DOCTORAL DISSERTATION

博 士 論 文

A STUDY ON ASSESSING IMPACT OF RESIDENTIAL SELF-SELECTION ON TRAVEL CHOICE BEHAVIOR IN DEVELOPING COUNTRIES: A CASE STUDY OF TRANSIT-ORIENTED DEVELOPMENT IN BANGKOK

開発途上国における居住地選択が交通選択行動に与える

影響評価に関する研究－バンコクを事例として－

Yokohama National University

Graduate School of Urban Innovation

国立大学法人　横浜国立大学大学院都市イノベーション学府

PEAMSOOK SANIT

ピームスック　サニット

September 2014

2014 年 9 月

A STUDY ON ASSESSING IMPACT OF RESIDENTIAL SELF-SELECTION ON TRAVEL CHOICE BEHAVIOR IN DEVELOPING COUNTRIES: A CASE STUDY OF TRANSIT-ORIENTED DEVELOPMENT IN BANGKOK

開発途上国における居住地選択が交通選択行動に与える影響評価に関する研究

ーバンコクを事例としてー

by

PEAMSOOK SANIT

ピームスック　サニット

A Dissertation Submitted to the Graduate School of Urban Innovation, Yokohama National University in Partial Fulfillment of the Requirement for the Degree of

Doctor of Engineering

Yokohama National University, Graduate School of Urban Innovation

国立大学法人　横浜国立大学大学院都市イノベーション学府

<u>Examination Committee</u>

Professor, Dr. Fumihiko NAKAMURA (Chair)

Associate Professor, Dr. Shinji TANAKA (Co-chair)

Professor, Dr. Yoko FUJIKAKE

Professor, Dr. Kimitoshi HAYANO

Associate Professor, Dr. Mihoko MATSUYUKI

September 2014

2014 年 9 月

ABSTRACT

Transit Oriented Development (TOD) is gaining popularity as a tool to promote smart growth and sustainable development in many metropolitans in developing countries where mass transit systems have implemented to relieved traffic congestion. However, there is tremendous resistance for the TOD to accomplish its goal. Although, the housing development near train stations is rapidly expanding along the urban railway corridor in most transit cities, transit authorities are facing the main problem that their transit ridership is lower than the expected level. Therefore, there is still no clear reason why people choose to live near the stations as well as whether or not they become regular users of rail transit after moving to live near the station.

There is a continuing debate which factors are effective in modifying household travel decisions. The role of residential self-selection is claimed to be one of the key issues that makes the research on these associations complicated. The residential self-selection is defined as the probability that households may choose residential locations that comply with their travel preferences. It is still questionable to what extent it influences travel choice behavior. Ignoring preference leads to an overestimation of the impact of the distance to railway stations on travel behavior. The main objective of this research is to understand the multi-dimensional relationship between location behavior, travel patterns, and travel attitudes of residents those residing close proximity to public transport within a behavioral analysis framework. The mechanisms of these interactions have not been fully understood in this research field. If policies towards public transport development in the city will be effective to encourage people to drive less and ride public transport more, it is crucial for urban and transport planners to explore which factors are the major determinants in enhancing transit ridership.

This research draws lesson from case example of transit-oriented metropolis of Bangkok that has direct relevance to cities in developing countries and elsewhere that are currently investing in mass transit systems. This city has prerequisites for the TOD characteristics of high-density and mixed land use in the areas served by rail transit lines. But there is still lack of strategies and regulations to integrate the land use and transportation development for the TOD enhancement. Therefore, mass transit ridership has failed to meet the expected ridership level. The main objective is to examine which factors potentially influence rail commuting using household travel survey data conducted in 2008, 2010 and 2013 respectively. Discrete choice models in the context of join-logit models including multinomial and nested logit model are employed to investigate the impact of built environment concerning to transit proximity, travel attitudes and residential self-selection on travel choice behavior. The originality of this research is to develop multi-dimensional nested logit model by integrating mode preferences together with locational and

travel choice behavior. Besides, the findings of discriminant analysis are also integrated to demonstrate which factors can potentially explain the decision on allocation to the transit passenger or driver since there is no data set of household travel survey data in 2010 applicable to the logit model.

From the results of discrete choice modeling and discriminant analysis, several significant factors affecting the transit ridership are finally presented. Firstly, the results of standard logit in context of binary and multinomial logit model demonstrate that built environment of residential and workplace location close proximity to transit stations has strongly influence on the decision to commute by the transit. But controlling these locational choices as endogenous in the model, household characteristics such as car ownership, income and compositions of household can be the potential predictors of transit ridership rather than transportation factors in terms of travel cost and time. These findings are equivalent to the results of discriminant analysis. Secondly, travel attitudes that are relevant to these household characteristics are thus added in the model. By controlling the built environment proximity to the stations, preference for transit mode choice is the strongest positive predictor for the rail commuting of the station-area residents as compared to other significant factors in the model. The powerful determinant of mode preferences illustrates that the so-called residential self-selection has taken place and there is a significant relationship between built environment, travel attitudes and travel choice behaviors. Travel attitudes have strong influence on travel choice behavior through residential choice. Lastly, to estimate the true effect of built environment of transit proximity on travel choice behavior by controlling self-selection bias, mode preferences are added in choice set of nested logit model. The log-sum coefficient confirms the applicable of this model. The model results reveals the real impact of the distance to railway stations on rail commuting. Low degree coefficient of the distance to the nearest stations implies its limited impact in explaining the patronages of transit service among the station-area residents after controlling self-selection effect.

This research originally focuses at individual-level initiatives of travel choice behavior taking into account the residential self-selection, which can recommend on the kinds of households who are most inclined to move to station areas and become the patronage of transit services. The findings in this research could provide not only an appropriate framework with valuable ideas to enhancing the TOD implementation and future urban land use and transportation planning for sustainable development but also an applicable methodology to estimate the true impact of the residential location proximity to mass transit on travel choice behavior in transit cities in developing countries.

ACKNOWLEDGEMENT

I take this opportunity to extend my heartiest thanks to all those who have contributed to make this Ph.D. thesis a success. First of all I would like to express my deepest gratitude towards my academic supervisors Prof. Fumihiko Nakamura and Assoc. Prof. Shinji Tanaka for their encouragement, valuable guidance and kind support during my PhD study at Transportation and Urban Engineering Research Laboratory, Yokohama National University. I would also like to extend my sincere appreciation to all committee members: Prof. Yoko Fujikake, Prof. Kimitoshi Hayano and Assoc. Prof. Mihoko Matsuyuki for their constructive comments and suggestions for the improvement of this dissertation.

My endless gratitude and indebtedness also go to Ministry of Education, Culture and Sports, Science and Technology, Japan for providing me the tremendous opportunity to fulfill my PhD degree in the most academic environment with a full financial support. Moreover, I really appreciate all support of my respect teachers from Chulalongkorn University, Thailand, Asst. Prof. Panit Pujinda, Asst. Prof. Apiwat Ratanawaraha and Assoc. Prof. Saksith Chalermpong at all phase of this research work. I also gratefully acknowledge the support of TEAM Logistics and Transport Co., Ltd. (TLT), Thailand and Mr. Wanchai Sakpongsatorn in data collection for my study. The kind support of Mr Grittigrai Karalak contributed to my success in model calibration.

My heartfelt appreciation is extended to all members in YNU. I give my sincere thanks to Dr. Rui Wang for his invaluable support and advice on my research work, my Japanese teachers, Ms. Tomoko Kuki, for her wholehearted effort to enable me to communicate in Japanese as well as enjoy living in Japan. My endless thankfulness is extended to the technical staffs: Mr. Masaru Harayama and Ms. Minako Koiwa for the kind co-operation and help in documentation and formalities during my stay in this laboratory. Moreover, I am very grateful to all colleagues in my laboratory as well as all dear friends in this university for making my life in Japan so joyful. Special thanks to my dearest junior, Mr Wakamiya Ryo, who is always with me and enjoys blissful moments together.

Finally, I would express the deepest sense of gratitude to my family, especially to my dearest parents, who have always stood by me and to whom I owe my life for their constant love, encouragement, moral support and blessings. Special thanks are due to my beloved friends Dr. Ruttapol Lertsirisopon and Dr. Saratchai Ongprasert who always strengthened my morale by standing by me in all situations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Accomplishing sustainable transport is a main challenge encountered by countries around the world, in particular, developing countries which have to cope with transport-related environmental problems associated with the increasing trend in car ownership and use. In the past decades, many metropolitans of the developing world have implemented mass transit systems to relieved traffic congestion (e.g. Bus Rapid Transit (BRT) in Jakarta, Seoul, Bogota and Curitiba as well as rail-based systems, Light Rail transit (LRT)/Heavy Rail Transit (HRT) in Bangkok, Delhi and Manila). The urban transport management in these cities has been receiving an increasing attention for its prospective to shift passengers from existing private motor vehicle to mass rapid transit.

Transit Oriented Development (TOD) is gaining popularity as a tool to promote smart growth and sustainable development. It provides an opportunity to design the urban form to be transit-oriented. The planners expect that the TOD is important for its contribution to increasing transit ridership, relieving traffic congestion, spurring economic development, increasing housing choice, creating a diverse community and reducing urban sprawl (Cervaro, 1996). Recently, some Asian cities such as Hong Kong, Taiwan and China have also begun to examine the possibility of implementing these concepts in order to tackle their urban problems, especially traffic congestion (Lin and Shin,2008; Renne et al.,2005; Ewing and Cervero, 2001). Past studies have provided fascinating insights into the TOD benefits and the future of its implementation in these countries especially in terms of the effective tool to reduce traffic congestion and increase transit use in urban and transportation planning. For example, the TOD application is much more effective in increasing transit ridership and housing prices than just transit adjacent development in a case study of Hong Kong (Cervero and Murakami, 2010). In addition, the study in Seoul, Korea, it also summarized that the strategies such as strengthening the transit service network, increasing the land-use mix index and restructuring the street networks as well as urban design to be more pedestrian friendly around rail stations play a vital role in increasing transit ridership in addition to increasing density development (Sung, 2011). These evidences well support that such transit neighborhood including a mix of housing, office, shops and other amenities integrated within a walkable neighborhood and located within walking distance will encourage more walking and cycling and reduce the load on road networks. However, the main problem faced by mass transit authorities in most transit cities is that transit ridership has failed to meet their expected ridership level. In other words, there's tremendous resistance for the TOD to accomplish its goal.

The lessons learnt for the case studies of TOD in these countries revealed that there is lack of the long-term visions of promoting sustainable patterns of urban growth supporting with transit systems. The transit has been guided primarily by the almost singular objective of enhancing mobility. City administrations and transit agencies have often adopt a short-term, narrow focus on rapidly relieving congestion. This mindset is reflected in the absence of strategies and regulations to create higher densities along transit corridors and high-quality urban spaces. Both can be vital to increasing transit and non-motorized transit use, thus reducing private automobile travel (Suzuki et al, 2013). However, there is still a challenge whether many of the additional trips caused by the increased density will theoretically be taken by transit - if these additional trips do not take transit, all the increased density accomplishes is then to increase automobile traffic. In other words, if transit-oriented development does not increase transit usage then it is basically a failure.

There is a continuing debate which factors are effective in modifying household travel decisions. Many studies confirm that the correct arrangement of built environment will result in the enhancement of public transport utilization. However, there is argument that this approach results only in 'self-selection', that is that only residents willing to travel by public transport will locate in these places with resultant less impact on auto-user households (Nurlaelaa and Curtis, 2012). The role of residential self-selection, the probability that the connection between the built environment and travel behavior is associative and that households may choose residential locations that comply with their travel needs, is claimed to be one of the key issues that makes the research on these associations complicated. (Bohte, 2010). If policies towards public transport development in the city will be effective to encourage people to drive less and ride public transport more, it is crucial for urban and transport planners to explore the multi-dimensional relationship between location behavior and travel patterns of residents residing close proximity to public transport since the mechanisms of these interactions are not fully understood.

1.2 STATEMENT OF PROBLEM

The inventory of housing near train stations is rapidly expanding along the urban railway corridor in most transit cities in developing countries. Some traditional households were drawn to inner city urban living as well as immigrant households were accustomed to living in more transit-oriented areas. However, there is still no clear reason why people choose to live near the stations as well as whether or not the transit-based residents become the regular users of rail transit after moving to live near the station. Past studies claimed that one important aspect in assessing housing location decisions is its relation with travel choice. They argued that travel patterns are partly a result of the decision on where to live and this needs to be accounted for when studying how urban design, including the TOD, influences travel behavior. The majority of these studies have concluded that there is indeed a linkage between the characteristics of residential locations and travel behavior, to some degree at least. However, the complexity of the relationship between the built environment and travel behavior means that there is still considerable disagreement on the extent of the assumed effects (see e.g. Ewing and Cervero, 2001; Dieleman et al., 2002; Bhat and Guo, 2007; Boarnet and Crane, 2001). This leads to the central research question; *to what extent the TOD neighborhood attributes do influence household's residential location choice and travel choice behavior as compared to other factors- ?* In other words, how much household consider the transit proximity in their location and commuting mode choice decision as compared to other factors such as the characteristics of individual/household and transport attributes is questionable. However, most research that included personal and household variables in analyzing travel behavior concluded that they were more important for explaining travel behavior than land-use variables (Van Wee et al., 2002). More specifically, the following two research questions are formulated;

1. *Do travel attitudes influence travel behavior?*

Prior research indicates the neighborhood of high-density urban development leads to decreased travel and thus sustainable mobility; however, personal attitudes seem to have greater effect on mobility than does the urban form (Olaru et al., 2011). There is thus the causality linkage between the built environment, travel behavior and travel-related attitudes. However, the few research studies, carried out directly on preferences for modes, show the existence of preferences for modes. Suppose the TOD characteristics can increase transit usage. It is uncertain whether or not these transit users have chosen to live in the TOD precisely because they wanted to take transit, and did not start taking transit simply because the option had become available. There is an argument upon whether or not to what extent ridership bonus can be assigned to transit-oriented living is due to transit proximity or the characteristics of people who opt to live in these settings (Cervero and Duncan, 2002).

2. *To what extent does residential self-selection play an important role in mediating the complexity link between the location behavior and travel pattern?*

Residential self-selection suggests the possibility that households endogenously self-select themselves into neighborhoods that support their preferences for certain transport modes. For example, the travel preference of an individual/household means they select a location where they can behave in this way. If they have travel preference to use public transport, they will move to a location where this travel mode is available (Nurlaelaa and Curtis, 2012). This means people with a preference for traveling by train will, on average, live closer to railway stations. Likewise, if their travel preference is to drive everywhere, they will live somewhere where driving is unconstrained. It is therefore critical for determining the influence of the built environment on travel behavior taking into account the indirect influence that travel-related attitudes have on travel behavior, through their role in residential choice.

3. How can nested-joint logit model be developed to investigate sequential decision process on location and travel choice?

Past research has modeled mode choices among residents of transit-based housing using single logit model structures (Cervero, 1994) or regression models based on highly aggregate data (Pushkarev and Zupan, 1977; Bernick and Carroll, 1991). Under a logit formulation, factors like travel times of competing modes and demographic characteristics of trip-makers are used to predict probabilities residents tend to choose rail transit as their commuting choice to go to work (Cervero and Duncan, 2002). The originality of this research is to further develop multi-dimensional nested logit model by integrating mode preferences together with locational and travel choice behavior based on the assumption that people hierarchically select to live in the location that complies with their travel preferences before choosing their commuting choice for work trip. In other words, the decision to live near the station is due to the decision to commute by rail and then travel pattern is partly a result of the decision where to live.

1.3 AIM AND RESEARCH OBJECTIVES

The main objective of this research is to understand the multi-dimensional relationship between location behavior, travel patterns, and travel-related attitudes within a behavioral analysis framework. There are the following five sub-objectives.

1. To evaluate the impact of TOD neighborhood on transit ridership as well as to investigate more significantly effective factors in promoting ridership. *(Chapter 4)*
2. To examine the existing situation on transit-based residents' travel choice behavior and factors influencing their mode choice decision *(Chapter 5)*
3. To determine factors influencing on residential location and mode choice decision by

integrating locational and travel choice model *(Chapter 6)*

4. To identify the role of residential location choice and travel preference in travel choice behavior. (Chapter 7)
5. To evaluate the effect of residential self-selection on rail commuting and to develop multi-dimensional nested logit model by integrating mode preference together with locational and travel choice behavior. (Chapter 8)

Thus, at least to some degree, households self-select towards a residential neighborhood that complies their travel preferences, and therefore the success or failure of spatial planning that aims to influence travel behavior will depend on whether this self-selection is properly taken into account. It is important for spatial planers to examine the fact whether households adjust their travel behavior conforming their travel preferences and thus to determine whether or not the self-selection will have a positive (e.g. less congestion, more sustainable) or negative impact (Bohte 2010).

Many substantial attempts to empirically investigate the impact of residential self-selection on travel behavior can be interpreted in developed countries. Their experiences cannot be directly applied and transplanted without some adaptation and adjustments to the developing countries. This research draws lesson from case example of transit-oriented metropolis of Bangkok that has direct relevance to rapidly growing and motorizing cities in the developing world and elsewhere that are currently investing in bus rapid transit (BRT) and other high-capacity transit systems. The aim is to provide an appropriate framework that can guide the urban and transport planning practices in these regions that are planning or investing in large-scale transit systems. Recommendations for creating more sustainable cities of the future range from micro-level strategies, such as TOD, that influence development patterns at the neighborhood scale to individual-level initiatives, such as research on self-selection, which can throw light on the kinds of households who are most inclined to move to station areas and become the patronage of transit services. Basically, the TOD is a modern-day version of traditional urban development. And it's driven by all these policy concerns, shifting demographics, and lifestyle preferences. A better understanding of the complex relationships among built environment, travel behavior, and household attitudes can support transport planners leverage the benefits of TOD and improve the quality of urban design and community life.

1.4 SCOPE AND LIMITATIONS

The research has attempted to provide a practical lesson to promote the sustainability of

TOD in enhancing transit ridership in transit cities of developing countries. The case study of the TOD cities is exclusively selected according to the following main criteria;

1. The rapidly growing and motorizing cities that are currently investing in mass transit systems to overcome transport-related environmental problems associated with the increasing trend in car ownership and use.

2. The transit cities that have prerequisites for the TOD with respect to the characteristics of high-density and mixed land use in the areas served by rail transit lines, but the ridership of mass transit has still been lower than the expected level.

3. There are the lack of strategies and regulations to integrate the land use and transportation development for the TOD enhancement.

Due to limitation of time and resource, only Bangkok, a capital of Thailand, is selected as a case study in this research as it satisfies all the criteria mentioned above. This research, nevertheless, is not able to deal with all mass transit available in this city (i.e. BRT, Airport Rail Link, elevated rail system and subway). Only elevated rail and subway, namely BTS and MRT respectively, are chosen due to their prerequisites for the TOD.

Next, the research applies discrete logit in the context of nested logit model to evaluate the influence of the built environment on travel behavior which addresses residential self-selection by including attitudinal variables. It aims to improve upon model specifications by expressing mode choice as a derivative of peoples' preference for travel mode. The decision to commute by rail, it is hypothesized, is significantly explained by mode preference.

Rather than the advancement of modelling, the empirical analysis of discrete outcomes on the travel choice behavior among the resident those residing close proximity to public transport is the most important outcome to achieve the goal of this research. In order to simplify the complexity of such model, the alternatives of location and travel choice are set in binary term based the reasons not only on sample-size considerations but also a desire to best support public policy-making on the TOD focusing almost exclusively on rail transit systems. Following the research of Cervaro and Duncan (2002), *"given that TODs are conceived as geographic entities with boundaries and edges, their planning and design tends to be binary in nature – i.e., either land lies within the TOD sphere or not"*. Therefore, in this research, location is expressed either one lives near of a rail station or not as well as mode choice is represented between rail transit and automobile alternatives. *"And given that the major public benefit of TOD is transit riding, travel demand is also best treated as binary as part of an integrated analysis of residential location and commute choice"* Cervero and Duncan (2002). Moreover, lot of alternatives result in the shortage of cases for some of the choice sets.

