m \psi_{nwm} + \varepsilon_{2nw} \quad (2)$$

Commuting mode choice:

$$u_{3nm} = \beta_{3m} x_{3nm} + \sum_i \pm \omega_{nim} + \sum_w \pm \psi_{nwm} + \varepsilon_{3nm} \quad (3)$$

where x_1, x_2, and x_3 are vectors of explanatory variables including individual and household characteristics, land use attributes, and/or those interaction terms; β_1, β_2, and β_3 are vectors of parameters; and ε_{1ni}, ε_{2nw}, and ε_{3nm} are error terms following an identical and independent Gumbel distribution, respectively. In this modeling system, the interdependencies among three choices are represented through random components π_{niw}, ω_{nim}, and ψ_{nwm}. Specifically, π_{niw} represents interdependencies between choices of residential location i and work location w, ω_{nim} represents interdependencies between choices of residential location i and commuting mode m, and ψ_{nwm} represents interdependencies between choices of work location w and commuting mode m. It is assumed that π_{niw}, ω_{nim}, and ψ_{nwm} are normally distributed with means 0 and variances σ^2_{iw}, σ^2_{im}, and σ^2_{wm}, respectively. The "±" signs in front of random components in equation (2) and (3) mean that the correlation in the common unobserved terms may be positive or negative. Notably, such common random components may include individual- or household-specific unobserved factors that influence thehouseholds' sensitivity to two of

the three above choices. Due to factors in such common random terms such as travel-related attitudes, people may self-select residential location, work location and commuting mode.

Generally, the residential choice might involve two or more household members in the decision-making process. There are two possible ways to reflect the influence of such decision-making at the household level. One is to build a choice model with intra-household interaction, where the choice utility function is defined as a function of each member's utility (Zhang and Fujiwara, 2009). The other is to introduce some household-related attributes into an individual choice model. In this study, the second method is adopted.

Assuming that decision-makers choose a set of alternatives that give highest utilities, the following conditional likelihood function can be derived:

$$L(\beta_{1i},\beta_{2w},\beta_{3m}\mid\pi_{niw},\omega_{nim},\psi_{nwm})=\prod_n\prod_i\prod_w\prod_m\left\{\frac{e^{\beta_{1i}x_{1ni}+\sum_w\pi_{ni\hat{w}}+\sum_m\omega_{ni\hat{m}}}}{\sum_i e^{\beta_{1i}x_{1ni}+\sum_w\pi_{ni\hat{w}}+\sum_m\omega_{ni\hat{m}}}}\times\frac{e^{\beta_{2w}x_{2nw}+\sum_i\pm\pi_{n\hat{i}w}+\sum_m\psi_{nwm}}}{\sum_w e^{\beta_{2w}x_{2nw}+\sum_i\pm\pi_{n\hat{i}w}+\sum_m\psi_{nwm}}}\times\frac{e^{\beta_{3m}x_{3nm}+\sum_i\pm\omega_{ni\hat{m}}+\sum_w\pm\psi_{nwm}}}{\sum_m e^{\beta_{3m}x_{3nm}+\sum_i\pm\omega_{ni\hat{m}}+\sum_w\pm\psi_{nwm}}}\right\}^{d_{ni}\times d_{nw}\times d_{nm}} \quad (4)$$

where d_{ni} is a dummy variable which is equal to 1 if individual n chooses residential location i and 0 otherwise, d_{nw} is a dummy variable which is equal to 1 if individual n chooses work location w and 0 otherwise, and d_{ni} is a dummy variable which is equal to 1 if individual n chooses commuting mode m and 0 otherwise. The unconditional likelihood function is:

$$L(\beta_1,\beta_2,\beta_3,\sigma_{iw},\sigma_{im},\sigma_{wm}) = \int_{\pi_{iw}}\int_{\omega_{im}}\int_{\psi_{wm}} \left[\begin{array}{l} L(\beta_1,\beta_2,\beta_3 \mid \pi_{iw},\omega_{im},\psi_{wm}) \times \\ \phi(\pi_{niw} \mid \sigma_{iw})\phi(\omega_{nim} \mid \sigma_{im})\phi(\psi_{nwm} \mid \sigma_{wm}) \end{array} \right] d\psi_{nwm} d\omega_{nim} d\pi_{niw} \quad (5)$$

where $\phi(\pi_{niw}|_{niw})$, $\phi(\omega_{nim}|\sigma_{im})$, $\phi(\psi_{nwm}|\sigma_{wm})$ are normally distributed with means being zero and variances being σ^2_{iw}, σ^2_{im}, and σ^2_{wm}, respectively. Thus, when all interdependencies are taken into account, the dimension of the integral would be 33 in empirical analysis (3 alternatives for residential location, 3 alternatives for work location, and 4 alternatives for commuting mode, i.e., (3×3) + (3×4) + (3×4) = 33 pairs of alternatives). Since we found that it is very difficult to make a stable estimate of the model with 33 random components, only 6 random components are first estimated in the empirical analysis.

The model estimation was done based on the Markov Chain Monte Carlo (MCMC) method by using the conventional software WinBUGS. A total of 110,000 iterations were done in order to obtain 10,000 draws: the first 10,000 iterations were used for burn-in in order to mitigate start-up effects, and the remaining 100,000 iterations were used to generate the 10,000 draws (i.e., every 10^{th} iteration was retained). The convergence of the model estimation is confirmed based on Geweke diagnostics (Geweke, 1992).

3.4. Data

Data for this study were collected from a household interview survey, which was implemented in Hanoi, Vietnam by the Japan International Cooperation Agency (JICA) in 2005 (JICA, 2007). In this survey, the following information was collected: i) household attributes, ii) individual attributes, iii) daily activities, iv) people's opinions on traffic congestion and safety, public transport and transport measures, and iv) people's satisfaction with current living conditions. In total, more than 20,000 households and more than 70,000 household members provided valid answers.

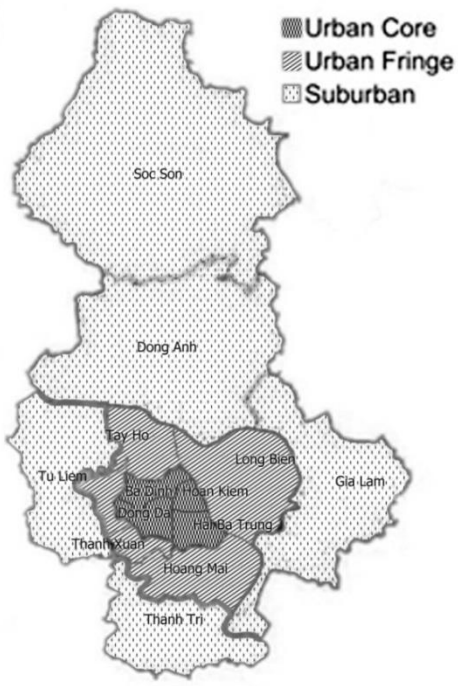


Figure 3.1: Study area

Here, urban areas in Hanoi were divided into urban core, urban fringe, and suburbs (see Figure 3.1), which become the three alternatives for choices of residential location and work location, respectively. Regarding commuting mode, the choice set is composed of walking, bicycle, motorcycle, and other modes (bus, car, taxi, three-wheelers, etc.)

Since it is expected that choice patterns of residential location and work location may not be the same across job types, respondents with jobs were extracted from the survey and then classified into labor-intensive workers and knowledge-intensive workers[2]. The former type consists of four groups of jobs: 1) workers in agriculture, forestry and fishery, 2) manual workers, 3) craft and trade-related workers, and 4) machine operators and assemblers. The latter type is composed of three specific groups of jobs: 1) professionals (i.e. highly qualified jobs), 2) associate professionals (i.e. moderately qualified jobs), and 3) clerical staff. As a result, 11,344 labor-intensive workers and 12,360 knowledge-intensive workers were extracted.

[2] The job category in questionnaire, retired person, student, jobless, and housewife and so on were also included.

There are significant differences between the two types of workers in choices of residential location, work location, and commuting mode. For labor-intensive workers, 14.5% of them lived in the urban core, 20.1% in the urban fringe, and 65.4% in the suburbs. Regarding the work location choice, 17.2% of labor-intensive workers worked in the urban core, 20.8% in the urban fringe, and 62% in the suburbs. It is shown that 23.3% of labor-intensive workers commuted by walking, 31.6% by bicycle, 38.9% by motorcycle, and 6.2% by other modes.

As for knowledge-intensive workers, 48.5% of them resided in the urban core, 32.5% in the urban fringe, and 19% in the suburbs. With respect to their work location choices, 57.6% of them worked in the urban core, 26% in the urban fringe, and only 16.4% in the suburbs. It is revealed that only 5.0% of knowledge-intensive workers commuted by walking, 10.3% by bicycle, 78.7% by motorcycle, and 6.0% by other modes.

Regarding home-to-workplace distance, because of the lack of GIS data, road-based distance information is not available. Based on administrative subdivision in 2005, Hanoi was divided into 228 zones. Then the straight-line distances from the centroid of zone of residential location to that of work location were measured and used in this study.

3.5. Model Estimation and Discussion

3.5.1. Explanatory Variables

Our first concern is how land use attributes affect choices of residential location, work location, and commuting mode. Typical land use attributes are introduced, including land use type, land use diversity, and population density. Generally speaking, neighborhoods with more mixed land use may encourage people to use active modes (such as walking and cycling) and reduce the use of vehicles. Here, the entropy index in equation (6), proposed by Cervero and Kockelman (1997), is used to represent the diversity level of different land uses, which have been widely used in the field of transportation (Cervero,

2002; Greenwald, 2006; Hong et al., 2013; Potoglou and Kanaroglou, 2008). It is expected that there is a positive relationship between land use diversity and active modes, but a negative relationship between land use diversity and motorcycles. Based on literature review, five types of land uses are selected: commercial and business land (e.g. shopping centers and head offices), educational and cultural land (e.g. university and exhibition buildings), industrial land (e.g. car factory), governmental and quasi-public land (e.g. offices of city government), and residential land (e.g. high-rise apartments and villas).

$$Entropy = -1 * \left[\sum_{k=1}^{K} proportion(k) * \ln\left(proportion(k)\right)\right] / \ln(K) \qquad (6)$$

where K is the total number of land use types (K=5), and k is a land use type.

As for residential location choice, it is expected that different households may prefer different types of land uses. Hence, interaction terms between land use and household attributes are introduced in the utility of residential location choice, where the number of workers, number of elderly, and household income as well as the number of motorcycles are introduced, as shown in Table 1. With the above information, the influence of economic affordability and social obligation related to household members can be partially reflected. Such interactions are excluded from the work location choice model because work location choice may be highly personal. More detailed types of jobs may better explain the choice behavior, so dummy variables for several types of jobs for both labor- and knowledge-intensive workers are defined.

3.5.2. Model Performance and Effects of Unobserved Terms

Model estimation results of residential location, work location, and commuting mode choices are presented in Table 3.1 ~ Table 3.3, respectively. Among the 147 parameters estimated, about 86% are statistically significant. Comparing labor-intensive

and knowledge-intensive workers, the latter have more significant parameters than the former. The adjusted Rho-squared values of the models for labor-intensive and knowledge-intensive workers are 0.698 and 0.633, respectively, indicating the high sufficiency of model accuracy. These results suggest that the proposed joint choice model is effective to represent the joint choice of residential location, workplace, and commuting mode.

As shown in Table 3.4, there are significant unobserved random components that simultaneously affect residential location and work location in both groups of labor-intensive and knowledge-intensive workers, indicating that these long-term choices correlate with each other. For both pairs of "urban core-urban core" and "suburban-suburban", the positively significant unobserved components suggests that some unobserved factors make people in Hanoi city have a tendency to choose residential and work location in the same area. Perhaps, they prefer short- or medium-distance commuting.

Additionally, unobserved random components significantly influence both work location and commuting mode in both groups of labor-intensive and knowledge-intensive workers, indicating significant correlation between long-term work location choice and short-term commuting mode. In particular, the positively significant unobserved component of "urban core – motorcycle" pair indicates that unobserved factors contributing to a person's work location in urban core are correlated with unobserved factors making a person more likely to drive a motorcycle. Possibly, such people have a strong preference for travelling by motorcycle. Similarly, the positively significant unobserved components of the "suburban – bicycle" pair is captured. As expected, the significant correlation between residential location and commute mode are observed only in the group of knowledge-intensive workers. This implies that self-selection effects caused by unobserved components seem to exist across knowledge-intensive workers'

choice of residential location and commute mode, perhaps because they face less constraints.

3.5.3. Total Variance of Utility Differences

To further clarify the effects of the interdependencies (i.e. unobserved factors) among residential location, work location and commuting mode choices, the total variance of utility differences in each sub-model is calculated, as follows (Table 3.5):

Residential location choice:

$$Var\left(u_{1ni}-u_{1n1}\right)=Var\left(\beta_{1i}x_{1ni}-\beta_{11}x_{1n1}\right)+\sigma_{iw}^{2}+\sigma_{im}^{2}+\pi^{2}/3 \quad (7)$$

Work location choice:

$$Var\left(u_{2nw}-u_{2n1}\right)=Var\left(\beta_{2w}x_{2nw}-\beta_{21}x_{2n1}\right)+\sigma_{iw}^{2}+\sigma_{wm}^{2}+\pi^{2}/3 \quad (8)$$

Commuting mode choice:

$$Var\left(u_{3nw}-u_{3n1}\right)=Var\left(\beta_{3w}x_{3nw}-\beta_{31}x_{3n1}\right)+\sigma_{im}^{2}+\sigma_{wm}^{2}+\pi^{2}/3 \quad (9)$$

where u_{1n1} and u_{2n1} are the utilities of urban fringe in the residential and work location choice sub-models; and u_{3n1} is the utility of other modes in the commuting mode choice sub-model.

There are 14 total variances in Table 3.5. In 10 out of the 14 total variances, observed factors (socio-demographic and land use attributes) explain more than 50% of the total variance. In the remaining 4 total variances, they are mainly captured by unobserved factors. This suggests that the introduced observed factors are useful to explain the choice behaviors under study. Looking at unobserved factors in all the 14 total variances, error terms only play a dominating role in mode choice, while their variance proportions in work

and residential location are moderate. It suggests that more observed variables should be included in the model of commuting mode choice.

The influences of self-selection effects caused by unobserved factors (i.e. common random components) across "residential location and commuting mode" or "work location and commuting mode" (i.e. terms ω_{nim}, and ψ_{nwm}) are not as large as expected. Irrespective of labor-intensive or knowledge-intensive workers, the variances explained by self-selection effects are below 5.0%, indicating that these self-selection effects caused by unobserved factors are not remarkable in the context of Hanoi city. Interestingly, the term ω_{nim} contributes on average to 4% of total variance of utility in knowledge-intensive workers' residential location choice, while it is only an average 2% of total variance of utility in labor-intensive workers' residential location choice. This implies that knowledge-intensive workers may be more able to self-select in the case of residential location choice because they face less constraints.

As for commuting mode choice, the influence of self-selection caused by unobserved factors is relatively significant in both groups of labor-intensive and knowledge-intensive workers, indicating that both types of workers may be more able to self-select in the case of short-term decisions (i.e. commuting mode). Unlike terms ω_{nim}, and ψ_{nwm}, the variances of terms π_{niw} significantly contribute to the total variance of utilities regarding residential and work location. Specifically, 3%~16% of total variance can be explained by the variances of terms π_{niw}. As expected, the self-selection effects caused by unobserved factors across residential and work locations (i.e. terms π_{niw}) on knowledge-intensive workers' choices seem to be larger than that on labor-intensive workers' choices. It is possible that knowledge-intensive workers face less constraints, so they can choose a pair of work and residential locations which is compatible with their neighborhood and travel preferences.

As for observed factors, the magnitudes of their influences on different choices are diverse. Looking at land use attributes, they are more influential in knowledge-intensive workers' location choices because of higher variance proportions (26.39% ~ 81.13%) explained by land use, than to labor-intensive workers' location choices (the corresponding proportions are 3.03% ~ 41.92%). Concerning socio-demographics, they are more influential to labor-intensive workers' location choices, implying that they may face more constraints in long-term decisions than knowledge-intensive workers. In particular, labor-intensive worker's total variances of utilities with respect to suburban areas are mostly explained by socio-demographic variables, 90.44% in work location and 86.58% in residential location, respectively. For other location choices, socio-demographics can explain 69.29% ~ 70.77% of the total variances. Regarding commuting mode choice, land use and commuting distance explained 81.13% of the total variable of knowledge-intensive workers' walking choice, relative to the choice of other modes, and larger influence of land use and commuting distance is also observed with respect to labor-intensive workers' walking choices. Socio-demographics have a larger influence on labor-intensive workers' motorcycle choices, but a lower influence on labor-intensive workers' bicycle choices.

3.5.4. Estimation Results of Each Choice Behavior

a) Residential location choice

As seen in Table 3.1, effects of land use attributes on residential location choice are captured in two ways: one is the main effects and the other is the interaction effects. The interaction effects are measured as a product of each land use attribute and a household attribute. Such interaction effects, in fact, reflect the heterogeneous responses of households to each land use attribute when choosing a residential location.

Differences in the influences of land use on residential location choice are observed between labor-intensive and knowledge-intensive workers. Knowledge-intensive workers

prefer areas with more educational/cultural land and medical/welfare land, but labor-intensive workers are less likely to reside in these areas. Additionally, the industrial-park land has a negative effect on knowledge-intensive workers' choices, while its effect on labor-intensive workers' choices is positive. The remaining land use attributes show almost similar influences on both types of workers' choices. The parameters of commercial and business land, transport and services land, and residential land are positive, indicating that both workers tend to choose residential areas with a high percentage of these land use types.

With respect to interaction terms, high-income households in both groups prefer areas with high percentage of commercial and business land. In addition, high-income households in the knowledge-intensive group tend to reside in areas with more educational and cultural land while labor-intensive workers are less likely to live in such areas. In both groups, households with more workers dislike areas with more commercial and business land. The parameter of interaction term between "medical and welfare land" and "number of elderly members" has a negative sign, implying that households with more elderly members are less likely to choose areas with a high percentage of medical and welfare land. In both groups, households owning more motorcycles are more likely to reside in areas with more transport and service land.

As for individual attributes, knowledge-intensive workers with a professional job are more likely to reside in the urban core, while they are less likely to live in the suburbs. Inversely, labor-intensive workers in agriculture, forestry and fishery as well as manual workers tend not to reside in the urban core, but prefer living in suburban areas. In both groups, the parameters of age have a positive influence on the urban core, but negative effects on suburban areas are observed. These indicate that older people prefer residing in the urban core and dislike the suburban residence. Knowledge-intensive workers with high

education levels (i.e. master or Ph.D. degree) are more likely to stay away from suburban areas. Labor-intensive workers with lower education level (i.e. high-school level) prefer suburban areas.

b) Work location choice

Relevant model estimation results are presented in Table 3.2. The interaction terms between land use at workplace and household attributes are excluded because preferences for work location are highly personal.

Regarding land use attributes, mixed effects of land use on work location choice are observed. Knowledge-intensive workers prefer to work in areas with higher percentages of commercial and business land, educational and cultural land, and medical and welfare land; however, labor-intensive workers are less likely to work in areas with more of these land use types. In addition, it is also found that knowledge-intensive workers are less likely to work in areas with more industrial-park land, while labor-intensive workers prefer to work in such areas. The rest of the variables have similar effects on work location decisions for both types of workers. While the mixed residential and commercial land shows a positive effect, the effect of rice-field and other agricultural land is negative.

People may self-select to work in a given area because of the particular features of their jobs. In the knowledge-intensive group, professionals and clerical staff prefer to work in the urban core and are less likely to work in the suburbs. In contrast, labor-intensive workers in agriculture, forestry and fishery are more likely to choose suburban locations. A similar tendency of manual workers in choosing work location is also observed. Regarding age, older workers in both groups tend to work in the urban core and are less likely to work in the suburbs. In the knowledge-intensive group, those with higher education levels are less likely to work in suburbs. Inversely, labor-intensive workers with lower education levels tend to choose their work location in suburbs.

c) Commuting mode choice

Table 3.3 shows the estimation results of commuting mode choice sub-model. As expected, commuting distance is negatively associated with choices of all three modes (i.e., walking, bicycles and motorcycles) in a statistically significant way for both types of workers. This indicates that people dislike commuting far from home.

As for land use attributes, land use diversity affects the two types of workers' mode choices while population density is only influential in knowledge-intensive workers' choices. Population density at residence and workplace shows an opposite effect on knowledge-intensive workers' mode choices. In contrast, land use diversity at residence and workplace shows an opposite effect on labor-intensive workers' mode choices. As for knowledge-intensive workers, the more dense the population at residential areas the more likely they will not use motorcycles and bicycles; however, those working in areas with a higher population density are more likely to ride motorcycles and bicycles. Looking at the diversity of land use, the more diverse the land use at residence, the less likely labor-intensive workers ride motorcycles and bicycles and the more likely knowledge-intensive workers walk to work. Those labor-intensive workers in areas with more diverse land use are more likely to use motorcycles and bicycles. The diversity of land use at workplace is positively linked with walking to work by knowledge-intensive workers.

For both types of workers, those with a higher level of bicycle or motorcycle ownership prefer to commute by cycling or motorcycle, and those with more children aged between 6 and 10 year old are less likely to commute by walking. It might reflect the fact that people often pickup and/or drop off their children by bicycles or motorcycles in Hanoi. Professionals in knowledge-intensive group are less likely to commute by bicycle, while clerical staffs prefer to commute by bicycle. Labor-intensive workers in the agriculture, forestry and fishery sector tend to commute by walking, while machine operators and assemblers and manual workers are less likely to ride a bicycle. Older knowledge-intensive

workers dislike commuting by motorcycle. Female workers in both types prefer to ride a bicycle to work, but are less likely to ride a motorcycle. Labor-intensive workers with high personal income tend to commute by motorcycle, but income is not influential to knowledge-intensive workers' motorcycle choice. Furthermore, knowledge-intensive workers with a master or Ph.D. degree tend not to commute by bicycle and motorcycle.

3.6. Conclusions

In the context of commuting, people may be able to self-select residential location, work location and commuting mode based on their neighborhood and travel preferences. It is likely that these self-selection effects may be varied across different job markets. But no relevant studies were found in existing literature. To fill this research gap, this study estimated a joint model of residential location, work location, and commuting mode choices by explicitly incorporating three types of self-selection effects with respect to pairs of the three choices. Analyzes were done using data collected in Hanoi, Vietnam to compare choices between labor-intensive workers (11,344) and knowledge-intensive workers (12,360).

The integrated models of residential location, work location and commuting mode have shown that:

- Self-selection effects caused by unobserved factors seem to exist across knowledge-intensive workers' choice of residential location and commuting mode (i.e. terms ω_{nim}). However, these self-selection effects are insignificant for labor-intensive workers. This finding suggests that the design of land use – transportation system in the future should consider the change in the structure of labor market, especially in developing countries.
- Self-selection effects caused by unobserved factors seem to exist across work location and commuting mode in both groups of workers (i.e. terms ψ_{nwm}). The

influencing magnitudes of terms ψ_{nwm} on work location and residential location are not as large as expected.

- The significant influences of self-selection effects caused by unobserved factors across residential and work location also are captured and their influencing magnitudes are relatively significant. In contrast, Paleti et al. (2013) estimated that unobserved factors common to residential location and workplace were not influential. Thus, different research contexts show inconsistent observations, suggesting that more case studies should be done in the future.
- Effects of land use attributes and socio-demographics on choices of labor-intensive and knowledge-intensive workers are mixed. Different types of land uses and different levels of land use diversity as well as population density also result in different choices. Labor-intensive and knowledge-intensive workers prefer different types of land uses in their location choices. In most of the cases, land use diversity at residence and at workplace shows opposite influences on the commuting mode choice. This is also true for the population density.

The differing influences of more detailed job categories on the three choices are also confirmed. As a trend, knowledge-intensive employment is centralized while labor-intensive employment is decentralized in the context of Hanoi City. Such findings may be useful to city planners and policy makers in Hanoi City. Hanoi government is planning to develop high-technology parks and eco-industrial parks in suburban areas from 2020, such as the Hoa Lac satellite city, one of five satellite cities, which will be developed as a city of science, a place of gathering intelligence and the most advanced technologies in Vietnam, and a center of high-quality human resources (Ministry of Construction, Government of Viet Nam, 2009).

To avoid issues of reverse commuting and even higher high car usage in future, it is important to design land use in such a way as to encourage people to work and live in close proximity. As for Hanoi, it is a motorcycle dependent city (Hung, 2006). Generally speaking, cars are suitable for longer trips while motorcycles are more suitable for shorter trips (Tuan, 2011). As expected, this study confirmed a significant influence of motorcycle ownership on residential location and commuting mode choices. Moreover, significant interdependencies between residential and work locations partially indicated that people prefer working and living in the same areas. Perhaps, the preferences of the residents of Hanoi for driving motorcycles lead to their preferences for shorter commuting distance. In other words, they may prefer to live closer to their workplaces.

Having summarized the findings of this study, there are several limitations that should be mentioned. First, the socio-economic environment of cities in developing countries, such as Hanoi, is evolving rapidly. It may therefore be desirable, if possible, to capture temporal dynamics between long-term and short-term choices. Second, high variance proportions explained by error terms in commuting mode choice suggest that more observed factors should be included in the model estimation. In the context of developing countries (Vietnam in the case of this study), people may face more internal constraints in choosing residential location choice, especially labor-intensive workers whose income is usually low. Additionally, external constraints should be considered such as the capacity constraint of a given area. Hence, cost variables related to location choices should be properly incorporated into the modeling process. Third, related to the life-oriented approach, this study only introduced workplace choice into the residential and travel behavior analysis framework. In future, residential and travel behavior should be analyzed jointly with more life choices. In particular, more surveys are needed which capture the effects of life choices and that of subjective factors such as attitudes and

lifestyle preferences. Fourth, it is worth representing joint decisions made by different household members and reflecting the influence of different household members into the location choice models. Fifth, this study observed the variation of self-selection effects for only two groups of workers. Classifying workers into more specific groups may derive more variety of self-selection effects. Finally, more case studies in different types of countries and cities should be carried out.

Table 3.1: Estimation results of residential location choice sub-model

Independent variables	Labor-intensive		Knowledge-intensive	
	Parameter	t-value	Parameter	t-value
Alternative-specific constant terms				
Urban core	-5.234***	-9.489	-3.692***	-21.378
Suburbs	3.645***	3.400	2.005***	7.884
Land use variables (including interaction terms with household attributes)				
Commercial and business land	0.160**	2.254	0.223***	10.225
Interacted with HH income	0.026***	2.738	0.003	1.608
Interacted with number of workers	-0.114***	-6.754	-0.061***	-9.188
Educational and cultural land	-0.098**	-2.028	0.050***	3.672
Interacted with HH income	-0.007	-0.970	0.007***	4.060
Medical and welfare land	-0.072*	-1.801	0.064***	5.995
Interacted with number of elderly	-0.041	-1.167	-0.019*	-1.722
Industrial-park land	0.058**	2.580	-0.102***	-10.377
Mixed residential and commercial land	0.266***	3.138	0.008	0.320
Transport and service land	0.123***	6.670	0.115***	12.802
Interacted with number of motorcycles	0.012	1.272	0.006*	1.714
Residential land	0.132***	21.714	0.101***	39.662
Individual attributes				
Job type				
Professional (*specific to urban core*)	-	-	0.378***	3.260
Professional (*specific to suburbs*)	-	-	-1.595***	-6.959
Clerical staff (*specific to urban core*)	-	-	0.142	1.621
Clerical staff (*specific to suburbs*)	-	-	-0.231	-1.503
Agriculture, forestry and fishery workers (*specific to urban core*)	-9.639***	-14.121	-	-
Agriculture, forestry and fishery workers (*specific to suburbs*)	21.650***	18.332	-	-
Machine operators and assemblers (*specific to urban core*)	0.275	0.878	-	-
Machine operators and assemblers (*specific to suburbs*)	-0.594	-0.842	-	-
Manual workers (*specific to urban core*)	-0.056	-0.216	-	-
Manual workers (*specific to suburbs*)	4.444***	8.174	-	-
Age (*specific to urban core*)	0.101***	8.763	0.030***	9.011
Age (*specific to suburbs*)	-0.224***	-10.646	-0.044***	-7.392
Educational level				
Master or PhD (*specific to urban core*)	-	-	0.117	0.709
Master or PhD (*specific to suburbs*)	-	-	-1.713***	-4.058
High school (*specific to urban core*)	-2.033***	-5.764	-	-
High school (*specific to suburbs*)	5.602***	7.049	-	-

Note: (*) Significant at 10% level, (**) Significant at 5% level, (***) Significant at 1% level, (-) not applicable.