Finally, the inclusion of attitude variables in the model is limited by the type of attitudes measured. The attitudes that individuals held at the time of making the residential choice is obtained from the retrospective questioning. Therefore the simple choices of travel mode preference are required because asking respondents retrospectively about their past behavior is unreliable: people do not remember everything and their memories may diverge from actual behavior. It's well recognized that the collection of attitudinal data before and after a residential move is the only method of actually measuring whether attitudes have changed after a move and have possibly been adjusted in line with the spatial structure of the new residential location. To be able to determine the exact influence of travel-related attitudes on the choice of residential location, and therefore on the degree of self-selection, it is important that these changes in attitudes are accounted for. Due to the lack of longitudinal data in most developing countries where the rail transit experience has been still young, the straightforward method of self-section questioning is thus applicable. In addition, this research has attempted to model the travel behavior using data set conducted in different time periods in order to compare how the travel pattern has been changing after the decades of its operation. Hopefully, the validity of this research will be enriched by the further studies in order to expedite the advancement of urban and transportation development in the city as well as developing countries.

1.5 OUTLINE OF DISSERTATION

There are a total of 9 chapters and appendices in this dissertation. This chapter starts to introduce the background why the impact of self-selection on travel behavior is important to study. The remaining chapters are arranged as follows:

Chapter 2 discusses in the literature on the role of residential self-selection in the relationship between built environment and travel behavior by reviewing theories and empirical research concerning to the basic knowledge of land use/transport connection as well as residential self-selection and travel choice behavior that have been used in the past studies.

Chapter 3 outlines the research framework, the hypotheses, data collection, the variables and the models used in this dissertation.

Chapter 4 evaluates the sustainability of TOD outcomes focusing on the impacts of TOD implementation on transit ridership. It investigates what factors are more significantly effective in promoting transit ridership.

Chapter 5 examines factors influencing on their mode choice decision. It assesses the level of

significance that built environment context plays in travel behavior and supporting individual characteristics as the main factor in explaining observed behavior.
Chapter 6 integrates model of location and mode choice to examine factors influencing the decision mechanism on where to live and how to go to work live compared with other factors in disaggregate manner. In particular, it tries to investigate to what extent the transit neighborhood plays a significant role in determining households' choices decision. Not only single-worker household but multi-worker family as well will be considered how they evaluate the overall utility of all working members when making decision on house location and travel mode for their work trip.

Chapter 7 originally adds attitude variables in travel choice model to further examine why people choose to live near rail transit station, whether their decision is related to the decision to commute by rail and whether they become regular railway users after moving to live near the station. Specifically, it takes residential self-selection into account in travel behavior research to provide a better understanding of a complex relationship among built environment, travel, socio-demographic characteristics and attitudes.

Chapter 8 further investigates the influence of residential self-selection on travel choice behavior based on a more complicated assumption of a sequential decision process on location and travel choice. It is assumed that people hierarchically select to live in the location that complies with their travel preferences before choosing their commuting choice for work trip. Therefore, the originality of this research is to develop multi-dimensional nested logit model by integrating mode preference together with locational and travel choice behavior.

Chapter 9 concludes the key findings and recommends important implications and contributions that can guide the planning and practice of urban and transportation in developing countries. It also postulates the possible prospects for further research that can enrich the validity of research findings.

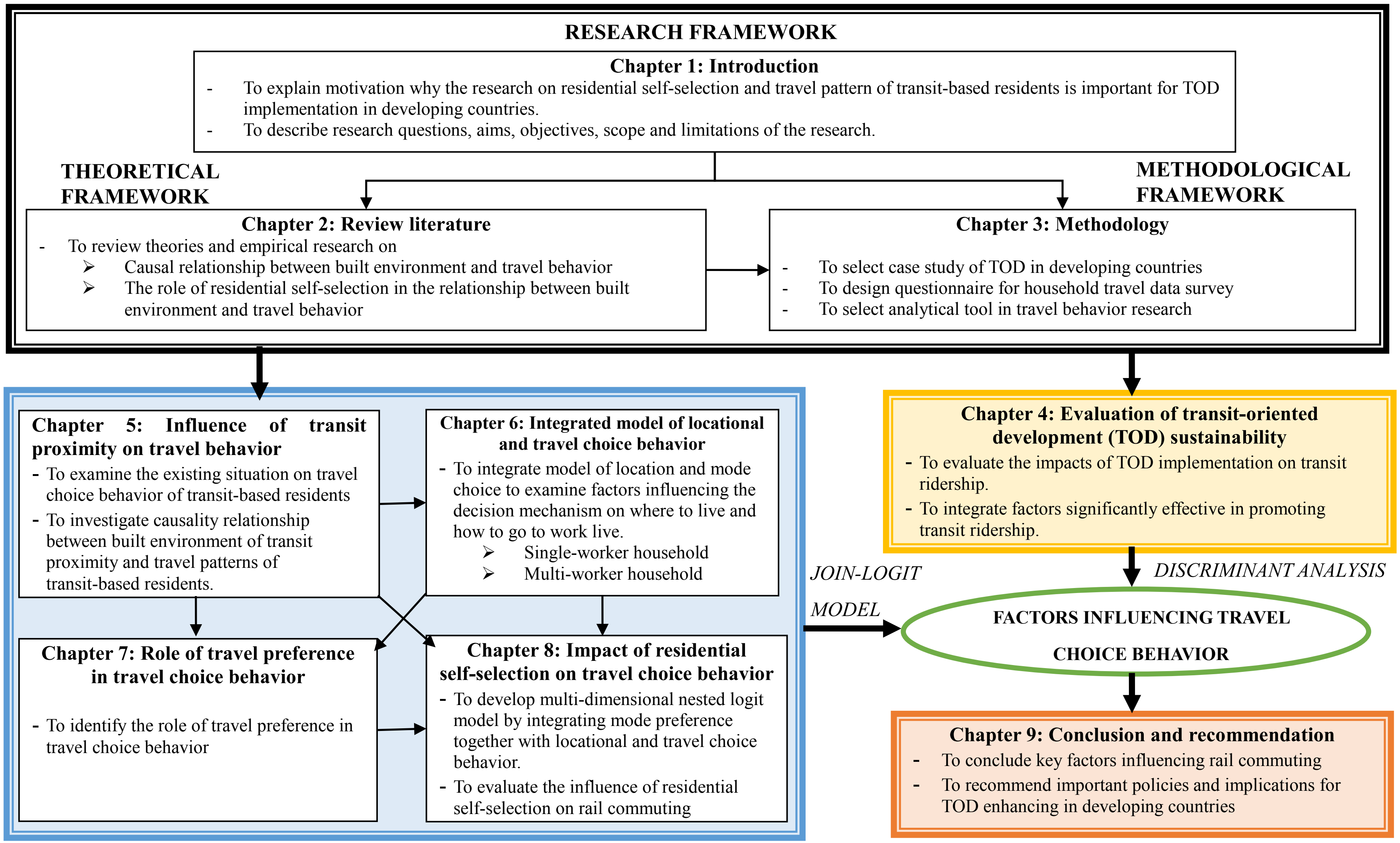


Figure 1.1 Interrelated outline of dissertation

CHAPTER 2

A REVIEW OF THEORIES AND EMPIRICAL RESEARCH ON RESIDENTIAL SELF-SELECTION AND TRAVEL CHOICE BEHAVIOR

Generally, travel behavior can be referred to as the study of what people do over space and how people use transportation (Hayes 1993). Goulias (2000) gave a more comprehensive definition stating that travel behavior is "the modeling and analysis of travel demand on the basis of theories and analytical methods from a variety of scientific fields. There is a continuing debate in the literature on whether which factors are effective in modifying household travel decisions. This chapter discusses the role of residential self-selection in the relationship between built environment and travel behavior. Olaru et.al. (2011) summarized that there are two streams of existing research investigate. The first group focuses on the impact of neighborhood attributes on residential location choice and travel choice behavior (Ewing et al., 1994;Friedman et al., 1994; Handy, 1996; Cervero and Wu, 1998; Cervero and Kockelman, 1997; Salomon and Mokhtarian, 1998; Crane, 2000; Cervero, 1996a, 1996b, 2003; Bagley and Mokhtarian, 2002; Khattak and Rodriguez, 2005; Nass, 2009; Pinjari A.R. et al, 2007, Ewing and Cervero, 2001, 2010; Hong et al., 2013, Wibowo and Chalermpong, 2010; Jayme and Chalermpong, 2013). The second group centers on the role of household structure and individual characteristics in explaining the diversity of travel and location decisions (Weisbrod et al, 1980; Kitamura et al., 1997; Guo and Bhat, 2006). The latter group scrutinizes the probability that the relationship between the built environment and travel behavior is associative and that households may choose residential locations that comply with their travel needs. This is known as residential self-selection. A combination of the two directions is also emerging (Cervero, 2002; Cao et al., 2005, 2006, 2008, 2009; Mokhtarian and Cao, 2008; Schwanen and Mokhtarian, 2005a,b, 2007; Tsai, 2008; Van Wee,2002, 2009; Pinjari er al.,2007; Bohte, 2010, Nurlaela and Curtis, 2012).

First of all, this research starts to understand the basic knowledge of land use/transport connection that has been used in the past studies in order to investigate how neighborhood characteristics affect travel behavior. Many studies confirm that the correct arrangement of built environment will result in the enhancement of public transport utilization. However, there is argument that this approach results only in 'self-selection', that is that only residents willing to travel by public transport will locate in these places with resultant less impact on auto-user households (Nurlaelaa and Curtis, 2012). If policies towards public transport development in the city will be effective to encourage people to drive less and ride public transport more, it is crucial to understand the multi-dimensional relationship between location behavior and travel patterns of residents residing close proximity to public transport. At this early stage of in the research this chapter focuses on the research framework by reviewing theories and empirical research concerning to residential self-selection and travel choice behavior.

2.1 CAUSAL RELATIONSHIP BETWEEN BUILT ENVIRONMENT AND TRAVEL BEHAVIOR

Research on housing and transport has become increasingly interested in determining the influence of the built environment on travel behavior since the development of spatial policies such as New Urbanism in the United States and the Compact City Policy in Europe aims to influence travel behavior (Bohte, 2010). Much research has evaluated this influence by analyzing the effect of land-uses such as compact development, mixed land-use and street design on the travel patterns of households. The majority of these studies have summarized that there is truly a connection between the characteristics of residential locations and travel behavior, to some degree at least (e.g. Geurs and Van Wee 2004; Handy, 2005; Bagley and Mokhtarian, 2002; Curtis and Olaru, 2010; Ewing and Cervero, 2010; Khattak and Rodriguez, 2005). However, the complexity of the relationship between the built environment and travel behavior means that there is still considerable disagreement on the extent of the assumed effects.

The relationship between built environment and transit ridership has been widely acknowledged and studied since 1990s. The need for travel by private motorized vehicles can be reduced by the creation of urban forms and spaces with well-integrated transit and land development. Areas with good access to public transit and well-designed urban spaces that are walkable and bikeable become highly attractive places for people to live, work, learn, play, and interact. Such environments enhance a city's economic competitiveness, reduce local pollution and global greenhouse gas emissions, and promote inclusive development. These goals are at the heart of transit-oriented development (TOD), an urban form that is increasingly important to sustainable urban futures. (Suzuki et. al, 2013)

Most studies suggest that the share of pedestrian and transit trips is higher in transit-based neighborhoods (e.g. Friedman et al., 1994; Handy, 1996; Kitamura et al., 1997; Cervero and Gorham, 1995; Cervero and Radisch, 1996). It is vital importance to transit planners and decision makers to understand how the densities, settlement patterns, land-use compositions, and urban designs of cities and neighborhoods influence transit usage. Whether a future rail transit extension will be a cost-effective investment or whether headways should be increased on a conventional bus route hinges critically on whether the built environment and the people living and working there will support these changes with their patronage (Transit Cooperative Research Program, 1995).

2.1.1 Built environment factors influencing transit ridership

This part summarizes the current reviewed research relating to how transit-oriented development (TOD) neighborhoods, places that are moderate to high-density development located within an easy walk (1/2 mile or 800 m) of a major public transport stop, invite people to drive their cars less and walk, cycle and take transit more. Currently, the concept of transit-oriented communities has been simplified under the Six "Ds" of built environments including density, diversity, design, destination accessibility, distance to transit and demand management (Trans link, 2010).

1) Destination : Regional accessibility

Regional accessibility is a key indicator of how well origins and destinations are connected. It is in part a function of the cost of a trip, which in turn is a function of the money, time, and distance involved in making that trip; the greater the cost to travel to a destination, the less accessible that destination is (Trans link, 2010).

Prior studies in regional scale found significant relationships between the size and extensiveness of employment centers and level of transit patronage in corridors leading to the employment centers (e.g. Arrington and Cervero, 2008; Badoe & Miller, 2000). Most find that concentrating jobs and housing where residents can be served by transit increases transit mode shares and reduces vehicle miles traveled (Transit Cooperative research Program, 1995).

> "The demand for mobility is derived from the need to connect origins with destinations. As the transit network increasingly links together concentrations of people with job and commercial centres, educational opportunities and cultural facilities, transit use increases" (Arrington and Cervero, 2008).

There is a difference in accessibility for every mode of transportation (Maat et al., 2004). For example, a destination may be more easily accessible by car than by transit; or may be accessible most conveniently by walking. There has been a challenge of the last half-century with the urban form since it was largely built to maximize automobile accessibility, with less consideration for other modes of transportation. This has resulted in a high degree of automobile dependence (Kenworthy & Laube, 1999). On a regional scale, improving the proximity of jobs to housing reduces the number of trip traveling (Cervero & Duncan, 2006). It is challenging to match jobs and housing within each neighborhood, as many people do not live, work, and play in the same neighborhood. This is why it is so important to connect key regional land use destinations with transit and promote sustainable regional travel (Badoe & Miller, 2000).

2) Distance to transit

The research at neighborhood and station-area scale indicates that significant transit trip generation rates from residential development proximate to rail stations, especially for systems and regions in which both housing and employment are found adjacent to transit. Empirically, the distance to transit varies case by case. Generally, current planning practice recommends a 400 to 800 meters radius as the pedestrian catchment area for transit service, representing a 5-minute to 10-minute walking distance (Canepa, 2007). For example, In Washington DC, transit mode share of commuters working in offices declined by 12 per cent and mode share of residents declined by 7 per cent for every 300 meters farther away from a subway station. The study in San Francisco found that employees working at offices within 800 meters of rapid transit stations had a 19 per cent transit mode share, compared to just 5 per cent region-wide (TCRP, 2007). In addition, pedestrian travel in both employment and residential areas can be induced and pedestrian trips lengthened by the provision of extensive and attractive pedestrian amenities (Transit Cooperative Research Program, 1995). Trans link (2010) summarizes that a higher propensity to use transit depends on the location of trip origins and destinations within close proximity to transit (within 400 meters of a bus stop with frequent transit service or within 800 meters of a rapid transit station). People are generally willing to walk farther to access higher capacity transit services or in areas that have a high degree of walkability and good quality urban design.

3) Density

Theoretically, the higher residential and employment densities would reduce levels of automobile dependence and increase the potential ridership of transit lines. “All else equal, residents of neighborhoods with higher levels of density, land use mix, transit accessibility, and pedestrian friendliness drive less than residents of neighborhoods with lower levels of these characteristics” (Handy et al., 2005). A review of the literature indicates that density is correlated with larger non-auto mode shares and higher transit ridership. Conversely, low density environments must rely primarily on the automobile for transportation because they are too spread out to be served effectively with transit. The most effective land use strategy for increasing transit ridership is to increase development not only residential densities but also employment densities within transit catchment area (Arrington & Cervero, 2008).

4) Diversity

There are two aspects of diversity including mixed land use and mixed housing type. The former means having a complementary and context appropriate combination of shops, services, housing types, offices, and employment opportunities within the same area that allow people to meet most of their daily needs nearby. It can include a vertical mixing within a building with commercial on the ground floor and residential above or horizontal mixing with commercial buildings located adjacent to residential buildings. Local mixed use at transit nodes and along transit corridors encourages trip chaining by combining more than one destination in each trip (Frank et al., 2008). The latter refers to a mixed, diverse housing stock with a variety of housing types, tenures and price points (Giuliano, 1995). There needs to be an adequate supply of a range of housing types accessible by transit in order to provide a range of options for people who would like to take transit. Much research conclude that locating mixed land uses and housing diversities with a variety of types, tenures, and price points near transit fosters increased transit ridership and also supports walking and cycling (e.g. Giuliano, 1995; Cervero, 2002; Cervero and Duncan, 2003; Cao et al., 2009)

5) Design

Urban design brings together and builds on the other "Ds" to create interesting and walkable environments that are conducive to transit use. It can be defined as a sense of place and a pedestrian-friendly environment including the arrangement of land uses, buildings, and facilities with sufficient levels of density and diversity, together with attractive and visually interesting buildings, yards, streetscapes, and public amenities (Trans link, 2010). Fundamentally, "individuals are likely to make decisions in their self-interest when given the option to do so. In other words, most choices are made on the basis of their feasibility and the relative costs and benefits to the individual. One would assume that people would be more likely to walk if walking trips were in any sense easier, if alternatives to walking became more difficult, or if the overall utility of walking was considered" (Burbidge, 2008). The previous studies found that a well-designed pedestrian environment will encourage people walk longer distances and they are more likely to walk to transit in areas that have shops, sidewalks, and trees (e.g. Canepa, 2007; Chen et al., 2008 and Pikora et al., 2003). The provision and design of transit passenger facilities and amenities such as providing real-time information at transit stops and stations can also influence the use of transit (Litman, 2008).

6. Demand management

Transportation Demand Management, or TDM, aims to encourage changes in travel behavior (how, when and where people travel) by discouraging the private vehicle use and promoting more environmental-friendly modes of transport. There are two key aspects of TDM influencing individual behavior and travel patterns including trip costs and parking availability. The former varies by mode and can impact the attractiveness of one mode compared to another. It includes the financial cost and the value of time spending during the trip. Kenworthy and Laube (1999) found that Asian and European cities were found to have the highest auto costs per kilometer and were the least auto-dependent as opposed to US cities. The latter has found to have an influence on mode choice decisions. Increasing the cost of parking and reducing the amount of free parking supply diminish the competitiveness of using private car due to higher cost and less convenience relative to using transit.

> "The cost and convenience of travel by private automobile and other modes influence levels of automobile dependence. To be effective in fostering a mode shift from auto to transit, demand management measures need to be accompanied with improvements to the supply of transit and pedestrian and cycling infrastructure" (Trans Link, 2010)

2.1.2 Other factors influencing transit ridership

From literature review, there are two key factors related to transit ridership, internal and external factors[1)]. Wibiwo and Chalermong (2010) stated that the internal factors are factors that transit authorities can control and manage such as aspects related to fare system, transit capacity and headway, station amenities, and so on. The external factors, on the other hand, are those that beyond the transit authorities' control such as number of population and employment in station area, land use system, and so on. Socioeconomic characteristics are part of the external factors since the authorities are unable to change or to modify the individual characteristics of the transit users. Several researchers found that external factors have stronger impact on ridership than internal factors or incorporated with demographic parameters, such as age, level of education, income, car ownership and household size. Past research has proven that a variety of personal factors make one individual behave differently than another (Golledge and Stimson 1997). These different factors also allow individuals to make personal decisions when it comes to their travel behaviors (Burbidge, 2008). For example, the likelihood of walking and biking is inversely associated with the number of automobiles owned per household (Browson and Boehmer, 2004). Low income households are related to higher levels of transit use (Ewing & Cervero, 2001).