Table 3.2: Estimation results of work location choice sub-model

Independent variables	Labor-intensive		Knowledge-intensive	
	Parameter	t-value	Parameter	t-value
Alternative-specific constant terms				
Urban core	-3.375***	-6.886	-5.052***	-25.671
Suburbs	2.556**	2.294	6.408***	20.000
Land use variables				
Commercial and business land	-0.137***	-5.988	0.074***	8.330
Educational and cultural land	-0.078***	-5.016	0.022***	3.634
Medical and welfare land	-0.124***	-4.601	0.036***	3.488
Industrial-park land	0.082***	3.697	-0.073***	-7.045
Mixed residential and commercial land	0.328***	4.233	0.160***	5.275
Rice-field and other agricultural land	-0.178***	-24.429	-0.221***	-54.207
Individual attributes				
Job type				
Professional (*specific to urban core*)	-	-	0.682***	4.906
Professional (*specific to suburbs*)	-	-	-1.589***	-5.894
Clerical staff (*specific to urban core*)	-	-	0.426***	4.185
Clerical staff (*specific to suburbs*)	-	-	-0.486***	-2.761
Agriculture, forestry and fishery workers (*specific to urban core*)	-10.330***	-17.500	-	-
Agriculture, forestry and fishery workers (*specific to suburbs*)	22.480***	18.970	-	-
Machine operators and assemblers (*specific to urban core*)	-0.008	-0.025	-	-
Machine operators and assemblers (*specific to suburbs*)	-0.820	-1.117	-	-
Manual workers (*specific to urban core*)	-0.570**	-2.282	-	-
Manual workers (*specific to suburbs*)	5.014***	8.978	-	-
Age (*specific to urban core*)	0.048***	4.579	0.011***	2.961
Age (*specific to suburbs*)	-0.175***	-8.846	-0.012*	-1.779
Educational level				
Master or PhD (*specific to urban core*)	-	-	0.307	1.450
Master or PhD (*specific to suburbs*)	-	-	-1.513***	-3.107
High school (*specific to urban core*)	-1.830***	-5.406	-	-
High school (*specific to suburbs*)	6.445***	7.823	-	-

Note: (*) Significant at 10% level, (**) Significant at 5% level, (***) Significant at 1% level, (-) not applicable.

Table 3.3: Estimation results of commuting mode choice sub-model

Independent variables	Labor-intensive		Knowledge-intensive	
	Parameter	t-value	Parameter	t-value
Alternative-specific constant terms				
Walk	1.047***	15.801	0.890***	4.985
Bicycle	0.483***	2.621	0.358**	2.097
Motorcycle	-1.124***	-3.865	1.169***	5.623
Commuting distance				
Walk	-0.588***	-14.010	-0.983***	-22.392
Bicycle	-0.179***	-10.804	-0.273***	-17.128
Motorcycle	-0.063***	-4.367	-0.149***	-19.257
Household attributes				
Bicycle ownership (*specific to bicycle*)	0.483***	17.155	0.844***	19.476
Motorcycle ownership (*specific to motorcycle*)	0.885***	16.185	0.576***	17.319
No. of children aged between 6 -10 (*specific to walk*)	-0.157***	-2.582	-0.289**	-2.385
Individual attributes				
Job type				
Professional (*specific to bicycle*)	-	-	-0.339*	-1.971
Clerical staff (*specific to bicycle*)	-	-	0.163	1.585
Agriculture, forestry and fishery workers (*specific to walk*)	1.093***	15.449	-	-
Machine operators and assemblers (*specific to bicycle*)	-0.638***	-4.606	-	-
Manual workers (*specific to bicycle*)	-0.210***	-3.188	-	-
Age (*specific to walk*)	0.0001	0.051	-	-
Age (*specific to motorcycle*)	-	-	-0.026***	-9.557
Female (*specific to bicycle*)	0.247***	4.181	0.951***	10.007
Female (*specific to motorcycle*)	-1.185***	-12.986	-0.142**	-2.057
Motorcycle driving license (*specific to bicycle*)	-0.624***	-8.055	-1.010***	-10.768
Motorcycle driving license (*specific to motorcycle*)	2.294***	16.917	1.975***	22.930
Personal income (*specific to motorcycle*)	0.249***	8.194	0.023	0.996
Educational level				
Master or PhD (*specific to bicycle*)	-	-	-1.555***	-3.825
Master or PhD (*specific to motorcycle*)	-	-	-0.268*	-1.748
High school (*specific to bicycle*)	0.245*	1.701	-	-
High school (*specific to motorcycle*)	-0.114	-0.802	-	-
Land use and location				
Land use mix at residence (*specific to walk*)	-	-	1.618***	4.259
Land use mix at residence (*specific to bicycle*)	-0.903**	-2.356	-	-
Land use mix at residence (*specific to motorcycle*)	-1.846***	-4.330	-0.493**	-2.379
Land use mix at work place (*specific to walk*)	-	-	0.383	0.972
Land use mix at workplace (*specific to bicycle*)	1.996***	5.389	1.050***	5.276
Land use mix at workplace (*specific to motorcycle*)	1.489***	3.723	-	-
Population density at residence (*specific to bicycle*)	-0.0003	-0.863	-0.001**	-2.474
Population density at residence (*specific to motorcycle*)	0.0001	0.400	-0.0004**	-2.439
Population density at workplace (*specific to walk*)	-	-	-	-
Population density at workplace (*specific to bicycle*)	-0.0004	-1.156	0.0002	0.682
Population density at workplace (*specific to motorcycle*)	0.0002	0.685	0.001***	2.796

Note: (*) Significant at 10% level, (**) Significant at 5% level, (***) Significant at 1% level, (-) not applicable.

Table 3.4: Covariance matrix for integrated model

a) Labor-intensive

	Residential			Work			Mode			
	Urban core	Urban fringe	Suburban	Urban core	Urban fringe	Suburban	Walk	Bicycle	Motorcycle	Others
Residential										
Urban core	1.0									
Urban fringe	0.0	1.0								
Suburban	0.0	0.0	1.0							
Work										
Urban core	4.895***	0.0	0.0	1.0						
Urban fringe	0.0	0.0	0.0	0.0	1.0					
Suburban	0.0	0.0	13.650***	0.0	0.0	1.0				
Mode										
Walk	0.0	0.0	0.0	0.0	0.0	0.0	1.0			
Bicycle	0.0	0.0	0.279	0.0	0.0	0.105**	0.0	1.0		
Motorcycle	0.356	0.0	0.0	0.747***	0.0	0.0	0.0	0.0	1.0	
Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

b) Knowledge-intensive

	Residential			Work			Mode			
	Urban core	Urban fringe	Suburban	Urban core	Urban fringe	Suburban	Walk	Bicycle	Motorcycle	Others
Residential										
Urban core	1.0									
Urban fringe	0.0	1.0								
Suburban	0.0	0.0	1.0							
Work										
Urban core	1.545***	0.0	0.0	1.0						
Urban fringe	0.0	0.0	0.0	0.0	1.0					
Suburban	0.0	0.0	3.609***	0.0	0.0	1.0				
Mode										
Walk	0.0	0.0	0.0	0.0	0.0	0.0	1.0			
Bicycle	0.0	0.0	0.205**	0.0	0.0	0.098***	0.0	1.0		
Motorcycle	0.218***	0.0	0.0	0.079***	0.0	0.0	0.0	0.0	1.0	
Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

Note: (*) Significant at 10% level, (**) Significant at 5% level, (***) Significant at 1% level.

Table 3.5: Estimation results of proportions of variances

	Labor-intensive workers			Knowledge-intensive workers		
Residential location choice	$Var(U_{UC} - U_{UF})$	$Var(U_{SB} - U_{UF})$		$Var(U_{UC} - U_{UF})$	$Var(U_{SB} - U_{UF})$	
Land use (βx)	11.39%	3.03%		35.11%	24.48%	
Socio-demographics (βx)	69.29%	90.44%		21.12%	27.82%	
Self-selection term (π_{niw})	7.01%	3.26%		10.88%	16.06%	
Self-selection term (ω_{nim})	1.89%	0.47%		4.09%	3.83%	
Error term ($\frac{pi^2}{3}$)	10.42%	2.90%		28.80%	27.81%	
Total	100.00%	100.00%		100.00%	100.00%	
Work location choice	$Var(U_{UC} - U_{UF})$	$Var(U_{SB} - U_{UF})$		$Var(U_{UC} - U_{UF})$	$Var(U_{SB} - U_{UF})$	
Land use (βx)	10.41%	8.02%		37.20%	51.93%	
Socio-demographics (βx)	70.77%	86.58%		34.95%	26.02%	
Self-selection term (π_{niw})	6.54%	2.73%		7.19%	7.55%	
Self-selection term (ψ_{nwm})	2.56%	0.24%		1.63%	1.24%	
Error term ($\frac{pi^2}{3}$)	9.73%	2.43%		19.03%	13.08%	
Total	100.00%	100.00%		100.00%	100.00%	
Commuting mode choice	$Var(U_{walk} - U_{other})$	$Var(U_{bike} - U_{other})$	$Var(U_{motor} - U_{other})$	$Var(U_{walk} - U_{other})$	$Var(U_{bike} - U_{other})$	$Var(U_{motor} - U_{other})$
Land use & Commuting distance (βx)	41.92%	4.48%	0.43%	81.13%	16.43%	6.51%
Socio-demographics (βx)	4.93%	12.90%	53.25%	0.07%	21.21%	23.38%
Self-selection term (ω_{nim})	-	10.54%	5.82%	-	6.97%	8.11%
Self-selection term (ψ_{nwm})	-	6.46%	8.43%	-	4.82%	4.88%
Error term ($\frac{pi^2}{3}$)	53.16%	65.62%	32.07%	18.79%	50.66%	57.12%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Chapter 4 The Dynamic Interdependence between Residence in Urban Fringe and Motorcycle Ownership in Hanoi city

4.1. Introduction

The population living in urban areas is forecast to reach 6.3 billion in 2050, accounting for approximately 68% of the total world population (United Nations, 2011). Much of the world's population growth is expected to be concentrated in urban areas in developing countries (Cohen, 2006). Coinciding with urbanization, there is also expected to be a rapid increase in motorized vehicle ownership (Dargay and Gately, 1999; Dargay, 2001; Tuan, 2011).

In the context of developed-country cities, it is generally argued that urban sprawl and car ownership are moving hand-in-hand (Dieleman and Wegener, 2004; García-Palomares, 2010; Glaeser and Kahn, 2003; Travisi, Camagni et al., 2010). In major Southeast Asian cities, however, the process of urbanization and motorization are quite different from that in Western cities (Cervero, 2013; Murakami et al., 2005). Firstly, motorization in Southeast Asian cities (e.g. Hanoi and Ho Chi Minh cities) is commonly characterized by the fast growth of motorcycle ownership rather than car ownership (Cervero, 2013; Hung, 2006). In other words, motorcycles play a main role in Southeast Asia citizens' daily travel. Secondly, urbanization in Southeast Asian cities is commonly characterized by monocentric urban form and higher density (Cervero, 2013; Hung, 2006). Specifically, population density of cities in Asian developing countries are generally more than twice as great as that in Europe and five-times as great as that in land-rich developed countries like the U.S. and Australia (Cervero, 2013). Such urban growth patterns and motorcycle ownership are likely to be interdependent, but this relationship is not yet well understood.

In travel behavior research, the interdependence between urbanization and motorization has been partially explained as the outcome of people's choices of residential location and vehicle ownership. It is generally assumed that residential location and vehicle ownership are interdependent. Such interdependence may be partially caused by self-selection effects that are induced by people's socio-demographics and attitudes (Bhat and Guo, 2007; Biying et al., 2012). For instance, people with a strong preference for motorcycles may prefer living in areas close to the city center and own more motorcycles, because cars are suitable for long-distance trips while motorcycles are suitable for short- or medium-distance trips (Tuan, 2011). However, most of our understanding of the interdependence between residential location and vehicle ownership comes from cross-sectional studies in the U.S. and European countries, where cars are dominant in their citizens' daily travel, and the economy, housing and transport supply are stable.

In the coming years, Southeast Asian developing countries will be one of the key drivers of world economic growth (OECD, 2015; World Bank, 2015a). This means that economic growth of such countries is moving forward. At the same time, housing and transport supply is expanding. Additionally, people' life situation and preferences may vary over time, leading to changes in self-selection effects over time. Hence, there is no reason to expect the interdependence between residential location and vehicle ownership to be unchanged either across geographies or over time; particularly in the rapidly growing cities of Southeast Asia. An emerging question here is "has the interdependence between residential location and vehicle ownership in Southeast Asian cities changed over time?". Taking Hanoi city as a case study, this study aims to capture the dynamic interdependencies between residential location and motorcycle ownership using longitudinal data from 2000 to 2011.

The remainder of this paper is organized as follows: a brief review of literature is given in Section 4.2. Following this section, the integrated model is presented in Section 4.3. Next, Section 4.4 presents case context, survey and data. After that, the estimation results of the joint model are given in Section 4.5. In the last section, conclusions and limitations are presented as well as several suggestions for future research.

4.2. Literature Review

People's residential location and vehicle ownership choices are often assumed to be interrelated. Hence, the joint analysis of residential location and vehicle ownership has been done in the transportation field, using either aggregate models (Bayer et al., 2011; Gaube and Remesch, 2013) or disaggregate models (Gabriel and Painter, 2012; Potoglou and Kanaroglou, 2008). Because this study collected disaggregated data[3], the literature review will focus on the disaggregate model.

The observed interrelationship between long-term choices (e.g. residential location) and mid-term choices (e.g. vehicle ownership) may be part of causal effect and part of self-selection effect (Bhat and Guo, 2007; Biying et al., 2012). People's choices generally are affected by not only objective factors but also subjective factors (e.g., attitudes or liking). An issue which emerged from this area of study is the role of travel preferences and neighborhood preferences in the relationship between land use and residential/travel choice (Handy et al., 2005; Van Wee, 2009). This issue is generally called attitude-induced self-selection. In the context of residential location, self-selection is defined as "the tendency of people to choose locations based on their travel abilities, needs and preferences" (Litman, 2011; Mokhtarian and Cao, 2008). Following this definition, Van Wee (2009) extends the scope of self-selection and gives a more general definition as follows: "the tendency of people to make choices that are relevant for travel behavior, based on their abilities, needs

[3] Disaggregate data refers to data collected by individuals or households.

and preferences". Generally, self-selection may be induced by people's socio-demographics and attitudes (Mokhtarian and Cao, 2008).

In the context of residential location and vehicle ownership, we re-define self-selection as "the tendency of people to make residential location and vehicle ownership choices based on their abilities, needs and preferences". For example, households with a strong preference for motorcycles are likely to reside in areas close to city center and own more motorcycles. If self-selection effects exist, there are three issues should be considered: i) simultaneity, ii) omitted variables and iii) non-random assignment. The first issue is that residential location and travel choices are chosen at the same time (Paleti et al., 2013). The second issue is the correlation between land use and unobserved variables (Herick and Mokhtarian, 2015). The third issue is that people who live in the same areas may share the same attitudes regarding travel and neighborhood (Herick and Mokhtarian, 2015).. Controlling for these issues, a possible approach for dealing with both issues is to model residential and travel choices simultaneously (Bhat and Guo, 2007; Paleti et al., 2013; Pinjari et al., 2008; Pinjari et al., 2007). By parameterizing random components that can partially incorporate self-selection effects caused by unobserved factors (e.g., travel attitudes or environmental-friendly lifestyle), Bhat and Guo (2007) proposed an integrated model of residential location and car ownership. Based on this approach, Pinjari et al. (2008) captured self-selection effects in the context of residential location and bicycle ownership. In a similar vein, Paleti et al. (2013) further examined self-selection effects in an integrated model of residential location, work location, car ownership, commuting distance, commute mode and number of stops on commute tours.

While numerous studies on self-selection can be found in developed countries, just a few studies were conducted in developing countries. Generally, studies in developing countries found that people's residential and travel choices in developing countries seem to

depend more on their socio-demographics rather than their attitudes (Masoumi, 2013; Sanit, 2014; Tsai, 2009). Additionally, almost all of these studies used cross-sectional data. As proposed by Scheiner (2014) and Zhang (2014), people's life situation and preferences may change over time (i.e. dynamic self-selection effects), leading to the change in interrelationships between residential and travel choices over time. For example, a young student may prefer commuting by bus and living close to a bus stop. After graduation and getting a job, he or she may prefer commuting by motorcycle and living in a motorcycle-oriented neighborhood. This may be especially true in developing countries where the change in socio-economic conditions is quite fast. In the context of developing countries, therefore, it is essential to control for the variation of self-selection effects when we model the dynamics of the interrelationship between residential and travel choices.

Based on existing studies of the joint analysis of residential location and vehicle ownership, three main points are summarized as follows: 1) the majority of studies are conducted in U.S. or European countries, 2) only a few articles have been developed to study the interrelationship between residential location and motorcycle ownership, and 3) there does not seem to be any modeling that accounts for dynamic self-selection effects. Therefore, this research makes a three-fold contribution to the literature. First, by focusing on a case study in Southeast Asia, this research gives an empirical finding from one of most rapidly developing areas in the world. Second, this research shows an insight into the interrelationship between residential location and motorcycle ownership. Such interrelationship has not been well studied and documented very widely in the literature. Third, this research attempts to develop a joint model of residential location and motorcycle ownership that accounts for dynamic self-selection. In summary, this is a unique study in the arena of residential location and travel choice as it controls for the dynamics of self-selection effects.

4.3. Fringe Development and Motorcycle Ownership in Hanoi city

In this study, Hanoi city is selected as a case study. Even though the administrative boundary of Hanoi city was expanded toward to the West in 2008, urbanization in Hanoi in the period 2000-2011 was basically concentrated in the area of old Hanoi (Pham and Yamaguchi, 2011). In this study, therefore, we only focus on old Hanoi. By 2011, more residents lived in urban fringe and suburban areas than in urban core areas (see Figure 4.1). In the 1950s, however, number of residents in the urban core is a half as large as that in suburban areas, 80,821 (persons) versus 136,079 (persons), respectively (Turley, 1975). The most rapid growth of population in urban core occurred in the 1960s, 1970s and 1980s. By 1985, the population in urban core reached approximately 900,000 residents, and is larger than that in suburban areas (Hanoi Statistical Office, 1986). From the 1950s to 1980s, Hanoi residents' settlement was basically concentrated in urban core areas. At the same time, bicycles were a dominant mode of transport in Hanoi residents' daily travel. After the reform of the economy in 1986, the economy has grown significantly. Coinciding with economic growth, urbanization and motorization in Hanoi city are characterized by fringe development and growth of motorcycle ownership rather than suburbanization and growth of car ownership. Due to the lack of population and vehicle ownership data in Hanoi in 1990s, we cannot analyze the trend of population by areas and vehicle ownership in Hanoi in this period. In the 2000s, the population in urban core areas was quite stable, around one million residents. The population in areas outside the urban core have continued to grow rapidly, especially in the urban fringe. The number of residents in the urban fringe increased sharply from 700,000 in 2000 to 1,200,000 residents in 2011 (See Figure 4.1). It means that half a million people have settled in the urban fringe areas within 10 years. As can be seen from Figure 4.2, the population densities in the urban core and suburban areas is stable in the 2000s, while that in urban fringe areas climbed rapidly. At

the same time, there was a fast increase in motorcycle ownership in Hanoi city. This phenomenon of urbanization and motorization can be partially explained as an outcome of people's residential location and motorcycle ownership choices. For example, a single and young man prefers using motorcycle for his daily travel and living in urban fringe areas close to the city center. After getting married with a woman with high preference for motorcycle, he bought one more motorcycle for his wife and keeps living in urban fringe areas. With respect to behavioral aspects, our hypothesis is that the interdependence between people's residence in urban fringe areas and motorcycle ownership choice has been strengthened over time.

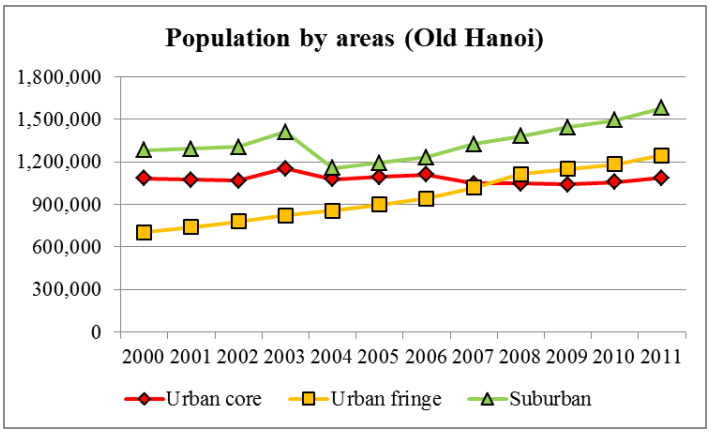


Figure 4.1: The population of old Hanoi city by areas, 2000-2011

Source: (Hanoi Statistical Office, 2007, 2011, 2012)

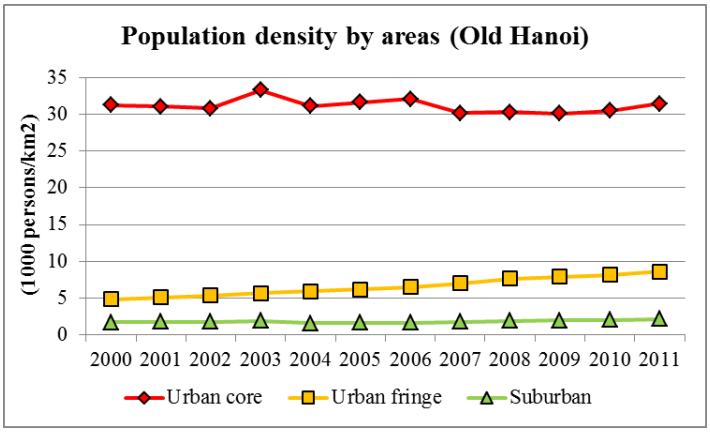


Figure 4.2: The population density of old Hanoi city by areas, 2000-2011

Source: (Hanoi Statistical Office, 2007, 2011, 2012)

4.4. Methodology

The basic idea of the joint model developed here is similar to Pinjari et al. (2008) and Chikaraishi et al. (2011). In this study, however, the distinctive point is that the dynamic interdependence between residential location and motorcycle ownership is explored. Basically, we added common random components into both equations of residential location and motorcycle ownership in order to represent the interdependence between residential location and motorcycle ownership. Such random components may include household-specific unobserved factors (such as attitudes or lifestyle) that impact households' sensitivity to both residential location and motorcycle ownership choices. Hence, these common random components can partially capture self-selection effects due to unobserved factors. Additionally, self-selection effects are also captured by common explanatory variables (i.e. socio-demographics) in both equations of residential location and motorcycle ownership. In this study, the joint modeling approach is further improved in order to consider dynamics in self-selection effects.

Let n ($n=1,2,..,N$), r ($r=1,2,..,R$), m ($m=1,2,...,M$), and t ($t=1,2,...,T$) represent households, residential location, motorcycle ownership and time, respectively. The utility function for each choice is defined as follows:

Residential location choice (binary logit):

$$u^*_{nr(t)} = \beta_r x_{nr(t)} + \omega_{n(t)} + \varepsilon_{nr} \; ; \; u_{nr(t)} = \begin{cases} 1, & u^*_{nr(t)} > 0 \\ 0, & otherwise \end{cases} \quad (1)$$

Motorcycle ownership choice (ordered probit):

$$u^*_{nm(t)} = \beta_m x_{nm(t)} \pm \omega_{n(t)} + \varepsilon_{nm} \; ; \; u_{nm(t)} = m \; if \; \varphi_{m-1} < u^*_{nm(t)} < \varphi_m \quad (2)$$

where $x_{nr(t)}$ and $x_{nm(t)}$ are vectors of explanatory variables including household characteristics, land use attributes, and/or those interaction terms; β_r and β_m are vectors of parameters; and ε_{nr} and ε_{nm} are error terms following an identical and independent Gumbel distribution, respectively. In this modeling system, the interdependencies between residential location and vehicle ownership choices are represented by common random component $\omega_{n(t)}$ which is assumed to be normally distributed with mean being zero and variance being $\sigma^2_{n(t)}$. The "$\pm$" signs in front of common random components in equation (1) and (2) mean that the correlation in the common unobserved terms may be positive or negative.

As mentioned above, the common random component may include household-specific unobserved factors. In other words, the interdependence between residential location and motorcycle ownership involve self-selection effects caused by unobserved factors. Probably, the interdependence between residential location and motorcycle ownership choices is likely to vary over time because of the change in people's life situation and preferences (e.g., attitudes and liking). It is very difficult to observe people's attitudes and liking over time. But it is possible to control for such issues when modeling the interdependence between residential location and motorcycle ownership. This can be done by setting up the magnitude of the standard deviation of the common random components as a function of time. In the context of Hanoi city, it is hypothesized that the interdependence between residence in urban fringe and motorcycle ownership has been strengthened over time. Hence, we assumed that the relationship between common random terms and time is simply linear. In this case, common random components $\omega_{n(t)}$ in equation (1) and (2) can be expressed as:

$$\omega_{n(t)} \sim N\left(0, \sigma_{n(t)}\right) \text{ in which } \sigma_{n(t)} = \exp(C + \lambda * time) \quad (3)$$

where C is a constant, $time$ is time series ($time$=1,2,…T), and λ is the corresponding parameter.

By year, assuming that decision-makers choose a set of alternatives that give the highest utilities, the following conditional likelihood can be written as:

$$L(\beta_r, \beta_m|\omega_{n(t)}) = \prod_t \prod_n \prod_r \prod_m \left(\frac{\exp[\beta_r x_{nr(t)}+\omega_{n(t)}]}{1+\exp[\beta_r x_{nr(t)}+\omega_{n(t)}]}\right)^{d_{nr(t)}} * \left(\frac{1}{1+\exp[\beta_r x_{nr(t)}+\omega_{n(t)}]}\right)^{1-d_{nr(t)}} *$$

$$\left(\Phi[\varphi_m - \beta_m x_{nm(t)} \pm \omega_{n(t)}] - \Phi[\varphi_{m-1} - \beta_m x_{nm(t)} \pm \omega_{n(t)}]\right)^{d_{nm(t)}} \quad (4)$$

where $d_{nr(t)}$ is a dummy variable which is equal to 1 if household "*n*" chooses residential location "*r*" at time point "*t*" and 0 otherwise and $d_{nm(t)}$ is a dummy variable which is equal to 1 if household "*n*" owns "*m*" number of motorcycles at time point "*t*" and 0 otherwise.

The unconditional likelihood function is:

$$L(\beta_r, \beta_m, \sigma_{n(t)}) = \int_{\omega_{n(t)}} [L(\beta_r, \beta_m|\omega_{n(t)}) * \phi(\omega_{n(t)}|\sigma_{n(t)})]\, d\omega_{n(t)} \quad (5)$$

where $\phi(\omega_{n(t)}|\sigma_{n(t)})$ is normally distributed with means being zero and variance being $\sigma^2_{n(t)}$.

The model estimation was done based on the Markov Chain Monte Carlo (MCMC) method by using the conventional software WinBUGS. A total of 150,000 iterations were done in order to obtain 10,000 draws: the first 50,000 iterations were used for burn-in in order to mitigate start-up effects, and the remaining 100,000 iterations were used to generate the 10,000 draws (i.e. every 10th iteration were retained). The convergence of the model estimation is confirmed based on Geweke diagnostics (Geweke, 1992).