Lastly, reliability of transit service is also an important factor affecting people's willingness to travel by transit. Transit users have been found to be more sensitive to unpredictable delay than predictable waiting times, indicating the importance of service reliability (TCRP, 2007).

2.2 RESIDENTIAL LOCATION CHOICE

Residential location choice is a prime determinant of almost all of the travel decisions made by households. It is critical parts of integrated land use and transportation models (Waddell 2010). It is significant long-term household decisions that profoundly relate with the daily activities and travel aspects of individual lives (Clark and Dieleman 1996; Dieleman 2001). Households make decision on housing choices will consider property value, accessibility and other factors such as the socio-economic characteristics, residential characteristics and neighborhood attributes (Vega, A. and A. Reynolds-Feighan, 2009). However, it is still not clear which factor is considered important, particularly in relation to areas where public transport accessibility has been improved (Nurlaela and Curtis, 2012).

The stream of research on modeling residential location based on discrete choice theory. The earliest attempts to apply discrete choice modeling to housing location is represented by the work of Lerman (1976), McFadden (1978), Weisbrod, Lerman and Ben-Akiva (1980) respectively. In the context of residential location, the consumption decision is a discrete choice between alternative houses or neighborhoods (Guo and Bhat, 2002). The choice of residential location is very complex and also relies on many other choices. This interdependency has lead researchers to model residential location choice jointly with other choice dimensions such as car ownership (Lerman, 1976; Bhat and Guo, 2007; Pinjari et al., 2011; Weisbrod et al., 1980; Cervero and Duncan, 2002), bicycle ownership (Pinjari et al., 2011), commuting mode (Lerman, 1976; Kim et al., 2003; Handy, 2004; Nurlaelaa and Curtis, 2012) work location (Waddell, 1996; Freedman and Kern, 1997; Rivera and Tiglao, 2005; Inoa et al.,2013), school location (Barrow, 2002; Guo and Bhat, 2002), housing mobility (Lee and Waddell, 2010), housing tenure (Ioannides, 1987; Waddell, 1993), and housing attributes (Guevara and Ben-Akiva, 2006; Hoshino, 2011). These studies differ essentially in their model structures, the choice dimensions modeled, the study region examined, and the explanatory variables considered in the analysis.

2.2.1 Transit proximity and residential location choice decision

Over the past decades, it has become increasingly clear that living proximity close to urban rail station is the determinant factor in residential location choice theory. An economic theory of location choice called utility maximization theory suggests that people will seek to minimize commuting costs by selecting a housing location which provides greater accessibility to their workplace, alternatively they may accept increased commuting costs in exchange for less expensive housing further from employment (Alonso 1964). This theory is also called the transportation and land cost 'trade-off' as it proposes that households literally trade-off commuting and housing costs against each other (Hoang & Wakely 2000; Krizek 2006).

Weisbrod et al. (1978) analyze consumers' tradeoffs in the decision to move and the selection among alternative residential locations focusing on the role of transportation level-of-service changes relative to various aspects of neighborhood quality, including crime, taxes, school quality, and demographic factors. Based on an analysis of the actual moving decisions and residential choices of individual households, the empirical results suggest that households make significant tradeoffs between transportation services and other public service factors in evaluating potential residences, but that the role of both in determining where people choose to live is small compared with socioeconomic and demographic factors.

2.2.2 Residential location choice of multi-worker household

The most powerful criticism of utility maximization theory, relate the changing structure of households and the location of employment in cities in many developed countries. For example, Waddell (1996) argues that "suburban employment centers have overtaken central business districts in importance, a dramatic rise in female labor force participation has made dual-earner households more prevalent than single-worker households, and non-work trips now outnumber home-based work trips". Presently, household choices regarding employment and place of residence are often jointly made decisions. The interaction between household location and commuting decisions is more complex since gender roles have been changing and prevalence of dual career households have been increasing (Curtis and Montgomery, 2006). Much research focuses on how multi-worker households make a decision on housing location. (e.g. Abraham & Hunt 1997; Chapple & Weinberger 2000; Davis 1993; Freedman & Kern 1997; Green 1997; Hanson & Pratt 1991; Rouwendal 1998; Rouwendal & Meijer 2001; Rouwendal & Rietvald 1994; Sermons & Koppelman 2001; Singell & Lillydahl 1986; Timmermans et al. 1992; Tkocz & Kristensen 1994; Van Ommeren, Rietvald & Nijkamp 1998; Waddell 1996). They have tried to improve model by including transport mode choice as part of household' location choice decision process. They have also attempted to make the modeling procedure complex in order to capture the influence of each household member to household's overall utility by considering all working members of the household in the model (Abraham et.al, 1997 cited in Rivera, 2005). As the residential decision is made by individuals and households, the outcome may be conditioned by the workplace decision or vice versa. If it is each household decision, it may be conditioned by one member's workplace choice, and condition a second member's workplace choice (Ben-Akiva and Bowman, 1998).

The presence of a second worker is hypothesized to add constraints on household choice. Evidence from five cities in USA show that women's earnings opportunities and commuting burdens influence not only the wife's choice of workplace but the husband's job site and the household residence as well (Freeman and Kern, 1997). However, in the case of Manila, the study concluded that the hypothesis that the utility of the primary worker is given more priority in the location choice decision does not hold true. The result implied that the degree of disutility is shared both by the two workers and no priority is given to either one (Rivera, 2005). Likewise, Plaut (2006) found that commute decisions in dual-income households operate as 'complements' rather than 'substitutes', that is in residential selection commute trips are jointly chosen to be either longer or shorter for both spouses (Montgomery and Curtis, 2006).

2.3 RESIDENTIAL SELF-SELECTION

Previous studies on the relationship between neighborhood and travel choice behavior stated that factors other than built environment had a stronger influence such as demographic and household characteristics (e.g. Kitamura *et al.*, 1997; Schwanen and Mokhtarian, 2005; Van Wee, 2002,2009; Cao et al, 2006) . Bhat and Guo (2007) assert the importance of the separation between the causal effect and the spurious relationship among built environment and travel behavior. One such failure has been the omission the 'self-selection' effect when explaining the relationship between residential location (i.e. built environment attributes) and travel behavior. Insights into self-selection processes might significantly improve the knowledge on location choices and travel behavior (Van Wee, 2009). A better understanding of the complex relationships among built environment, travel, socio-demographic characteristics, and household attitudes can help transport planners leverage the benefits of TOD and improve the quality of urban design and community life (Olaru et. al, 2011).

2.3.1 The definition of residential self-selection

In the last fifteen years it has become more common to take residential self-selection into account in travel behavior research, with numerous studies focusing on its role (e.g. Cao et al.,2009; Tsai, 2008; Van Wee, 2002; Van Wee, 2009; Bohte, 2010; Cervero and Duncan, 2002). People can theoretically self select them with respect to other location choices, such as job locations or with respect to travel behavior. For example, residents who prefer driving over using public transport may choose remote and spacious neighborhoods, while households with a preference for public transport may opt for more urban residential locations within walking or cycling distance of a railway station (Bohte et al, 2009). One study of residents living near Santa Clara County's light-rail line in the San Francisco Bay Area in the U.S. state of California found that they patronized transit as their predominant commute mode five times as often as residents countywide; self-selection was evident in the 40 percent of the respondents who moved close to rail stops saying that they were influenced in their move by the presence of light rail (Cervero and Duncan, 2002)

Self-selection in the transportation/land-use arena can be defined as mode-specific and/or built-environment-specific preferences. In a narrow sense, it could be defined as preferences to travel by public transit modes and also preferences to live in neighborhoods that can accommodate such travel preferences (Cervero and Duncan, 2002; Van Wee, 2003; Krizek, 2003a,b). In general, researchers do not include preferences in their studies, and literature on these preferences is very scarce. If preferences are either not, or only partly, related to personal and household variables, ignoring these preferences results in an overestimation of the impact of proximity to railway station on travel choice behavior (Cervero and Duncan, 2002).

Self-selection with respect to residential location refers to as "the tendency of people to choose locations based on their travel abilities, needs and preferences" (Litman, 2005 p. 6). Suppose that people have preferences for travel modes (especially car or rail transit), apart from their personal characteristics. The preferences for travel modes may be correlated to residential choice: people with a preference for traveling by train will, on average, live closer to railway stations. For example, Pickup and Town (1983) concluded that people with an explicit preference to travelling by public transport do not consider living in a residential location far away from public transport nodal points, such as railway stations. Van Wee (2009) argued self-selection may hold keys to a better understanding of people's location choices that are relevant for travel behavior. The study argued that insights into self-selection processes might significantly improve the knowledge on location choices, travel behavior, and transport externalities. The result exhibited the most important categories that self-selection relates to (1) travel behavior preferences (mode choice, travel frequency, travel time, travel distances) and related location choices, (2) exposure to transport externalities (congestion, safety/risk, noise), and (3) vehicle choice and driving behavior.

However, it can be claimed that the studies of the role of residential self-selection are still limited, due to such issues as the use of different methodologies, different attitude measures, the difficulty of measuring attitudes and limited data availability (for an overview of studies addressing residential self-selection; see Cao et al, 2008).

2.3.2 The inclusion of attitudes in travel behavior models

Since the mid-1990s, several studies on residential choice using different research methods have indicated that travel-related attitudes and preferences indeed influence residential choice (e.g. Van Wee, 2003,2009; Schwanen and Mokhtarian, 2007; Bohte et al, 2009, Cao et al., 2009). These results exhibit that attitudes influence travel behavior both directly and indirectly through residential choice. Most households select a residential location that complies with their travel-related attitudes at least to some degree, and therefore attitudes influence the relation between the built environment and travel behavior through residential self-selection (Van Wee, 2003).

There are various definitions of attitude existing in social psychology theory (Bohte, 2010). Eagley and Chaiken (1993, p.1) broadly define attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor". The definition of evaluating refers to affective responses (e.g. I like riding a bicycle) as well as cognitive and behavioral responses. Cognitive responses are often referred to as beliefs. They refer to the probability that a particular object or relationship exists (e.g. riding a bicycle is environmentally friendly). Behavioral refers to overt actions on the part of people that are related to the attitude object (e.g. riding a bicycle or signing a petition in favor of bicycle infrastructure) (Eagley and Chaiken, 1993). The specificity of travel-related attitudes can be defined in very general (e.g. attitude towards driving a car or using a rail transit) to very specific (e.g. attitude towards taking the bus to get to the campus next time (Bamberg et al.; 2003)).

In attitudes-behavior studies, the specificity with which attitudes and behavior are measured is important. Research often fails to identify a link between attitudes and behavior because there is a mismatch between aggregation levels – for example, very general attitudes are related to specific behaviors (Eagley and Chaiken, 1993). Ajzen and Fishbein (1977) distinguished four elements of behavior: action (e.g. driving), target (a car), context (in the city) and time (Saturday morning), and argued that the compatibility of the degree of specificity or generality of the attitudes and behaviors analyzed should concern all four of these elements. The specificity of travel-related attitudes and travel behavior can vary from general (a positive cycling attitude; a built environment that is cycle-friendly) to very specific (if someone likes to take the bus to the swimming pool on Saturday mornings, the availability of a good bus connection on Saturday morning to the swimming pool indicates self-selection). When seeking to identify residential self-selection, travel-related attitudes, travel behavior and built environment characteristics must all preferably be measured at the same level of specificity (Bohte, 2010).

Previously, research on the effect of attitudes on travel behavior is broadly based on Theory of Planned Behavior (TPB). Since the late 1960s, travel behavior research trend has been shifted to micro-economic utility-maximization theory. Based on this approach, travel alternatives are treated as bundles of attribute levels; the total utility of an alternative is therefore determined by the utility an individual derives from its attribute levels (Bohte, 2010). It is assumed that individuals always prefer the alternative with the highest utility or satisfaction. The utilities that an individual derives from the attributes of an alternative are not measured directly but deduced from actual behavior ('revealed preferences'), the characteristics of the alternatives (e.g. speed, cost, and comfort in the case of mode choice), personal characteristics (e.g. gender, age and income) and the decision context, which can include land-use characteristics (Ben-Akiva and Lerman, 1985). However, there is a debate whether or not households' characteristics and lifestyle directly influence behavior or only influence behavior through attitudes. Particularly in residential self-selection analyses that use current travel-related attitudes, the fact that residential moves often coincide with other important life decisions, such as having children or changing jobs, must be taken into account. These other life decisions may also change household's travel-related attitudes (Bohte, 2010).

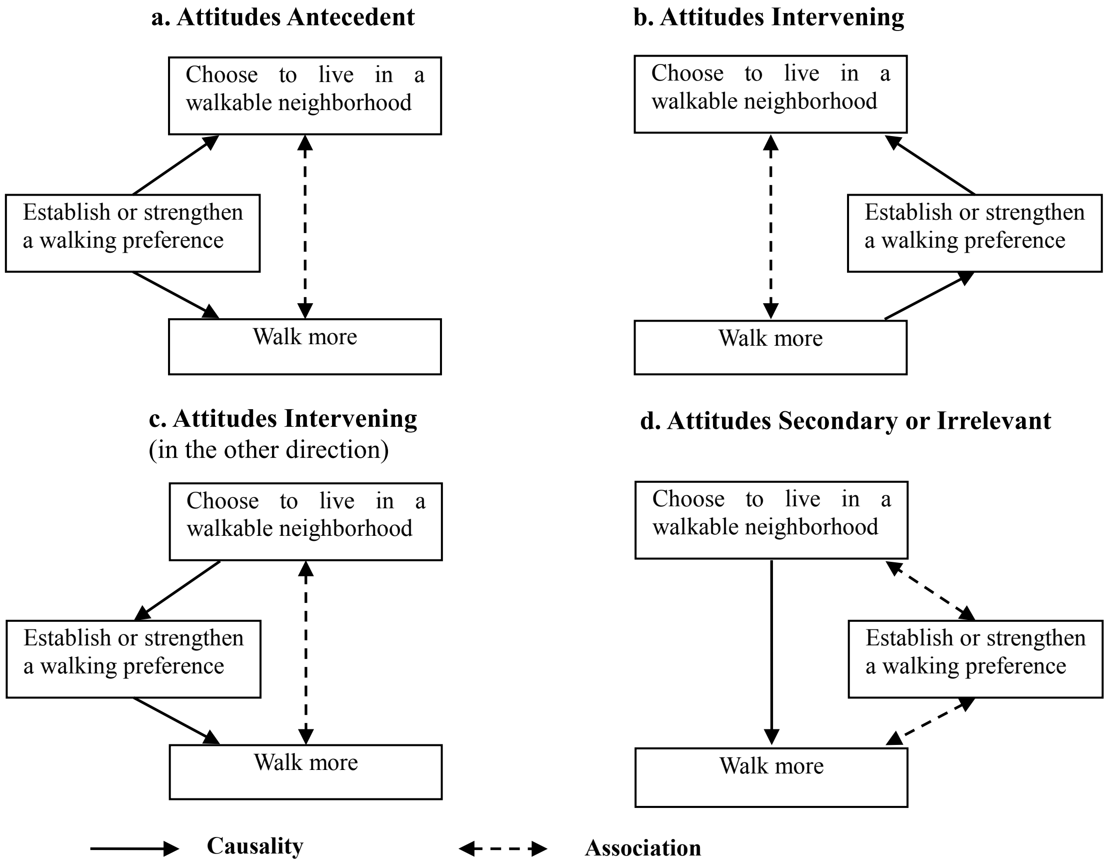
There are examples of studies adding attitudes in explaining travel behavior. Muconsult (1994) modeled peoples' car ownership choice. The result showed the share of preferences and attitudes towards modes about 40%. In other words, preferences and attitudes have a significant impact on car ownership levels. Kitamura et al. (1997) researched on the impact of attitudes on modal choice. They concluded that the share the car takes in the total number of trips is related to the attitudes towards the car and to public transport. Bagley and Mokhtarian (2002) researched on the impact of attitudes and lifestyles, combined with land-use variables, on travel behavior. They concluded that attitudes and lifestyles have much more impact on travel behavior than residential location type. The result of the Pickup and Town study showed that preferences are more important for 'public transport lovers' than for 'car lovers'. Accessibility of locations by public transport varies much more than accessibility by car. Since only a small number of all dwellings are situated within walking distance from a railway station, the choice of location for people with a preference for public transport is more important than for people preferring the car. The study on the relationship between preferences for modes, residential location and travel behavior showed that that model preference seems to be strongly associated with both travel behavior and the choice of residential location. It might lead to an overestimation of the effects of land use on travel behavior if this is ignored. Therefore, also models based on empirical research ignoring these preferences may overestimate the impact of land use on travel behavior. (Van Wee 2003).

2.3.3 Relationships among travel attitudes, built environment, and travel behavior

The number of studies on the influence of the built environment on travel behavior which address residential self-selection by including attitudinal variables has been increasing. Figure 2.1 presents relationships among travel attitudes, built environment, and travel behavior proposed by Mokhtarian and Cao (2007). This study claimed that association between the built environment and travel behavior is insufficient to establish causality. To robustly infer causality, scientific research generally requires at least four kinds of evidence (Schutt, 2004; Singleton and Straits, 2005; for a more extensive discussion of these in this context, see Cao et al., 2006): 1) association (a statistically significant relationship), 2) nonspuriousness (a relationship that cannot be attributed to another variable), 3) time precedence (cause precedes effect), and 4) causal mechanism (a logical explanation for why the alleged cause should produce the observed effect). As shown in Fig. 2.1, there are in fact a number of plausible relationships among attitudes (AT), built environment (BE), and travel behavior (TB), and the chosen methodology will ideally be capable of distinguishing among the various possibilities.

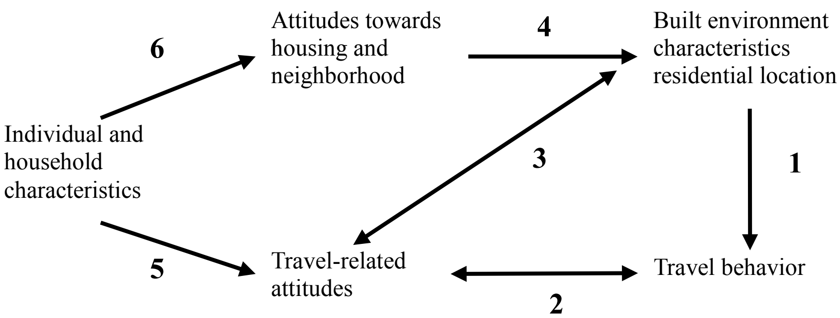
Bohte (2010) identified the relationship between residential self-selection concerning the distances to activity locations and travel behavior. This study disentangled the influence of residential location and travel-related attitudes on the total number of kilometers travelled and the share of trips that is travelled by car. Figure 2.2 summarizes the influence of attitudes and residential self-selection on travel behavior. First of all, arrow 1 and 2 show that travel-related-attitudes and built environment characteristics of the residential location are assumed to have an influence on travel behavior. Secondly, arrow 3 and 4 explain the impact of attitudes towards travel behavior and attitudes towards housing and the neighborhood on built environment characteristics of the residential location through the evaluation of housing alternatives when searching for a new home. It can thus be assumed that residential self-selection takes place and that people select themselves according to the built-environment characteristics of a new house that at least to some degree conform to their attitudes towards travel behavior. Consequently, arrow 1 and

3 assumed that there is an effect of travel-related attitudes on travel behavior indirectly through residential choice. Finally, arrow 5 and 6 indicate that individual and household characteristics are assumed to affect travel-related attitudes and attitudes towards housing and the neighborhood.