4.5. Survey and Data

When the dynamic interdependence between residential location and vehicle ownership is studied, longitudinal data is required. Two approaches to collecting longitudinal data are panel survey and retrospective survey. Due to numerous difficulties in conducting panel surveys in developing countries, data of a retrospective survey was used in this study. A retrospective survey covering the 20-year period from 1991 to 2011 was conducted in September 2011 in Hanoi city. In this survey, we designed the life course calendar that includes several matrices with a same horizontal time axis for the observed time period from 1991 to 2011. Additionally, items of several life domains are arranged on the vertical axis. Specifically, respondents were asked to report four life domains, including: residence (e.g. household address and household property), household composition (e.g. household size and types of households), employment/education (e.g. job categories and level of education) and vehicle ownership (e.g. number of bicycles, motorcycles and cars). The survey method is face-to-face household interview survey. The survey locations are 4 sites in urban fringe areas and 2 two sites in suburban areas. At each site, 50 households were interviewed, so the total sample size of this survey is 300 households.

Because the data of population and other areal characteristics in the 1990s in Hanoi is not available, we cannot model residential locations for this period. This study only focuses on the 10-year period from 2000 to 2010. Descriptive analysis of the shares of residential location by areas and vehicle ownership is shown in Figure 4.3, 4.4 and 4.5. As for residential location, intuitively, the increase in the share of urban fringe and suburban areas in the 10-year period from 2000 to 2010 is partially caused by migrants from other provinces and people moving out of urban core areas. At the same time, there was a fast

growth of household motorcycle ownership, while the increase in household car ownership is modest.

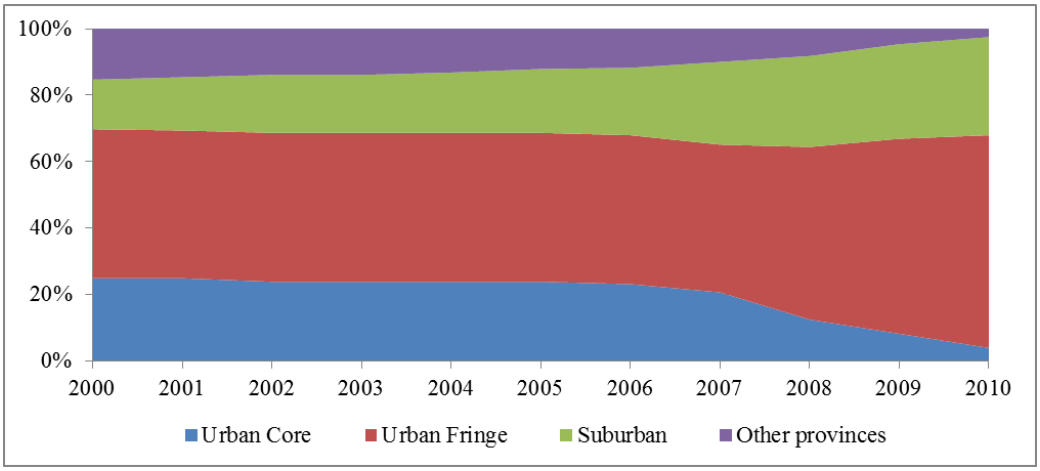


Figure 4.3: The share of residential location by areas

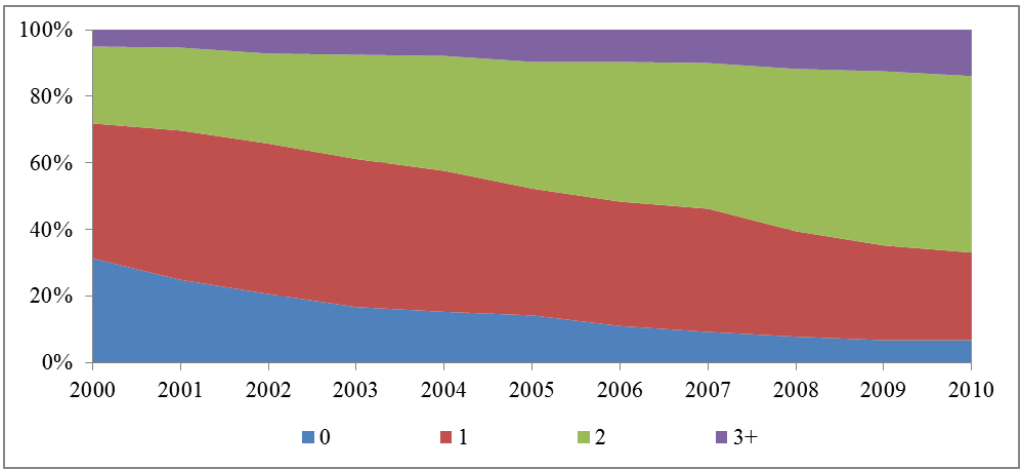


Figure 4.4: The share of motorcycle ownership by level

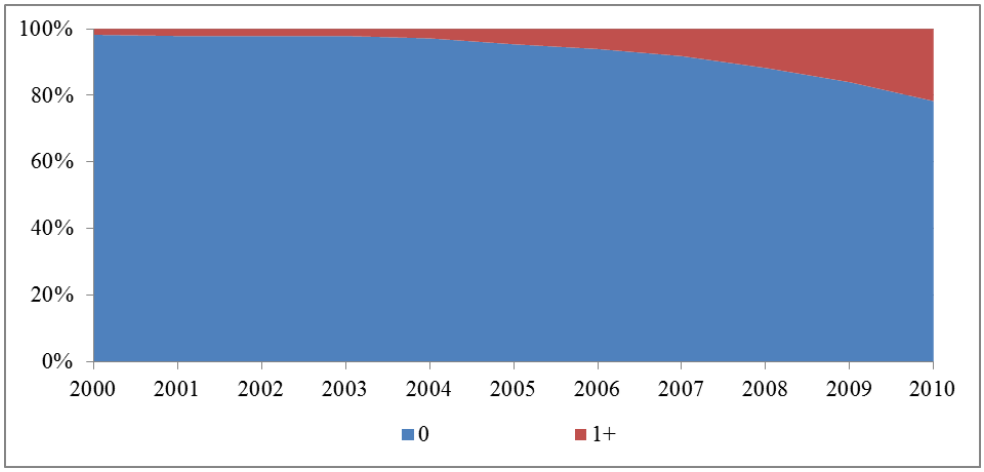


Figure 4.5: The share by car ownership by level

4.6. Results and Discussion

The model estimation results are shown in Table 4.1. The binary logit model of residential location choice (urban fringe or not) is presented in first block of Table 4.1. Excluding number of children, all of the explanatory variables included in the model of residential location are statistically significant. Firstly, the constant term is statistically significant, but it does not have substantial interpretation. Secondly, population density is positively associated with choosing to live in the urban fringe, but the interaction term between this variable and household income is negatively associated with choosing to reside in urban fringe areas. These imply that densely-populated areas in the urban fringe attract households, but high-income households do not prefer residing in such areas in urban fringe. Thirdly, the density of non-state companies has a positive influence on households' urban fringe choice, but the interaction term between this variable and number of household workers has a negative influence on households' urban fringe choice. These indicate that employment-center areas in the urban fringe attract households, but households with more workers are less likely to reside in such areas. Fourthly, the estimated parameter of household income has a positive sign, indicating that high-income households are more likely to live in urban fringe areas. Fifthly, the number of children is negatively associated with choosing to live in urban fringe areas. Similarly, the number of senior members has negative influences on households' urban fringe choice. These imply that households with more children or more senior members may not choose urban fringe areas.

The ordered probit model of motorcycle ownership choice is presented in the second block of Table 4.1. All of the explanatory variables included in the model of motorcycle ownership are statistically significant. As expected, household income is positively associated with motorcycle ownership, indicating that growth of motorcycle

ownership results from the increase in household income. Similarly, living area has a positive influence on household motorcycle ownership. The number of senior members is negatively associated with households' motorcycle ownership, while the number of children is positively associated with households' motorcycle ownership. This may be because residents of Hanoi city often pick up or drop off their children by motorcycle, so they need more motorcycles. Unsurprisingly, the number of household members having a motorcycle driving license has a positive influence on household motorcycle ownership.

The self-selection effects can be due to both socio-demographics and attitudes (Bhat and Guo, 2007; Mokhtarian and Cao, 2008). The results in the first and second blocks of Table 4.1 indicate the presence of socio-demographics that cause self-selection effects. Specifically, high-income households do not prefer living in densely populated areas in the urban fringe and those households have a high preference for motorcycles. Generally, it is expected that high-density areas will lead to low levels of motorized vehicle ownership and usage (Zhang, 2004). People are more likely to choose low-density areas when they prefer riding motorcycles. Next, households with more senior members are less likely to choose urban fringe areas and have a low preference for motorcycles. Finally, households with more workers do not prefer residing in employment-concentrated areas in urban fringe and own more motorcycles. Commonly, people's residence and workplace are close to each other and they may use active modes such as walking and cycling (Schwanen et al., 2001). People may choose a residence far away from their workplaces when they prefer riding motorcycles.

The parameters for variables in the standard deviation of the common random term between residential location and motorcycle ownership choices (i.e. $\omega_{n(t)}$ term) are presented in the third block of Table 4.1. It is noted that these variables are representative of the dynamics in self-selection effects due to household-specific unobserved factors (e.g.,

change in lifestyle and attitudes). The parameter of "time" variable is statistically significant, indicating that unobserved self-selection effects vary over time. The positive sign of the "time" variable means that, the influences of such unobserved self-select will increase over time. In other words, the interdependence between people's urban fringe and motorcycle ownership choices is strengthened over time.

Table 4.1: Estimation Results of Dynamic Joint Residential Location and Motorcycle Ownership Choice Model

Explanatory variables	Parameter	t-stat
In Residential Location Choice (binary logit)		
Constant (Urban Fringe)	-5.606***	-15.492
Population density (person/km2)	0.485***	11.055
Interacted with household income	-0.036***	-4.242
Density of non-state companies (companies/km2)	0.295***	10.777
Interacted with No. of workers	-0.013*	-1.918
Household income	0.449***	6.850
Number of children	-0.039	-0.706
Number of senior members	-0.156**	-2.331
In Motorcycle Ownership Choice (Ordered probit)		
Constant	-0.837***	-8.594
Household income	0.091***	6.060
Living area (m2)	0.170***	7.631
Number of senior members	-0.100***	-3.024
Number of children	0.142***	5.079
Number of workers	0.100***	3.431
Number of household members having motorcycle driving license	0.503***	16.296
Threshold	1.193***	63.060
Threshold	1.254***	67.953
In Standard Deviation Equation of Common error terms between Residential Location and Motorcycle Ownership [$\omega=exp(\beta 0 + \beta 1*t)$]		
Constant	-0.400*	-1.646
Time	0.489***	5.308

Note: (***) Significant at 1% level; (**) Significant at 5% level; (*) Significant at 10% level

Additionally, the joint model of urban fringe choice and car ownership choice was estimated by using the same joint-equation structure model. The parameter of the "time" variable is also statistically significant, indicating that unobserved self-selection effects vary over time. But the sign of the "time" variable is negative, which means that the influences of self-selection induced by unobserved factors may decrease over time.

4.6. Conclusions

The interdependence between residential location and vehicle ownership may be influenced partly by causal effects and partly by self-selection effects. Self-selection effects are often induced by socio-demographics and attitudes (Mokhtarian and Cao, 2008). Probably, the changes in life situation and attitudes over time induced the variation of self-selection effects, leading to the change in the interdependence between residential location and vehicle ownership. To shed light on this issue in the context of residential location and motorcycle ownership, this paper develops a joint model of residential location and motorcycle ownership that controls for self-selection effects. Unlike existing studies, this research accounts for the dynamics in self-selection effects by assuming a linear relationship between unobserved self-selection effects (i.e. random components) and time. This analysis was done by using longitudinal data of 300 households collected in Hanoi, Vietnam in 2011. The results indicate the presence of self-selection effects due to both observed socio-demographics and unobserved factors. Furthermore, this study confirms that self-selection effects vary over time. Based on this finding, this study gives an important message that ignoring the dynamics in self-selection effects may lead to a bias of land use and transport policies, especially in developing-country cities experiencing rapid economic growth and expanding housing and transport systems.

There are several limitations in this study. First, the relationship between self-selection effects and time is assumed to be linear. Depending on context, this relationship

is likely to be quadratic or fluctuating. In Japan or several European countries, for instance, the economic growth reached its peak and is even going down. Therefore, future research in the arena of residential and travel choices should examine such relationships across geographic contexts. Second, the number of available alternatives of residential location may change over time, but the choice set of residential location is fixed in this study. Choice set generation should be further considered in future studies in modeling dynamic choices of residential location. Adding to this, Palma et al. (2007) showed the importance of capacity constraints of spatial units in modeling residential location choice. Such capacity constraints of residential areas closer to city center may increase over time. Hence, future studies of residential location choice should deal with such issue. Finally, it is worth considering the relationships between household members and reflecting the influence of different household members into location choice models.

Chapter 5 Interdependences between current choices and future expectations in the context of Hanoians' residential location choices

5.1. Introduction

Revealed preference (RP) data are often used in the analysis of choice behavior. However, numerous studies indicate the value of future expectations (FE) in understanding and explaining choice behavior (Chan and Stevens, 2004; Van der Klaauw and Wolpin, 2008; van der Klaauw, 2012). Hence, the need to combine RP and FE data has been suggested directly and indirectly by researchers in the fields of both psychology and economics. Manski (1999) argued that RP analysis and expected choice analysis should be complementary. In a similar vein, Khan and Dhar (2007) conceptually argued that current choices can be affected by future choices.

Why do current choices influence expectations about future choices and vice versa? From the perspective of backward-looking behavior, choices are made "completely on the basis of the reinforcements (and punishments) for past behavioral choices" (Burke and Gray, 1999). This concept may refer to causal links between past and current behavior (also called state dependence). In the context of tourist behavior, for example, Wu et al. (2012) found that state dependence was negatively associated with tourism participation behavior, but positively associated with destination and travel mode choice behavior. From the perspective of forward-looking behavior, choices are made "on the basis of consequences of those choices bringing perceptions of the situation closer to (or further from) being in line with an internally held standard or goal" (Burke and Gray, 1999). This concept may refer to causal links between current choices and future expectations or goals. From an economic viewpoint, Bayer et al. (2011) indicated two sources inducing forward-

looking behavior in the context of the neighborhood choice problem, namely moving costs and wealth accumulation. For instance, households may be aware of housing prices and rationally select a neighborhood that shows lower current period utility in return for an increase in wealth.

Residential location choice has been studied by researchers in the fields of economics, urban geography, transportation, and psychology. Pagliara et al. (2010) summarized two main streams in the literature on residential location modelling. The first is rooted in economics, such as the theory of rent. The second is rooted in spatial interaction. Random utility theory is a branch of the first stream. Based on this theory, discrete choice models have been developed and widely applied in the transportation field. By applying discrete choice models, RP data have often been collected and used in modelling residential location choice (Bhat and Guo, 2007; Sermons and Koppelman, 2001; Zondag and Pieters, 2005); however, little attention has been paid to FE data. Zhang et al. (2012) confirmed the strong influence of future expectations on residential mobility over the life course based on data from a life history survey conducted in Japan. Furthermore, combining multiple sources of data is a useful way to analyze behavior (Hensher et al., 1999). Motivated by the above findings, this study aims to empirically explore the interdependences between current choices and future expectations with respect to residential location choice behavior. Such interdependences may occur within a location and/or between locations, where the former is called within-alternative interdependences and the latter between-alternative interdependences. The representation of interdependences is conducted by building a bivariate paired combinatorial logit (PCL) model to jointly estimate RP data (current choices) and FE data on residential location choice.

Furthermore, income has been treated as a key factor to explain housing affordability (Chen et al., 2010; Haffner and Boumeester, 2010). Bhat and Guo (2007) empirically revealed that household income is a dominant factor in the residential sorting. Particularly, low-income households reside in areas far away from their workplaces. This suggests that different income groups may have different preferences for residential locations. On the other hand, in large cities of developing countries, the target of this study, the large gap between house prices and income often hinders households from purchasing a house that satisfies their preferences and needs. However, it is expected that such a barrier may be reduced in the future due to increases in income or government interventions in the real estate market (e.g., providing loans with preferential interest rates), especially for low-income individuals. In this study, therefore, an additional objective is to measure and assess disparities in residential location choices between income groups from the perspective of interdependences between current choices and future expectations.

The remainder of this paper is structured as follows. Existing studies of future expectations are briefly reviewed in Section 2. Section 3 presents data sources, introduces the study area, and provides the results of aggregate analysis. Section 4 introduces the method for combining RP and FE data. Section 5 describes and discusses the results of model estimation. Section 6 summarizes the main findings, limitations, and avenues for future research.

5.2. Review of Future Expectations Studies in Choice Modelling

Numerous economic decisions are forward looking, where expectations of future outcomes are probably involved. Hence, understanding individuals' expectations is important to analyze their behavior and to evaluate the effects of policies in health, education, finance, migration, social protection, and many other areas (Delavande et al., 2011). A long-term objective of economists engaged in research on expectations is to

improve our ability to predict choice behavior (Manski, 2004). There are two main approaches to using subjective expectations about future events or decisions to explain observed choice decisions.

The first approach is to use choice expectations. Manski (1999) posed three incomplete scenarios in which researchers ask respondents about their expected choices. It is argued that stated choices may differ from actual choices because researchers typically provide respondents with less information than they would have in reality. When scenarios are incomplete, stated choices are point predictions of uncertain actual choices (Manski, 2004). A group of studies used expectations to predict choice behavior. In the literature on retirement behavior, Chan and Stevens (2004) investigated the relationship between retirement incentives and retirement behavior by using retirement expectations rather than directly observing actual retirement behavior. They found significant impacts of earnings, social security, and assets on individuals' expectations of continuing to work into their sixties. Van der Klaauw (2012) incorporated expectations of future choices in the estimation of dynamic models by assuming that expectations data were generated by the same model governing the actual choices. The results showed that expectations data could also provide similar information about the decision process to that provided by objective data on current or retrospective behavior.

The second approach is to use expectations about future events and choice data. In political science, Kuklinski and West (1981) found that individuals' expectations about financial well-being during the following year are significantly and strongly related to support for senate candidates. In consumer research, Stephens (2004) found an insignificant relationship between job loss expectations and household consumption using data collected in the U.S. Due to the importance of labor supply in national economics, economists have paid much attention to individuals' earning expectations and their college

major choices. The empirical evidence shows the significant influence of expectations about future earnings on college major choices (Arcidiacono et al., 2012; Berger, 1988).

In the first approach, future choices and current choices have been combined in a dynamic framework by assuming that expectations of future choices are functions of current information sets, and thus will generally depend on the same observed and unobserved factors that affect current choices (van der Klaauw, 2012). However, the interdependences between current choices and future choices are ignored.

Additionally, in transportation research, one can only find a limited number of studies dealing with the influence of future expectations. Using a dynamic generalized extreme value (DGEV) model proposed by Swait et al. (2000), Kuwano et al. (2011) and Wang et al. (2010) investigated the impacts of future expectations on travel mode choice and vehicle type choice. This study only focuses on future expectations about residential location choices. To the authors' knowledge, future expectations about residential location choices are a kind of residential preference. In the transportation field, numerous studies have investigated the role of residential preferences in explaining the relationship between residential neighbourhood characteristics and travel behavior by asking respondents about their preferences regarding location factors (Cao et al., 2009; Handy et al., 2005; Masoumi, 2013; Næss, 2009). These studies are related to the prevalent problem known as "residential self-selection". Litman (2011) defined residential self-selection as "the tendency of people to choose locations based on their travel abilities, needs and preferences". There are two main sources of residential self-selection: attitudes and socio-demographics (Mokhtarian and Cao, 2008). With respect to the former, the existing literature mainly focuses on location-related attitudes at the current time, so this study attempts to explore location-related attitudes in the future. The latter will be explained in the Method section.

In summary, the value of FE data in the analysis of choice behavior has not been well recognized in transportation studies. The above review suggests that backward-looking and forward-looking decisions might co-exist with respect to the same behavior, although this has been ignored in the literature (at least in that relating to transportation). Therefore, this study aims to fill this gap. Here, it should be noted that future expectations differ from stated preferences (SP). SP is usually measured by providing respondents with (hypothetical) information about their choice conditions in the future (Ben-Akiva and Morikawa, 1990). In contrast, "future expectations" is a term used to describe people's forward-looking behavior, which is in line with "an internally held standard or goal" (Burke and Gray, 1999). Such forward-looking or goal-oriented behavior may be not necessarily linked with any future conditions.

5.3. Method

Here, choice of residential location is represented by a discrete choice model, following the principle of random utility maximization, where the choice alternatives include locations indexed $i = 1, \ldots, I$. There are two types of choices: one from RP data and the other from FE data. It is expected that the two types of data may involve different levels of random noise. Following the idea proposed by Ben-Akiva and Morikawa (1990), to accommodate such influence of random noise in this study, it is assumed that error terms in RP and FE utility functions have the following relationship, where σ_{RP}^2 and σ_{FE}^2 are the respective variances of RP and FE error terms and μ is an unknown scale parameter to explain different levels of random noise in RP and FE data.

$$\sigma_{\mathrm{RP}}^2 = \mu^2 \sigma_{\mathrm{FE}}^2 \tag{1}$$

Accordingly, the utility functions for RP and FE can be written as follows:

$$U_{ni}^{RP} = V_{ni}^{RP} + \varepsilon_{ni}^{RP} = \beta X_{ni}^{RP} + \sum_k \gamma_k^{FE} d_{nk}^{FE} + \varepsilon_{ni}^{RP}, \quad (2)$$

$$\mu U_{nh}^{FE} = \mu\left(V_{nh}^{FE} + \tau_{nh}^{FE}\right) = \mu\left(\beta X_{nh}^{RP} + \sum_k \alpha_k^{RP} d_{nk}^{RP} + \tau_{nh}^{FE}\right), \quad (3)$$

where, *n* indicates a household, and *i* (or *h* or *k*) refers to alternatives in the choice set. The influence of RP and FE is reflected by introducing two dummy variables, d_{nk}^{FE} and d_{nk}^{RP}, which take a value of 1 if alternative *k* is chosen by household *n*, and γ_{nk}^{FE} and α_{nk}^{RP} are the parameters expressing the influence. In addition, $X_{ni/h}^{RP}$ represents a vector of factors explaining the RP choice and β is the corresponding parameter vector. Finally, ε_{ni}^{RP} and τ_{nh}^{FE} are error terms of the RP and FE utility functions.

In fact, the scale parameter in the study by Ben-Akiva and Morikawa (1990) is introduced to treat SP. SP data are "typically collected in a survey context under one or more detailed hypothetical market situations" (Ben-Akiva et al., 1994). In contrast, FE may "depend in part on conditions known to the individual at the time of survey and in part on events have not yet occurred and are not perfectly foreseeable" (van der Klaauw, 2012). First, this implies that people may partially rely on current information to shape their future expectations. Second, this may also suggest that expectations about future choices are not necessarily linked with a specified future context. Especially, expectations about future choices may just represent people's pure preferences that are formed without any future conditions. Van der Klaauw (2012) argued that future choice probabilities can be a function of the same parameters that determine the current choice probabilities. But current choices and expectations about future choices may be formed at different time points. Hence, an additional role of scale parameter, specified in equation (3), is to represent the influences of current attributes on FE.

Spatial correlation across alternatives arises naturally when alternatives correspond to spatial units (Bhat and Sener, 2009). In this study, the paired combinatorial logit (PCL) model developed by Koppelman and Wen (2000) was used, because it allows differential correlation between pairs of alternatives (see Figure 1). The choice probability for the combined FE/RP data is the product of probability of RP choice (P_{ni}^{RP}) and probability of FE choice (P_{nh}^{FE}):

$$\mathrm{P_{ni}} = \mathrm{P_{ni}^{RP}} \cdot \mathrm{P_{nh}^{FE}} = \left[\frac{\sum_{j\neq i} \exp\left(\frac{V_{ni}^{RP}}{1-sp_{ij}}\right)\left[\exp\left(\frac{V_{ni}^{RP}}{1-sp_{ij}}\right)+\exp\left(\frac{V_{nj}^{RP}}{1-sp_{ij}}\right)\right]^{-sp_{ij}}}{\sum_{k=1}^{J-1}\sum_{m=k+1}^{J}\left[\exp\left(\frac{V_{nk}^{RP}}{1-sp_{km}}\right)+\exp\left(\frac{V_{nm}^{RP}}{1-sp_{km}}\right)\right]^{1-sp_{ij}}}\right] \cdot \left[\frac{\sum_{j\neq h} \exp\left(\frac{V_{nh}^{FE}}{1-sp_{hj}}\right)\left[\exp\left(\frac{V_{nh}^{FE}}{1-sp_{hj}}\right)+\exp\left(\frac{V_{nj'}^{FE}}{1-sp_{hj}}\right)\right]^{-sp_{hj'}}}{\sum_{k=1}^{J-1}\sum_{m=k+1}^{J}\left[\exp\left(\frac{V_{nk}^{FE}}{1-sp_{km}}\right)+\exp\left(\frac{V_{nm}^{FE}}{1-sp_{km}}\right)\right]^{1-sp_{hj'}}}\right], \quad (4)$$

where sp_{ij} ($sp_{hj'}$) expresses the similarity between alternatives i and j (h and j'), and P_{ni}^{RP} and P_{nh}^{FE} are the probabilities that respondent n chooses alternatives i and h, respectively.

The PCL model is consistent with random utility maximization if the condition $0 \leq sp_{ij} < 1$ is satisfied for all pairs of alternatives. With respect to similarity parameter identification, it is necessary to set one or more of the similarity parameters equal to zero (Koppelman and Wen, 2000). Therefore, in this study, similarity parameter $sp_{UC\&SB}$ is normalized to make the estimation possible.

The log-likelihood function for the combined FE/RP model is described below. The maximum likelihood method is used to estimate this model by using the software R:

$$\mathrm{L} = \sum_{n=1}^{N}\sum_{i(h)=1}^{I(H)} \delta_{ni}^{RP} \log\left(\mathrm{P_{ni}^{RP}}\right) + \delta_{nh}^{FE} \log\left(\mathrm{P_{nh}^{FE}}\right), \quad (5)$$

where δ_{ni}^{RP} ($\delta_{\mathrm{nh}}^{\mathrm{FE}}$) are dummy variables that are equal to 1 if household n chooses alternative i (h) and 0 otherwise.

5.4. Data and Model Specification

5.4.1. Data Sources

This study uses data from the Household Interview Survey conducted by the Japan International Cooperation Agency (JICA) in Hanoi, Vietnam in 2005. Although the administrative boundary of Hanoi city was officially expanded toward the west in 2008, we only focus on 14 districts within the area of old Hanoi (see Figure 2). The survey was conducted as part of the Comprehensive Urban Development Programme in Hanoi (HAIDEP) (JICA, 2007). The survey area consists of old Hanoi city (including 14 districts or 228 traffic analysis zones) and adjacent areas in Hà Tây and Vĩnh Phúc provinces.

In this survey[4], respondents were asked to report not only their current residential location but also their expectations about housing type and location in future. The exact question on future expectations was: "Please choose the housing type and location in which you would like to live in the future." Respondents were asked to choose one type of housing and one location from a given choice set. In this study, we only used the data on location choices. Note that the survey is not a stated preference experiment, in which respondents usually make a decision based on clearly defined hypothetical choice attributes (Ben-Akiva et al., 1994). The choice set includes 14 districts within the old Hanoi area and some towns in adjacent areas, and no concrete alternative attributes were provided. In the literature on forward-looking behavior, it is emphasized that expectations of future outcomes (i.e., choices or events) play an important role in explaining and understanding choice behavior (Kuklinski and West, 1981; Berger, 1988; Carvajal et al.,

[4] Detailed contents of the questionnaire survey can be obtained directly from the first author.

2000; Chan and Stevens, 2004; Stephens Melvin, 2004; Delavande et al., 2011). Delavande et al. (2011) provided an excellent review of methods used to collect expectation data in developing countries. There are two methods used: non-probabilistic and probabilistic. The non-probabilistic method either uses Likert scales or asks simple questions such as "What do you think?" or "What do you expect?" These simple questions are often adopted in large-scale surveys in developing countries (Delavande et al., 2011), and in this study data on future expectations were collected using similar questions.

In this study, it is assumed that current residential choices are influenced by future expectations. Strictly speaking, it is necessary to collect data about future expectations at the time when the current choices were made. However, different people's choices about their current residential locations were made at different time points. Therefore, it is difficult to observe future expectations for all respondents at the same time. For this reason, future expectations recorded in 2005 were adopted as a proxy variable of future expectations that respondents had at the time they chose their current residential locations.

The final sample for the analysis in this paper consists of 13,712 individuals who are representatives of their households. Other data sets are also used in this analysis, including land-use characteristics and socio-economic and demographic information for each district. Land-use characteristics were obtained from the HAIDEP project. The land-use profile for 2005 is available at the administrative unit level (district level). Socio-economic and demographic data were obtained from the Hanoi Statistical Yearbook 2010, which includes detailed information about each district in 2005 such as population and number of elementary schools by district.

As mentioned in the first section, one of the purposes of this study is to measure and assess disparities in residential location choices between income groups. For this purpose, to simplify the discussion, we grouped respondents into either a low-income

group or a medium-to-high-income group. With regard to the cut-off point, average annual income per capita in Hanoi city in 2005 was about US$1,492 (exchange rate: US$1 = 16,000 VND) (Hanoi Statistical Office, 2007), meaning that monthly income per capita was US$124.38. We therefore placed respondents with a monthly income below US$125 in the low-income group and those with a monthly income of US$125 or more in the medium-to-high-income group.

5.4.2. Definition of Alternatives

Over the past few decades, urban and transport planners have been very interested in the urban form of a city: compact, decentralized, or some other form. For the purpose of investigating urban form, studies of residential location choice behavior often use spatially aggregated alternatives in their analysis. Tayyaran et al. (2003) examined the effects of telecommuting and intelligent transportation systems (ITS) on urban development patterns by assessing households' residential location choice decisions in the Ottawa–Carleton Region in Canada. Based on the current map, Tayyaran et al. divided this region into three distinct areas. The first area comprises central cities. The second area includes first-tier satellite nodes that are relatively close to the central cities. The third area consists of second-tier satellite nodes that are further from the central cities. In a similar vein, Vega and Reynolds-Feighan (2009) investigated the link between residential location and commuting mode under central, non-central, and suburban employment patterns. In their study, the definition of spatially aggregated alternatives is based on a geographic information system (GIS) and road distance to work. In a monocentric city model, three spatial areas were generated as follows: less than 5 km, 5–20 km, and more than 20 km from the city center. In a polycentric city model, six spatial areas were generated as follows: less than 5 km, 5–<10 km, 10–<20 km, 20–<30 km, 30–≤40 km, and more than 40 km from each of the employment sub-centers and the city center.

As described in Section 5.1, the main purpose of this study is to explore the interdependences with respect to residential location choice behavior, where the differences between current choices and future expectations are emphasized. To simplify the discussion, this study follows the idea of Tayyaran et al. (2003) to divide the residential locations in Hanoi into three types: urban core (UC), urban fringe (UF), and suburban (SB) (see Figure 1). The first area consists of four inner districts that are closest to the central business district (CBD) and are most densely populated. The second area includes five mediate districts that are further from the CBD and less densely populated. The third area comprises five outer districts that are a long way from the CBD and have low population density. It is noted that the choice set in the analysis of both RP and FE data consists of three alternatives: UC, UF, and SB.

Table 5.1: Means and standard deviations of actual choices and expected choices

Explanatory variable	Whole sample		Low income (LI)		Medium-to-high income (HI)		$Mean_{LI} - Mean_{H}$
	Mean	SD	Mean	SD	Mean	SD	
RP data (current choice)							
Current choice is urban core	0.396	0.489	**0.268**	0.443	**0.497**	0.500	-0.229 [a]
Current choice is urban fringe	0.291	0.454	0.260	0.439	0.315	0.465	-0.055 [a]
Current choice is suburban	0.313	0.464	**0.472**	0.499	**0.188**	0.390	0.284 [a]
FE data (future expectation)							
Future expectation is urban core	0.420	0.494	**0.312**	0.463	**0.504**	0.500	-0.192 [a]
Future expectation is urban fringe	0.280	0.449	0.251	0.433	0.303	0.460	-0.052 [a]
Future expectation is suburban	0.300	0.458	**0.437**	0.496	**0.192**	0.394	0.245 [a]

Note: [a] Means of low income are significantly different from that of higher income (significant at 5% level)

Table 5.1 shows the distributions of residential locations in RP and FE choices. In both choices, a majority of respondents prefer UC, followed by SB and UF areas. Significant differences between the low-income and medium-to-high-income groups are found in all three types of spatial choices. In RP data, 47.2% of the low-income group lived in SB areas and 26.8% lived in UC areas. Conversely, nearly half (49.7%) of the

medium-to-high-income group resided in UC areas and only 18.8% resided in SB areas. The shares of FE choices are quite consistent with those of RP choices. The FE choice of SB areas is most preferred by low-income individuals (43.7%) and least preferred by medium-to-high-income individuals (19.2%). In addition, the preferred alternative for medium-to-high-income respondents was UC areas, accounting for 50.4%; the share of UC areas among low-income respondents showed a modest increase from 26.8% (RP data) to 31.2% (FE data).

5.4.3. Explanatory Variables for Residential Location Decisions

In this study, explanatory variables in Table 5.2 were selected based on the literature review and preliminary studies. In the literature on residential location choices, the focus is on location factors and household-specific attributes. With respect to location attributes, the important role of measures of land-use composition (percentages of district-level area under different types of land use) and locational density (e.g., population density) in explaining and modelling residential location choice has been confirmed in numerous existing studies, especially in the transportation field (Bhat and Guo, 2004, 2007; Pinjari et al., 2009; Pinjari et al., 2007). Regarding household-specific attributes, measures of income and life-cycle characteristics (e.g., presence of children or number of children) have been mainly used in model estimations of residential location choice (Bayoh et al., 2006; Pinjari et al., 2011; Waddell et al., 2007). Additionally, differences in the sensitivities to neighbourhood characteristics across households are taken into account by adding interaction terms between household demographics and neighbourhood characteristics, following existing studies (Bhat and Guo, 2007; Minh Tu et al., 2013). These interaction terms may not only moderate effects of land use on residential location choice, but also control for the self-selection issue. In this study, therefore, four kinds of

explanatory variables are tentatively used for the residential location choice model: land-use composition, location density, household-specific attributes, and interaction terms.

As for data availability, the first group of variables (i.e., land-use composition) consists of 21 different types of land use, such as percentages of residential land, educational land, and other land. The second group is locational density. Several measures were used in this study, such as the ratio of number of primary schools to population (schools/1,000 persons), ratio of population living in urban area to total population, and ratio of number of non-state industrial companies to population (companies/1,000 persons). The third group is a set of household-specific variables, including income, number of children aged between 6 and 10 years old, number of seniors (i.e., who are aged 60 or above), number of adults (i.e., who are aged between 16 and 60), number of workers, and number of motorcycles. In fact, the household-specific attributes have been excluded in the model estimation. One practical reason for this is that adding income or other household-specific attributes as dependent variables did not result in statistically significant parameters. Another methodological reason is that the choice models for two income groups are estimated in this study, and just like other segmentation models based on age or other household attributes, which are usually ignored, income as dependent variable are ignored in this study. Finally, interactions between household-specific attributes and locational characteristics are included in the model. Because households are not homogeneous in their income levels and may sort themselves according to their ability to pay, it is necessary to include household income in the interaction terms. Additionally, it is expected that households in different life-cycle stages may prefer different locational characteristics. For example, households with more children aged between 6 and 10 years old prefer to reside in areas with a high ratio of primary schools, while households with more seniors prefer to reside in areas with a high percentage of medical land. With respect

to transport policy, it is interesting to see how residential location choices are affected by vehicle ownership.

5.5. Model Estimation and Discussion

Three models were estimated in the analysis. Model 1 was estimated using the entire sample of 13,712 households. Then, the entire sample was divided into low-income and medium-to-high-income groups, which were estimated in Model 2 and Model 3, respectively. Table 3 shows the results of three combined FE/RP models, including the estimated parameters, p-values, and levels of statistical significance for variables. Regarding model accuracy, the values of adjusted McFadden's rho-squared in Model 1, Model 2, and Model 3 are shown in the bottom line of Table 5.3; 0.5023, 0.5468, and 0.4916, respectively. These results suggest that the developed models are good enough to represent individuals' decisions on where to live. The estimated scale parameters (μ) in the three models are less than one and are all statistically significant, indicating that the error terms from the FE data have larger variances than those from the RP data. The scale parameter with a value close to one implies that the distribution of the FE error term is quite similar to that of the RP error term. As for the second role of scale parameter, its value being close to one indicates that influences of current attributes on FE are quite similar to those on RP. Interestingly, there is a large difference in numerical values of scale parameters between two income groups. The scale parameter in the model of the medium-to-high-income group is 0.7055, while that in the model of the low-income group is 0.1290. These results suggest that, (1) FE data of the medium-to-high income group contain less random noise than those of the low-income group, and (2) current attributes can be used to better explain the FE of the medium-to-high income group than that of the low-income group. In addition, similarity parameters that capture the spatial correlations of pairs of residential locations, "UC&UF" and "UF&SB", are also statistically significant and are

within the required value range between 0 and 1, supporting the paired structures of the models.

To further understand the effects of state dependence (the influence of current choices on future expectations) and future expectations on choice behavior, the proportion of variance for each factor in the total variance of the utility is calculated as shown below. The proportion of variance results express to what extent explanatory variables influence choice behavior (Biying et al., 2012; Wu et al., 2012). The larger the proportion of variance, the more influence on choice behavior. Results are summarized in Table 5.4.

$$\text{Proportion of variance (\%)} = \frac{var(\beta_k x_{nik})}{var(\sum_k \beta_k x_{nik})} = \frac{\beta_k^2\, var(x_{nik})}{\sum_k \beta_k^2\, var(x_{nik})} \quad , \qquad (6)$$

where β_k is an estimated parameter of attribute "k" and x_{nik} refers to attribute "k" of alternative "i". In the denominator, the total variance of the utility of each alternative is calculated as the sum of all variances of explanatory variables. In this study, there are three alternatives in RP data and three alternatives in FE data. Hence, six total variances of the utility will be calculated in each model.

5.5.1. Interdependences between RP Choices and FE Choices

The rows of Table 5.3 are arranged into seven groups: 1) alternative-specific constants, 2) land-use variables, 3) locational density, 4) effects of future expectations on current choices, 5) effects of current choices on future expectations, 6) scale parameters, and 7) convergence and goodness-of-fit. Looking at groups 4 and 5 in Table 5.3, except for "the effect of choosing UF in FE on choosing UC in RP", all effects representing interdependences between RP and FE choices are statistically significant for the entire sample, i.e. the low-income group and the medium-to-high-income group. Concerning

within-alternative interdependences, positive parameters are obtained with respect to UC residence. This result reconfirms the existence of positive state dependence and, more importantly, current choices are clearly influenced by future expectations in the context of residential location choice. This observation applies to both income groups. As for between-alternative interdependences, except for "the effect of choosing UF in RP on choosing UC in FE", all effects are negative. This implies that competitive relationships exist between different alternatives, irrespective of RP and FE data as well as different income groups. Those choosing to live in UF areas in the RP data tend to choose their residence in UC areas in the FE data. This suggests that Hanoians regard UC and UF areas similarly when choosing their residence.

Following the structure of Table 5.3, the rows of Table 5.4 are arranged into four groups, consisting of 1) land-use variables, 2) locational density, 3) effects of future expectations on current choices, and 4) effects of current choices on future expectations. As shown by groups 3 and 4 in Table 5.4, 26.42%–55.28% of the total variance of current residential location choice utility can be explained by future expectations and 40.81%–99.37% of future expectations can be captured by current choices (i.e., state dependence). The influence of within-alternative interdependences with respect to UC residence for the low-income group is almost double that for the medium-to-high-income group. For between-alternative interdependences, a similar influence is observed for both the low-income and medium-to-high-income groups; that is, it can explain 37.37%–58.55% of the total variance for SB residence; however, little influence (0.00%–0.89%) is confirmed for UC residence. These findings suggest that future expectations should be reflected in the analysis of residential location choice behavior.

Hereafter, results with respect to different urban areas are mainly discussed, with a focus on income disparities. Results of parameter signs are shown in Table 3 and those of the magnitude of influence are shown in Table 5.4.

a) Urban Core (UC)

The first type of interdependences is within-alternative interdependences. For the entire sample, future expectations toward residence in UC areas are positively associated with current residence in UC areas. Similarly, current residence in UC areas has a positive influence on future residence in UC areas (Table 3), which implies that current choices and future choices of residence in UC areas reinforce each other. Comparing the RP and FE models for UC residence, the influence of future expectations on current residence is lower than that of current residence on future expectations in that 34.58% of the total variance of the current residence is explained by future expectations and 59.97% of future expectations is described by the current residence.

By income, the positive interaction between current choices and future choices of residence in UC areas is also captured. This indicates that residence in UC areas is preferred by both low-income and medium-to-high-income groups. Comparing low-income and medium-to-high-income groups for UC residence, contributions to the choice of UC areas by low-income individuals are much larger than those to UC choice by medium-to-high-income individuals in the RP and FE models. For the low-income group, variances of these variables account for 55.28% and 99.37% of the total variance of UC residence utility in the RP and FE models, respectively. For the medium-to-high-income group, contributions to the total variance of UC residence utility in the RP and FE models are only 26.42% and 55.13%, respectively.

The second type is between-alternative interdependences. For the entire sample, the effects of the UC alternative on other alternatives are captured on the one hand. In

particular, future expectations toward residence in UC areas are negatively associated with current residence in SB areas. Coincidentally, current residence in UC areas has a negative influence on future residence in SB areas. These results indicate that choices of residence in UC areas may weaken the possibility of residing in SB areas. Comparing the RP and FE models for SB residence, the influence of current residence in UC areas on future expectations toward residence in SB areas is lower than that of future expectations toward residence in UC areas on current residence in SB areas, 37.91% versus 43.88%, respectively. On the other hand, the effects of other alternatives on the UC alternative are also captured. Specifically, future expectations toward residence in UF areas are negatively associated with current residence in UC areas, implying that individuals with such future expectations tend not to reside in UC areas at present. However, current residence in UF areas is positively associated with future residence in UC areas, perhaps due to the similarity and proximity of the UC and the UF. Table 5.4 shows the marginal influence of these variables on the total variance of UC utility in the RP and FE models, with variances of 0.00% and 0.30%, respectively.

With respect to income disparity, the negative influence of future choices and current choices of residence in UC areas on current residence in SB areas is also captured. These indicate that choices of residence in UC areas may reduce the possibility of residing in SB areas. Comparing low-income and medium-to-high-income groups for SB residence, contributions to the choice of SB residence by the low-income group are smaller than those to SB choice by the medium-to-high-income group in the RP and FE models. For the low-income group, future expectations toward residence in UC areas make up 37.37% and 40.81% of the total variance of SB residence utility in the RP and FE models, respectively. For the medium-to-high-income group, the figures are 48.18% and 42.57%, respectively. Regarding the effects of other alternatives on UC areas, future expectations toward

residence in UF areas have a negative influence in both the low-income and the medium-to-high-income group. However, this parameter is not statistically significant and its variance proportions are mostly equal to zero. However, current residence in UF areas is positively associated with future residence in UC areas, perhaps due to the similarity and proximity of the UC and the UF. This implies that individuals are likely to live in UC areas if their current residence is in UF areas.

These results imply that the UC alternative for low-income individuals in the RP and SE data is more affected by future choices and current choices of UC areas, while the SB alternative for medium-to-high-income individuals in the RP and SE data is more affected by future choices and current choices of UC areas.

b) Urban Fringe (UF)

Due to parameter identification, the dummy choices of residence in UF areas are normalized to zero in the utility functions of UF in the RP and FE models. Hence, the within-alternative interdependences of UF are not captured.

With respect to between-alternative interdependences, only the effects of the UF alternative on other alternatives are captured for the entire sample. Future expectations toward residence in UF areas have a negative influence on current residence in UC areas, but this parameter is not statistically significant. However, current residence in UF areas is statistically positively associated with future residence in UC areas. The contributions of these parameters to the total variance of UC utility in the RP and FE models are insignificant. In addition, future expectations toward residence in UF areas are negatively associated with current residence in SB areas. Similarly, the negative effect of current residence in UF areas on future residence in SB areas is captured. This indicates that individuals tend to stay away from SB areas if their current residence or future expectations toward residence is in UF areas. Comparing the RP and FE models for SB

residence, the influence of future expectations toward residence in UF areas on current residence is lower than that of current residence in UF areas on future residence in SB areas in that 44.28% of the total variance of current residence is explained by future expectations and 48.59% of future expectations are described by the current residence.

By income, the different effects of future expectations toward residence in UF areas on current residence in UC areas are captured. While this influence is positive for the low-income group, it is negative for the medium-to-high-income group. However, this parameter is not statistically significant for either group. Consequently, the variance proportions of this parameter are very small. Current residence in UF areas shows a positive influence on the choice of UC in the FE model. This parameter is statistically significant, but its contributions to the total variance of UC utility are small for both the low-income and medium-to-high-income groups. Current residence in UF areas is negatively affected by future expectations toward residence in SB areas for both the low-income and medium-to-high-income groups. Its contribution to the choice of SB areas by low-income individuals is lower than that to the choice of SB areas by medium-to-high-income individuals, 43.95% versus 45.78%, respectively. Current residence in UF areas also has a negative influence on the future choices of SB areas for both the low-income and medium-to-high-income groups. However, the contribution of this parameter to the choice of SB areas by the low-income group is larger than that to the choice of SB areas by the medium-to-high-income group, 58.55% versus 53.74%, respectively.

c) Suburban (SB)

To avoid correlation between dummy choices of location alternatives, dummy choices of SB are normalized to zero in all utility functions in both the RP and SE models. Hence, within-alternative interdependences of the SB alternative and the effects of SB on other alternatives are not captured. Only the effects of other alternatives on SB are

captured in this study. As can be seen from Table 3, the parameters of these variables show a negative influence on choice of SB in the present and future, implying that people dislike SB areas. In other words, people tend to reside in places close to the city center and stay away from outlying areas if their current residence or choice expectations are UF or UF areas.

5.5.2. Effects of Neighborhood Characteristics

Tables 5.3 and 5.4 show the significant influence of neighborhood characteristics in considering the interdependences between RP choices and FE choices.

First, “medical and welfare land” has a positive influence on residential location choice with respect to the entire sample, indicating that people are likely to choose places with better health-care and social facilities. However, its variance only contributes significantly to the total variance of UC residence utility in the RP and FE models. With respect to UC residence, the effect of this land-use attribute on current choice is larger than its effect on future expectations, 21.37% versus 12.98%, respectively. This explains why people prefer places close to the city center, because hospitals and social facilities are often located in such areas.

By income, the positive influence of this variable is also captured. Regardless of income level, people generally select places close to the city center, again because they presumably wish to have convenient access to health-care and social facilities. Table 5.4 shows that the influence of medical and welfare land on the choice of UC areas by low-income individuals is lower than its influence on UC choice by medium-to-high-income individuals. For the low-income group, variance proportions of this land-use attribute are only 17.41% and 0.24% of the total variance of UC residence utility in the RP and FE models, respectively. For the medium-to-high-income group, the contributions to total variance of UC residence utility in RP and FE data are 29.72% and 17.77%, respectively.

Second, the percentage of "park and recreational land" is positively associated with decisions about where to live, indicating that individuals tend to choose areas with a high percentage of "park and recreational land". Its variance is significant for UC choice, but not for SB choice. Comparing the RP and FE models for UC residence, the influence of park and recreational land on current choice is larger than its influence on future expectations, 8.30% versus 5.04%, respectively. According to income level, the parameter of this land-use attribute has a positive sign for both low-income and medium-to-high-income groups. Similar to the results for medical and welfare land, the effects of park and recreational land on the choice of residence in UC areas in the RP and FE models for the low-income group are much lower than its effects on UC choice in these models for the medium-to-high-income group, 4.45% and 0.06% versus 20.95% and 12.52%, respectively.

Third, the parameter of the variable "urban residential land" has a positive sign for the entire sample, implying that people may prefer areas with a high percentage of urban residential land. Unexpectedly, its variance is insignificant for UC and SB choices. However, its interaction term with household income shows a positive influence on residential location choice behavior, indicating that medium-to-high-income households prefer areas with a high percentage of urban residential land. For UC residence, the variance proportion of this interaction term in the RP model is larger than its proportion in the FE model, 19.61% versus 11.91%, respectively. The contribution of this interaction term is insignificant for SB residence.

Fourth, the variable "primary schools" shows a positive influence on residential location choice for the entire sample. Its contributions to the total variance of UC and SB areas are highly significant. Analogous to the land-use attribute, the influence of primary schools on current choices of UC and SB areas is almost double its influence on future

expectations toward these areas, 11.32% and 12.20% versus 6.87% and 5.15%, respectively.

By income, the positive effects of this variable on residential choice are also captured, indicating the very important role of schools in residential neighborhoods. For the low-income group, the substantial influence of this variable on the choices of UC and SB areas in the RP model is shown, but a marginal influence is captured in the FE model. For the medium-to-high-income group, the influence of primary schools on the choices of UC and SB areas is significant in both the RP and FE models.

Finally, for the entire sample, the variable "non-state industrial companies" is found to have a negative influence on residential location choice, implying that households may stay away from areas with a high concentration of non-state industrial companies. Its variance only contributes slightly to the choices of SB areas in the RP and FE models. Obviously, industrial companies are often located in outlying areas, so this has no effect on the choice of UC areas. In contrast, its interaction term with the number of workers is found to have a positive influence on residential location choice. Table 5.4 shows that the contributions of its interaction term to the total variance of SB utility are also slightly significant in the RP and FE data. Comparing the RP and FE models for SB residence, the influence of this interaction term on current choices is larger than its influence on future expectations, 3.57% versus 1.51%, respectively.

By income level, the variable "non-state industrial companies" is statistically negatively associated with residential location choice for the low-income group, but is insignificantly positively associated with residential location choice for the medium-to-high-income group. This indicates that low-income individuals shy away from areas with a high concentration of non-state industrial companies, while medium-to-high-income individuals are likely to reside in such areas. The interaction term of this variable is

significant for the low-income group, but insignificant for the medium-to-high-income group. Consequently, its variance contributes significantly to the total variance of UC and SB areas for low-income households, with little influence for medium-to-high-income households.

5.6. Conclusions

Expectations about future choices may be a key driver of people's decisions about where to live. However, existing studies in the context of residential behavior have only provided descriptive analysis, and little is known about the quantitative influence of future expectations on current residential choices, and vice versa. In line with the concepts of backward-looking and forward-looking behavior, this study clarified the interdependences between current choices and future expectations in the context of residential location choice by building combined FE/RP PCL models, with an additional emphasis on the disparities between income groups. In the models, we incorporate not only the effects of state dependence and future expectations but also the heterogeneous effects of neighborhood characteristics. From the results of analysis of large-scale questionnaire survey data collected in Hanoi, Vietnam, it is empirically confirmed that RP and FE choices clearly mutually influence each other. It is found that 26%–55% of the total variance of residential location choice utility can be explained by future expectations, and 56%–99% of future expectations can be captured by current choices. The influence of future expectations on current choices is higher in the choice of SB areas than in the choice of UC areas for both low-income and medium-to-high-income groups. Regarding the influence of current choices, 99% of the total variance of the utility of future expectations can be explained. Given these findings, this study recommends paying more attention to future expectations in the analysis of residential location choice behavior.

According to the Hanoi Capital Construction Master Plan to 2030 and Vision to 2050 (Vietnam Ministry of Construction, 2009), future development will be concentrated in the core cities and satellite cities that are located on well-defined transport corridors. This means that future urban development will be decentralized. However, by emphasizing the interdependences between RP and FE choices of residential location, the findings of this study suggest that Hanoians prefer to live close to the city center and to stay away from outlying areas. In other words, Hanoians prefer more compact city development.

Our findings are encouraging for further studies on future expectations to support evidence-based transport policy decisions. However, it should be noted that there are also several limitations in this study. First, future expectations may change over time due to changes in numerous influential factors such as job, income, household composition, and so on. Hence, how to design a survey in order to capture changes in future expectations remains an unanswered question. Second, undisclosed information about future expectations may result in preference heterogeneity, which should be properly represented by more advanced choice models. Third, this study has not dealt with people's expectation formation and updating mechanisms that may further influence their learning behavior. Fourth, this study observed income-related disparities in residential location choices for only two income groups. Classifying households into more income groups may derive more different types of income-related disparities. Finally, how to make use of future expectations to capture the influence of new types of transport and land-use policies on different time scales is also a challenging issue.