Source : Mokhtarian and Cao (2007)

Figure 2.1 Some Potential Relationships among Travel Attitudes, Built Environment, and Travel Behavior



Source : Bohte, 2010

Figure 2.2 Conceptual model of the influence of attitudes and residential self-selection on travel behavior

2.3.4 Methodologies in studies on residential self-selection and travel choice behavior

Cao et al. (2009) provided an extensive review of 38 empirical studies addressing attitudinal self-selection issue, dividing them into nine methodological categories: direct questioning, statistical control, instrumental variables, sample selection, propensity score, joint discrete models, structural equation models, mutually dependent discrete choice models and longitudinal designs. (For further explanation of these methodologies see Mokhtarian and Cao, 2008). This research originally applies joint discrete model in the context of joint nested logit model in explaining the influence of attitudes and residential self-selection on travel behavior.

Joint Discrete Models: Nested-joint logit model and multinomial logit model

Joint logit is a technique where the analyst has a multidimensional choice sets with shared observed attributes. The observed endogenous variables measuring both residential choice (RC) and travel behavior (TB) are both discrete. This model can estimate the join probabilities of residential location and commute mode choices. Both choices are treated as nominal, and in which one choice (most naturally, TB) is conditioned on the other (RC). This approach can be further subdivided into two: sequential and simultaneous models. The former is represented by multidimensional nested logit model while the latter is displayed by multinomial logit model (Ben-Akiva and Lerman, 1985). In the case that the nested logit model is not proven to be significant, the model becomes a simple multinomial logit model.

Past research has modeled mode choices among residents of transit-based housing using single logit model structures (Cervero, 1994) or regression models based on highly aggregate data (Pushkarev and Zupan, 1977; Bernick and Carroll, 1991). Under a logit formulation, transport factors like travel cost and time of competing modes and demographic characteristics of travelers were used to predict probabilities residents were likely to reach their workplaces by rail transit (Cervero and Duncan, 2002).

Nurlaela and Curtis (2012) proposed the modelling framework analyzing household residential location choice and travel behavior and its relationship with public transport accessibility using nested –joint logit model and multinomial logit model. The models were formulated into two different approaches, i.e. considering the mode choice decision conditional on residential location decision, vice versa, and considering the residential location decision conditional on the mode choice decision as shown in Figure 2.3. These two approaches have a different theoretical consequence, the former indicates a causality relationship, while the later specifies the self-selection dominance. However, their model is at the early stage of development, the process of verification and validation of the models has yet to be conducted.

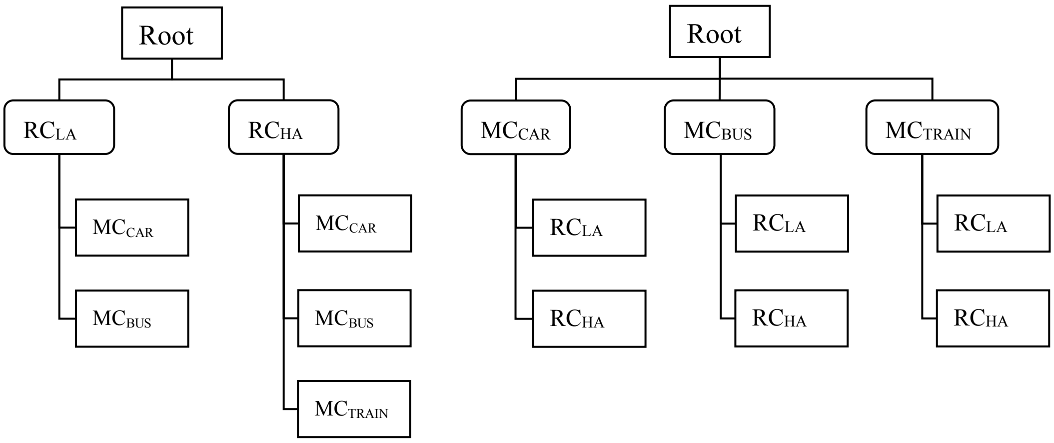


Fig. 2.3a. Structure of nested-joint logit model for causality relationship

Fig. 2.3b. Structure of nested-joint logit model for self-selection bias

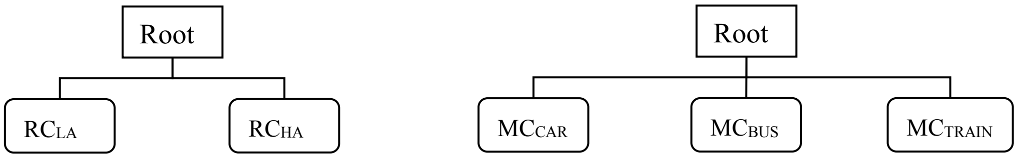


Fig. 2.3c. Structure of MNL model for residential location choice

Fig. 2.3d. Structure of MNL model for mode choice

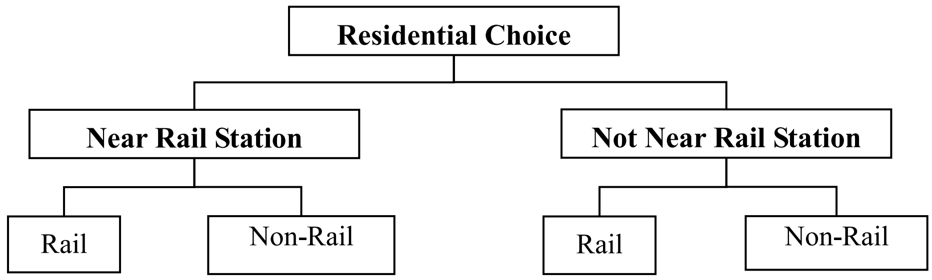
RC_{LA} = Residential Location Choice with Low Accessibility
RC_{HA} = Residential Location Choice with High Accessibility

MC= Mode Choice

Source : Nurlaela and Curtis, 2012

Figure 2.3 Nested-joint logit and multinomial logit modelling framework of household residential location choice and travel behavior analysis

Cervero and Duncan (2002) explored the self-selection question by constructing a nested logit model that jointly estimates the probability someone will reside near a rail stop and in turn commute by rail transit. This study developed a two-level nested logit model, with the upper level indicating the binary choice of residential location (whether or not to live near or far from a rail station) and the lower level representing the binary choice of commute mode (rail or auto). The joint probability of an (RC, TB) bundle being chosen is modelled as Pr[RC] Pr[TB|RC]. The research revealed that residential location and commute choice are jointly related decisions among station-area residents. A comparison of odds ratios among those living near and away from transit, controlling for the influences of other factors, suggested that residential self-selection accounts for approximately 40 percent of the rail-commute decision.



Source: Cervero and Duncan; 2002

Figure 2.4 Two-tier nested choice structure: residential sorting-commute mode

Olaru et al., 2011 evaluates how households consider transit-oriented development (TOD) characteristics in their location decisions with regard to the operation of new railway line. A combined multivariate statistical and discrete choice model based on stated choice experiments was constructed with latent constructs and classes designed to account for preferences and attitudes in the decision process. The results found that the choice of residence reflects neighborhood and housing attributes, with significant heterogeneity in the populations of the three precincts in terms of their valuation of various housing characteristics, proximity to urban facilities, and transport. There is also significant variation in households' attitudes to natural and artificial environments. The study suggested urban and transport planners to have a greater understanding of the complex relationships among environment, travel, socio-demographic characteristics, and household attitudes in order to leverage the benefits of TOD and improve the quality of urban design and community life.

2.3.5 Research on residential self-selection and travel behavior in developing countries

While most studies on residential self-selection originate from the USA, the research in this arena has been receiving an increasing attention and gaining popularity in developing countries. This region has been started implementing mass transit to cope with transport-related environmental problems associated with the increasing trend in car ownership and use. Wibowo and Chalermpong (2010) developed multinomial logit model explain the regular mode choice of those residing in transit catchment areas in Bangkok, Thailand and Manila, Philippines. The results revealed that access distance and car availability have crucial influence on the tendency of regular mass transit use. This implied that within acceptable walking distance, increasing the quality of walking environment proves an important strategy that can make walking to station more attractive, thereby inducing modal shift to transit. They suggested that, for longer distance, improving feeder bus service is still indispensable, especially in the case where other access modes are very limited.

Also, Malaitham (2013) investigated the influencing factors impact on the residential location choice behavior in Bangkok using discrete choice models, i.e., rank-ordered logit (ROL) and rank-ordered nested logit (RONL). The study concluded that travel behavior and socio-demographics (i.e. car ownership) are the dominant factor in residential sorting. In contrast, residential location decision impacts on the travel behavior and car ownership decisions as well. The proximity to transit stations is the dominant factor in rail transit user group as well as car ownership influences the decision to live closer to expressway access. Other socio-demographic factors, i.e., household income and the size of household are the potential factor of segregation phenomenon in residential location choice.

Lastly, evidence from Taipei rapid transit system, Tsai (2008) explored the impacts of self-selection and proximity to transit at both residence and workplace. The research hypothesis is self-selection and proximity to transit increase the probability of workers commuting by rapid rail transit. Using binomial logit modeling and sensitivity analysis, the results support the idea that transit proximity to both work and residence increase the probability of transit commuting, but the hypothesis about the impact of self-selection is only partly supported.

2.4 DEFINITION OF TERMINOLOGIES USED IN THIS STUDY

Based on literature reviews mention above, the terminologies used in this study are defined as following below;

Station-area resident/transit-based resident: Residents who live in condominium/ apartment located within 1 kilometer distance rings of the rail stations

Residential self-selection: The tendency of people to choose house locations based on their travel abilities and preferences.

Station-area resident self-selection (SAR self-selection): Residents who had preference for transit proximity and moved to live in condominium/apartment located within 1 kilometer distance rings of the rail stations after its first operation. In other words, the station-area residents who relocated due to the preference for transit proximity, no mode choice preference before moving.

Transit-driven SAR self-selection: Residents who moved to live near station because they would like to use rail transit. In other words, the station-area residents who have preference for rail transit before relocating.

Travel-related attitude: A psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor. (e.g. attitude towards driving a car or using a rail transit).

Mode preference: Attitudinal variables like attitudes toward travelling by each mode chosen normally at the time of residential location choice decision. (e.g. 1) I would like to commute by rail hopefully, 2) I would like to commute by auto hopefully and 3) I am not considering about the commuting mode).

Commuting mode choice: Set of vehicle choices for daily work trip travelling, chosen normally just before the start of the trip (e.g. 1) I will go to work by rail or 2) I will go to work by auto)

CHAPTER 3

RESEARCH METHODOLOGY AND STUDY AREA CHARACTERISTICS

It is evident that high-density urban development associated with TOD transit-oriented development (TOD) characteristics results in the decreasing travel and thus sustainable mobility; however, personal attitudes seem to have greater effect on mobility than does the urban form. The methodology used in this dissertation responds to the relationship between residential self-selection and travel behavior and aims to offer new evidence on the potential for TOD neighborhood to influence travel behavior. This chapter outlines the research framework, the hypotheses, data collection, the variables and the models used in this dissertation.

3.1 METHODOLOGICAL FRAMEWORK

Methodological framework was developed to achieve the main goals of research in analyzing the multi-dimensional relationship between location behavior and travel patterns within a behavioral analysis framework. Figure 3.1 describes all overall process that had been done. A brief explanation on the research structure is as follows;

1. From TOD framework, it is necessary to make clear understanding whether transit cities in developing countries which have young experience with mass transit system operation achieve the TOD goals for sustainable development to reduce over-reliance on private automobile and promote more transit ridership. Therefore, to assess sustainability of TOD based on empirical aspect of outcomes is performed at first. This research draws lesson from case example of transit-oriented metropolis of Bangkok, Thailand. Several significant factors affecting the transit ridership are explored by using discriminant analysis. Only socio-demographic variables are considered. (See more detail illustrated in Chapter 4)

2. Based on literature review, it is important to clear separate between the causal effect and the spurious relationship among built environment and travel behavior. There are two approaches concerning to built environment and travel behavior modeling e.g. a causality and self-selection relationship. To start with the causality relationship, to scrutinize how TOD neighborhood potentially affects transit ridership is done by using discrete choice model. The main goal is to make an extensive analysis for assessing the extent to which transport, built environment and other factors influence travel behavior.

2.1 Built environment in terms of residential location can be added as exogenous variable in travel choice modeling based on the assumption that the location of house is one of the main factors influencing individual's mode choice decision (For more detail, see Chapter 5).

2.2 Also, residential location choice can be utilized as endogenous variable in the integrated locational and mode choice modeling. It is based on the assumption that people simultaneously makes their decisions on where they live and how to go to work. The discrete choice in context of simple multinomial logit model is then employed (For more detail, see Chapter 6).

3. Next, the issue of residential self-selection need to be proved since previous studies stated that attitudes had a strong influence on travel behavior both directly and indirectly through residential choice. The inclusion of attitudes in travel choice modelling is based on the assumption that people sequentially select their residential location and commuting choice for their work trip. They choose to live in the location that complies with their travel preferences. The question whether residential self-selection exists or not is examined (For more detail, see Chapter 7). With respect to sequential process decision mechanism, multi-dimensional nested logit model is developed. This research originally attempts to model the relationship between locational and commuting choice behavior by adding mode preference in nested logit modeling (For more detail, see Chapter 8).

4. There is the requirement of good quality compatible data to help develop modelling frameworks. There are 3 data set using in this research obtaining from household travel behavior survey (2008), condominium resident travel behavior survey (2010) and condominium resident travel behavior survey (2013) respectively.

5. Finally, research questions will be answered after the significant factors in explaining transit ridership are revealed. All model results are integrated to clarify the hidden or underlying mechanisms that affect travel behavior and then proceeded in policy development. The policies for TOD implementation sustainability in developing countries where the urban railway experience is still young will be drawn carefully from the valuable information the lessons learnt from this research. Thus, the proper policies can be concluded and recommended.

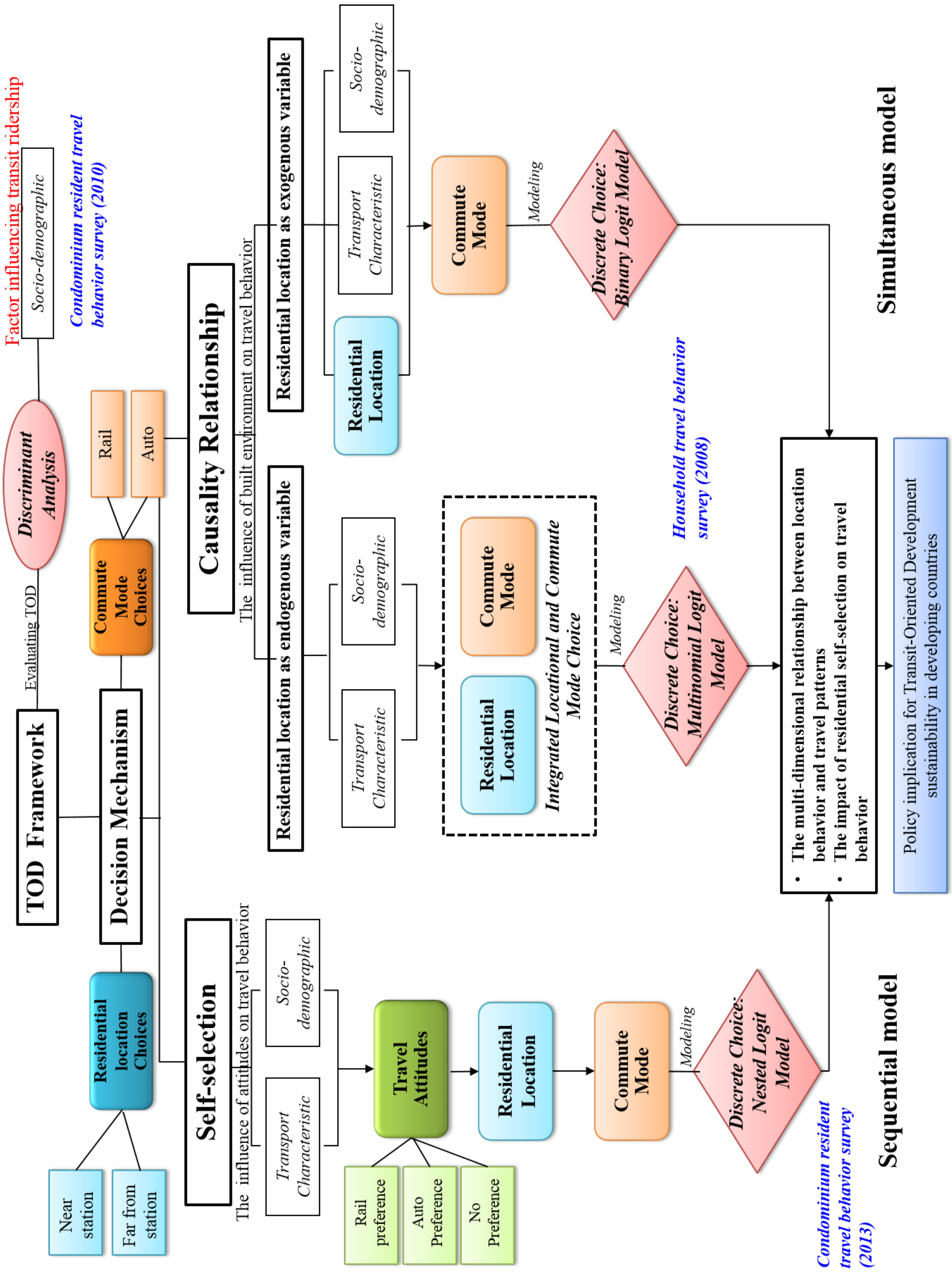


Figure 3.1 the concept of methodology framework

3.2 CHARACTERISTICS OF STUDY AREA: BANGKOK

This research aims to study on transit cities in developing countries where urban transportation relies mainly on land-based transportation while mass transits system have recently inaugurated e.g. Bangkok, Jakarta, Kuala Lumpur, Manila and Rio de Janeiro. Empirically, mass transit investments have been introduced after high level of motorization and road investments have continued in competition with mass transits. These cause more difficulties and impediments of mass transit developments. Nevertheless, these cities have continued the future developments of mass transit planning.

Bangkok is selected as a case study in this research due to its rapid growth in economic and motorization as well as high-density land use development. After first transit systems operation, this city has been facing the main problem that transit ridership has failed to meet their expected ridership level. The characteristics of transit cities in developing countries including Bangkok do not evaluate and integrate the impact of transportation development as part of the urban land use master plan. Therefore, it is challenging for planners in this region to create sustainable TOD that requires planning and coordination at the level of the transit station, corridor and region. From the theoretical aspect, based on population density and metropolitan size, this city thus seems very well-suited to the TOD implementation. Obviously, the city has many prerequisites for TOD. It has revealed the characteristics of mixed land use and densely populated high rise in the downtown areas served by this transit line. Rationally, this seems to be the great opportunity for TOD fostering in this city. Therefore, the characteristics of Bangkok satisfies research goals to improve transit ridership in developing countries.

3.2.1 Mass transit systems development

The Greater Bangkok area has a population of 15 million in 2013, or 23.4 percent of the national population and is 7,761.6 sq km in size resulting in a density of 1,900 persons/sq km and persistence of severe transportation problems. Travel speed by private car head to the inner city is less than 12 kilometer per hours (Office of Transport and Traffic Policy and Planning, OTP). Recently, two rail transit systems known as BTS and MRT, was first operated with route covering the central business district and inner city area in 1999 and 2004 respectively. The former is elevated rail system comprising two main lines with the total of 36.8 kilometers, 35 stations and the latter is the subway line on the 21 kilometer-service length with 20 stations as shown in figure 3.2. The BTS extension plans are explained in the followings.

- In 1999, the first two routes of the BTS were operated, Sukhumvit Line with a total distance 22.25 km of 22 stations and Silom Line with a total distance 14.5 km of 13 stations.

- In 2009, a 2.2 km extension of Silom line was opened after many years of delay.

- In 2011, Sukhumvit line was extended more 5.2 km distance.

- In 2013, a further extension 5.3 km distance of 4 stations was delayed for many months by the Bangkok floods of late 2011. The first station of extension was opened on January 2013. The second station of the extension was opened on February 2013. The remaining two stations were opened on December 2013.

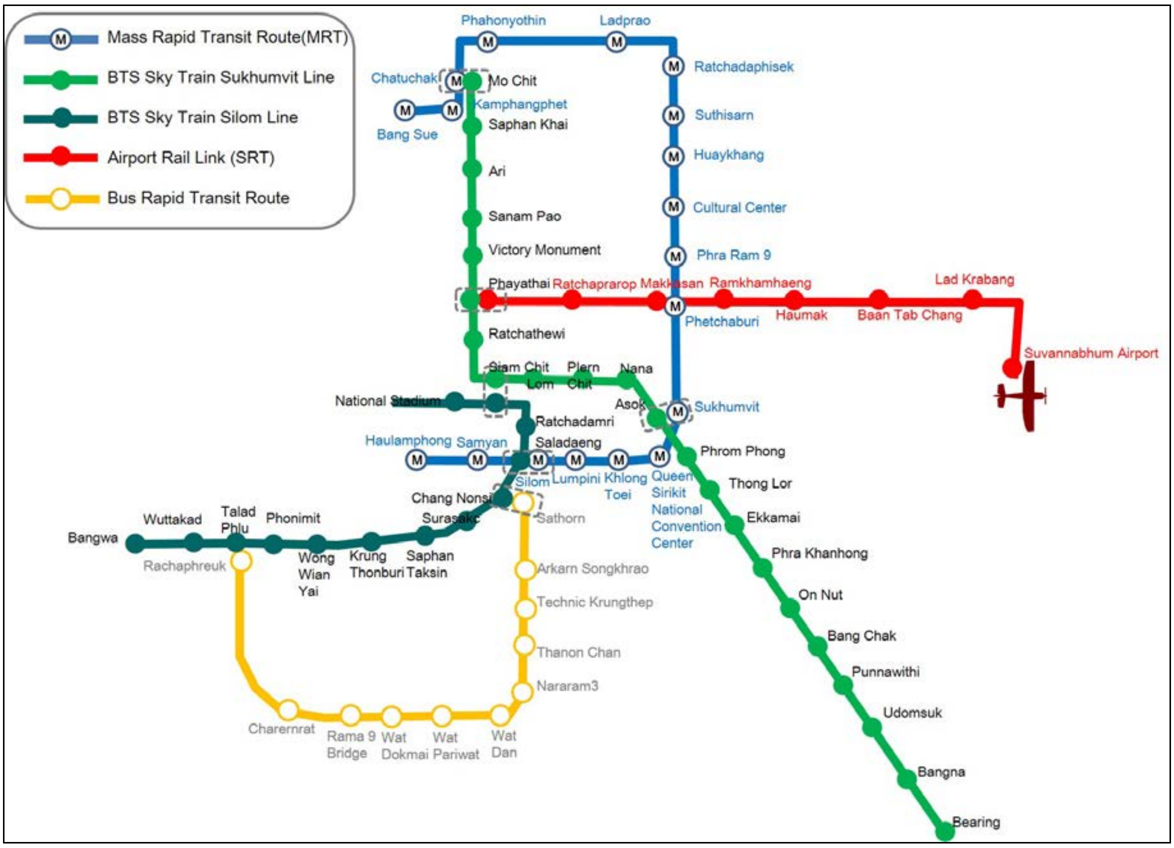
Moreover, network extension plans called the Mass Rapid Transit Master Plan (M-MAP) are in the process of being implemented containing a 20-year development plan for urban railway during 2010 to 2029. There will be totally 12 routes with a total distance of 509 km which extends the plan of 2008 to cover fast-growing suburban areas as seen in figure 3.3 (Office of Transport and Traffic policy and Planning, 2010).

Current both BTS and MRT have been the alternatives for residents those living near these mass transit routes to daily commute to work-places and avoid heavy congestion. There is an upward trend of demand for rail mass transit in BMR especially for the BTS. The BTS initially had lower-than-predicted ridership, with 200,000 passenger trips per day. Ticket revenue was only enough to meet the trains' operating cost, and not sufficient to service construction loans. However, its daily passenger numbers have steadily increased since then. In 2005, more than 500,000 single trips were made in a single day for the first time. Over the past decade of its operation, its ridership has succeeded to meet the expected ridership level of 672,200 passengers per day (Office of Transport and Traffic policy and Planning, 2010). In 2013, it served around 600,000 passengers on an average day, with a peak of 715,000, and is upgrading to a fleet of 35 four-car trains (Wikipedia.org).

In contrast, the MRT have less daily commuters due to its function of ring line covering less attractive spots as compared to the BTS. Now it serves more than 240,000 passengers each day. Its ridership has still been below than the forecast level of 373,000 passengers per day in 2014. As of 2011, two extensions of the MRT are under construction. When completed, it will become a loop line around the centre of Bangkok, with an extension to the western side of the city (Wikipedia.org). The average daily passengers of the BTS and MRT is shown in figure 3.4 below.

Ridership forecast is determined by using the extended Bangkok Urban Model (eBUM) (TDMC V, 2007). In 2008, travel demand in Bangkok and Metropolitan area is approximately 15.3 million trips per day which includes approximately 8.37 million trips per day travel by personal vehicle (PV) (54.7%) and approximately 6.93 million trips/day travel by public transport (PT) (45.3%). The share of mass transit passenger is 0.6 million trips/day. As a result of socio-economic changes travel demand in Bangkok and Metropolitan area is expected to increase up to 16.46 million trips/day in 2014, 18.34 million trips/day in 2019 and 22.42 million trips/day in 2029. According to the Master Plan, passenger forecast was shown that total passenger will increase from 1,840,000 person-trip/day in 2014 to be 4,384,000 person-trip/day in 2019 and 7,680,000 person-trip/day in 2029. Increasing passenger growth rate is approximately 8.22 % per year.

In 2008, the share of mass transit was 3.7% and private car 35.1% among main modes of transport. In case of master plan implementation, travel by the transit will have higher proportion at 20.7% in 2029 while the travel by car will account for 41.1% as presented in figure 3.5. Once the 20-year plan is carried out, the rail transport will become the main mode in Bangkok Metropolitan Region (BMR). Several transport demand management (TDM) measures will be used, e.g. increase in automobile tax, limitation of car park areas, etc. These measures will increase the travel cost of those using personal cars and they will tend to use the public transport instead. In case of implementation of TDM measures in 2029, the proportion of travel by car will be reduced to 38.2%. The travel by the transit will be increased to 22.5%.



Source: http:// http://www.bts.co.th/customer/th/images/Master_RouteMap.jpg

Figure 3.2 map of mass transit system in Bangkok

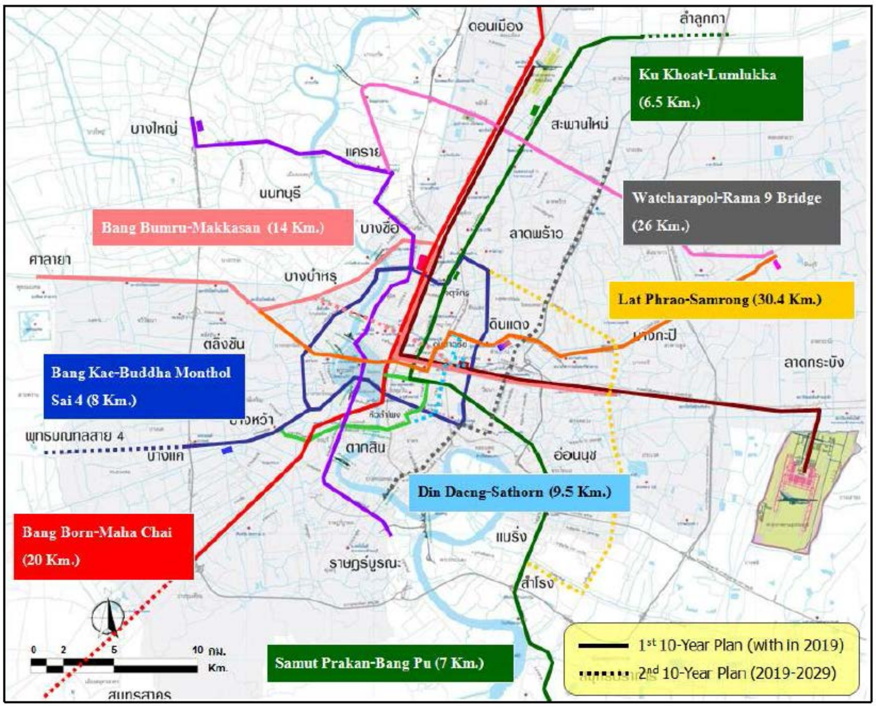


Figure 3.3 map of future network extension plan

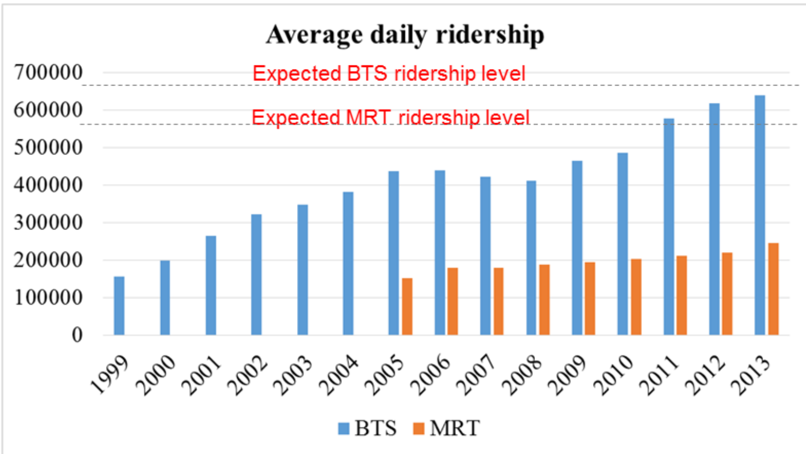
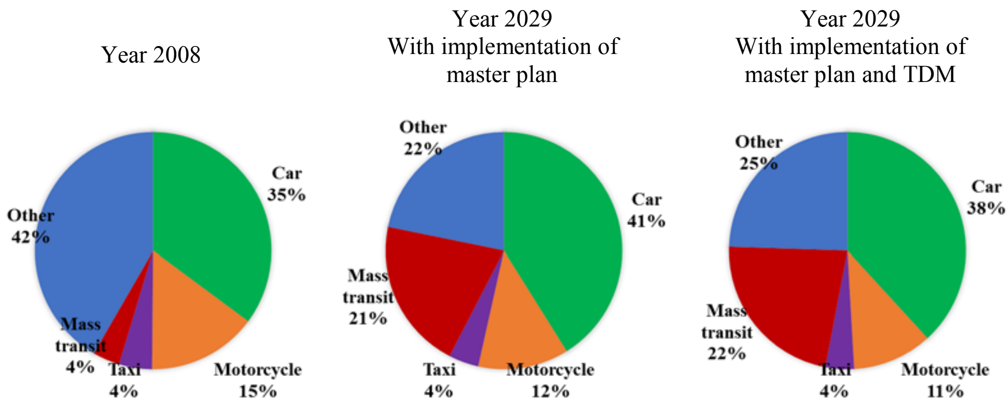


Figure 3.4 Average daily passengers of BTS and MRT



Source: Office of Transport and Traffic policy and Planning, 2010

Figure 3.5 Main modes of transportation share

3.2.2 Land use and transit-based housing development

From the urban development–related plans and projects in Bangkok and surrounding areas, the future urban development direction will place emphasis on the decentralization of activities in the central business districts (CBD) to surrounding areas with a major aim to alleviate the high–density land use in the existing commercial centers. Due to the congestion problem, the downtowns are expanded to cover the surrounding areas. Rail and road systems have been developed to provide the convenient transport network within the 7 commercial sub-center areas and linkage with CBDs, thus promoting the job and housing balance concept. The aforesaid urban development concept complies with the changes in travel behavior. Some people move to live in suburbs, increasing the number of commuters between suburban areas and CBDs, especially the northeastern and western Bangkok. At the same time, some people move to CBDs to live near their offices, raising the number of trips in the same area.

About a decade ago, the first railway line, BTS, was built in the middle of some of the city's most congested and highest rent arterial roads. These include Silom Road, the backbone of one of Bangkok's Central Business Districts, and Sukhumvit Road, lined with hotels, shopping centers, and high-priced condominiums. There is a horizontal mix of commercial and residential land use along the transit corridors as seen in figure 3.6 below. Both BTS and MRT have been the alternatives for residents those living near these mass transit routes to daily commute to workplaces and avoid heavy congestion. Consequently, proximity to the BTS and MRT systems is now one of the major concerns when buying residential properties as people value their time and cost saving from commuting to their workplaces. The attractiveness of the location along the transit corridors encourages the development of residential land use as shown in Figure 3.7. In 2009, the total downtown condominium supply reached 58,006 units, increasing 1,737 units or 3% from the previous year. It is expected that the greater the land development along the BTS route, the greater the number of potential users of the BTS. Traffic condition along this transit line is being improved as people are changing mode to travel by the transit instead of driving private car in the congested traffic under the BTS structure (Vichiensan et al.2007).

Many planners have predicted that Bangkok's real estate and housing developments would follow patterns previously established in Asian mega-cities such as Hong Kong and Tokyo. In these two major cities, the mass transit lines and especially the areas near or adjacent to mass-transit stations have become key new-development areas, both for office buildings and housing. Presently, many station areas of the BTS and MRT have become some of the most desirable areas to live and work for Bangkok resident. The mushrooming of high-rise residential and commercial buildings along the rail corridor can be seen in figure 3.8.

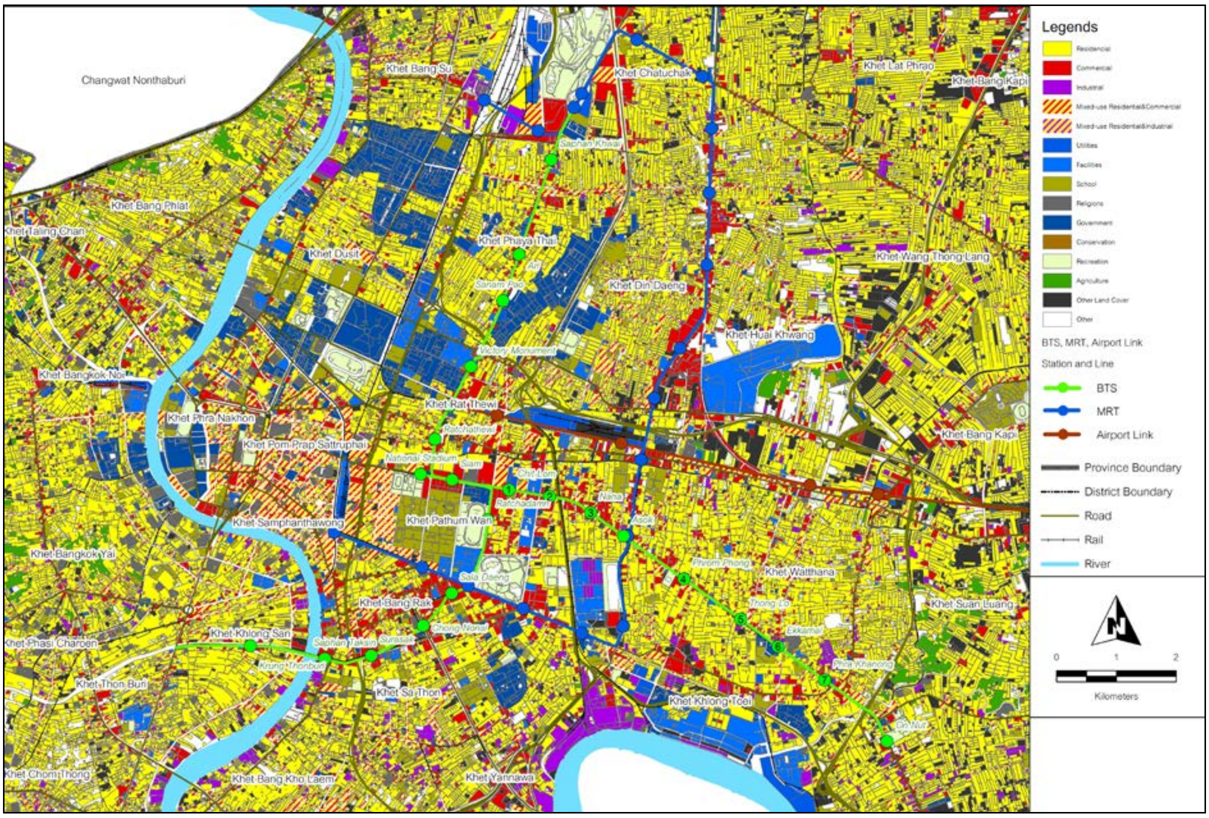
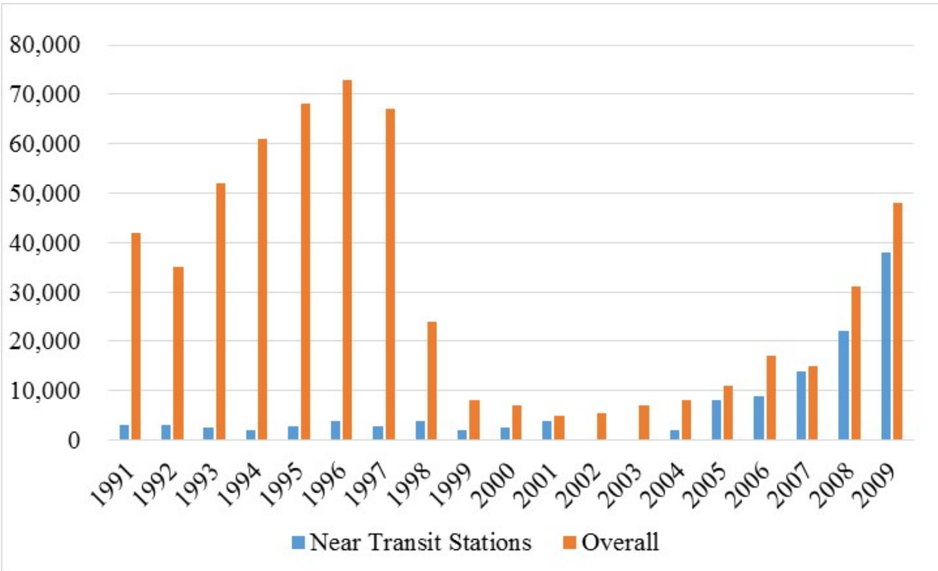


Figure 3.6 Map of land use along the urban railway corridors



Source: Chalermpong (2011)

Figure 3.7 New Condominium Units within 1000m of Transit Stations comparing to overall area in Bangkok

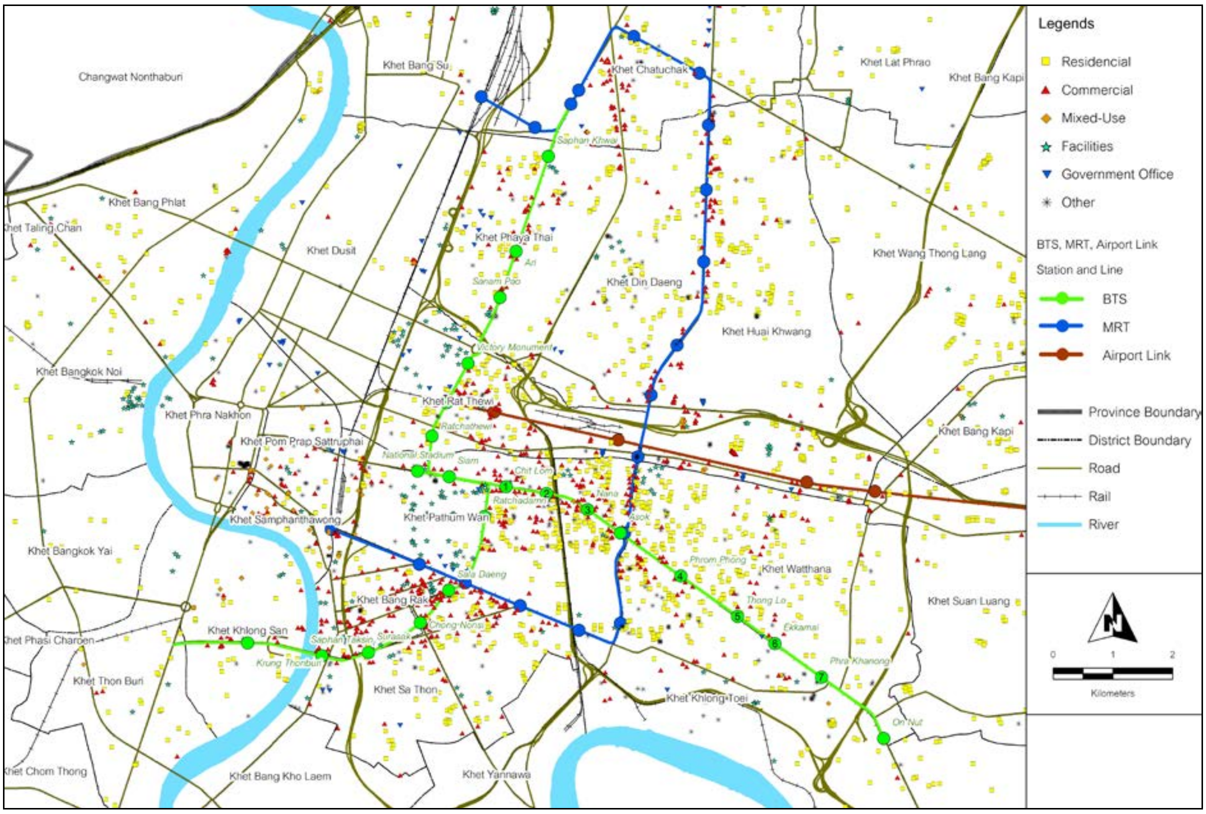


Figure 3.8 Distribution of high-rise residential and commercial building along the rail transit lines

In the past three or four years, both high-end and the middle-income condominium developers have launched successful projects in the area. The Real Estate Information Center's (REIC) statistics show that in 2007, the average home size in Bangkok had fallen. More people were choosing to purchase smaller-sized condominiums, many of which were located near or adjacent to mass-transit lines rather than purchasing more-costly single family homes. This new trend for city condominium living is also creating a new type of owner, executives that wish to live in condominiums during weekdays and in their homes outside the city on weekends(GH bank Housing Journal).