Table 5.2: Explanatory variables used for model estimations

Explanatory variable	Definition	Entire sample		Low income		Medium-to-high income	
		Mean	SD	Mean	SD	Mean	SD
Household socio -demographics							
HH income	Monthly household income (million VNDs)	6.143	5.403	-	-	-	-
No. of children 6 - 10	Number of children aged between 6 and 10 years old	0.183	0.418	0.191	0.426	0.177	0.411
No. of senior members	Number of senior members aged above 60 years old	0.632	0.799	0.572	0.775	0.679	0.814
No. of adults 16 -60	Number of active adults aged between 16 and 60 years old	2.793	1.336	2.472	1.303	3.047	1.307
No. of motorcycles	Number of motorcycles	1.476	1.002	0.946	0.764	1.894	0.969
Presence of car	Car availability (1=Yes, 0=No)	0.013	0.115	0.003	0.051	0.022	0.146
No. of workers	Number of workers	1.993	1.156	1.723	1.147	2.207	1.118
Land use attributes							
Commercial and business land	Percentage of commercial and business-related land	1.886	2.009	1.873	1.917	1.896	2.079
Medical and welfare land	Percentage of medical and welfare land	0.755	0.975	0.764	0.974	0.748	0.976
Mixed residential and commercial land	Percentage of mixed residential and commercial land	0.219	0.311	0.217	0.297	0.221	0.321
Park and recreational land	Percentage of park and recreational land	1.602	1.678	1.593	1.623	1.609	1.720
Transport and service land	Percentage of transport and service land	8.14	3.451	8.108	3.353	8.165	3.526
Urban residential land	Percentage of urban residential land	29.489	20.184	29.315	20.133	29.627	20.224
Locational density							
Primary schools	Ratio of number of primary school to population (schools/1000 persons)	0.077	0.018	0.077	0.019	0.077	0.018
Urban population	Ratio of population living in urban area	0.690	0.439	0.689	0.441	0.690	0.438
Non-state owned industrial establishments	Ratio of number of non-stated industrial companies to population (establishments /1000 persons)	5.089	2.657	5.078	2.701	5.097	2.622

Table 5.3: The estimation results of combined FE/RP model

Explanatory variable	Entire sample		Low income		Medium-to-high income	
	Parameter	P-value	Parameter	P-value	Parameter	P-value
Alternative-specific constants						
Urban fringe (RP)	4.7104**	0.0000	2.6799**	0.0000	4.2775**	0.0000
Suburban (RP)	10.0512**	0.0000	5.1553**	0.0000	-3.0472**	0.0000
Urban fringe (FE)	4.7904**	0.0000	2.6720**	0.0000	4.5993**	0.0000
Suburban (FE)	11.1917**	0.0000	15.8710**	0.0000	-2.0745**	0.0000
Land use variables (including interaction terms with household attributes)						
Commercial and business land	0.0140*	0.0834	0.0026	0.7200	-0.0224**	0.0000
Interacted with HH income	-0.0009	0.4219	-	-	-	-
Interacted with No. of workers	-0.0038**	0.0025	0.0011	0.4111	-0.0005	0.1691
Medical and welfare land	1.3263**	0.0000	0.7090**	0.0000	1.2743**	0.0000
Interacted with No. of senior members	0.0028	0.2656	0.0026	0.3631	-0.0008	0.1536
Mixed residential and commercial land	-0.3913**	0.0000	-0.2203**	0.0003	-0.9949**	0.0000
Interacted with HH income	-0.0509**	0.0000	-	-	-	-
Park and recreational land	0.3724**	0.0000	0.1623**	0.0000	0.4802**	0.0000
Interacted with No. of adults 16-60	0.0021	0.1671	0.0014	0.4407	0.0003	0.4509
Transport and service land	0.0475**	0.0000	0.0345**	0.0000	0.0293**	0.0000
Interacted with No. of motorcycles	0.0007	0.3131	0.0006	0.4217	-0.00005	0.7236
Interacted with Presence of Car	0.0128**	0.0184	-0.0025	0.8536	0.0015	0.1360
Urban residential land	0.0429**	0.0000	0.0331**	0.0000	0.0561**	0.0000
Interacted with HH income	0.0025**	0.0000	-	-	-	-
Locational density (including interaction terms with household attributes)						
Primary schools	56.0505**	0.0000	35.3510**	0.0000	50.0820**	0.0000
Interacted with No. of children 6-10	1.0816**	0.0000	-0.0510	0.9136	0.4986**	0.0000
Urban population	2.6632**	0.0000	-0.3535**	0.0059	9.8889**	0.0000
Interacted with No. of adults 16-60	-0.0477**	0.0027	-0.0720**	0.0055	-0.1760**	0.0000
Non-state industrial companies	-0.1364**	0.0000	-0.1635**	0.0000	0.0011	0.8884
Interacted with No. of workers	0.0343**	0.0000	0.0489**	0.0000	0.0012	0.1731

Table 5.3: The estimation results of combined FE/RP model (Continued)

Explanatory variable	Entire sample		Low income		Medium-to-high income	
	Parameter	P-value	Parameter	P-value	Parameter	P-value
Effects of future expectations on current choices						
Effect of FE choice "UC" on alternative UC in RP	1.8649**	0.0000	1.2501**	0.0000	1.4525**	0.0000
Effect of FE choice "UC" on alternative SB in RP	-2.4104**	0.0000	-2.4868**	0.0000	-2.8454**	0.0000
Effect of FE choice "UF" on alternative UC in RP	-0.0162	0.1857	0.0026	0.8203	-0.0237	0.1156
Effect of FE choice "UF" on alternative SB in RP	-2.8629**	0.0000	-2.8826**	0.0000	-3.0170**	0.0000
Effects of current choices on future expectations						
Effect of RP choice "UC" on alternative UC in FE	3.1802**	0.0000	14.8330**	0.0000	2.7135**	0.0000
Effect of RP choice "UC" on alternative SB in FE	-4.0258**	0.0000	-14.6950**	0.0000	-3.4226**	0.0000
Effect of RP choice "UF" on alternative UC in FE	0.2416**	0.0000	0.0436*	0.0550	0.3711**	0.0000
Effect of RP choice "UF" on alternative SB in FE	-4.5604**	0.0000	-17.7560**	0.0000	-4.1378**	0.0000
Scale parameters						
Scale coefficient RP:FE	0.4869**	0.0000	0.1290**	0.0000	0.7055**	0.0000
Similarity between UC and UF	0.9489**	0.0000	0.9841**	0.0000	0.9917**	0.0000
Similarity between UF and SB	0.5715**	0.0000	0.6362**	0.0000	0.2574**	0.0000
Number of observations	13,712		6,050		7,662	
Log-likelihood at zero	-30128.34		-13293.21		-16835.13	
Log-likelihood at convergence	-14960.81		-5992.29		-8526.81	
Rho-square	0.5034		0.5492		0.4935	
Adjusted McFadden rho-square	**0.5023**		**0.5468**		**0.4916**	

Note: (-) Not relevant; (*) Significant at 10% level; (**) Significant at 5% level

Table 5.4: Proportions of variances

Explanatory variable	Proportions of variances (%)																	
	Entire sample						Low income						Medium-to-high income					
	RP			FE			RP			FE			RP			FE		
	UC	UF	SB	UC	UF	SB	UC	UF	SB	UC	UF	SB	UC	UF	SB	UC	UF	SB
Land use variables (including interaction terms with household attributes)																		
Commercial and business land	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.03	0.00	0.05	0.03	0.00
- Interacted with HH income	0.02	0.01	0.00	0.01	0.01	0.00	_	_	_	_	_	_	_	_	_	_	_	_
- Interacted with No. of workers	0.02	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medical and welfare land	**21.37**	2.00	0.00	**12.98**	2.00	0.00	**17.41**	1.38	0.00	**0.24**	1.38	0.00	**29.72**	2.85	0.00	**17.77**	2.85	0.00
-Interacted with No. of senior members	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mixed residential and commercial land	0.37	0.06	0.00	0.22	0.06	0.00	0.29	0.04	0.00	0.00	0.04	0.00	3.81	0.65	0.00	2.28	0.65	0.00
-Interacted with HH income	1.80	0.11	0.00	1.09	0.11	0.00	_	_	_	_	_	_	_	_	_	_	_	_
Park and recreational land	**8.30**	4.07	0.01	**5.04**	4.07	0.00	**4.45**	2.44	0.00	**0.06**	2.44	0.00	**20.95**	8.81	0.01	**12.52**	8.81	0.01
- Interacted with No. of adults 16-60	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport and service land	0.36	0.65	0.07	0.22	0.65	0.03	0.52	0.84	0.07	0.01	0.84	0.00	0.21	0.38	0.01	0.13	0.38	0.01
-Interacted with No. of motorcycles	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Interacted with Presence of car	0.01	0.02	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban residential land	0.88	14.37	0.48	0.54	14.37	0.20	1.32	23.11	0.41	0.02	23.11	0.01	2.42	35.51	0.53	1.45	35.51	0.32
-Interacted with HH income	**19.61**	37.88	0.11	**11.91**	37.88	0.05	_	_	_	_	_	_	_	_	_	_	_	_

Table 5.4: Proportions of variances (Continued)

Explanatory variable	Proportions of variances (%)																	
	Entire sample						Low income						Medium-to-high income					
	RP			FE			RP			FE			RP			FE		
	UC	UF	SB	UC	UF	SB	UC	UF	SB	UC	UF	SB	UC	UF	SB	UC	UF	SB
Locational density (including interaction terms with household attributes)																		
Primary schools	**11.32**	35.15	**12.20**	**6.87**	35.15	**5.15**	12.58	39.44	7.73	0.18	39.44	0.26	13.70	39.49	5.07	8.19	39.49	3.09
Interacted with No. of children 6 – 10	0.04	0.15	0.05	0.03	0.15	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.01	0.04	0.01
Urban population	0.00	0.00	0.06	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.25
Interacted with No. of adults 16 – 60	0.17	0.73	0.00	0.10	0.73	0.00	1.45	5.04	0.00	0.02	5.04	0.00	2.65	12.24	0.01	1.59	12.24	0.00
Non-state industrial companies	0.36	0.90	1.25	0.22	0.90	0.53	1.41	3.83	2.64	0.02	3.83	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Interacted with No. of workers	0.75	3.88	**3.57**	0.45	3.88	**1.51**	5.28	23.86	7.83	0.07	23.86	0.27	0.00	0.01	0.00	0.00	0.01	0.00
Effects of future expectations on current choices																		
Effect of FE choice "UC" on alternative UC in RP	**34.58**	_	_	_	_	_	**55.28**	_	_	_	_	_	**26.42**	_	_	_	_	_
Effect of FE choice "UC" on alternative SB in RP	_	_	**37.91**	_	_	_	_	_	**37.37**	_	_	_	_	_	**48.18**	_	_	_
Effect of FE choice "UF" on alternative UC in RP	0.00	_	_	_	_	_	0.00	_	_	_	_	_	0.01	_	_	_	_	_
Effect of FE choice "UF" on alternative SB in RP	_	_	**44.28**	_	_	_	_	_	**43.95**	_	_	_	_	_	**45.78**	_	_	_
Effects of current choices on future expectations																		
Effect of RP choice "UC" on alternative UC in FE	_	_	_	**59.97**	_	_	_	_	_	**99.37**	_	_	_	_	_	**55.13**	_	_
Effect of RP choice "UC" on alternative SB in FE	_	_	_	_	_	**43.88**	_	_	_	_	_	**40.81**	_	_	_	_	_	**42.57**
Effect of RP choice "UF" on alternative UC in FE	_	_	_	**0.30**	_	_	_	_	_	**0.00**	_	_	_	_	_	**0.89**	_	_
Effect of RP choice "UF" on alternative SB in FE	_	_	_	_	_	**48.59**	_	_	_	_	_	**58.55**	_	_	_	_	_	**53.74**
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Note: (-) Not relevant; **Bold**: numerical values are mentioned in text

Chapter 6 A Life-Course Analysis of Residential And Motorcycle Ownership Mobilities in Hanoi, Vietnam

6.1. Introduction

In the field of transportation research, travel behavior is commonly considered in connection with residential location choice (Krizek, 2003, 2006; Srinivasan and Ferreira, 2002). Different from this traditional way, Lanzendorf (2003) proposed a mobility biography approach that emphasizes stability and changes in travel behavior over an individual's life course. Based on such a mobility biography approach, Scheiner and Holz-Rau (2013) provided empirical evidence that changes in car ownership and travel mode usage are significantly affected by changes in household structure along with relocations. Consequently, Scheiner (2014) argued that it is necessary to investigate the stability and the change in travel behavior in the wider context of life course in which not only residential choices but also other domains (i.e. household structure and employment) are embedded. Similarly, Zhang (2014) proposed life-oriented approach which argued that travel behavior may result from various life choices in different domains such as job, health, family life and budget, neighborhood, education and learning, and leisure and tourism. Unlike other approaches, Zhang's approach emphasizes the two-way relationships between different life domains.

Studies based on the mobility biography approach have been conducted in developed countries where people may have more freedom in residential and transport choices. In developing countries, however, these choices may be more constrained by not only affordability of individuals but also the limited alternatives in their choice sets. For example, citizens in the USA or Japan can use various types of public transport modes (e.g., subway and bus), but people in Vietnam can only use buses even in big cities. Additionally,

cities in Vietnam are motorcycle-dependent cities (Hung, 2006), while cities in the USA or Japan are often more car-dependent (Newman and Kenworthy, 1999). Generally speaking, cars are suitable for longer trips while motorcycles are more suitable for shorter trips (Tuan, 2011). In summary, citizens' transport choices in Vietnamese cities are more constrained. Consequently, people may live in a place to be closer to everyday activities because of the constraint of transport choices in part (Robert Cervero, 2013). However, such constraints may be relaxed in the near future because the rapid economic growth and the improvement in transport systems may result in people having more freedom in residential and transport choices.

Hence, our concern here is that the future expectations may be the most important predictors of people's residential and transport choices in the context of developing countries. Using data of a Web-based life history survey in Japan, Zhang *et al*. (2014) found that the occurrence of mobilities in the household structure and employment/education biographies in the target year are the two most important predictors regarding the occurrence of residential mobility (i.e., relocation). With respect to mobility in car ownership biography, the most important predictor is the car ownership plan made 5 years later. This result indicates that future expectation in car ownership mobility play the main role in predicting car ownership mobility. In the transportation field, numerous studies have confirmed the key role of socio-economics or land use in explaining and understanding residential and travel behavior, while little has been know about the influence of future expectations. As discussed above, residential and transport choices of individuals in developing countries like Vietnam may be quite different from those in the U.S. or Japanese cities due to differences in many aspects such as culture, social viewpoint, and level of economic development. Consequently, the findings in the U.S. or Japanese context may be not consistent with those in developing countries like Vietnam, which is

targeted in this study. Studying changes in residential and travel behaviors in the context of developing countries may improve our understanding based on more empirical evidence.

Since dealing with changes in residential and travel choices over time requires longitudinal data, a retrospective life history survey was conducted in Hanoi in 2011. This retrospective survey consists of four domains: residential, household structure, employment/education, and vehicle ownership domains (including motorcycle, car and bicycle ownership). The aim of this study is to capture the interdependences between four life domains over the life course by applying an exhaustive Chi-squared Automatic Interaction Detector (CHAID) approach. In the remainder of this paper, Section 2 presents data sources and provides the results of descriptive statistics. Section 3 describes and discusses the results of CHAID analysis. Finally, this study is concluded in Section 4.

6.2. Survey and Data

6.2.1. Survey

In this study, biography refers to a series of mobilities in each life domain over the life course, while mobility refers to a change occurring in each domain (Zhang *et al*., 2014). The following four types of biographies using the concept of mobility are defined as follows:

a) Residential biography: a series of residential mobilities caused by relocation over the life course.
b) Household structure biography: a series of mobilities in status of household members (e.g. getting married or child-birth).
c) Employment/education biography: a series of mobilities in individuals' jobs and/or schools (e.g., change of job or education).
d) Vehicle ownership biography: a series of mobilities of motorcycle, car and bicycle ownership as tools for travel. In this study, travel biography only refers to vehicle

ownership biography.

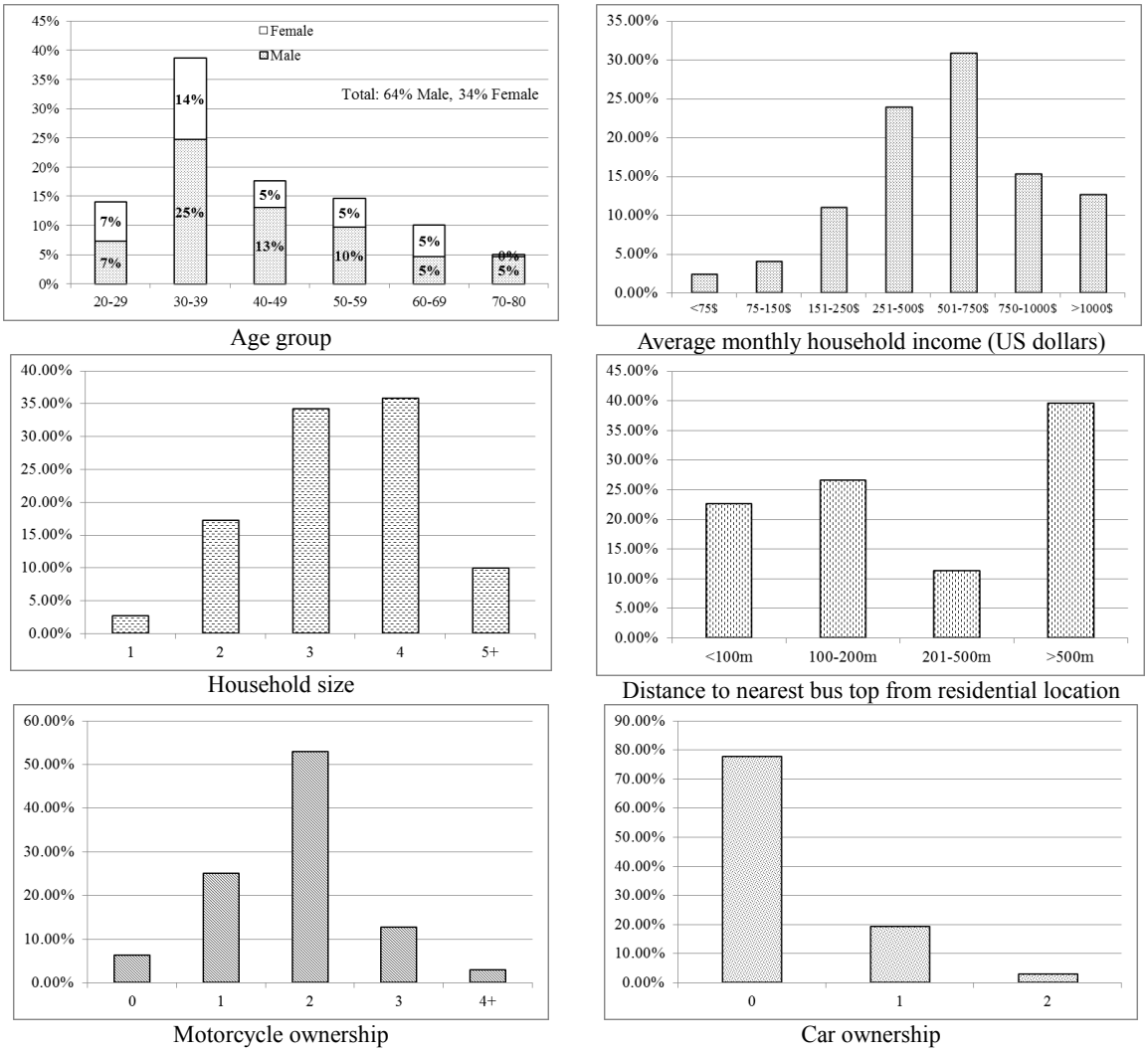


Figure 6.1: Descriptive statistics of the selected samples on the survey year

Longitudinal data is required when the dynamics of long-term and short-term mobility decisions is taken into account. In the transportation field, panel surveys have been used to observe the changes in individuals' travel behavior over time. The most obvious advantage of panel surveys is that they offer more accurate estimation. But it is accompanied by a number of difficulties, as detailed in Kitamura (1990). Hence, a growing body of research of residential and travel behavior use retrospective survey as an alternative approach (Beige and Axhausen, 2008, 2012; Zhang *et al*., 2014). In this study, such retrospective survey was applied to the data collection in Hanoi, Vietnam. To capture the main mobility decisions (including residential location mobility, household structure

mobility, employment/education mobility, and vehicle ownership mobility) during the life course, a retrospective survey covering the 20-year period from 1991 to 2011 was conducted in September 2011 in Hanoi city. The survey was done based on face-to-face interviews because of the following reasons. Unlike in Japan or USA, first, in Vietname it is quite difficult to collect data in a short time by using web-based or mail-based survey. Second, respondents may need the assistance of surveyors because the questionnaire of retrospective surveys is often complicated.

There are four parts in the questionnaire, including: i) current household information (in 2011), ii) mobilities in residential, household structure, employment/education, and car ownership biographies (from 1991 to 2011), iii) current information about commuting trip (e.g., time, mode and distance) and frequencies in use of different types of transport modes in a typical month, and iv) travel attitudes and life satisfactions. The first two parts (called household form) were answered by household heads, and other family members (aged 16 and above) only fill in the part of the questionnaire (called person form). In the first part, respondents (i.e. household heads) were asked to give a short description of all persons living in the household such as age, gender, occupation, education level, and availability of driving license. In the second part, the mobilities in the above-mentioned four types of biographies were collected by using a life course calendar. The life course calendar includes several matrices with a same horizontal time axis for the observed time period from 1991 to 2011. On the vertical axis, the different items of the retrospective survey are arranged. The detail information of the second part with respect to each biography is reported as follows:

1) Residential biography: household address, relocation timing, household income, house property, distance to various facilities (including bus stops, elementary school, hospital, park, traditional/super market, convenience store/grocery).

2) Household structure biography: household size and status of household structure (e.g., single, only couple, couple with unmarried children only and three generations).
3) Employment/education biography: job category.
4) Vehicle ownership biography: number of motorcycles, number of cars, number of bicycles, engine size of car and motorcycle.

Because people need to recall their memory in retrospective survey, their answers are strongly dependent on their memory. To reduce the influence of memory, respondents were only asked to fill in their four recent relocations in the 20-year period from 1991 to 2011, where the 20-year period was divided into four episodes. For each individual, the number of episodes is no less than one but no more than four. Additionally, the attributes in the years between two consecutive mobilities remain unchanged because we have the information for each episode in residential mobility. Hence, the life course data are further expanded to the panel data in which information about whether mobility occurs in each biography as well as the explanatory factors and attributes in each year is included. Based on this panel data, the inter-domain and intra-domain interdependencies among four above-mentioned biographies can be captured.

6.2.2. Descriptive Analysis of Data

In this survey, respondents aged 18 and above at the time of the survey were selected. The questionnaires were distributed to 300 households. Overall, 300 household forms and 985 person forms were collected. Our purpose is to capture the interrelationships between four biographies, thus, only household forms were used for further statistical analysis in this study. Because of the difference in the age of respondents, the observed period in the survey differs. In our survey, specifically, the oldest respondent was aged 80

while youngest one was aged 20. Hence, the oldest respondents reported his/her period from 60 years of age (in 1991) to 80 years of age (in 2011). But the youngest respondent reported his/her period from 1 year of age (in 1991) to 20 years of age (in 2011). Descriptive statistics for collected data is illustrated in Figure 6.1. The resulting samples show a wide distribution by age, gender, household monthly income, household size, residential location, and vehicle ownership (i.e., motorcycles and cars). Regarding age, respondents aged 30-39 have the highest share, followed by age groups of 40-49, 50-59, 20-29, 60-69, and 70-80. Because Vietnam is now in a period of golden population structure, the dominance of respondents from a relatively young labor force in the survey sample is reasonable. By gender, male is dominant in survey sample. It is understandable because household heads in Asian culture, who are in charge of important decisions of family, especially for long-term mobility decisions, are often male. With respect to monthly household income, the shares of middle-income (i.e., $251 - $501) and high-income households ($750 and above) are much larger than that of low-income ones. Note that Hanoi is the capital city, thus, the average household income in Hanoi often is higher than that of other parts of Vietnam. In addition, the 3- or 4-member households account for nearby 70% of the whole sample. Due to the government's two-child policy, a typical family in Vietnam often consists of one married couple and no more than two children. Further, 60% of households in the sample are located within a radius of 500 m from a bus stop. This result may be reasonable because survey locations are in the old Hanoi area which has a well-developed network of bus routes. More than 50% of households have two motorcycles. Finally, 77% of households do not have any car. This is understandable considering the lower income level in Hanoi, compared with cities in developed countries.

6.3. Method Specification and Results

6.3.1. Method Specification

In the field of transportation, residential and travel choice behavior have been given much attention due to the key interest in transport and land use policies. In a similar vein, this study used only residential, motorcycle and car ownership mobilities as dependent variables and the information relating to the other two biographies as a set of independent variables. In this study, the interrelations among four domains refer to the influences of state dependent and future expectation which are captured by using CHAID method (typical data mining). The mobilities are observed in the 10 years prior to the target year under study and those in the 5 years after target year for all observations in panel data. The interval of 5 years is defined. We only selected the former 10 years and the following 5 years due to two reasons: i) with the 1991-2011 panel data, a total of 20 years is covered, so it is difficult to divide the former year and the following year into longer periods, and ii) people may only consider the changes in four domains in the near future. Therefore, whether or not there is an occurrence of mobility for each life domain in this 15-year period is identified by four sets of dummy variables (see Figure 6.2). The capital letters "R", "H", "E", "M", and "C" represent residential location, household structure, employment/education, motorcycle ownership and car ownership, respectively. Concretely, the changes in the former 10 years are illustrated by two sets of dummy variables: target year is denoted by one set, and another set is defined for the following 5 years. For example, "Rp6to10" and "Rp1to5" means residential relocation experienced in the 10 years prior to the target year. In addition, "R-change" refers to whether or not the occurrence of residential mobility in the target year and "Rf1to5" is defined as residential relocation made in the next 5 years.

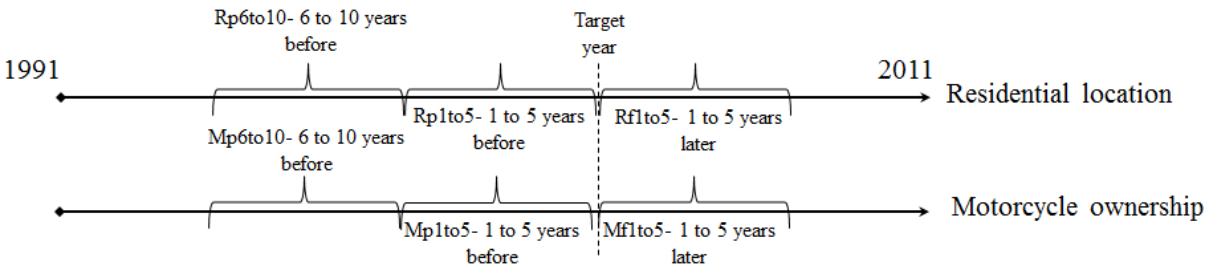


Figure 6.2: Example of four sets of dummy variables in two domains: residential location and motorcycle ownership

In the analysis of exhaustive CHAID, residential mobility, motorcycle ownership mobility and car ownership mobility are treated as dependent variables in three decision trees with a maximum of 10 levels (i.e., branches of the tree). These dependent variables refer to the dummy variable of occurrence of mobility in the target year, including: "R-change", "M-change" and "C-change". Specifically, the occurrence of residential mobility in target year is represented by dummy variable "R-change". "M-change" and "C-change" are representatives of the occurrences of motorcycle and car ownership mobilities, respectively. Theoretically, each respondent is expected to provide information for 20 time points (from 1991-2011). Therefore, a total of 6,000 time points (i.e. 300*20=6000) were collected. It means that the maximum sample of dependent variable (i.e. dummy variable of occurrence of mobility in the target year) is 6,000. However, information of 10 years prior to the target year and also the next 5 years is required. Therefore, only information of several target years can be used in further analysis. After data processing, the sample size of each dependent variable used in the CHAID analysis is 1,729.

6.3.2. Results and Discussion

The intra-domain and inter-domain influences on residential mobility (i.e., the occurrence of relocation in target year) are illustrated in Figure 6.3. As expected, the variable "Rf1to5" (residential location changed or not in the 5 year later) are showed in the

first level in the tree structure with residential mobility being the dependent variable. This implies that the occurrence of mobility in residential biography in the following 5 years is most influential regarding to the occurrence of residential mobility in target year. In other words, the future expectation in the residential biography plays the most important role in predicting residential mobility in the target year. In the second level, the issue of whether the household structure changed or not in the 10 years prior to the target year (i.e., Hp6to10 and Hp1to5) plays an important role in further segmenting the subsample. Following them, the plan of household structure made in the near future (the following 5 years) and the plan of employment/education made in the previous 5 years (Hf1to5 and Ep1to5) are present in the third level. This indicates that residential mobility in the target year is largely affected by the changes in household structure biography not only in the past (the previous 10 years) but also in the near future (the 5 years later). In the fourth level, first, the influences are identified from residential mobility experienced in the 5 years prior to the target year. Here, the existence of state dependence and future expectation in residential biography is observed. The residential mobility experienced in the previous 5 years and also in the near future (the following 5 years) significantly influence the occurrence of residential mobility in the target year. No significant influence of car ownership mobility is identified. But the influence is identified from motorcycle ownership mobility made in the previous 5 years. It is understandable because Hanoi citizens' daily travel mainly depends on motorcycles. Hence, their residential decisions may be more affected by motorcycle ownership rather than car ownership.

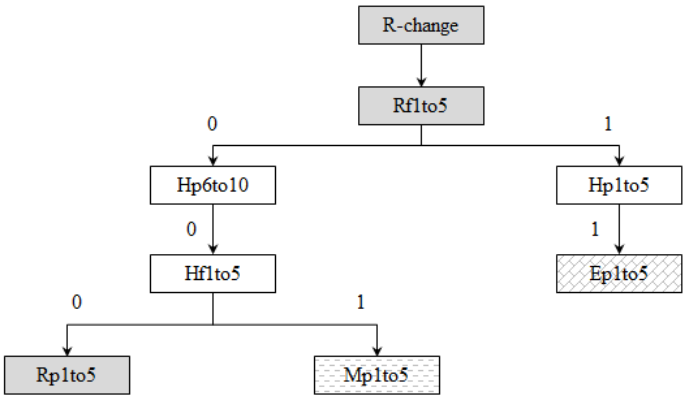


Figure 6.3: Tree structure of residential mobility (relocation) decisions

Regarding motorcycle ownership mobility, the intra-domain and inter-domain influences are presented in Figure 6.4. The variable "H-change" (Household structure changed or not in the target year), "E-change" (Employment/Education changed or not in the target year) and "Hf1to5" are the most important predictors since it is shown in the first two level of tree structure. This indicates that the occurrence of mobility in household structure biography in the target year and also in the near future (the following 5 years) are most influential regarding the occurrence of motorcycle ownership mobility, along with the occurrence of mobility in employment/education biography. Following them, influences are identified from motorcycle ownership biography during the previous 5 years and the next 5 years, as well as the employment/education biography during the following 5 years. These imply that state dependent (i.e. motorcycle ownership plan made in 5 year prior to the target year and also in 5 year later) play an important role in predicting the occurrence of mobility in motorcycle ownership biography in the target year. Here no significant effects of car ownership and residential biographies were found. With respect to car ownership mobility, only the influence of mobility in motorcycle ownership biography in the previous 6 to 10 years was found (see Figure 6.5). Residential, household structure and employment/education biographies do not significantly influence the occurrence of

mobility in car ownership in target year. This result is understandable because of the low rate of car ownership in Hanoi.

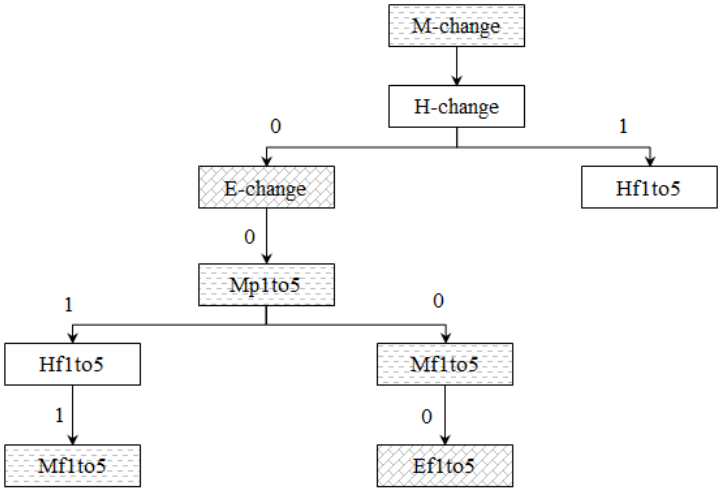


Figure 6.4: Tree structure of motorcycle ownership mobility as dependent variable

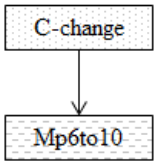


Figure 6.5: Tree structure of car ownership mobility as dependent variable

In fact, a similar survey was conducted in Japan. By applying the same approach, a comparison of the main findings between Vietnam and Japan will be discussed here. With respect to residential mobility, the occurrence of mobilities in household structure and employment/education in the target year is most influential in Japan, while the predominant factor in Vietnam is residential mobility made 5 years later (i.e. expectation about future choices). With respect to car ownership mobility, the car ownership mobility made 5 years later is the most important factor in Japan, while the past experience in the motorcycle ownership mobility is most influential in Vietnam. The remarkable differences in the results may be due to the difference in income in part. Generally, Japanese people face less economic constraints in changing residential location and car ownership.

6.4. Conclusions

Studies on residential and travel behavior are important for land use and transport policy decisions. Relationships between residential and travel behavior have been therefore investigated by many researchers based on either cross-sectional data or panel data. Recently, capturing such relationships over the life course (i.e., biographical interactions) (Zhang et al., 2014; Scheiner, 2014) has been recognized to be essential for land use and transportation policies, because such decisions could impose impacts on people's lives over a much longer time period. A few relevant studies have been conducted in the context of developed countries; however, little has been done in the context of developing countries, especially in motorcycle-dependent cities like Hanoi, Vietnam. To fill this research gap, this study made an initial attempt to clarify biographical interactions across different life domains by implementing a retrospective life history survey in Hanoi in September 2011. As a result, 300 households provided valid data over up to 20 years with respect to residential mobility, motorcycle and car ownership mobility, household structure mobility, and employment and education mobility. Decomposing the 300 household data into mobility episodes with a five-year interval over the life course resulted in 1,729 samples, which were analyzed based on a typical data mining approach called exhaustive CHAID.

As expected, it is first confirmed that future expectations play an important role in predicting the mobilities in residential and motorcycle ownership biographies. Regarding residential mobility, specifically, plan of residential location made in the following 5 years is the most important predictor. This implies that future expectation about residential location should be considered in explaining and modelling residential location choice behavior in the context of Hanoi. With respect to motorcycle ownership mobility, the most influential factors are the household structure and employment/education biographies in

the target year, followed by household structure, employment/education and motorcycle biographies in the following 5 years. Such an importance of intra-domain and inter-domain future expectations may be due to the fact that there are more constraints in choice decisions in Hanoi than in cities of developed countries and consequently people in Hanoi are less likely to rely on their past experience but more likely to show forward-looking behavior. This finding has important policy implications. If people's residential and travel behavior is forward-looking, people should be better informed about future plans of land use and transport in order to make more satisfactory residential and travel decisions. On the other hand, land use and transport decision-makers need to understand people's residential and travel decisions. In this sense, mutual communications and information sharing between policy makers and citizens are extremely important.

Second, household structure and employment/education biographies are identified to be important for explaining residential and motorcycle ownership biographies and more influential to motorcycle ownership mobility than residential mobility. Residential biography is significantly affected by motorcycle ownership biography; however, no significant effects of residential biography on motorcycle ownership were found. Different from cars, motorcycles are necessities for most people in Hanoi. This may be the reason why motorcycle ownership is not affected by residential biography. Surprisingly, car ownership mobility is only influenced by motorcycle ownership in the past. Neither residential mobility nor employment/education mobility was found to be influential to car ownership, probably because of the lower car ownership level in the collected 300 household samples (about 20%).

Finally, there are several limitations that should be mentioned. In the life history survey, respondents were asked to only describe four relocation changes at most, and the influence of unobserved mobilities has been ignored. As confirmed by Zhang (2014) in the

context of Japan, residential and travel behaviors are not only influenced by household structure and employment/education domains, but also by other life domains such as family life, family budget, neighborhood, and leisure and recreation. Therefore, in future, more life domains should be incorporated into the residential and travel behavior analysis. In addition, this study applied a data mining approach, considering complex interrelations in the four mobility biographies. Models reflecting choice decision-making mechanisms should be developed for a more realistic study. Lastly, but not the least, more case studies applying the life course data in the field of land use and transport should be done in both developed and developing countries.

Chapter 7 Conclusions and Recommendations

7.1. Conclusions

Cities in Asian developing countries are growing in terms of both population size and area of urbanized space (United Nations, 2011; World Bank, 2015b). At the same time, the number of both motorcycles and cars is rapidly increasing throughout Asia (Senbil et al., 2007; Tuan, 2011). On the one hand, fast urbanization and motorization improve people's quality of life and increase their daily mobility, thereby helping to eliminate urban poverty (World Bank, 2015b). On the other hand, there are several negative impacts of fast urbanization and motorization, such as traffic congestion, air pollution and use of energy.

While it is a challenge to slow down the high rate of urbanization and motorization, it is possible to consider ways to manage it better. From the perspective of demand side, urbanization and motorization can be explained as the outcome of citizens' residential and travel choices. It may therefore be possible to adjust or modify people's residential and travel choices towards more environmental-friendly choice behavior. There are a lot of long-term and short-term measures, in which land use has emerged as a key measure due to its long-term effects. Additionally, land use planning is a major component in city planning that generally guides city development. Therefore, city planners and transport researchers are interested in investigating the influences of land use on people's residential and travel choices.

Generally, people's choice behavior is affected by not only objective factors (e.g. land use) but also subjective factors (e.g. attitudes, liking or taste). Hence, identifying the role of land use in people's residential and travel choices is a key point in policy debate (Bhat and Guo, 2007; Ewing and Cervero, 2010; Zhang, 2004). Concerning the influence of subjective factors, several questions emerge, as follows:

i) In developing countries, how will attitudes and preferences be involved in people's residential and travel choice?

ii) As constraints are reduced, will people be more able to self-select in the future?

iii) Whether or not people's choice behavior is not only backward-looking but also forward-looking.

In an effort to answer such questions, this dissertation is comprised of two main parts: the first part is to solve self-selection and the second part is to deal with future expectation and state dependence. The detailed findings of the study were as follows:

(1) Static Self-selection

Traffic congestion and related issues caused by commuting traffic are still a major concern of transport policy makers. It is therefore worth encouraging people to live closer to their workplaces and commute by environmentally-friendly travel modes. Focusing on commuting, a joint analysis of residential location, work location and commuting mode choices was conducted in Chapter 3. The self-selection with respect to these three choices may exist. However, such self-selection may vary across different job markets. Generally speaking, labor-intensive workers (i.e. low income) may face more financial deterrents and other constraints (such as housing and transport supply) to self-select their residential and travel choices, while knowledge-intensive workers (i.e. high income) may face less deterrents and constraints. Therefore, two separate joint-equation modeling frameworks were developed: one for labor-intensive workers and another for knowledge-intensive workers. The main findings in this chapter were as follows:

- Firstly, the statistical significance of multiple self-selection is confirmed, which suggests that the joint estimation of the above three choices is a useful approach.
    - Specifically, self-selection effects seem to exist across residential location and work location in both groups of workers.

- Self-selection effects seem to exist across work location and commuting mode in both groups of workers.
- Self-selection effects seem to exist across residential location and commuting mode, but were only significant for knowledge-intensive workers' choices.
- To further clarify the influences of self-selection, the total variance of utility difference is calculated. The results indicated self-selection is more influential in knowledge-intensive workers. In other words, knowledge-intensive workers seem to be more able to self-select in the context of commuting.

- Secondly, the influences of land use attributes on choices of labor-intensive and knowledge-intensive are mixed. Different types of land uses and different levels of land use diversity as well as population density also result in different choices. The results indicated that labor-intensive and knowledge-intensive workers prefer different types of land use in their location choices.
- Thirdly, the differing influences of more detailed job categories on the three above choices are also confirmed. As a trend, knowledge-intensive employment tended to be geographically centralized while labor-intensive employment is decentralized in Hanoi city.
- Fourthly, it was found that residential location and commuting mode are affected by motorcycle ownership. This is a distinctive point of Hanoi city, where motorcycles are dominant in people's daily travel.

Such findings may be useful to city planners and policy makers in Hanoi city. Coinciding with economic growth, there may be a shift in the structure of labor market

from labor-intensive sectors to knowledge-intensive sectors in Hanoi city. It means that more residents of Hanoi city will be able to self-select in their decisions. This may result in significant changes in land use-transportation systems. In the context of commuting, such phenomenon can be explained as changes in residential location, work location and commuting modes.

(2) Dynamic Self-Selection

As a further improvement of the previous chapter, a joint model which incorporated dynamic self-selection effects is introduced by using a joint-equation modeling framework. Taking Hanoi as a case study, it is generally assumed that urban fringe and motorcycle ownership are interdependent. Such interdependence may involve self-selection effects. For example, people with strong preference for motorcycles may prefer living in areas close to city center and own more motorcycles.

However, most of our understanding of the interdependence between residential location and vehicle ownership comes from cross-sectional studies in the U.S. and European countries where cars are the dominant mode and the economy, housing and transport supply are quite stable. In contrast, the economic growth of Southeast Asia developing countries is moving forward. At the same time, housing and transport supply are expanding. Additionally, people's life situation and attitudes may change over time, leading to the variation of self-selection effects over time. Hence, there is no reason expect the interdependence between residential location and vehicle ownership to be stable either across geographies or over time. In Chapter 4, therefore, self-selection effects are incorporated in the joint model of urban fringe choice and motorcycle ownership by allowing common random components to vary over time.

This is a unique study in the arena of residential and travel choices as it controls for self-selection and the dynamics of such effects. As a result, the following findings were obtained:

- The parameter of the "time" variable is statistically significant, indicating that unobserved self-selection effects vary over time. In other words, the interdependence between urban fringe and motorcycle ownership is strengthened over time. Furthermore, it suggests that the joint-equation modeling framework is a useful approach.
- Additionally, self-selection effects due to observed socio-demographics are also captured.
    - Specifically, high-income households do not prefer living in densely-populated areas in the urban fringe and those households have a high preference for motorcycles.
    - Households with more senior members are less likely to choose areas in the urban fringe and have a low preference for motorcycles.
    - Households with more workers do not prefer residing in employment-concentrated areas in the urban fringe and own more motorcycles.

Such findings first show a feasible approach to controlling for dynamic self-selection in modeling residential and travel choices. Next, this study gives an important message that ignoring dynamics in self-selection effects may lead to a bias in land use and transport policies, especially in developing-country cities. In the Hanoi context, this study indicated that urban fringe development and motorcycle ownership seem to be moving hand-in-hand. In other words, the increasing motorcycle ownership may reinforce people's preference for residing in areas close to city centers.

(3) Future Expectations and State Dependence in a static case

Expectations about future choices may be a key driver of people's decisions about where to live, especially in Southeast Asian developing countries which are experiencing rapidly-growing economies and expanding housing and transport systems. However, existing studies in the context of residential location choice behavior have only provided descriptive analysis, and little is known about the quantitative influence of future expectations on current residential choices and vice versa. From the perspective of both forward-looking and backward-looking behavior, expectations about future choices and current choices may be interdependent.

To clarify such interdependence, the combined Future Expectation/Revealed Preference Paired Combinatorial Logit models were developed in Chapter 5, with an additional emphasis on the disparities between groups by income. In the models, we incorporate not only the effects of state dependence and future expectations but also heterogeneous effects of neighborhood characteristics. From the analysis of a large-scale questionnaire survey data collected in Hanoi city, several remarkable findings emerged:

- The high goodness-of-fit suggested that the developed models are good enough to represent people's decisions on where to live.
- It is empirically confirmed that expectations about future choices and current choices clearly mutually influence each other. Specifically, it is found that 26%-55% of the total variance of current residence utility can be explained by expectations about future choices, and 56-99% of future expectations can be captured by current choices.
- The estimated scale parameter in models are less than one and statistically significant, indicating that the error terms from the FE data (i.e. expectations about future choices) have larger variance than those from RP data (i.e. current choices).

- Interestingly, there is a large difference in magnitudes of scale parameters between the low and medium-high income groups. The scale parameter in the model of the medium-to-high-income group is 0.7055, while that in the model of the low-income group is 0.1290. These results suggest that:
  - FE data of the medium-to-high-income group contains less random noise than those of low-income group;
  - And current land use attributes and socio-demographics can be used to better explain the FE of the medium-to-high-income group than that of low-income group.
- Residents of Hanoi city prefer living close to the city center.

Our findings suggest that researchers in transportation field should pay more attention to future expectations in the analysis of residential location choice behavior.

(4) Future Expectations and State Dependence in a dynamic case

Following the previous chapter, the influences of state dependence and future expectation of different life domains on residential location and motorcycle ownership were examined by using life-course survey data collected in Hanoi city in 2011. First, our analysis is based on a typical data mining approach called exhaustive CHAID. The following results were found:

- As expected, it was confirmed that future expectations play an important role in predicting the mobilities in residential and motorcycle ownership biographies.
- Regarding residential mobility, specifically, the plan of residential location made in the following 5 years is the most important predictor. This implies that future expectations about residential location should be considered when explaining and modelling residential location choice behavior in the context of Hanoi.

- With respect to motorcycle ownership mobility, the most influential factors were household structure and employment/education biographies in the target year, followed by household structure, employment/education and motorcycle biographies in the following 5 years.

Such findings indicate that residents of Hanoi are more likely to show a forward-looking behavior. This may be because of the rapid changes in the economy, leading them to consider future outcomes.

7.2. Policy Implications

The findings of this dissertation could provide several implications for future land use and transportation planning in order to achieve sustainable urban development in Hanoi city.

a) Joint development of employment centers and housing units (i.e. job-housing balance)

First, this study suggests that policy makers should consider the development of employment centers (e.g. industrial parks and working offices) in connection with housing development in order to avoid the increase in reverse commuting in the future. This finding is partly support by the empirical research in Chapter 3. In this chapter, it was found that Hanoi residents' residential and work locations are interdependent; simply put, they prefer living and working in the same areas. Additionally, the descriptive analysis of commuting distance by job types revealed that the average distances is in the range of 2 km to 5 km. In other words, Hanoi residents may prefer short- and medium-distance commuting. Hence, job-housing balance at the local level should be considered by city planners and policy makers.

The Government of Hanoi is planning to develop high-technology parks and eco-industrial parks in suburban areas from 2020, such as the Hoa Lac satellite city, one of five satellite cities (Ministry of Construction, Government of the Socialist Republic of Viet

Nam, 2009). Additionally, several industrial parks along with numerous government offices, universities and colleges in old Hanoi will be moved into suburban areas. To avoid issues of reverse commuting and even higher car usage in future, it is important to design land use in such a way as to encourage people work and live closely.

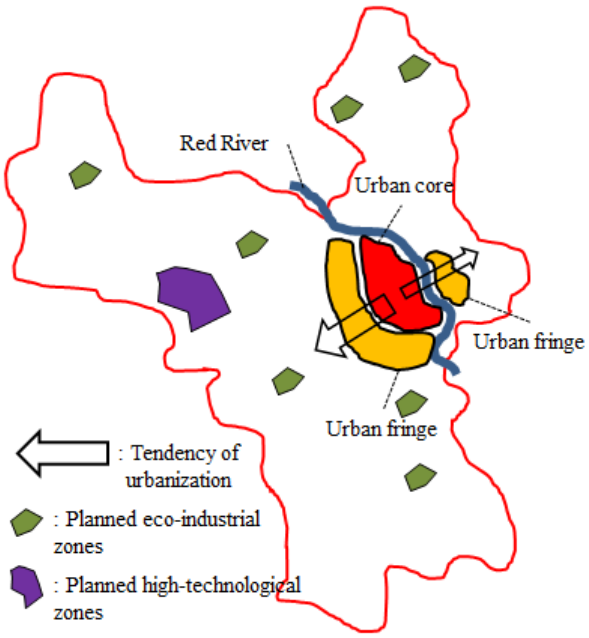


Figure 7.1: Planning of industrial networks in Hanoi up to 2030

Source: Adapted from Google Map

b) Role of motorcycles as main mode in future transportation system

Second, this study has an implication in determining the future role of motorcycles. Motorcycles are suitable for short- and medium-distance trips, while cars are suitable for long-distance trips (Tuan, 2011). In a sense, the advantage of motorcycles is that people prefer living closer to their main daily destination. In other words, the domination of motorcycles may reinforce compact urban development. This finding was partially supported by the empirical analysis presented in this dissertation. Specifically, the effects of motorcycle ownership on Hanoi residents' residential and travel choices were confirmed through this dissertation in Chapters 3, 4, 5, and 6. One of reasons for Hanoi residents' preferences for living closer to their workplaces is the use of motorcycles for commuting.

Hence, motorcycles may play an important role in determining future land use patterns in Hanoi city. This study suggests that policy makers should utilize motorcycles as a main travel mode in the future transport system in Hanoi city.

Figure 7.2: Main travel modes in future Hanoi

The Government of Hanoi is planning to shift Hanoi's spatial form from a monocentric to a polycentric city in which several new centers will be developed (Ministry of Construction, Government of the Socialist Republic of Viet Name, 2009). The prevalent use of motorcycles as a mean of transport may be one of the reasons why Hanoi's polycentric structure can currently function (World Bank, 2011). Therefore, determining the role of motorcycles in the future transport system will strongly influence land use – transportation systems in the future Hanoi.

c) Compact urban development at city level

Third, this study investigated Hanoi residents' preferences and the residential location choice at city level. The findings of this dissertation revealed that residents of Hanoi city seem to prefer residing close to the city center and stay away from outlying areas, especially in the case of medium-to-high income group or knowledge-intensive workers. In the context of Hanoi city, Hanoi government is planning to promote a polycentric urban form in which urban development will be concentrated in not only the core city but also satellite cities. Additionally, there are several planned mass transit lines in order to connect the core city with satellite cities. However, all existing mass transit projects can only serve Hanoi residents in the area of core city. Hence, this suggests that policy makers should consider future urban development close to the existing urban structure (i.e. core city).

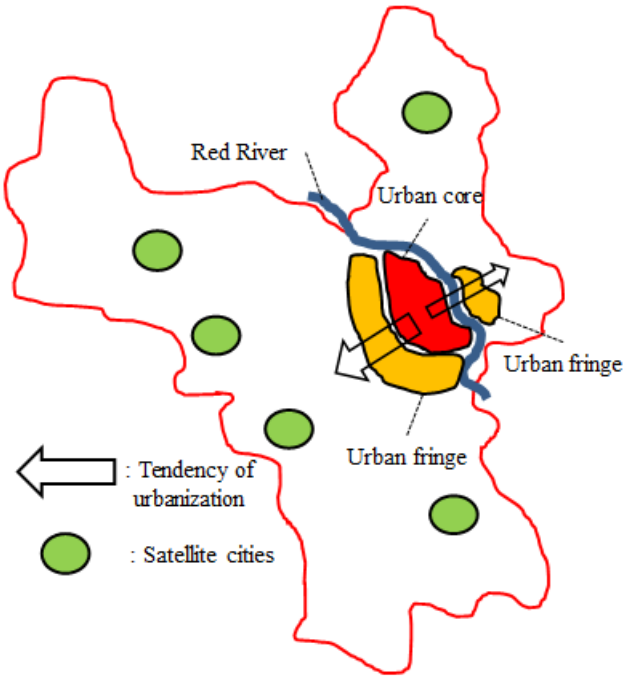


Figure 7.3: Planned polycentric urban form in Hanoi

d) Mixed land use at community level

Fourth, the outcomes of this dissertation can assist policy makers in Hanoi city in solving the issue of motorcycle usage. The finding in Chapter 3 revealed that mixed land use at residential neighborhood may partially reduce the use of motorcycles for commuting and encourage active modes (i.e. walking and cycling). This study suggested that city planners and policy makers should increase the diversity of land use such as residential, commercial and other types of land use at community level.

7.3. Future Studies

This study attempts to give insights into the interdependence between residential and travel choices in Hanoi city, a rapidly-growing city in Southeast Asia. However, there are still several points which may be improved. Some of these improvements can be accomplished with more explanatory variables, but some still have uncertainties in theoretical, methodological and contextual aspects. Here, the limitations of the present study are described and some relevant suggestions are recommended.

(1) Self-selection

In this study, self-selection effects were treated basically by using joint-equation modeling framework in which common random components are incorporated. Such random components are used to capture unobserved self-selection such as omitted attitudes. Based on this, it is difficult to clarify what self-selection is in the context of Hanoi city. This calls for more efforts in designing surveys to capture people's attitudes and preferences regarding travel or neighborhood in the context of developing countries.

Additionally, we simply assumed the linear relationship between self-selection and time. Depending on context, however, such relationships can be quadratic or fluctuating. Hence, we call for more modelling efforts in order to solve such issues in future studies regarding residential and travel choices. Additionally, more case studies in both developed and developing countries should be conducted. Then, we may summarize common points or different points of the interdependencies between residential and travel choices. These will be useful for city planners and policy makers in managing and designing cities.

(2) Future Expectation

Firstly, the question of expectations about future choices is a kind of self-reported item. In this sense, people's answers may reflect people's social desirability, where people are more concerned with how their responses might make them look good (Holtgraves, 2004) . Therefore, how to capture an accurate and truthful answer is a challenging issue in data collection. Additionally, future expectations may change over time due to changes in numerous factors such as jobs, income and market conditions. Hence, how to design a survey in order to capture changes in future expectations remains an unanswered question. Following this, peoples' expectations and updating mechanisms regarding residential and travel choices should be further investigated. Finally, how to make use of future

expectations to capture the influences of new types of transport and land use policies on different time scales is also a challenging issue.

(*3) Coexistence of self-selection and future expectations*

As suggested by Zhang (2014), people's residential and travel choice may be affected by both self-selection and future expectations at the same time. The link between these concepts has not been explored in this study. Hence, this study calls for more efforts for model development that can incorporate both influences of self-selection and future expectations on residential and travel choices.

(*4) Residential location*

Residential location choice is a key part of this dissertation. However, there are several limitations regarding modeling residential location choice. Due to lack of data, first, the information on land price has not been obtained and included in model estimation. However, land price might have a strong impact on people's residential location choice, especially in developing-country cities where the gap between land price and income may be large. It is important to include such information in future studies. Second, Hanoi city is still developing, so the capacity of spatial areas is still increasing over time. In order tp redevelop numerous old high-rise buildings developed in the 1970s in the urban core and urban fringe areas, new housing projects are planned or are under construction. Hence, in this study, we have not taken capacity constraints into account. Up to a given time, the capacity constraints of urban areas of Hanoi will reach peak point, so future studies on residential location choice in Hanoi city should consider this issue. Third, three types of location of residential location (i.e. urban core, urban fringe and suburban) are fixed. However, people's residential location choice may affect the built environment of residential location. For example, with more people choosing to live in the suburbs, suburban areas may become more crowded. In other words, there may be locational

externalities due to the changes in people's residential location choice. In addition to this issue, choice set generation in dynamic modeling of residential location remains an issue of available alternatives over time. However, the change in internal and external constraints could lead to the change in choice set over time. Hence, future studies in the context of developing-country cities should take these issues into account. Fourth, neighborhood reputation may influence on people's residential location choice. This is may be true for some neighborhoods in all three areas (i.e. urban core, urban fringe and suburban) in Hanoi city. Neighborhood reputations can be measured by either people's perceptions or objective neighborhood characteristics (Permentier et al., 2008). With respect to perceived neighborhood reputation, such information is not available, so we did not take it into account. Objective neighborhood reputation may be measured by three groups of factors, including: 1) functional factors 2) physical factors and 3) social factors (Permentier et al., 2008). Basically, objective measures of neighborhood reputation are based on objective neighborhood characteristics. For details, please refer to the paper of Permentier et al. Due to data limitations, we could only partially reflect objective neighborhood reputation by including land use attributes in the model estimation. Future studies of residential location choice in Hanoi should consider this issue. Fifth, a large amount of Hanoi residents were born and brought up in Hanoi city. In such a situation, the bonding (i.e. place attachment) between individuals and their meaningful places (i.e. home and neighborhood) may occur (Scannell and Gifford, 2010). This is an interesting topic for future studies on residential location choices in the Hanoi context. Sixth, it is worth looking at how each household member contributes to their household residential location choice in the context of Asia developing-country cities where the social, cultural and economic context may differ from that in Western countries. This has not been done in this study, so future studies should consider this.

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- Minh Tu TRAN, Makoto CHIKARAISHI, Quynh Huong PHAM, Junyi ZHANG, Akimasa FUJIWARA (2015). Perceive neighborhood walkability and mode choice of short-distance trips. Journal of the Eastern Asia Society for Transportation Studies (accepted)
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Appendix A: Questionnaire Form of Household Interview Survey in 2005

It is noted that this questionnaire form was designed by JICA.

Form1: HOUSEHOLD INFORMATION

INSTRUCTION: To be completed by HEAD of HOUSEHOLD

Q4 Name

_____

Q5 Address of household

(No) _____(Name of street) _____

(To) _____(Phuong/Xa) _____

(Quan/Huyen) _____ (City/Province) _____

Q5a

Q6 Tel. Number (optional) _____

Q7 Household composition

		6 year-old and above	Under 6 year-old
Number of Household Members	living currently together	Q7a	Q7c
	living outside	Q7b	Q7d

Household Members living together (Q7)	01		06	
	02		07	
	03		08	
	04		09	
	05		10	

Q8 Total monthly household income (000 VND/month) Q8a

01.	below 200
02.	201 – 400
03.	401 – 800
04.	801 – 1,500
05.	1,501 – 2,000
06.	2,001 – 3,000
07.	3,001 – 4,000
08.	4,001 – 5,000
09.	5,001 – 6,000
10.	6,001 – 8,000
11.	8,001 – 10,000
12.	10,001 – 15,000
13.	15,001 – 20,000
14.	more than 20,001

Estimated by Surveyors?
1. Yes 2. No.
Q8b

Q9 Number of vehicles owned by household

		Number of Units				Number of Units
1. Bicycle	Q9-1		6. Van (>5 pax)	Q9-6		
2. Cyclo	Q9-2		7. Lambreta	Q9-7		
3. Motorcycle< 50cc	Q9-3		8. Taxi	Q9-8		
4. Motorcycle >= 50cc	Q9-4		9 Truck	Q9-9		
5. Car (<= 5 pax)	Q9-5		10. Others	Q9-10		

Q10 How long has your family been staying in the present address?

_____**Years** Q10

Q11 Where was your previous address? Q11

_____ _____ _____

Phuong / Xa District City / Province

Q12 Housing and land ownership

a. Type of house (filled by surveyors) — Q12a

1. Traditional house	**3.** High-rise apartment
2. Apartment	**4.** Detached house

b. Structure of house (filled by surveyors) — Q12b

1. Permanent	**3.** Stable wooden frame with leaf roof
2. Semi-permanent	**4.** Temporary house

c. Maintenance condition (filled by surveyors) — Q12c

1. Very bad **2.** Bad **3.** So-so **4.** Good **5.** Very Good

d. Housing ownership — Q12d

1. Self-owned	**4.**Group-owned or religion's house
2. Sate-owned house for rental	**5.** Joint ownership of state and individual
3. Private-owned house for rental or borrow	**6.**Uncertain ownership

e. If rented, how much do you pay per month? Q12e VND ☐☐☐,☐☐☐,000

f. Landuse right ownership — Q12f

1. Self-owned	**4.**Group-owned or religion's land
2. State-owned land for rental	**5.** Joint ownership of state and individual
3. Private-owned land for rental or borrow	**6.**Uncertain ownership

g. Living area [m^2] Q12g ☐☐☐

h. Number of rooms Q12h ☐☐

i. Age of house (Write 99 if do not know, write 98 if more than 100 years) Q12i ☐☐

Q13 Is your house connected with following urban services?