3.3 HOUSEHOLD TRAVEL SURVEY DATA

There are 3 data set using in travel choice behavior analysis as described in table 3.1. In 2013, paper-based questionnaire surveys were formulated to interview the residents residing close proximity to rail stations along BTS and MRT corridors in Bangkok. The definition of proximity to the station in the sense of Bangkok people is defined by the distance between their house and the nearest station within 5 minutes traveling. Generally, there is paratransit, i.e. van pool or golf cart, provided by the condominium located within 1-2 kilometers rings the station to service their resident to commute between their building and the station. Also, motorcycle taxi is the regular choice for the station-area resident to access the station. The 5 minutes travelling by these paratransit modes can be referred to the distance within 1 kilometer. Thus, we define the station-area resident as people those reside within 1 kilometer distance rings of the rail stations.

Table 3.1 Data set of household travel survey using in travel choice behavior analysis

Year	Purpose	Area	Number of observations	Modeling	Chapter
Household travel survey data 2008	Bangkok Mass Transit Master Plan	Bangkok Metropolitan Region	10,340 observations	Join-logit model - Standard Logit model	Chapter 5 Chapter 6
Condominium resident travel survey data 2010	Condominium resident travel behavior	Condominium near the station in Sukhumvit zone	360 observations	Discriminant analysis	Chapter 4
The station-area resident travel survey data 2013	Residential self-selection	Condominium/ apartment near the station	1,036 observations	Join-logit model - Standard Logit model - Nested logit model	Chapter 7 Chapter 8

Condominium/apartment residents in four prime residential zones along the BTS/MRT corridor were interviewed individually by the survey staffs in the evening (5.00 pm – 8.00 pm). The selected zones are shown in figure 3.9. The survey staffs visited each condominium/apartment, asked for corporation and explained the questionnaire details. The respondents were requested to fulfill all questions and return the given questionnaires to the staffs after completion. To gain more respondents, the on-site survey was also conducted around the station areas in five main stations of BTS/MRT including interchange stations and terminal stations where there is a large number of passenger during the morning and evening peak hours (6.00 am -8.00 am and 5.00 pm - 8.00 pm). Only worker or student those have regular work trip or school trip were interviewed. Two data collections were conducted at the selected areas. The first data collection was conducted during May, 2012, and the second survey was launched during December, 2013. The details of these two data collections are discussed below.

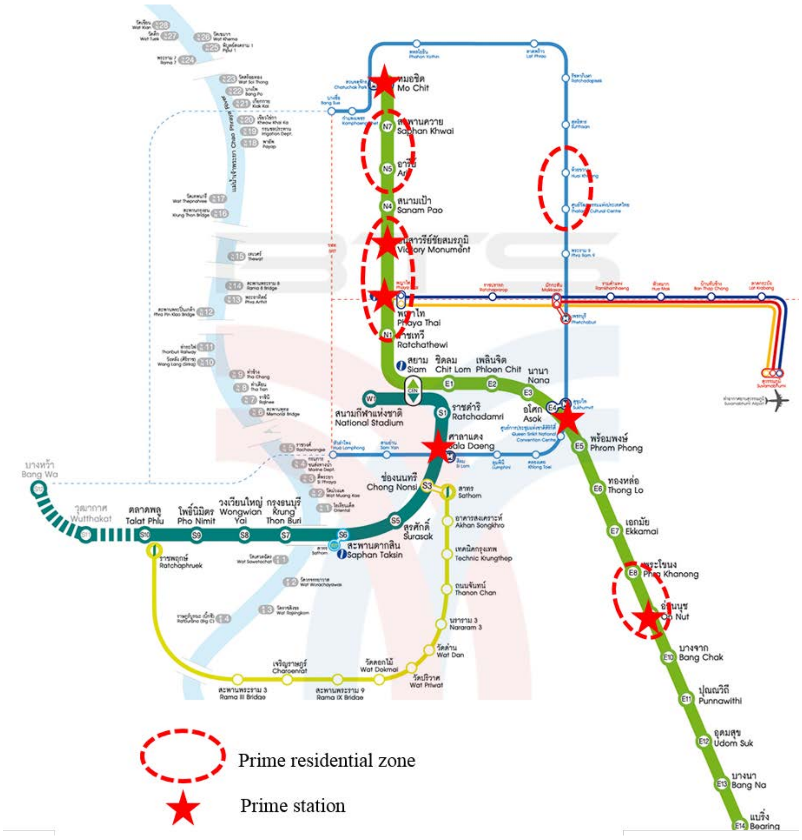


Figure 3.9 map of selected residential zones and stations in conducting field survey

3.3.1 Phase I questionnaire design and survey

The main objective of the first survey is to understand the multi-dimensional relationship between location behavior and travel patterns of residents living in proximity to public transport within a behavioral analysis framework, focusing on the self-selection question. Questionnaire was designed focusing on self-selection questions by asking the residents why they move to live near the station and how they go to work at their presence residence.

The questionnaire was divided into 4 parts including;

- *Location characteristics and attitudes*, residents were required to explain their house characteristics (house type, tenure type, price, size, parking space, etc.), neighborhood near by their house (the distance to the nearest station, relative importance of location, etc.), reasons for moving as well as reasons for choosing area and dwelling.
- *Travel behaviors*, respondents were required to explain their present daily trips to work or education (mode and frequency), travel time and cost for traveling by private automobile and rail transit as well as previous mode choice before moving house.
- *Travel attitudes*, respondents were asked about their attitudes toward mode choice at the time of residential choice decision and the reason for choosing mode choice.

- *Individual characteristics*, the respondents were asked about their demographics (sex, age, education, car ownership, driving license, household type, household size, income, etc.)

Since travel attitudes were measured at the time of residential choice, retrospective questioning on the attitudes that individuals held at the time of making the residential choice is required. To obtain more reliable results of the exact role of travel attitudes in residential choice because of the complexity of such decisions, the questionnaires were distributed to residents by door to door home interview survey. Mainly, we conducted field survey on weekend as the respondents had more time and were willing to fill out the questionnaires. If respondents need more time to answer all questions, they can return the given questionnaires by mail after completion, preferably within two weeks. The total 469 respondents of 28 condominiums/apartments from 5 prime residential zones along the railway corridor were randomly selected.

Furthermore, we focused solely on journeys to work since classic location theory holds workers trade-off commuting and housing costs when choosing a residential location. In the case of multi-worker households, only the primary worker earning the highest income of the household was interviewed.

3.3.2 Phase II questionnaire design and survey

The main objective of the second survey is to examine the impact of residential self-selection concerning to living close proximity to the rail station on the rail commuting decision. The questionnaire was designed including travel behavior, attitude on mode choice as well as house location choice and individual characteristics. It were distributed to the residents not only by door to door home interview survey, but also nearby the station exits. It is firstly important to define the residents who have preference for transit proximity as the station-area residential self-selection, here after SAR self-selection. Then, we identified who is the exact SAR self-selection, Therefore, only the respondents those moved to live near the railway after its first operation in 1999 were collected. Secondly, workers who both live and work near the stations as well as who are the decision maker of relocation near the station were exclusively selected. These respondents' characteristics express high degree of SAR self-selection, which is particularly important if self-selection per se, or its impact exists in this research.

The questionnaire was divided into 4 parts as same as the structure of the first questionnaire described above. For travel behavior data, respondents were asked to describe their trips from home to their workplace in detail (itinerary trip data). Every mode, including non-motorized mode, time and cost for the particular mode was asked to be written down. Also, they had to explain the changing of their travel behavior by writing down which mode choice they used before moving house and whether or not they had a plan on commute mode choice after moving. About travel and location attitudes, they had to indicate their degree of agreement with different items that represent either a favorable or unfavorable attitude toward the location and mode choices by means of a five-point scale: strongly agree, agree, undecided, disagree, strongly disagree.

The total 698 respondents of 66 condominiums/apartments from 5 prime residential zones along the railway corridor were interviewed. 85 respondents cannot be used due to incomplete and missing data or the destination beyond the study area.

3.4 DISCRIMINANT ANALYSIS

Discriminant function analysis or discriminant analysis is a statistical technique with the main purpose to classify the dependent variable between two or more categories or groups. It was used to predict the value of two categories from the beginning. To deal with more than two categories, the multiple discriminant analysis had been developed by an extension of the simple discriminant analysis. The most common application of this analytical tool is to include several measures in the study, in order to determine the ones that discriminate between groups. It also has a regression technique, which is used for predicting the value of the dependent categorical variable. The procedure starts with a set of observations where both categories and the values of the independent variables are known. The procedure develops a model that allows prediction of group membership while only the independent variables are available. Another purpose is an understanding of the data set from the prediction model that can give insight into the relationship between group membership and the variables used to predict group membership.

In case of no acceptable data set compatible with discrete choice models in the context of multinomial choice, the discriminant analysis is the best option that can be then applied to explore the extent to which factors distinguish between the mode choice decisions of the transit-based residents. There are important assumptions of discriminant analysis which are reviewed as follows;

- *Sample size:* There must be at least two cases for each category of the dependent variable, and unequal sizes are acceptable. However, it is recommended that there should be at least 20 samples or four or five times as many cases as independent variables, while the maximum number of independent variables is $(n - 2)$, where n is the sample size.

- *Variance:* No independents have a zero standard deviation in one or more of the groups formed by the dependent.
- *Homogeneity of variances:* Variance with each group of independent variables should be equal. It is better to review the within-groups variances and correlation matrices.
- *Non-multicollinearity:* If one of the independent variables is very highly correlated with another, or one is a function of other independents, then the tolerance value for that variable will approach 0 and the matrix will not have a unique discriminant solution. To the extent that independents are correlated, the standardized discriminant function coefficients will not reliably assess the relative importance of the predictor variables.
- *Normally distribution:* It is assumed that the predictor variables represent a sample from a multivariate normal distribution. However, violations of this assumption are not severe and the resultant significance tests are still reliable as long as non-normality is caused by skewness and not outliers (Tabachnick and Fidell 1996).

In transportation and urban planning fields, it is vital to understand the differences of people demographic, psychographic and attitudinal factors related to products they consume. The discriminant analysis has found to be a useful tool for analyzing market segmentation. For example, Burning et al., (1985) studied the effects of experiences and preferences of passengers in the process of consuming airline service attributes. The analysis results showed that environmental factors (convenience, economy and safety) and personality factor (life style) were discriminating variables; however, none of demographic variables were found significant. The results of each segment were used in developing strategic implications for airline marketing plans.

A multiple discriminant analysis was applied to examine the differences and similarities in residential movement patterns and motivations among generations - young, pre-elderly and elderly households – in Franklin County, Ohio metropolitan area (Morrow-Jones and Kim, 2009). This study expressed the effects of land use, needs of moving, and travel and accessibility related attributes based on the different age groups of home buyers. These results would be valuable information for planning transportation and housing in dealing with the future movements of each generation.

3.5 DISCRETE CHOICE MODEL

A discrete choice model is one in which decision makers choose among a set of alternatives. To fit within a discrete choice framework, the set of alternatives – the choice set – needs to exhibit three characteristics: (i) alternatives need to be mutually exclusive, (ii) alternatives must be exhaustive, and (iii) the number of alternatives must be finite (Train, 2009). Internationally, there is an extensive research literature on the determinants of various aspects of travel behavior, and in particular commuting behavior. Due to the nature of such decisions and the data available, discrete or qualitative choice methods are typically employed. The models are grounded in consumer utility theory whereby the individual chooses among alternatives with the aim of maximizing personal utility. Given the standard form of logit model, the calibration of this research fundamentally involves estimating the various constants and parameters for the model. The coefficients are estimated by fitting the data to the model. The Maximum Likelihood Estimation method is the fitting technique commonly used in practice.

3.5.1 Multinomial Logit Model (MNL)

1) Assuming the Independence of Irrelevant Alternatives

A major limitation of the multinomial logit model is that the construction necessitates that alternatives do not violate the assumption of the independence of irrelevant alternatives (IIA). The IIA assumption is described by Luce and suppes (1965).

> "Where any two alternatives have a non-zero propbability of being chosen, the ratio of one probability over the other is unaffected by the presence or absence of any additional alternative in the choice set"

As can be seen, in the MNL case the ratio :

$\frac{P_j}{P_i} = \exp\{\beta(V_j - V_i)\}$ is indeed a constant independent of the rest of the options.

2) Multinomial/Conditional Logit Model

A more general model may be obtained by combining the multinomial and conditional logit formulations, so the underlying utilities U_{nj} depend on characteristics of the individuals as well as attributes of the choices, or even variables defined for combinations of individuals and choices (such as an individual's perception of the value of a choice). The basic utility equation for individual n choosing alternative j an MNL model is shown below.

$U_{nj} = V_{nj} + \varepsilon_{nj}$

The systematic component of the utility function is given as:

$V_{nj} = Z_n \gamma_j$

So,

$U_{nj} = Z_n \gamma_j + \varepsilon_{nj}$

γ_j is a vector of alternative-specific parameters i.e. the parameters are subscripted by j.These parameters relate the characteristics of a respondent (Z) to the respondent's utility for the

j^{th} choice –they are individual-specific characteristics. This means that the effect of the independent variables will vary across all of the choices. In other words, there will be a separate coefficient on each independent variable for each possible outcome. For example, if the age of the individual was an independent variable, then the effect of age on choosing alternative 1 would be different to its effect on choosing alternative 2, alternative 3 etc. Z_n is a matrix of individual or case-specific characteristics. Note that Z_n is just subscripted by n. In other words, these individual characteristics have nothing to do with the alternatives that are available.

The probability that individual n chooses alternative i in the multinomial logit model is:

$$P_{nj} = \frac{e^{V_{in}}}{\sum_{j \in \mathrm{Cn}} e^{V_{nj}}}$$

$$P_{nj} = \frac{e^{Zn\gamma j}}{\sum_{j} e^{Zn\gamma j}}$$

3) Estimation

Estimation of this model is relatively easy since the log likelihood function is globally concave. To specify the likelihood, first define d_{ni} = 1 if individual n chooses alternative i, d_{ni} = 0 otherwise. This means that there are J lots of d_{ni}, each indicating a choice. These indicators are then used to select the appropriate terms in the likelihood function. Thus, the likelihood function for individual n is:

$$L_n = P_{n1}^{dn1} \times P_{n2}^{dn2} \times P_{n3}^{dn3} \times ...... \times P_{nj}^{dnj}$$

where P_{ni} is the probability that individual n chooses alternative i. The likelihood function for the entire sample is:

$$L = \prod_{n=1}^{N} \; (P_{n1}^{dn1} \times P_{n2}^{dn2} \times P_{n3}^{dn3} \times ...... \times P_{nj}^{dnj})$$

Thus, the log-likelihood function is just:

$$\ln L = \sum_{n=1}^{N} \sum_{i=1}^{J} d_{ni} \ln\left(\frac{e^{x_{ni}\beta}}{\sum_{j} e^{x_{ni}\beta}}\right)$$

3.5.2 Nested Logit Model

1) Generalized Extreme Values Models

Generalized Extreme Value (GEV) models allow for a variety of substitution patterns among the alternatives. The common attribute among all GEV models is that they assume that the error terms are distributed according to a generalized extreme value distribution. GEV models, as the name suggests, are a generalization of the univariate extreme value distribution that is used in the MNL and CL models examined earlier. When all the correlations in a GEV model are 0, the GEV model becomes the product of independent extreme value distributions and the GEV model becomes a standard logit model. It can be tested to see if the correlations are 0, thereby testing whether the standard logit model is an accurate reflection of the substitution patterns. The most widely used member of the GEV family of models is the nested logit (NL) model. Train (2009, 81) notes that the nested logit model is appropriate when the choice set facing a decision maker can be partitioned into subsets, known as nests, in such a way that the following properties hold:

1. For any two alternatives in the same nest, the ratio of probabilities is independent of the attributes or existence of all other alternatives in the nest. In other words, IIA holds within each nest.

2. For any two alternatives in different nests, the ratio of probabilities can depend on the attributes of other alternatives in the two nests. In other words, IIA does not hold in general for alternatives in different nests.

2) Choice Probabilities

One way to come up with the nested logit model is the following. Let the set of alternatives j be partitioned into K non-overlapping subsets denoted B_1, B_2,……B_K and called nests. The utility that individual *n* obtains from alternative j in nest B_k is denoted in the usual manner as $U_{nj} = V_{nj} + \varepsilon_{nj}$. The nested logit model is obtained by assuming that the vector of unobserved utility, $\varepsilon_n = (\varepsilon_{n1}, ; \varepsilon_{n2}, \ldots \varepsilon_{nJ})$ has the following cumulative distribution:

$$\exp\left(-\sum_{k=1}^{K}\left(\sum_{j \ni B_k} e^{-\varepsilon_{nj}/\lambda_k}\right)^{\lambda_k}\right)$$

This distribution is a type of GEV distribution. For a logit model, each ²nj is independent with a univariate extreme value distribution. However, the ε_{nj}'s are correlated within the nests. For any two alternatives j and m in nest B_k, ε_{nj} is correlated with ε_{nm}. For any two alternatives in different nests, the unobserved portion of utility is still uncorrelated: $cov(\varepsilon_{nj}, \varepsilon_{nm}) = 0$ for any $j \in B_k$ and $m \in B_l$ with $l \neq k$.