1. Electricity	1.Yes,	2.No.	Q13-1 ☐
2. Piped water supply	1. Yes	2.No	Q13-2 ☐
3. Toilet facility	1.Yes,	2.No.	Q13-3 ☐
4. Gas	1. Yes	2. No	Q13-4 ☐
5. Telephone (fixed)	1. Yes	2. No	Q13-5 ☐
6. Solid waste collection	1. Yes	2. No	Q13-6 ☐
7. Internet	1. Yes	2. No	Q13-7 ☐

Q14 Do you have the following items in your house?

1. Air-con	1. Yes	2. No	Q14-1 ☐
2. Washing machine	1. Yes	2. No	Q14-2 ☐
3. Refrigerator	1. Yes	2. No	Q14-3 ☐
4. TV	1. Yes	2. No	Q14-4 ☐
5. Radio	1. Yes	2. No	Q14-5 ☐
6. Computer	1. Yes	2. No	Q14-6 ☐
7. Mobile phone	1. Yes	2. No	Q14-7 ☐

Q15 What is average monthly expenditure of your household?

1. Transportation (gasoline, parking, public transport use)	Q15-1 VND	☐☐☐,☐☐☐,000
2. Electricity	Q15-2 VND	☐☐☐,☐☐☐,000
3. Water supply	Q15-3 VND	☐☐☐,000
4. Sewerage services	Q15- VND	☐☐☐,000
5. Solid waste management	Q15-5 VND	☐☐☐,000

S/N (Q3b) ____

Form2: HOUSEHOLD MEMBER INFORMATION

INSTRUCTION: To be completed by EVERY HOUSEHOLD MEMBER aged 6 years and above.

Q16 Name

_____ Q7a [ ] [ ] (1) M

Q17 Personal Information

a. Age [ ] [ ] Q17a

b. Sex [ ] Q17b
1. Male
2. Female

c. Registration [ ] Q17c
1. Permanent
2. Temporary (KT3)
3. Temporary (others)
4. Non-Registered

Q18 Do you have a driver's license of car and / or motorcycle? [ ] Q18
1. Motorcycle 2. Car 3. Both 4. None

Q19 Do you have a vehicle for your own use? Q19 a [ ] b [ ] c [ ]

a. Car	b. Motorcycle	c. Bicycle
1. Yes, 2. No	1. Yes, 2. No	1. Yes, 2. No

Q20 If no, how do you manage to travel ? [ ] Q20
1. Use household vehicle
2. Sent off/pick-up by others
3. Use of public transport
4. Walk
5. Seldom going out
6. Others

Q21 Occupation [ ] [ ] Q21
01. Leader of branches, administration levels and units
02. Professional
03. Technical and associate professional
04. Clerical worker
05. Service workers and shop and market sales worker
06. Skilled agriculture, forestry and fishery worker
07. Craft and related trades worker
08. Plant and machine operator and assembler
09. Elementary occupation
10. Student (Elementary)
11. Student (High school & Univ.)
12. Housewife
13. Jobless / Retired/too young
14. Small venders
15. Military people, police
16. Others

Q22 Type of Company [ ] Q22
1. Government
2. Collective
3. Capital
4. Mixed
5. Foreign

Q23 Employment Sector [ ] [ ] Q23
01. Agriculture and forestry
02. Fishery
03. Mining & quarrying
04. Manufacturing
05. Electricity, gas & water supply
06. Construction
07. Wholesales & retail trade; repair of motorcycle, personal & household goods
08. Hotels & restaurants
09. Transport, storage and communications
10. Financial intermediation
11. Scientific activities and technology
12. Real estate, renting & business activities
13. Public adm. & defense; compulsory social security
14. Education and training
15. Health & social work
16. Recreational, cultural and sporting activities
17. Activities of Party and of membership organization
18. Community, social and personal service activities
19. Other Industries
20. Services (people who work in barbershop, beauty salon)

Q24 Personal Income [ ] [ ] Q24
(000 VND/month)
01. No Income
02. below 200
03. 201 – 400
04. 401 – 800
05. 801 – 1,500
06. 1,501 – 2,000
07. 2,001 – 3,000
08. 3,001 – 4,000
09. 4,001 – 5,000
10. 5,001 – 6,000
11. 6,001 – 8,000
12. 8,001 – 10,000
13. 10,001 – 15,000
14. 15,001-20,000

Q25 Obtained Education [ ] Q25
1. Master / Doctor
2. University
3. Junior College
4. High school or below

Q26 What was your previous job 5 years before? (please select from above)

1. Occupation Q26-1 [ ] [ ]
2. Type of Company Q26-2 [ ]
3. Employment sector Q26-3 [ ] [ ]

Q27 Work or School Address [ ] [ ] [ ] Q27

(No) _____ (Name of street) _____

(To) _____ (Phuong/Xa) _____

(Quan/Huyen) _____ (City/Province) _____

Form3: DAILY ACTIVITY INFORMATION

INSTRUCTION: To be completed by EVERY HOUSEHOLD MEMBER aged 6 years and above.

INSTITUTION of ORIGIN

01. Residence
02. Office/ Bank
03. Public administrative offices
04. Factory/ Warehouse
05. School/ University
06. Medical/ Welfare
07. Religious/ Social
08. Wholesale/ Retail shop
09. Restaurant/ Entertainment
10. Park/ Green space
11. Field/garden/forest
12. Railway station/bus station

TYPE

1. Home (answer in Q5)
2. Workplace/School (answer in Q27)
3. Others

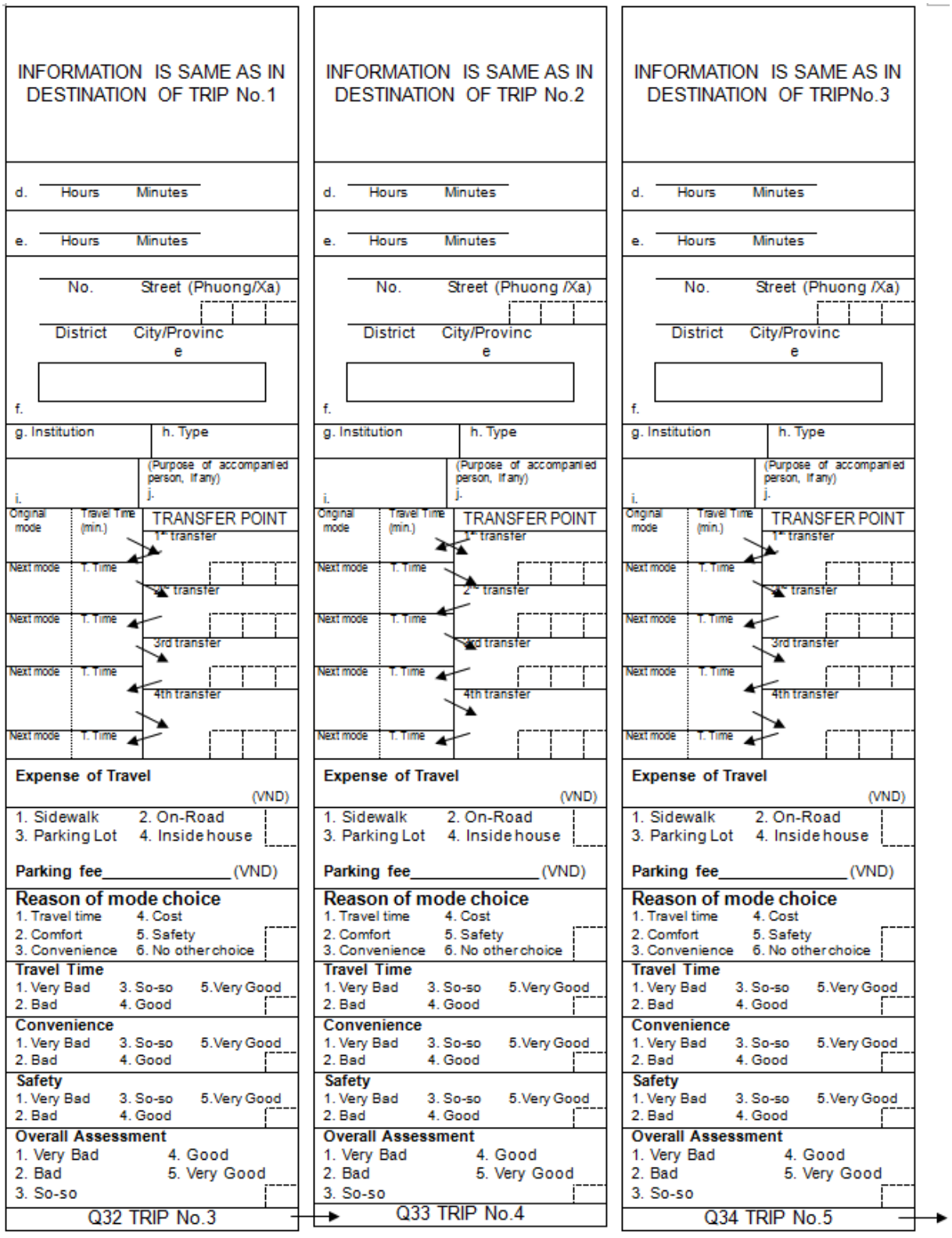
TRIP PURPOSE

01. To Home
02. To Work
03. To School (to study)
04. At work / Business
05. To send / To pick up other family member or friends
06. To go shopping/Market
07. To eat (not at home)
08. To have an exercise
09. Joy riding
10. Social/ Recreation/ Religious
11. Other private purposes

MODE of TRAVEL

01. Walking
02. Bicycle
03. Motorcycle - driver
04. Motorcycle – passenger (NOT Xe Om)
05. Car - driver
06. Car - passenger (NOT taxi)
07. Minibus (<=25 pax)
08. Standard Bus (>25 pax)
09. Cyclo
10. Xe Om
11. Taxi
12. Tourist Bus
13. Company Bus
14. School Bus
15. Truck
16. Ferry
17. Rail Train
18. Air
19. Others

TRIP INFORMATION	Q30 TRIP No.1
(1) ORIGIN Where did this trip begin? (Give address/ land mark, famous building, nearby)	No. Street (Phuong/Xa) District City/Province a.
(2) INSTITUTION of ORIGIN, and Type	b. Institution | c. Type
(3) TIME STARTED (24-hour timming)	d. Hours Minutes
(4) TIME of ARRIVAL (24-hour timming)	e. Hours Minutes
(5) DESTINATION Where did this trip begin? (Give address/ land mark, famous bldg, nearby)	No. Street (Phuong/Xa) District City/Province f.
(6) INSTITUTION of DESTINATION, and Type	g. Institution | h. Type
(7) TRIP PURPOSE	i. | (Purpose of accompanied person, if any) j.
(8) MODE of TRAVEL (9) TRAVEL TIME (min.) (10) TRANSFER If you transferred to another vehicle/mode of travel during the trip, state the mode you changed to another place. (Give street intersection/famous bldg, or land mark)	Original mode | Travel Time (min.) | TRANSFER POINT 1st transfer Next mode | T. Time 2nd transfer Next mode | T. Time 3rd transfer Next mode | T. Time 4th transfer Last mode | T. Time
(11) EXPENSE of TRAVEL	(VND)
(12) PARKING	1. Sidewalk 2. On-Road 3. Off-road 4. Inside house **Parking fee** _____(VND)
(13) Reason of mode choice	1. Travel time 4. Cost 2. Comfort 5. Safety 3. Convenience 6. No other choice
(14) Assessment of Trip – Travel Time	1. Very bad 3. So-so 5.Very good 2. Bad 4. Good
(14) Assessment of Trip – Convenient	1. Very bad 3. So-so 5.Very good 2. Bad 4. Good
(14) Assessment of Trip – Safety	1. Very bad 3. So-so 5.Very good 2. Bad 4. Good
(14) Assessment of Trip – Overall Assessment	1. Very bad 3. So-so 5.Very good 2. Bad 4. Good


INFORMATION IS SAME AS IN DESTINATION OF TRIP No.1
INFORMATION IS SAME AS IN DESTINATION OF TRIP No.2
INFORMATION IS SAME AS IN DESTINATION OF TRIPNo.3
d. Hours Minutes
e. Hours Minutes
No. Street (Phuong/Xa)
District City/Provinc e
f.
g. Institution
h. Type
(Purpose of accompanied person, If any)
j.
i.
Original mode
Travel Time (min.)
TRANSFER POINT
1st transfer
Next mode
T. Time
2nd transfer
3rd transfer
4th transfer
Expense of Travel
(VND)
1. Sidewalk 2. On-Road
3. Parking Lot 4. Inside house
Parking fee_____(VND)
Reason of mode choice
1. Travel time 4. Cost
2. Comfort 5. Safety
3. Convenience 6. No other choice
Travel Time
1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good
Convenience
Safety
Overall Assessment
1. Very Bad 4. Good
2. Bad 5. Very Good
3. So-so
Q32 TRIP No.3
Q33 TRIP No.4
Q34 TRIP No.5

INFORMATION IS SAME AS IN DESTINATION OF TRIP No.4

d. Hours Minutes

e. Hours Minutes

No. Street (Phuong /Xa)

District City/Provinc e

f.

g. Institution | h. Type

i. | (Purpose of accompanied person, if any) j.

Original mode | Travel Time (min.) | TRANSFER POINT

1st transfer

Next mode | T. Time

2nd transfer

Next mode | T. Time

3rd transfer

Next mode | T. Time

4th transfer

Next mode | T. Time

Expense of Travel (VND)

1. Sidewalk 2. On-Road
3. Parking Lot 4. Inside house

Parking fee_____(VND)

Reason of mode choice

1. Travel time 4. Cost
2. Comfort 5. Safety
3. Convenience 6. No other choice

Travel Time

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Convenience

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Safety

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Overall Assessment

1. Very Bad 4. Good
2. Bad 5. Very Good
3. So-so

Q35 TRIP No.6 → Q36 TRIP No.7

INFORMATION IS SAME AS IN DESTINATION OF TRIP No.5

d. Hours Minutes

e. Hours Minutes

No. Street (Phuong /Xa)

District City/Provinc e

f.

g. Institution | h. Type

i. | (Purpose of accompanied person, if any) j.

Original mode | Travel Time (min.) | TRANSFER POINT

1st transfer

Next mode | T. Time

2nd transfer

Next mode | T. Time

3rd transfer

Next mode | T. Time

4th transfer

Next mode | T. Time

Expense of Travel (VND)

1. Sidewalk 2. On-Road
3. Parking Lot 4. Inside house

Parking fee_____(VND)

Reason of mode choice

1. Travel time 4. Cost
2. Comfort 5. Safety
3. Convenience 6. No other choice

Travel Time

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Convenience

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Safety

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Overall Assessment

1. Very Bad 4. Good
2. Bad 5. Very Good
3. So-so

INFORMATION IS SAME AS IN DESTINATION OF TRIP No.6

d. Hours Minutes

e. Hours Minutes

No. Street (Phuong /Xa)

District City/Provinc e

f.

g. Institution | h. Type

i. | (Purpose of accompanied person, if any) j.

Original mode | Travel Time (min.) | TRANSFER POINT

1st transfer

Next mode | T. Time

2nd transfer

Next mode | T. Time

3rd transfer

Next mode | T. Time

4th transfer

Next mode | T. Time

Expense of Travel (VND)

1. Sidewalk 2. On-Road
3. Parking Lot 4. Inside house

Parking fee_____(VND)

Reason of mode choice

1. Travel time 4. Cost
2. Comfort 5. Safety
3. Convenience 6. No other choice

Travel Time

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Convenience

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Safety

1. Very Bad 3. So-so 5.Very Good
2. Bad 4. Good

Overall Assessment

1. Very Bad 4. Good
2. Bad 5. Very Good
3. So-so

S/N (Q3b) _____

Form 4: People's Opinion on Transport Environment

INSTRUCTION: *to be completed by representative of HOUSEHOLD*

Q40 2) M

Traffic Congestions

Q41 How do you feel about traffic situtuation (congestions)? Q41

1. Very bad **2.** Bad **3.** so-so **4.** Good **5.** Very good

Q42 If "bad" or "very bad", what are causes of traffic congestions ? (choose two) Q42

1. Increase of car traffic	**5** Undisciplined people's driving manner
2. Increase of motorcycle traffic	**6.** Insufficiency of public transport
3. Lack of traffic lights	**7.** Lack of traffic management and enforcement
4. Lack of roads	**8.** Others (please specify _____)

Q43 How do you feel about present traffic situation compared to 5 years ago ?

	Very much worse	Worse	Worse but not much	Same	better	
1. Congestion	1	2	3	4	5	Q43-1
2. Safety	1	2	3	4	5	Q43-2
3. Convenience	1	2	3	4	5	Q43-3

Traffic Safety

Q44 Have you got involved in traffic accidents in the past 5 years ?

1. Fatal	**1.** none	**2.** once	**3.** more than once	Q44-1
2. Seriously injured	**1.** none	**2.** once	**3.** more than once	Q44-2
3. Light	**1.** none	**2.** once	**3.** more than once	Q44-3

Q45 How do you feel about traffic safety in Hanoi City ?

	Very Dangerous	Dange-rous	So-so	Safe	Very safe	
1. When you use motorcycle	1	2	3	4	5	Q45-1
2. When you use bicycle	1	2	3	4	5	Q45-2
3. When you walk in your community	1	2	3	4	5	Q45-3
4. When you walk in city center	1	2	3	4	5	Q45-4
5. When you cross the roads	1	2	3	4	5	Q45-5

Q46 How do you find driving manner of motorcycle in Hanoi City ? Q46

1. Very bad **2.** Bad **3.** so-so **4.** Good **5.** Very good

Q47 What makes traffic safety bad? (choose two). Q47

1. People's driving manner	**5** Inefficient traffic enforcement
2. Increase of motorbike traffic	**6.** Poor road condition
3. Increase of car traffic	**7.** Lack of facilities for traffic safety
4. Lack of traffic light	**8.** Lack of education

Q48 What do you think is necessary to improve traffic safety in Hanoi City? (choose two) Q48-1 | 2

01. Enhancement of people's awareness	**06.** More traffic lights
02. Improvement of road	**07.** More safety facilities for pedestrian
03. Traffic safety education / campaign	**08.** More strict enforcement of traffic roles/Increase of fine
04. Control of motorcycles use	**09.** Compulsory use of helmet in city area
05. Control of car use	**10.** Others (please specify _____)

Public Transport

Q49 How often do you use bus services? Q49 ☐

1. Five days a week	**3.** Once a week	**5.** Never
2. Three days a week	**4.** Rarely	

Q50 If you answer "rarely" or "never" in Q49, why don't you use bus? Q50 ☐

1. Far from bus stops	**3.** Not punctual schedule	**5.** Too high fare
2. No available bus route	**4.** Uncomfortable on-board	**6.** Low frequency of bus operation
7. Others (Please specify):----------		

Q51 Please assess bus service in Hanoi city on the following aspects.

	Very Bad	Bad	So-so	Good	Very Good	
01. Route network	1	2	3	4	5	Q51-1 ☐
02. Operating hours	1	2	3	4	5	Q51-2 ☐
03. Frequency	1	2	3	4	5	Q51-3 ☐
04. Bus speed	1	2	3	4	5	Q51-4 ☐
05. Bus fare	1	2	3	4	5	Q51-5 ☐
06. Accessibility to bus stop	1	2	3	4	5	Q51-6 ☐
07. On-board comfort	1	2	3	4	5	Q51-7 ☐
08. On-board security	1	2	3	4	5	Q51-8 ☐
09. Driver/conductor's attitude	1	2	3	4	5	Q51-9 ☐
10. Waiting condition (bus-stop)	1	2	3	4	5	Q51-10 ☐
11. Convenience of transfer	1	2	3	4	5	Q51-11 ☐
12. Don't know anything about bus services						Q51-12 ☐

Q52 Please select three (3) most important factors to improve bus services from the above list (Q51) Q52-1 ☐☐ 2 ☐☐ 3 ☐☐

(Do not ask if don't know about bus services)

Q53 Do you think public transport services must be improved and expanded in the future? Q53 ☐

1. Yes	**2.** No	**3.** don't know

Q54 If yes, what types of public tranposrt services must be developed? (choose two) Q54-1 ☐ 2 ☐

1. Taxi	**3.** Rapid bus	**5.** Underground railway
2. Bus	**4.** Tramway	**6.** Elevated railway

Transport Measures

Q55 Do you support following transport measures which are currently implemented?

	Strongly support	Support	Not sure	Not support	
01. Construction / improvement of roads	1	2	3	4	Q55-01 ☐
02. Strict control of traffic	1	2	3	4	Q55-02 ☐
03. Restricting motorcycle registrations	1	2	3	4	Q55-03 ☐
04. Installation of traffic signals	1	2	3	4	Q55-04 ☐
05. Strict control of parking	1	2	3	4	Q55-05 ☐
06. Improvement of walking conditions	1	2	3	4	Q55-06 ☐
07. Introduction of bus lanes	1	2	3	4	Q55-07 ☐
08. Expansion of bus services	1	2	3	4	Q55-08 ☐
09. Restriction of truck traffic entering to city center	1	2	3	4	Q55-09 ☐

Q56 Do you agree following transport improvement measures in the future?

	Agree	Disagree	Not sure	Not support	
10. Restriction of motorcycle use in designated road	1	2	3	4	Q56-10
11. Restriction of car use in designated area (e.g. ancient quarter)	1	2	3	4	Q56-11
12. Increase of user-charges for car (registration, license, fuel tax, parking fees)	1	2	3	4	Q56-12
13. Increase user charges for motorcycle (registration, license, fuel tax, parking fees)	1	2	3	4	Q56-13
14. Construction of bus exclusive lane /busways	1	2	3	4	Q56-14
15. Construction of urban railway (elevated/ underground)	1	2	3	4	Q56-15
16. Construction of tram (at-grade)	1	2	3	4	Q56-16
17. Control of air pollution	1	2	3	4	Q56-17
18. Promotion of people's understanding on transport problems and measures	1	2	3	4	Q56-18
19. others (please specify)	1	2	3	4	Q56-19

Q57 Please select three (3) most important measures from the above listed ones in Q55 and Q56 (01 to 19) Q57-1 ☐☐ 2 ☐☐ 3 ☐☐

Form 5: People's Satisfaction /Perception on Living Conditions

INSTRUCTION: *to be completed by representative of HOUSEHOLD*

Housing Condition

Q58 Are you satisfied with your present housing conditions? Q58 ☐

1. Not at all **2.** No **3.** so-so **4.** Yes **5.** Yes, very much

Q59 If no, please give items why ? (choose two) Q59 ☐☐

1. Space **2.** Air flow / Ventilation **3.** Sunlight **4.** Location **5.** Rent (if applicable) **6.** Design **7.** Structure **8.** Others

Q60 Please select the most important factor your future house (choose from Q 59) Q60 ☐

Q61 How many square meters (m^2) do you need for living space to accommodate your family? Q61 ☐

1. below 30 m^2 **2.** 30-50 m^2 **3.** 50-75 m^2 **4.** 75-100 m^2 **5.** 100-150 m^2 **6.** more than 150 m^2

Q62 Up to how much you can afford to pay to purchase your desired house (million VND)? Q62 ☐

1. less than 150 **2.** 51 - 100 **3.** 101 to 250 **4.** 250 to 500 **5.** 501 – 1,000 **6.** 1,001 – 1,500 **7.** more than 1,501

Q63 Please choose the housing type and location that you want to live in the future.

a. Housing Type Q63-a ☐

1. Traditional house **2.** High-rise apartment **3.** Medium-rise (4-5 story) **4.** Detached house **5.** Others

b. Location Q63-b ☐☐

a. Urban center	**01.** Hoan Kiem **02.** Hai Ba Trung **03.** Dong Da **04.** Ba Dinh
b. Other urban districts	**05.** Hoang Mai **06.** Thanh Xuan **07.** Cau Giay **08.** Tay Ho **09.** Long Bien **10.** Ha Dong (Ha Tay Province)
c. Rural districts	**11.** Soc Son **12.** Dong Anh **13.** Gia Lam **14.** Tu Liem **15.**Thanh Tri **16.** Dan Phuong (Ha Tay) **17.** Hoai Duc (Ha Tay) **18.** Me Linh (Vinh Phuc Province).
d. New urban chain	**19.** Xuan May - Hoa Lac **20.** Bach Ninh

Park / Green Space

Q64 Do you have a park or green space that you can use in your neighborhood? Q64 ☐

1. Yes within a walking distance **2.** Yes within an area where can be reached easily **3.** No

Q65 Do you think it is important for you to have a good access to park and green space? Q65 ☐

1. Yes, very much **2.** Yes **3.** No **4.**Not at all **5.** Not sure

Q66 For those answered yes in Q 64 and Q 65, what do you do in the park and green space?

Activities		**1.** Yes **2.** No	How often do you use? Daily	2-3 times /week	Once a week	Others	
1. to take a rest	Q66-1		1	2	3	4	Q66-8 ☐
2. to do exercise	Q66-2		1	2	3	4	Q66-9 ☐
3. to take a walk	Q66-3		1	2	3	4	Q66-10 ☐
4. to play with children	Q66-4		1	2	3	4	Q66-11 ☐
5. to gather	Q66-5		1	2	3	4	Q66-12 ☐
6. to see performance	Q66-6		1	2	3	4	Q66-13 ☐
7. others	Q66-7		1	2	3	4	Q66-14 ☐

Q67 Are you satisfied with the park in Hanoi in general? Q67 ☐

1. Not at all **2.** No **3.** so-so **4.** Yes **5.** Yes, very much

Q68-1 ☐ 2. ☐

Q68 If no, what are the reasons? Choose two (2).

1. Facilities	**4.** Environment (green)	**7.** Design	**10.** Others
2. Space (size)	**5.** Air pollution	**8.** Landscape	
3. Location	**6.** Noise	**9.** Safety	

Q69 What do you think kinds of functions the park /garden space in Hanoi must be provided? Choose two (2)

Q69-1 ☐ 2. ☐

1. Exercise / sports	**4.** Walking	**7.** Shelter against disaster
2. Rest	**5.** Play for children	**8.** Others
3. Gathering	**6.** Greenery (trees, plants, flowers)	

Q70 What kinds of facilities the park /garden space in Hanoi must be provided? Choose two (2)

Q70-1 ☐ 2. ☐

1. Bench	**4.** KIOSK (vendors)	**7.** Bulletin board for public information
2. Footpath	**5.** Lighting	**8.** Play ground /equipment for children
3. Public Toilet	**6.** Space for gathering	**9.** Others

Q71 What are your most favorite parks and /or green spaces in the City? Choose two (2) Q71-1 ☐☐

-2 ☐☐

1. Lenin Park	**5.** Thu Le Zoo	**9.** Hanoi Water Park (Ho Tay)
2.Botanical Garden	**6.** Cau Doi Park	**10.** Vang Trang Park
3. Tuoi Tre Park	**7.** Nghia Do Park	**11.** Thanh Cong Lake Park
4.Ly Thai To Park	**8.** Thong Nhat Park	**12.** Others

Landscape

Q72-1 ☐

Q72 What do you think are important factors which affect landscape? (choose two) -2 ☐

1. Historical buildings and structures (pagoda, church, opera house, monuments, etc.)
2. Preserved / symbolic streets (Trang Tien, Le Duan, Dien Bien Phu, etc)
3. Modern buildings (Hanoi towers, melia hotel, Noi Bai airport, etc.)
4. Water space (Hoan Kiem, Ho Tay, Song Hong, etc)
5. Park and green spaces (Quang Trung Ba Dinh, Lenin Park, etc)
6. Street trees and plants **7.** Design of ordinary buildings and housing
8. Traditional street scene (vendors and noodle shop on the side walk)
9. Others

Q73 Choose five (5) most favorite landscapes in Hanoi. Q73-1 ☐☐

01. Ancient quarter (36 street)	**13.** Lenin park (Thong Nhat)
02. French quarter	**14.** Ho Tay lake area
03. Hanoi church area	**15.** Hoan Kiem lake area
04. Area surrounding opera house	**16.** Hong river and surroundings
05. Long Bien bridge	**17.** Tu Liem new development area
06. area Trang Tien street	**18.** Lin Dam new development area
07. Dien Bien Phu street	**19.** Sea Game Stadium park
08. Phan Dinh Phuong street	**20.** Traditional market place
09. Than Nien street	**21.** Traditional street scene (street vendors, café and shops, etc.)
10. Hoang Dieu street	
11. Le Duan street	**22.** Rural landscape (rice fields, etc)
12. Ho Chi Minh Shrine area (Lang Chu Tich HCM)	

Q73-2 ☐☐
Q73-3 ☐☐
Q73-4 ☐☐
Q73-5 ☐☐

Q74 How do you find change in landscape in historical areas compared with five years ago? (36 Streets and French Quarter) Q74 ☐

1. Very much worsened	**2.** Worsened	**3.** Not changed	**4.** Improved	**5.**Improved much

Q75 Are you satisfied with the landscape in your neighborhood? Q75 ☐

1. Not at all	**2.** No	**3.** so-so	**4.** yes	**5.**Yes very much

Q76 Do you think the following items affect the landscape in Hanoi City?