The parameter λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest B_k; it is sometimes referred to as a dissimilarity parameter. A high λ_k means greater independence and less correlation i.e. the alternatives in the nest are less similar for unobserved reasons. The statistic $1-\lambda_k$ provides a measure of correlation i.e. when this statistic is high, there is more correlation and when this statistic is low, there is less correlation. A value of

$\lambda_k = 1$ means complete independence in nest B_k. Obviously, if $\lambda_k = 1$ for all nests, then the GEV distribution simply becomes the produce of independent extreme value terms i.e. the nested logit reduces to the standard logit model.

With this distribution, the probability that individual n chooses alternative i from the choice set is:

$$P_{nj} = \frac{e^{V_{ni}/\lambda_k}\left(\sum_{j\in Bk} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{\sum_{i=1}^{K}\left(\sum_{j\in Bl} e^{V_{nj}/\lambda_k}\right)^{\lambda_l}}$$

From this equation it is relatively easy to show that IIA holds within nests but not across nests. Consider alternatives $i \in B_k$ and $m \in B_l$. Since the denominator in Eq. above is the same for all alternatives, the ratio of probabilities for these two alternatives is just:

$$\frac{p_{ni}}{P_{nm}} = \frac{e^{V_{ni}/\lambda_k}\left(\sum_{j\in Bk} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{e^{V_{nm}/\lambda_l}\left(\sum_{j\in Bl} e^{V_{nj}/\lambda_k}\right)^{\lambda_l - 1}}$$

If k = l, or alternatively i and m are in the same nest, then the stuff in parentheses cancel out:

$$\frac{p_{ni}}{P_{nm}} = \frac{e^{V_{ni}/\lambda_k}}{e^{V_{nm}/\lambda_l}}$$

This last ratio is independent of all other alternatives i.e. there is IIA within nests. In contrast, if $k \neq l$, or alternatively i and m are in different nests, then the stuff in parentheses does not cancel out and so the ratio of probabilities depends on the attributes of all alternatives in the nests that contain i and m. Note, though, that in this latter case, the probabilities still do not depend on the attributes of alternatives that are not in the nests containing i and m. In other words, there is what Ken Train calls the independence from irrelevant nests (IIN). Thus, in a nested logit model there is a relaxation of the IIA assumption compared to a normal logit model but there still are (i) IIA holding over alternatives in each nest and (ii) IIN holding over alternatives in different nests.

Another thing to note is that λ_k is subscripted by k. In other words, the parameter λ_k can differ over nests, reflecting different correlation among unobserved factors within each nest. It is possible for the analyst to constrain the λ_k's to be the same for all (or some) of the nests, indicating that the degree of correlation is the same in each of these nests. It can be conducted hypothesis tests to see if these constraints are reasonable using a likelihood ratio test.

Another thing worth noting is that λ_k must be within a particular range if the model is to be consistent with utility-maximizing behavior. Specifically, $\lambda_k \; \forall k$ must be between 0 and 1. If $\lambda_k > 1$, then the model is consistent with utility-maximizing behavior for only some range of the independent variables. A negative value of λ_k is inconsistent with utility maximization since it implies that improving the attributes of an alternative actually decreases the probability that it will be chosen. One way to think about this is that an estimated λ_k outside the (0, 1] bounds suggests a misspecification problem with the model: the systematic component could be misspecified, the grouping could be misspecified, or both could be misspecified.

3.6 MODEL STRUCTURE: JOIN-LOGIT MODEL

Chapter 5 6 7 8 are interrelated with respect to model structure of join logit model as illustrated in figure 3.10.

- Chapter 5 evaluates impact of transit proximity on travel choice behavior by using household travel survey in 2008. Binary logit model is employed adding transport factors, household characteristics and built environment of transit proximity factors in the model.
- Next, location choices are added as endogenous, or integrated with mode choices in chapter 6. This chapter models location choice and mode choice of single-worker household and multi-worker household that have more constraint in house location and mode choices. Therefore, the choice set of workplace location of each worker is added as endogenous or integrated with that of mode choice of each worker. Multinomial logit is then employed to examine factors influencing locational and mode choice decision of these households.
- Chapter 7 further evaluates the impact of travel attitudes on travel choice using the station-area survey data 2013. Attitudes factors with respect to mode preferences are added in the model by controlling house location choice that is close proximity to transit stations.
- Chapter 8 continues developing nested logit model by adding mode preference as endogenous. This means mode preferences are included in the choice set joining with mode choices to assess the influence of residential self–selection on travel choice behavior.

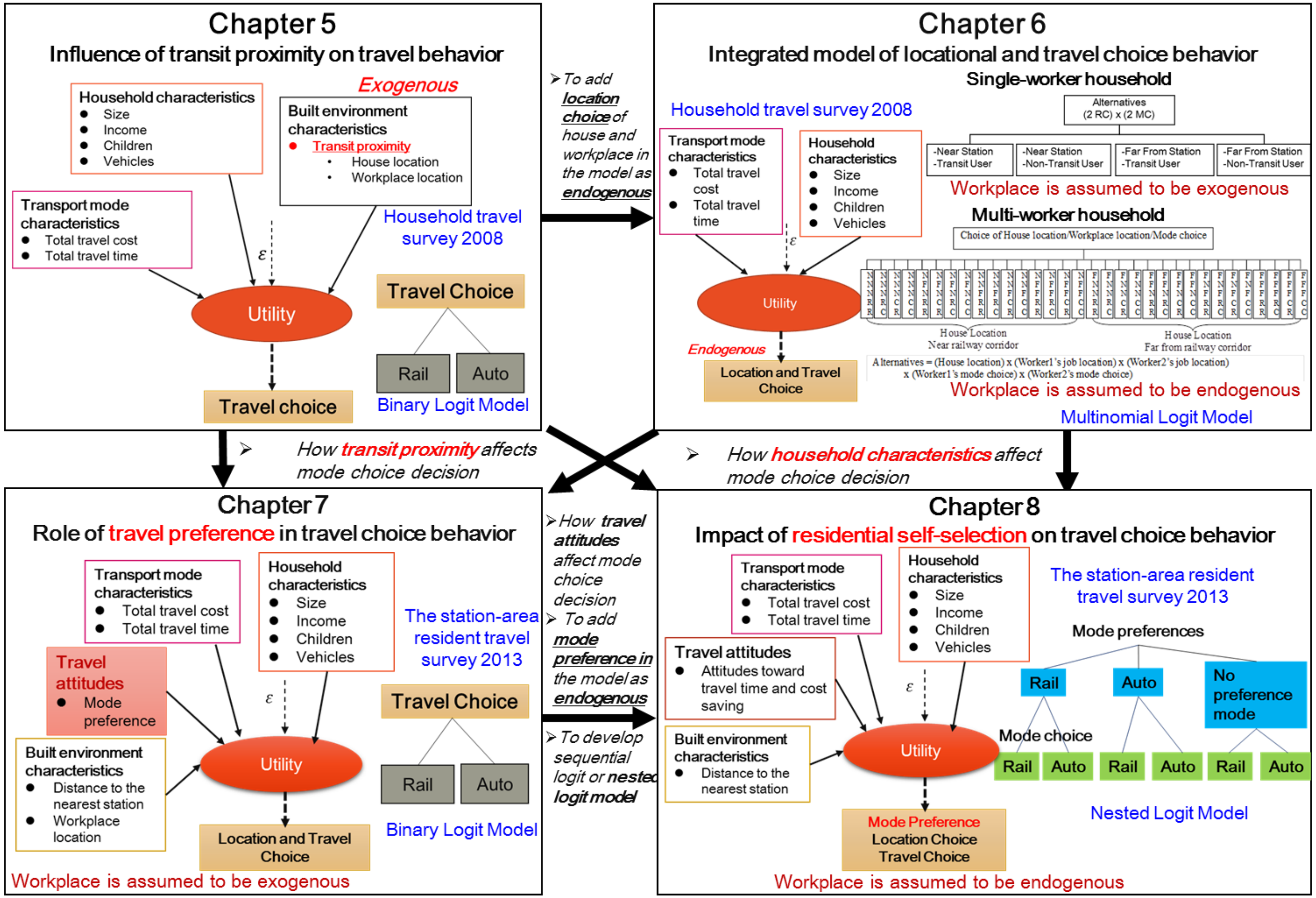


Figure 3.10 Interrelationship of model structure in Chapter 5, 6, 7 and 8

CHAPTER 4

EVALUATION OF TRANSIT-ORIENTED DEVELOPMENT (TOD) SUSTAINABILITY

It is evident that Transit Oriented Development (TOD) is gaining popularity as a potential tool to promote smart growth and sustainable development in transit cities in developing countries. This chapter explores whether these cities have achieved the TOD goals for sustainable development to reduce over-reliance on private automobile and promote more transit ridership. It evaluates sustainability of the TOD based on empirical aspect of outcomes by using discriminant analysis. Several significant factors affecting the transit ridership are finally presented.

4.1 BACKGROUND

Many cities in developing countries, including Bangkok city, Thailand, are seeking to reduce the growth of car-based travel by developing public transport networks. After the decade of the first rail transit system known as BTS and MRT operating with route covering the central business district and inner city area, of course, Transit-Oriented Development or TOD approach can be expected to increase the level of the mass transit users in this city. As this approach is today widely considered to be one of most sustainable forms of urban development, it is being practiced in many parts of the world as a means of reducing the dominance of private automobile travel and promoting settlement patterns that are conducive to transit riding (Calthrope, 1993; Cervero et al, 2004, Dunphy et al., 2004).

Unlike other Asian cities, it seems like TOD implementation in Bangkok, Thailand, has been developed in a haphazard manner because there has not yet been holistic visions and comprehensive plans to promote TOD in this city since the 47 km of rail transit system began operation in 1999. The lack of a long term vision and strategic plan has also resulted in an inability to manage the transit adjacent development. The introduction of the first urban railway has significant effects on property market development along the transit line particularly near the major stations by raising land values nearby a station (Chalermpong, 2007). From the theoretical aspect, based on population density and metropolitan size, this city, however, seems very well-suited to TOD implementation. The city has many prerequisites for TOD. It has revealed the characteristics of mixed land use and densely populated high rise in the downtown areas served by this transit line. Rationally, this seems to be the great opportunity for TOD fostering in this city. While there are signs of growing demand for TOD, the city has many problems with land-use transport systems to implement this approach (Wasuntarasook, 2012).

According to definitions of TOD by Calthorpe (1993) (e.g., density, diversity and design, so called 3Ds), the goals of TOD are correspondent with concepts of sustainable development (e.g., economical efficiency, environmental protection, and social equality). The 3Ds' strategies and concepts of TOD will guide urban development more sustainable. Therefore, there are three key components in sustainable goals of TOD (Lil and Lai, 2006). First, environmental protection means that TOD will restrain land development from environmental sensitive areas and guide it to corridors and station of transit in order to protect ecological environment. Secondly, economic efficiency means that high density and mixed development of land use around transit stations and corridors will raise transit ridership, promote economic development and improve location efficiency. Finally, social equality means that TOD will offer affordable housing with diverse type and more choices of transportation modes to keep social. However, from land use and transport perspective, the priority in this regard is to reduce automobile dependence through development of mixed land use and compact city.

The main objective of this chapter is to evaluate whether the TOD outcomes in Bangkok reach the goal for sustainable development. The benefit of TOD on urban land development in raising density and increasing property value around transit stations has been well recognized; however whether TOD outcomes have achieved the main goals to reduce traffic congestion and attract more ridership is still questionable. In this regard, it is thus necessary to assess impacts of TOD implementation on transit ridership in the real world. Moreover, what factors are more significantly effective in promoting transit ridership in the city should be investigated.

Studies of transit ridership factors can be grouped into two general catagories1) research that focuses on travel attitudes and perceptions, with both travelers and operators as the units of analysis, and 2) studies that examine the environmental, system, and behavioral characteristics associated with transit ridership. The latter includes disaggregate studies focusing on the individual mode choice decisions of travelers (Taylor and Fink, 2003. However, such studies in Bangkok are still rare. For example, the study on what effects total patronage levels of the public transit system in Bangkok focuses on the public transport accessibility of the passenger. (Braun, 2011). Different from the previous studies, this chapter originally attempts to examine not only transit user but also non-user selected as target and considers all metropolitan trips.

4.2 PROSPECTS OF TRANSIT-ORIENTED DEVELOPMENT IN BANGKOK

Sukhumvit, high potential zone of TOD development, is rationally chosen as the study area covering 8 stations namely Chitlom, Phernchit, Nana, Asok, Phromphong, Thonglhor, Ekkamai and Phrakhanong as shown in figure 4.1. It is located further from the central business districts but it is also accessible via both the BTS and MRT (Sirikolkarn, 2008). This area is recognized as the typical characteristic of TOD development displaying the appropriate density, mix of uses, size of neighborhood, transport infrastructure and connectivity. After the operation of the BTS railway, substantial building activity had already occurred around these stations. Similar development situation to BTS will happen with MRT, but may take longer time because more than half of the MRT sections are not in the high density area (Vichiensan et al.,2003).

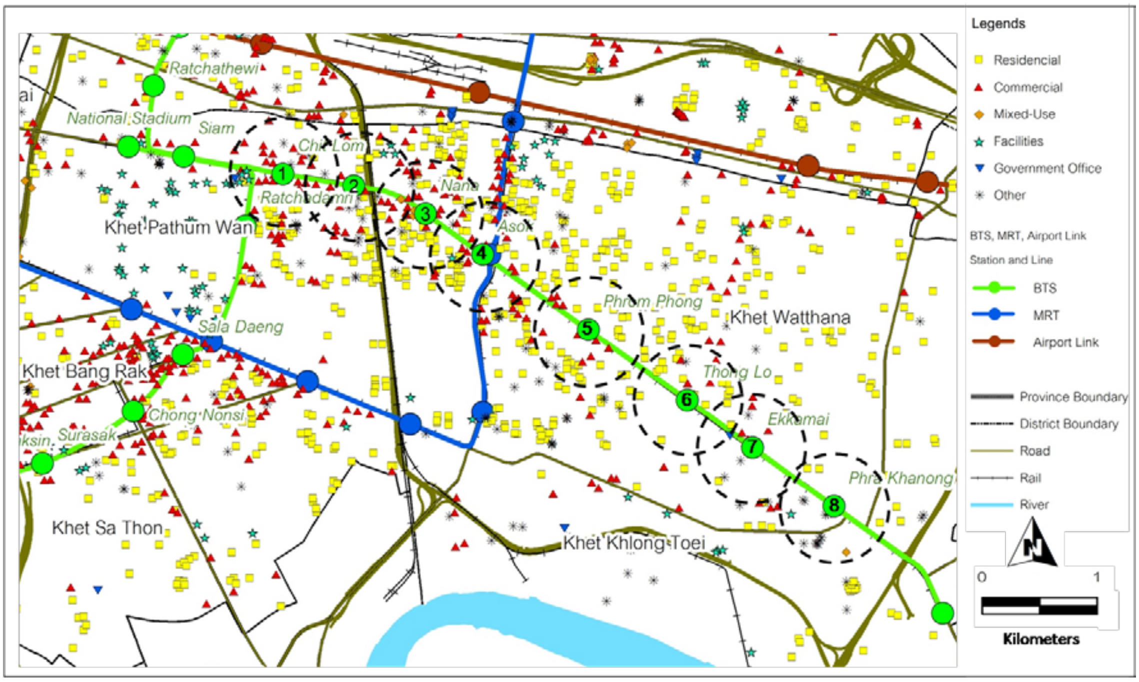


Figure 4.1 Map of study area

Most of the new developments in the Sukhumvit area had been shopping centers, condominiums, and hotels catering to high income earners. The price of condominium is in range of THB 100,000 to above 150,000 per square meter whereas the standard price of condominium in other area is in the range of THB 60,000 to 99,999 per square meter (Knight Frank Research Report, 2010). Because BTS stations are for the most part surrounded by privately owned land, which in Thailand is subject to minimal regulation and taxation, private landowners and leaseholders have been willing and able to quickly capitalize by constructing larger buildings for uses which can command higher rents. From the land use regulation 2006, the area within

500-meter distance from BTS center-line is permitted for buildings with floor space greater than 10,000 sq m. Further away, such big buildings are not allowed. Therefore, in this area, development such as office building, shopping area, and condominium will continue (Vichiensan et al., 2003).

4.3 STUDY FOCUS AND METHODOLOGY

4.3.1 Hypothesis

The empirical results of past studies on TOD outcomes, particularly on increasing transit ridership, have varied from place to place. To implement and foster this policy to reach the TOD goals for sustainable development, the key factors in promoting transit ridership must be clearly realized. This study is proposed to scrutinize what certain factors are high potential to attract transit ridership and to reveal the existing situation on TOD proliferation though the case study of the transit use of TOD resident in Sukhumvit area.

A main hypothesis of this study is that certain factors might be more important to sustainability in reducing vehicle travel and promoting transit use. Based on the concept of true TOD, residents of TOD tend to own significantly fewer automobiles, drive less, and rely more on a combination of alternative modes (walking, cycling and public transit) much more than in automobile-dependent communities. This study focuses on whether or not the resident chooses such transits as one of mode choices for their trip. Hence, linked trip, a trip from the origin to the destination on the transit system, is selected for measuring a wide range of transit uses. Both transit user and non-user are involved in this study. In other words, not only rail transit users but also conventional public transport user and private vehicle users are included in the target groups.

There are various factors especially demography, and travel characteristics influencing travelers on making decision. Among these typical factors, the demography of TOD resident particularly personal income is assumed to be the key factor affecting transit uses as mentioned by many researchers. From the previous study on travel behavior in this city, the income groups are categorized into three groups that are (1) low income – those who earn less than THB 10,000 a month, (2) middle income- those whose income are THB 10,000-20,000 and (3) high income-those who obtained revenue more than THB 20,000 (Tangphaisankun, 2010). In addition, the ability to use or travel by private vehicle determined by resident who own car or motorcycle is supposed to be the main category to distinguish captive rider from mode choice rider. This ability could be one of the main variables influencing user to choose transit as mode choice. Finally, other than resident demographic factors, the distance between home and station is expected to be significant factor to predict the volume of riders. The distance allows a greater portion of trips to be made by walking and cycling and allow some households to reduce their car ownership, which together can result in large reductions in vehicle travel.

4.3.2 Analytical tool

To measure precisely TOD sustainability in inducing transit ridership, it is necessary to gather information on the existing situation in much more detail on the ridership. Data on transit ridership, differentiated by trip transit mode, was obtained from the travel behavior survey of resident in condominiums totally 4,533 units of 34 condominiums along the BTS line on Sukhumvit Road. The questionnaire was formulated as the tool to collect travel behavior data including socio-economic status and mode choice. Due to the limitation of approaching the condominium resident, by accidental sampling method, around 1,300 sets of questionnaire were sent to the target groups and 360 of them were returned to the researcher.

TOD resident demographic and travel behavior data particularly in transit use are gathered. Descriptive statistics and discriminant analysis are then applied to achieve the main objective of this study. Since the first aim of this survey was conducted to examine the existing travel behavior of resident by using descriptive statistics, for this chapter, there is a lack of acceptable data set compatible with discrete choice models in the context of multinomial choice. Therefore, the discriminant analysis is the best option that can be then applied to explore the extent to which different factors distinguish between the ridership of the four main mode choices in order to find out what factors are more significantly effective in promoting transit ridership in the city. The empirical results could provide informative value and insights for the interactions between land use, planning, urban growth management, and transport development in this city.