	Yes seriously	Yes	A little	No	Don't care
1. Electric wire	1	2	3	4	5
2. Parking on sidewalk	1	2	3	4	5

Q76-1 ☐
Q76-2 ☐

3. Advertisement in ancient quarters	1	2	3	4	5	Q76-3
4. Advertisement in urban area	1	2	3	4	5	Q76-4
5. Advertisement in suburban area	1	2	3	4	5	Q76-5
6. Design of buildings	1	2	3	4	5	Q76-6
7. Over scale buildings	1	2	3	4	5	Q76-7

Q77 Do you support control of advertisement (posters, boards, and banners) in the Ancient Quarter and the French Quarter. Q77

1. Yes very much **2.** Yes **3.** No **4.** Not at all **5.**not sure

Access to Water

Q78 Does your family have a connection to piped water supply? Q78

1. Yes **2.** No

Q79 If No, what is your main sources of water ? Q79

1. Public well **2.** Private well **3.** Rain water **4.** Others

Q80 (For those answered Q 79) what are problems ? (choose all applicable) Q80-1 2 3

1. Distance to water **2.** Water quality **3.** Water quantity **4.** Others (please specify)

Q81 If Yes in Q78, are you satisfied with the current water supply services?

	Highly unsatisfied	Unsatisfied	So-so	Satisfied	Highly Satisfied	
1. Water pressure	1	2	3	4	5	Q81-1
2. Hours of supply	1	2	3	4	5	Q81-2
3. Water quantity	1	2	3	4	5	Q81-3
4. Water quality	1	2	3	4	5	Q81-4
5. Price	1	2	3	4	5	Q81-5

Q82 Please select the most important point from 5 aspects in (Q81) Q82

Q83 If you can be provided with good water supply services, up to how much are you willing to pay per month? Q83

1. less than 10,000 VND **3.** 31,000 to 50,000 VND **5.** more than 100,000 VND
2.10,000 to 30,000 VND **4.** 51,000 to 100,000 VND

Access to Sanitation

Q84 Toilet Facility

1. Flushing toilet
2. suilabh toilet
3. simple toilet
4. shared toilet

Q84

Q85 Sanitation Treatment

1. Connect to urban sewerage system
2. On-site sanitation facility (e.g. septic tank) and collected by public sector
3. no sanitation treatment

Q85

Q86 How do you find sanitary condition in and around your house? Q86

1. Very bad **2.** Bad **3.** so-so **4.** Good **5.**Very good

Q87 If you have problems, please specify.

	Always	Sometimes	No problem	
1. Offensive odor (bad smell)	1	2	3	Q87-1
2. Pipe clogging	1	2	3	Q87-2
3. Overflow of wastewater	1	2	3	Q87-3

Q88 If sanitary condition in your house is improved, up to how much are you willing to pay per month? Q88

1. less than 10,000 VND **3.** 30,000 to 50,000 VND **5.** more than 100,000 VND
2.10,000 to 30,000 VND **4.** 50,000 to 100,000 VND

Q89 Do you think providing more public toilet in urban area is necessary ? Q89

1. Yes **2.** No

Q90 If yes, where and up to how much are you willing to pay for use? Q90-1 [ ] 2 [ ]

1. Where?	**1.** park **2.** lakeside **3.** market **4.** major roads **5.** others(_____)
2. Fee (VND)	**1.** less than 1,000 **2.** 1,000 to 2,000 **3.** over 2,000 **4.** free

Drainage

Q91 How do you find drainage conditions in your neighborhood? Q91 [ ]

1. Very bad **2.** Bad **3.** So-so **4.** Good **5.**Very good

Q92 How often is your neighborhood area flooded up to ankles? Q92 [ ]

1. All the time
2. Sometimes when it rains heavily
3. Every time when it rains heavily
4.Rarely
5. Never

Q93 When your area is flooded, how deep is the water level and how long it lasts?

		Normal flooding	The most serious flooding in the past 3 years	The most serious flooding in the past
Water level	**1.** up to ankles **2.** up to knees **3.** up to waist **4.**more than waist	Q93-1 [ ]	Q93-2 [ ]	Q93-3 [ ]
Duration of the flood	**1.** less than half day **2.** half day- one day **3.** one to three days **4.** three to five days **5.**more than 6 days	Q93-4 [ ]	Q93-5 [ ]	Q93-6 [ ]

Solid Waste Collection

Q94 Are you provided with solid waste collection services? Q94 [ ]

1. Yes **2.** No

Q95 If Yes, who and how often is collection service provided?

		1. Yes **2.** No	**Frequency**					**Fee** (000 VND/month/household)		
			Daily	2-4 days a week	Once a week					
1. Public	Q95-1		1	2	3	Q95-4 [ ]	Q95-7			
2. Private	Q95-2		1	2	3	Q95-5 [ ]	Q95-8			
3.Community	Q95-3		1	2	3	Q95-6 [ ]	Q95-9			

Q96 Do you separate the combustible garbage from noncombustible one? Q96 [ ]

1. Yes **2.** No

Q97 (for those who have services) Are you satisfied with the current services?

	Highly unsatisfied	Unsatisfied	So-so	Satisfied	Highly satisfied	
1. Frequency of collection	1	2	3	4	5	Q97-1 [ ]
2. Method of collection	1	2	3	4	5	Q97-2 [ ]
3. Fee	1	2	3	4	5	Q97-3 [ ]
4. Cleanness of dump site	1	2	3	4	5	Q97-4 [ ]

Q98 (for those who do NOT have services), how do you dispose solid waste? Q98 [ ]

1. Treated in own land **2.** Throw to nearby dump sites
3. Throw to nearby drainage or river

Q99 Up to how much are you willing to pay for improved solid waste collection services per month? Q99 [ ]

1. less than 10,000 VND **3.** 31,000 to 50,000 VND **5.** more than 100,000 VND
2.10,000 to 30,000 VND **4.** 51,000 to 100,000 VND

Daily Life / Living Environment

Q100 Did you go anywhere out of Hanoi with anyone in 2004?

1. No 2. yes, once 3. yes, 2-3 times 4. yes, more than 3 times

With whom?	
a. friends	Q100-a
b. family	Q100-b
c. alone	Q100-c

Where did you go? Please give the name of the province where you went to (at most 4)

Q101 How do you use your free time? (choose 2)

01. At home	**05.** Go camping	**09.** Play sports	Q101-1
02. going around the city	**06.** Movie	**10.** Go to the friends'	
03. Study	**07.** Visit historical places	**11.** See relatives	-2
04. Go shopping	**08.** Go having specialties	**12.** Others	

Q102 How do you find living environment and services in your neighborhood with regard to the following aspects?

		Highly unsatisfied	Unsatisfied	So-so	Satisfied	Highly Satisfied	
Living Environment	**01.** Safety/ security	1	2	3	4	5	Q102-1
	02. Flood	1	2	3	4	5	Q102-2
	03. Housing	1	2	3	4	5	Q102-3
	04. Air quality	1	2	3	4	5	Q102-4
	05. Tranquility	1	2	3	4	5	Q102-5
	06. Sanitary condition	1	2	3	4	5	Q102-6
	07. Landscape	1	2	3	4	5	Q102-7
	08. Greenery	1	2	3	4	5	Q102-8
Urban Services	**09.** Power supply	1	2	3	4	5	Q102-9
	10. Water supply	1	2	3	4	5	Q102-10
	11. Gas supply	1	2	3	4	5	Q102-11
	12. Telecom	1	2	3	4	5	Q102-12
	13. Solid waste collection	1	2	3	4	5	Q102-13
Access to services	**14.** to market (daily supply)	1	2	3	4	5	Q102-14
	15.to health care	1	2	3	4	5	Q102-15
	16. to public transport	1	2	3	4	5	Q102-16
	17. to primary school	1	2	3	4	5	Q102-17
	18. to park and green space	1	2	3	4	5	Q102-18
	19. to entertainment facilities	1	2	3	4	5	Q102-19
	20. to public administrative office	1	2	3	4	5	Q102-20

Q103 Please select five (5) most important point from 20 aspects in (Q102)

Q101-1 2 3 4 5

Vision of Hanoi City

Q104 Please select two (2) most suitable images for future Hanoi City. Q104-1 2

01. Harmony	**04.** Water	**07.** Peaceful	**10.** Modern
02. Clean	**05.** Culture/heritage	**08.** International/global	**11.** Development
03. Greenery	**06.** Friendly	**09.** Scientific/ high-tech	

Appendix B: Questionnaire Form of Household Interview Survey in 2011

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

Part 1: General information of household member

INSTRUCTION: To be completed by HEAD OF HOUSEHOLD

Q1-1: Please, write general information of *EACH MEMBER* of the household. (NOTE: use code tables on the left and fill in each row in turn)

Role of member:
1. HEAD OF HOUSEHOLD (*HOHH*)
2. HOHH's Son/daughter
3. HOHH's Husband/wife
4. HOHH's Brother/sister
5. HOHH's Father/Mother
6. HOHH's Grandfather /grandmother
7. Others

Gender:
1. Male
2. Female

Marital Status:
1. Married
2. Single

Average monthly personal income (000 VND):
1. None
2. < 1,500
3. 1,500 – 3,000
4. 3,001 – 5,000
5. 5,001 – 10,000
6. 10,001 – 15,000
7. 15,001 - 20,000
8. > 20,000

Main Job:
1. Government services
2. Private company services
3. Worker in factories
4. Farmer
5. Police, military
6. Merchant
7. Freelancer
8. Student, pupil
9. Retired
10. Housewife
11. Unemployed
12. Others

Education Level:
1. High school or below
2. Junior college
3. Bachelor
4. Mater/Doctor

Driving license:
1. Motorcycle
2. Car
3. Both
4. None

Car/Motorcycle for your own use:
1. Yes
2. No

Member No.	Age	Role of member	Gender	Marital Status	Average monthly personal income	Main job	Education Level	Driving license	Car for your own use (Yes/No)	Motorcycle for your own use (Yes/No)	Year that you got motorcycle license	Year that you start driving motorcycle
1 (*HEAD OF HOUSEHOLD*)		1										
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

Part 2: Retrospective survey in residential relocation and travel behavior *(1991-2011)*

INSTRUCTION: To be completed by HEAD OF HOUSEHOLD.

2-1. Residence and general household information: (Please, use code tables on the left and fill in ***each column*** in turn for ***last 4 times*** at which you change residence).

Address:
S: Street
C/W: Commune/Ward
D: District
Ci/P: City/Province

Housing tenure:
1. Owner
2. Renter
3. Others

Household Composition:
1. Single
2. Only a couple
3. Couple and their unmarried children only
4. A single parents and children only
5. Three generations
6. Non-family group
7. Others

Type of house:
1. Detached house
2. Townhouses or row house of 1-3 stories
3. Apartment (old)
4. Apartment (new)
5. Villa
6. Others

Total living area:
1. <30 m2
2. 30-50 m2
3. 50-80 m2
4. >80 m2

Total household monthly income (000 VND):
1. < 1,500
2. 1,500 – 3,000
3. 3,001 – 5,000
4. 5,001 – 10,000
5. 10,001 – 15,000
6. 15,001 - 20,000
7. > 20,000

Distance to nearest main places:
1. < 100m
2. 100-200m
3. 201-500m
4. > 500m

2011 →

	Location A *(Current)*	Location B	Location C	Location D	Location E
1. Address (Note: please, write down clearly *COMMUNE/WARD)*	S: …… C/W: …… D: …… Ci/P: ……	S: …… C/W: …… D: …… Ci/P: ……	S: …… C/W: …… D: …… Ci/P: ……	S: …… C/W: …… D: …… Ci/P: ……	S: …… C/W: …… D: …… Ci/P: ……
2. Relocation timing *(month and year)*					
3. Household composition	……	……	……	……	……
4. Total household monthly income	…..	…..	…..	…..	…..
5a. Housing tenure	……	……	……	……	……
5b. If you are house owners, write down purchase cost (billion VND), otherwise skip this	……..	……..	……..	……..	……..
5c. If you are house renters, write down average monthly renting (million VND), otherwise skip this	……..	……..	……..	……..	……..
6. Type of house	……..	……..	……..	……..	……..
7. Total living area	……	……	……	……	……
8. Distance to nearest bus *stop/rail station*	……	……	……	……	……
9. Distance to nearest *elementary school*	……	……	……	……	……
10. Distance to nearest *hospital*	……	……	……	……	……
11. Distance to nearest *park*	……	……	……	……	……
12. Distance to nearest *market*	……	……	……	……	……
13. Distance to nearest *convenience store/ grocery*	……	……	……	……	……
14. Total number of household members	…..	…..	…..	…..	…..
15. Number of members aged 65 and above	…..	…..	…..	…..	…..
16. Number of members aged under 16	…..	…..	…..	…..	…..

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

2-2. Detailed Information about Household and Yourself within 1990-2011: (NOTE: please, use the pencil/pen to draw on each part in the following tables)

***Household Composition*:**
1. Single
2. Only a couple
3. Couple and their unmarried children only
4. A single parents and children only
5. Three generations
6. Non-family group
7. Others

Year		1991	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	2011
a. Household composition	Single																					
	Only a couple																					
	Couple and unmarried children only																					
	A single parent and children only																					
	3 generations																					
	Non-family group																					
	Others																					
Code *(only for surveyor)*																						

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

Occupation:
1. Government services
2. Private company services
3. Worker in factories
4. Farmer
5. Police, military
6. Merchant
7. Freelancer
8. Student, pupil
9. Retired
10. Housewife
11. Unemployed
12. Others

Year		1991	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	2011
b. Your main occupation	Government services																					
	Private company services																					
	Worker in factories																					
	Farmer																					
	Police, military																					
	Merchant																					
	Freelancer																					
	Student, pupil																					
	Retired																					
	Housewife																					
	Unemployed																					
	Others																					
Code (***only for surveyor***)																						

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

Household motorcycle ownership:
1. None
2. One
3. Two
4. Three
5. More than 3

Household car ownership:
1. None
2. One
3. Two
4. More than 2

Household bicycle ownership:
1. None
2. One
3. Two
4. More than 2

Year		1991	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	2011
c. Household *Motorcycle* Ownership	None																					
	One																					
	Two																					
	Three																					
	More than 3																					
Code (*only for surveyor*)																						
d. Household *Car* Ownership	None																					
	One																					
	Two																					
	More than 2																					
Code (*only for surveyor*)																						
e. Household *Bicycle* Ownership	None																					
	One																					
	Two																					
	More than 2																					
Code (*only for surveyor*)																						

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

Engine size of your motorcycle:
1. None
2. < 50cc
3. 50-100cc
4. 101-150cc
5. > 150cc

Engine size of your car:
1. None
2. < 1500cc
3. 1501-2500cc
4. > 2500cc

Year		1991	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	2011
f. Engine size of your *motorcycle*	None																					
	< 50cc																					
	50-100cc																					
	101-150cc																					
	> 150cc																					
Code ***(only for surveyor)***																						
g. Engine size of your car	None																					
	< 1500cc																					
	1500-2500cc																					
	> 2500cc																					
Code (***only for surveyor***)																						

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

2.3: Please, record ***4 HOUSEHOLD COMPOSTION CHANGE*** within 1991-2011 in ***part 1.2*** . (NOTE: use the code tables on the left and fill in ***each column*** in turn about your adult *household member* who ***aged 16 and above***)

Household Composition:
1. Single
2. Only a couple
3. Couple and their unmarried children only
4. A single parents and children only
5. Three generations
6. Non-family group
7. Others

Main job:
1. Government services
2. Private company services
3. Worker in factories
4. Farmer
5. Police, military
6. Merchant
7. Freelancer
8. Student, pupil
9. Retired
10. Housewife
11. Unemployed
12. Others

Car for your own use:
1. Yes
2. No

Motorcycle for your own use:
1. Yes
2. No

Role of member:
1. HEAD OF HOUSEHOLD (*HOHH*)
2. HOHH's Son/daughter
3. HOHH's Husband/wife
4. HOHH's Brother/sister
5. HOHH's Father/Mother
6. HOHH's Grandfather /grandmother
7. Others

Monthly personal income (000 VND):
1. None
2. < 1,500
3. 1,500 – 3,000
4. 3,001 – 5,001
5. 5,001 – 10,000
6. 10,001 – 15,000
7. 15,001 - 20,000
8. > 20,000

Driving license:
1. Motorcycle
2. Car
3. Both
4. None

Gender:
1. Male
2. Female

Travel mode:
1. Walking
2. Bicycle
3. Motorcycle
4. Bus
5. Car
6. Others

Marital Status:
1. Married
2. Single

Address:
C/W: Commune/Ward
D: District
Ci/P: City/Province

		Event B	Event C	Event D	Event E
i. Timing (Month and Year)		.....	.....	.....	.....
ii. Household composition		.....	.....	.....	.....
1. Member *No.1 (current head of household)*	**a. Age**	.....	.....	.....	.....
	b. Role of member	.....	.....	.....	.....
	c. Gender				
	d. Marital status	.....	.....	.....	.....
	e. Main job	.....	.....	.....	.....
	f. Monthly personal income	.....	.....	.....	.....
	g. Driving license	.....	.....	.....	.....
	h. Most frequently travel mode	.....	.....	.....	.....
	i. Car for your own use	.....	.....	.....	.....
	k. Motorcycle for your own use	.....	.....	.....	.....
	l. Workplace/ school place (Note: please, write down clearly *COMMUNE/WARD)*	C/W: ..... D: ..... Ci/P:	C/W: ..... D: ..... Ci/P:	C/W: ..... D: ..... Ci/P:	C/W: ..... D: ..... Ci/P: .....
2. Member *No.2*	**a. Age**	.....	.....	.....	.....
	b. Role of member	.....	.....	.....	.....
	c. Gender	.....	.....	.....	.....
	d. Marital status	.....	.....	.....	.....
	e. Main job				
	f. Monthly personal income	.....	.....	.....	.....
	g. Driving license	.....	.....	.....	.....
	h. Most frequently travel mode	.....	.....	.....	.....
	i. Car for your own use	.....	.....	.....	.....
	k. Motorcycle for your own use	.....	.....	.....	.....
	l. Workplace/ school place (Note: please, write down clearly *COMMUNE/WARD)*	C/W: ..... D: ..... Ci/P:	C/W: ..... D: ..... Ci/P:	C/W: ..... D: ..... Ci/P:	C/W: ..... D: ..... Ci/P: .....

Household No. | | | |

HEAD OF HOUSEHOLD will answer all part from 1 to 5.
Other members only answer part 3, 4, 5.

Role of member:
1. HEAD OF HOUSEHOLD (*HOHH*)
2. HOHH's Son/daughter
3. HOHH's Husband/wife
4. HOHH's Brother/sister
5. HOHH's Father/Mother
6. HOHH's Grandfather /grandmother
7. Others

Monthly personal income (000 VND):
1. None
2. < 1,500
3. 1,500 – 3,000
4. 3,001 – 5,000
5. 5,001 – 10,000
6. 10,001 – 15,000
7. 15,001 - 20,000
8. > 20,000

Gender:
1. Male
2. Female

Driving license:
1. Motorcycle
2. Car
3. Both
4. None

Address:
C/W: Commune/Ward
D: District
Ci/P: City/Province

Marital Status:
1. Married
2. Single

Travel mode:
1. Walking
2. Bicycle
3. Motorcycle
4. Bus
5. Car
6. Others

Main Job:
1. Government services
2. Private company services
3. Worker in factories
4. Farmer
5. Police, military
6. Merchant
7. Freelancer
8. Student, pupil
9. Retired
10. Housewife
11. Unemployed
12. Others

Car for your own use:
1. Yes
2. No

Motorcycle for your own use:
1. Yes
2. No

		Event B	Event C	Event D	Event E
3. Member *No.3*	**a. Age**	.....	.....	.....	.....
	b. Role of member	.....	.....	.....	.....
	c. Gender	.....	.....	.....	.....
	d. Marital status	.....	.....	.....	.....
	e. Main job	.....	.....	.....	.....
	f. Monthly personal income	.....	.....	.....	.....
	g. Driving license	.....	.....	.....	.....
	h. Most frequently travel mode	.....	.....	.....	.....
	i. Car for your own use	.....	.....	.....	.....
	k. Motorcycle for your own use	.....	.....	.....	.....
	l. Workplace/ school place (Note: please, write down clearly *COMMUNE/WARD)*	C/W: …… D: …… Ci/P: ……..	C/W: …… D: …… Ci/P: ……..	C/W: …… D: …… Ci/P: ……..	C/W: …… D: …… Ci/P: ……..
4. Member *No.4*	**a. Age**	.....	.....	.....	.....
	b. Role of member	.....	.....	.....	.....
	c. Gender	.....	.....	.....	.....
	d. Marital status	.....	.....	.....	.....
	e. Main job	.....	.....	.....	.....
	f. Monthly personal income	.....	.....	.....	.....
	g. Driving license	.....	.....	.....	.....
	h. Most frequently travel mode	.....	.....	.....	.....
	i. Car for your own use	.....	.....	.....	.....
	k. Motorcycle for your own use	.....	.....	.....	.....
	l. Workplace/ school place (Note: please, write down clearly *COMMUNE/WARD)*	C/W: …… D: …… Ci/P: ……..	C/W: …… D: …… Ci/P: ……..	C/W: …… D: …… Ci/P: ……..	C/W: …… D: …… Ci/P: ……..

Household No. ☐☐☐ *Member code* ☐☐ *NOTE*: should be the same as ***member No.*** in part 2.3

Part 3: Travel behavior of household member

INSTRUCTION: Get information of EVERY HOUSEHOLD MEMBER aged 16 years and above.

Q3-1: Please, fill in information about your trips from home to workplace/school

a. Times per week	b. Travel mode(s)	c. Distance from home to main workplace (one-way)
……………………………(times)	1. ☐ Walking 2. ☐ Bicycle 3. ☐ Motorcycle 4. ☐ Bus 5. ☐ Car 6. ☐ Others	………………………………..(km)

If you use *bus* to commute, please fill in (*otherwise*, move to question Q3-2):

d. Access Mode to Bus stop	1. ☐ Walking 2. ☐ Drop off by bicycle 3. ☐ Drop off by motorcycle	4. ☐ Drop off by car 5. ☐ Other modes	
e. Average access time to Bus stop (*minutes*)	1. ☐ 1-5 2. ☐ 6-10	3. ☐ 11-20 4. ☐ 21-30	5. ☐ >30
f. Average waiting time at Bus stop (*minutes*)	1. ☐ 1-5 2. ☐ 6-10	3. ☐ 11-20 4. ☐ 21-30	5. ☐ >30

Q3-2: How often do you use the following means of transport from your home to destinations that you *most often* come in a typical month?

Trip purpose	a. Motorcycle	b. Bus	c. Car	d. Bicycle
1. Shopping	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday
2. Recreation and leisure	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday
3. Visiting friends/relatives	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday	1. ☐ Never 2. ☐ Once a month 3. ☐ Twice a month 4. ☐ 1 or 2 times per week 5. ☐ 3 or 4 times per week 6. ☐ Almost everyday

Part 4: Attitudes

INSTRUCTION: Get information of EVERY HOUSEHOLD MEMBER aged 16 years and above.

Q4-1: Can you indicate attitudes towards some following means of transport? (Note: *please answer all questions*)

		Strongly disagree	Partly disagree	Neutral	Partly agree	Strongly agree
a. Walking/ Cycling	01. You like walking/cycling (pro-travel)	1	2	3	4	5
	02. Walking/Cycling is safer than the others mode (safety)	1	2	3	4	5
	03. Travelling by walking/cycling will lose time	1	2	3	4	5
	04. Travelling by walking/cycling will save money	1	2	3	4	5
b. Motorcycle	*01. You like driving a motorcycle (pro-travel)*	1	2	3	4	5
	02. Motorcycle driving is safer than the others mode (safety)	1	2	3	4	5
	03. Travelling by motorcycle will lose your time	1	2	3	4	5
	04. Travelling by motorcycle will save money	1	2	3	4	5
c. Car	01. You like driving a car (pro-travel)	1	2	3	4	5
	02. Car driving is safer than the others mode (safety)	1	2	3	4	5
	03. Travelling by car will lose your time	1	2	3	4	5
	04. Travelling by car will save money	1	2	3	4	5
d. Bus	*01. You like riding a bus (pro-travel)*	1	2	3	4	5
	02. Bus is safer than the others mode (safety)	1	2	3	4	5
	03. Travelling by bus will lose your time	1	2	3	4	5
	04. Travelling by bus will save money	1	2	3	4	5

Q4-2: In general, how happy would you say that you are?

1. Very happy	2. Unhappy	3. Normal	4. Happy	5. Very happy

Q4-3: In general, how are you satisfied with the following areas of your life?

	Strongly dissatisfied	Somewhat dissatisfied	Neither satisfied or dissatisfied	Somewhat satisfied	Strongly satisfied
1. Your residential environment	1	2	3	4	5
2. Your household budget conditions	1	2	3	4	5
3. Your health conditions	1	2	3	4	5
4. Your relationship with neighborhood	1	2	3	4	5
5. Your education	1	2	3	4	5
6. Your employment	1	2	3	4	5
7. Your household life	1	2	3	4	5
8. Your leisure and recreational activities	1	2	3	4	5
9. Your overall life satisfaction	1	2	3	4	5

Household No. | | | | *Member code* | | | *NOTE*: should be the same as ***member No***. in part 2.3

Part 5: Neighborhood perceptions

INSTRUCTION: Get information of EVERY HOUSEHOLD MEMBER aged 16 years and above.

Q5-1: How do you think about the living environment with regard to following the aspects? (Note: *please answer living environment in urban core and outside*)

		Not at all true	Not a bit true	A bit true	Entirely true
a. Urban core	01. Easy access to downtown	1	2	3	4
	02. Easy access to leisure and entertainment facilities	1	2	3	4
	03. Good public transport services	1	2	3	4
	04. Easy access to park and open space	1	2	3	4
	05. Easy access to health care and educational services	1	2	3	4
	06. Good security or safety (low crime rate)	1	2	3	4
	07. Good urban services (power, gas and water supply)	1	2	3	4
	08. More opportunities to buy a house	1	2	3	4
b. Outside urban core	*01. Easy access to downtown*	1	2	3	4
	02. Easy access to leisure and entertainment facilities	1	2	3	4
	03. Good public transport services	1	2	3	4
	04. Easy access to park and open space	1	2	3	4
	05. Easy access to health care and educational services	1	2	3	4
	06. Good security or safety (low crime rate)	1	2	3	4
	07. Good urban services (power, gas and water supply)	1	2	3	4
	08. More opportunities to buy a house	1	2	3	4

Q 5-2: Types of residences

		None	A few	Some	Most	All
1	How common are *detached single-family residences* in your immediate neighborhood?	1	2	3	4	5
2	How common are *townhouses or row houses of 1-3 stories* in your immediate neighborhood?	1	2	3	4	5
3	How common are old *apartments or old condos 1-5 stories* in your immediate neighborhood?	1	2	3	4	5
4	How common are old *apartments or new condos 1-10 stories* in your immediate neighborhood?	1	2	3	4	5
5	How common are *apartments or condos 10-15 stories* in your immediate neighborhood?	1	2	3	4	5
6	How common are *apartments or condos more than 15 stories* in your immediate neighborhood?	1	2	3	4	5
7	How common are *villa* in your immediate neighborhood?	1	2	3	4	5