4.4 THE FACTORS INFLUENCING TRANSIT RIDERSHIP: DISCRIMINANT ANALYSIS

4.4.1 The relationship between socio-economic and transit ridership characteristics

The personal demographics data derived from questionnaire are summarized in table 4.1. From the table, most of condominium residents in Sukhumvit area are well-education and high-income people whose average monthly personal income is THB 80,777.78**.** There is no low income respondent in this study because of the main characteristic of the study area served mostly for rich people. Furthermore, the married group accounts for the vast majority of the condominium residents. Finally, 73.33% of them own private vehicle like car.

Table 4.1 Summary of respondents' socio-economic characteristics

Characteristic	%	Characteristic	%
Sex)%(		Status)%(	
Female	*64.72*	Single	*47.78*
Male	*35.28*	Married	*52.22*
Average age)year(	*40.94*		
)Standard deviation(	13.02		
Career)%(		Household member	
Student	*7.22*	*1*	*38.3*
Office staff	*55.00*	*2*	*40.0*
Owner	*16.39*	*3*	*11.7*
Governor	*10.56*	*More than 3*	*10.0*
Other	*10.83*		
Education)%(		Monthly personal income (Baht)	
Primary	*0*	Low income group	*0*
Secondary	*6.67*	Middle income group	*3.3*
Under graduate	*45.83*	High income group	*96.7*
Graduate	*47.50*		
Car ownership		Property Type	
No	26.67	Owner	78.3
Yes	73.33	Rental	21.7

The Sukhumvit's resident characteristics are somewhat unique from Bangkok's resident. This zone has stronger demographics as residents in this area are mainly mixture between middle to high – income people and affluent expatriates. Considering household income, it shows that households in Bangkok Metropolis earn the highest average income of about THB 35,007 (The National Statistical Office of Thailand, 2012). The Bangkok, in similar fashion to other Asian cities, has a relatively young middle-income population. The housing provision towards housing affordability targets these middle-income earners as main buyers. Unlike high-income, this group will relatively create significant demand for smaller unit sizes in exchange for high quality condominium and housing units in quiet locations but with access to mass transit lines. However, Sukhumvit zone stands out among transit's residential area by its major resident –the elite middle to high income group. The high class is more likely to prefer to live in proximity to people of a similar group and therefore willing to pay high cost of condominium in order to take advantages of living in the desirable neighborhood. Therefore, this area is the main target of high-end condominium market. This is the reason why the rich person is the main respondent in the study area.

Table 4.2 Transit ridership characteristics

Category	Transit user	Transit non-user
Gender		
Male	51.4%	48.6%
Female	43.5%	56.5%
Worker		
No	56.7%	43.3%
Yes	40.0%	60.0%
Income group		
Middle income group	66.7%	33.3%
High income group	47.4%	52.6%
Station proximity		
< 500 m	48.3%	51.7%
> 500 m	48.7%	51.6%
Status		
Single	40.0%	60.0%
Married	56.7%	43.3%
Extended Family		
No	53.2%	46.8%
Yes	30.8%	69.2%
Car ownership		
No	70.0%	30.0%
Yes	47.7%	52.3%
Total	48.3%	51.7%

Table 4.3 Car ownership characteristics

Category		**No car (%)**			**Car owner (%)**		
		Middle income (%)	**High income (%)**	**Total**	**Middle income (%)**	**High income (%)**	**Total**
Gender	Female	-	24.32	**24.32**	5.41	70.27	**75.68**
	male	-	30.43	**30.43**	4.35	65.22	**69.57**
Status	Single	-	20.00	**20.00**	10.00	70.00	**80.00**
	Married	-	33.33	**33.33**	0.00	66.67	**66.67**
Worker	Yes	-	26.67	**26.67**	3.33	70.00	**73.33**
	No	-	26.67	**26.67**	6.67	66.67	**73.33**
Extended family	Yes	-	27.66	**27.66**	6.38	65.96	**72.34**
	No	-	23.08	**23.08**	-	76.92	**76.92**
Station proximity	<500 m	-	31.03	**31.03**	-	68.97	**68.97**
	>500 m	-	22.58	**22.58**	9.68	67.74	**77.42**
Total		-	**100**	**26.67**	**6.81**	**93.19**	**73.33**

The transit ridership characteristics of respondent are showed in table 4.2. Empirically, the difference in personal characteristics of the trip maker such as gender, status, income, car ownership, etcetera results in the difference in travel behaviors on selecting transportation modes. Totally, most of respondents are non-transit user. This means private vehicles is the most selected mode. Intuitively, among respondents who are able to use private vehicles, the car is the most preferable; otherwise, transit like BTS and MRT is the most selected mode. Interestingly, what kinds of respondent own the car should be examined since the ability to use the car is supposed to be the main category to distinguish captive rider from mode choice rider. The result shows that the vehicle occupancy rate of middle and high income group is very high (Table 4.3). Therefore, no matter what the characteristics of respondent are, most of them are car ownership namely choice rider. The question what kinds of choice rider is likely to be transit user is continually investigated.

The unexpected results can be seen. A middle-class worker accounting for the major group of car occupancy tends to be transit user more than that high class that is mostly auto-reliance. However, the latter also uses the transit for some trip purposes. The retired high-income respondent who doesn't have a car is the main group of high-class transit user. Even though their travel frequency is somewhat lower than others, the transit is the most selected mode for their recreational trip. Surprisingly, less female and single person are the transit user; although they are typically supposed to be the main group of transit ridership. This result supports the previous findings that female office workers and students seemed to rely on personal automobiles rather than public transports (Tangphaisankun, 2010).

4.4.2 The transit ridership factors

A discriminant analysis is applied to explore the factors that could classify transit ridership in the study area. Stepwise discriminant analysis is an attempt to find the best set of predictors. The interpretation of the discriminant coefficients (or weights) is like that in multiple regressions. Without the correlation between respondent' socio-economic characteristics and mode choices, Table 4.4 provides an index of the importance of each predictor like the standardized regression coefficients (beta's) did in multiple regression. The sign indicates the direction of the relationship. On Function 1 the transit user has negative mean and the non-user has positive mean, indicating that this function will be better to distinguish the transit user from the non-user. There are several factors that can be the significant predictors of transit ridership such as income, gender, status and occupation. Single status and office worker are the influential factors of respondent who decides to use private car as shown by standardized canonical coefficients, while female and the middle class can strongly differentiate the transit passenger from the non-passenger. Finally, Overall 75% of the case is correctly classified. This indicates the ability to distinguish between the two passenger groups.

Table 4.4 The best set of predictors on transit ridership

		Function 1
Means of the discriminant function	Transit user Non-user	-.800 .746
Standardized canonical discriminant function coefficients of the variables	Female Office worker Single Income < 20,000 baht/month	-.316 .336 .559 -.342
% of correctly classified 75.0 %	Eigen value	.619
	Canonical correlation	.618
	Wilkes Lambda	.617
	Significant (Pr<F)	<0.0001

Table 4.5 The best set of predictors on each mode choices

	Rail transit	**Public transit**	**Automobile**	**Non-motorized**
Standardized Canonical Discriminant Function Coefficients				
Female	.379		.444	.597
Office worker	.292		.281	
Single	.837	-.604	-.581	
Income < 20,000 baht/month	-.354	.798	.570	-.537
Family size > 3 persons	.377			
Means of "use" function	-.856	1.196	.849	-.727
Means of " not use" function	.801	-.239	-.649	.452
Eigen value	.709	.296	.570	.339
Canonical correlation	.644	.478	.620	.503
Wilkes Lambda	.585	.772	.637	.747
Significant (Pr<F)	<0.01	<0.01	<0.01	<0.01
% of correctly classified	80.0%	86.7%	76.7%	66.7%

As focusing on discrimination (separation) of each group (separation of one particular group from another) rather than on classification of observations as a whole, the ordinal discriminant analysis is then employed. Table 4.5 presents the ordinal discriminant analysis results for all available mode choices included in the two passenger groups. From the questionnaire, the respondents rely on rail transit with a combination of other alternative modes (walking, cycling and public transit). Therefore, it can be categorized the riders according to the mode choices in their linked trip in addition to the two rail transit, BTS and MRT, that are automobile user (private car and motorcycle), public transit user (bus and paratransit like motorcycle taxi) and non-motorized user (walking and biking).

Firstly, it is obvious that the income group is the best classification factors of all mode choices. In other words, it can be the strongest predictor for respondent's mode choice selection. It can be noted that the respondent whose personal income is less than 20,000 Baht per month refers specifically to the middle income group because there is no low income respondent in the study area as mentioned previously. Since the middle income group accounts for the vast majority of car owner group or choice riders, this can explain clearly why they will select public transit and automobile. As discussed earlier, office worker is a crucial factor affecting the propensity of private vehicle user, and impeding the proportion of transit user. Automobile becomes the competitive mode to other modes particularly to the BTS and MRT and tends to be the most preferable mode for this worker group. Likewise, female can be the strong predictor of using car as the alternative. They tend to be auto-reliance rather than transit passenger and non-motorized. Furthermore, the single status with large coefficient stands out those that strongly predict allocation to the rail transit or not rail transit rider. However, it is less successful as predictor for the public transport passengers possibly because of its highest percentage of car ownership mentioned in Table 4.3. Finally, it is interesting that family size seems to discourage the number of BTS and MRT passengers. The extended family basically chooses the private car for their trip. However, there are two variables not selected as the best set of predictors that are station proximity and car ownership. This means that they are no significant to the respondent's mode choices selection. It can be summarized that the respondents basically use transit for their trips regardless of the ability to use the private vehicles. This true choice rider characteristic will be the great chance for TOD sustainability in the city.

The classification functions correctly classify 80.0% of the rail transit, 86.7% of the public transit, 76.7% of automobile and 66.7% of non-motorized.

4.5 KEY FINDINGS

This chapter is set out to evaluate the sustainability of TOD outcomes that are primarily expected to reduce traffic congestion and increase transit use through the case study of Bangkok. The previous studies have been written about the importance of TOD in leveraging transit investments for greater ridership by creating districts within walking distance of transit stations that offer appropriate density, a diversity of land uses and pedestrian-oriented design. However, these applications are still not enough for TOD implementation in Bangkok as mentioned in the transit ridership characteristic. Not surprisingly, the study reveals that automobile is considerably selected nearly the same proportion of transit mode. Therefore, it can be concluded that TOD outcomes have not yet achieved the main goals to increase attractiveness of transit despite the city has enormous potential for TOD due to high density and mixed land use.

From the hypothesis mentioned above, the study explores several factors statistically significant for understanding the prospect of improving transit ridership. The empirical results from the discriminant analysis indicate that the hypothesis is identified since the certain factors more important to TOD sustainability in promoting transit use are finally found. Rather than station characteristics, travelers' explanatory characteristics can potentially explain their decision on allocation to the transit passenger or non-passenger.

The study exhibits significant factors such as income group, worker, single status and gender affecting the proportion of the transit user. With respects to the typical characteristic of the study area that mainly serves the rich people, it is not surprising if the percentage of car ownership as well as the private car utility is relatively high and the transit use is relatively low. As public transit systems in the study area has lost market share for most trip to private vehicles, the importance of transit market for traveler with limited access to private vehicles like the poor people should be grown. Therefore, providing more target groups like the low income will be better to extend the number of transit passengers. This can be supported by the previous finding that the low income group tends to be more captive riders than the middle and high income group. They rely on the public transportation such as rail transit, bus and paratransit for their work trip. Conversely, the two other groups seem to be choice transit riders who have a vehicle but choose the transit for some trips. Also, the previous study stated that one main reason of the failure to attract ridership is the incomplete and small networks that generally follow middle- and high-income residential areas. Consequently, the use of rapid transit is beyond the means of most low income Bangkokians (Charoentrakulpeeti et al., 2006). Finally, from the case study of Bangkok, the car ownership as well as distance between home and the station are no significant for the respondent's decision on their mode choices. Therefore, the hypothesis that these variables are expected to be significant factor to predict the volume of riders could be denied.

CHAPTER 5

INFLUENCE OF TRANSIT PROXIMITY ON TRAVEL CHOICE BEHAVIOR

The inventory of housing near train stations is rapidly expanding along the urban railway corridor in most transit cities. It is important to evaluate the extent to which transit-based neighborhoods can invite people to drive their cars less and take transit more. Therefore, the question whether residents those living close proximity to mass transit stations become the rail passengers is investigated within a behavioral analysis framework. This chapter examines causality relationship between location behavior and travel patterns of transit-based residents. Not only built environment of transit proximity but also transport and non-transport related attributes are used in discrete logit model. Empirically, the existing situation on travel choice behavior of the station-area residents as well as what factors are significantly influencing on their mode choice decision are revealed.

5.1 BACKGROUND

Bangkok city has been facing the main problem of failure to meet their expected ridership level. Although rail mass transit usage has seen a gradual rise but its trend has been slower than expected. In 2012, the modal share of the railway is still small or only 5% as shown in figure 5.1. Major of travels in Bangkok are made on road. The transportation by private car has steadily increased. Although roads are becoming more congested, people still prefer traveling by private cars rather than the rail mass transit. The share of private mode is 29% of all trips made by Bangkok residents on an average weekday.

Several reasons explain the lower-than-expected ridership; high income earners use personal car and the limited coverage area of existing railway routes (Sirikolkarn, 2008). The BTS was built in the middle of some of the city's most congested and highest rent arterial roads. Since the decade of its operation, it is expected that the urban railway system has been the alternatives for Bangkok residents to daily commute to workplaces and avoid heavy congestion. Surprisingly, the previous research on travel behavior of the BTS residents showed that most of residents expected to be the BTS passenger choose private car as mode choice, while the BTS shares about 33% of all trips (Sakpongsatorn, 2010). Therefore, the research examines factors influencing on their mode choice decision choosing Bangkok, Thailand, where there is urban railway system available but car ownership and use is still high, as a case study.

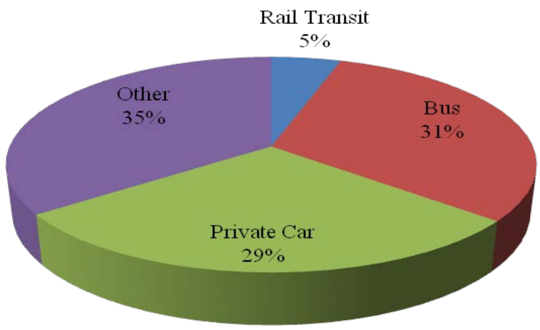


Figure 5.1 Bangkok's mass transit market share

Substantive work is questioning the level of significance that built environment context plays in travel behavior and supporting individual characteristics as the main factor in explaining observed behavior. As the mechanism of household mode choice decision-making plays an important part in transportation planning, it is worthwhile to study what makes people particularly in households those living near the mass transit routes using car or railway.

5.2 THE FRAMEWORK OF TRAVEL CHOICE BEHAVIOR ANALYSIS

The empirical results of past studies on travel choice behavior have varied from place to place. However, our study is somewhat complicated because such study in Bangkok is still rare, in particular given the lack of experience of urban railway mode in this city. As such the primary focus of this research is to evaluate how much the railway impacts on the decision of people to choose mode choice traveling, the main research question is thus stated as why households reside near the railway mainly are not regular users of the railway. Conversely, why households reside far from the railway become to be the regular railway passenger is also examined. In this context, knowledge of the factors influencing the demand for the railway passenger is crucial. This chapter concentrates on transport demand for a specific journey purpose, namely the journey to work, and examine the influence of neighborhood, socio-demographic and transport factors on choice of transport mode for work trip in Bangkok using discrete choice econometric methodology.

In addition, this study originally attempts to examine not only the station-area residents, but also non-station-area resident selected as target. These residents are divided by the proximity to rail stations. Likewise, not only focusing on travel behavior of railway user, non-user is also selected as target group. As the previous studies mostly deals with the use of either the car or public transport as the primary mode of transport (Anable and Gatersleben, 2005). Therefore, the travel choice behavior using private car and rail transit are analyzed as the two main choices as well as focusing exclusively on home-based work trip. Intuitively, work trip is selected as the typical trip in most travel choice behavior studies. Finally, residential location and work location are conditioned as exogenous in our analysis.

The majority of the previous studies provided some debate on the role of a variety of factors that influence the travel choice behavior. From literature review, there are three key factors included in these previous studies; the first factor is built environment. Areas with good access to public transit become highly attractive places for people to shift from car dependent to transit user (Cervaro et. al, 2013). Secondly, transport facilities in terms of travel time and travel costs are considered as the main variables to develop utility functions. The other key factor concerns socio-demographic factors (Kawada et al., 2010; Alvinsyah, et al.,2005; Nurdden et al., 2007; Cantwell et al., 2009). Finally, various authors cite gender, household composition and income, habit and car ownership amongst others as significant factors in influencing travel behavior (Best, and Lanzendorf, 2005; Boarnet and Sarmiento, 1998). Then the main hypothesis is set. There is there is a connection between the characteristics of residential locations and travel behavior, to some degree at least. Among these typical factors, transit accessibility will be found to play a significant role in explaining the mode choice decision of people.

5.3 METHODOLOGY

5.3.1 Household travel survey data

This chapter analyzes the household travel survey data to assess the factors affecting the selection of mode choice. Data was obtained from the household travel survey of Bangkok conducted in December 2008 by Team Logistic and Transportation Consultant Company, providing information on the purpose, mode, origins and destinations, and other features of the journey. The aim of this household survey was conducted to examine the existing travel behavior of Bangkok residents for urban model development namely eBUM (The Extended Bangkok Urban Model) used for the Bangkok Transport Development Project. The respondents of 10,340 randomly were selected from households in a whole Bangkok city area.

The survey questionnaire addressed location and socioeconomic variables as well as individual travel patterns. This data can be employed to consider the influence of proximity to rail connections on mode choice decision. Two target groups based on the proximity to the transit line; the station-area residents and non-station-area residents are intentionally selected. The former are those living within 1 kilometer ring of the stations while the latter are those living outside this interval. This provides a crude proxy for public transit availability with the expectation that those living near the railway will have better public transit options than those living far from the railway. Each target group is intentionally chosen for 300 respondents so there are totally 600 respondents used in this study.

5.3.2 Variables

To analyze the transport choice behavior of railway and car user, the discrete choice models in the context of binary logit model is then applied to explore which major factors behind the mode choice chosen of people. Particularly, the extent to which transportation factors impact on people's mode choice selection comparing to other factors is quantified. Probabilistic models generally and logit models in particular make a possibility to develop useful choice models that do not include all variables that influence the choice being modeled. Notwithstanding, there are certain types of variables that must be included to obtain a useful model.

Table 5.1 variables of the model

Variables	Type	Definition
Mode choice	Dependent variable	Rail is equal to 1 Car is equal to 2
House location proximity to station	Location characteristics	Dummy variable is equal to 1 for household those living within 1 kilometer ring of rail stations; equal 0 for other locations.
Workplace Location proximity to station	Location characteristics	Dummy variable is equal to 1 for household those working near stations (within 1 kilometers along the railway corridor); equal 0 for other locations.
Travel Time	Transport characteristics	Total two-way travel time(in minutes)
Travel Cost	Transport characteristics	Total two-way travel cost(THB)
Low Income	Household characteristics	Dummy variable is equal to 1 for household income less than 10,000 THB and 0 otherwise.
Middle Income	Household characteristics	Dummy variable is equal to 1 for household income 10,000-20,000 THB and 0 otherwise.
High Income	Household characteristics	Dummy variable is equal to 1 for household income more than 20,000 THB and 0 otherwise.
Households with children	Household characteristics	Dummy variable is equal to 1 for household that has children and 0 otherwise.
Multi-worker household	Household characteristics	Number of workers in household
Car Proportion	Household characteristics	Number of automobiles owned divided by the number of travelers in household

There is a data set compatible with discrete choice model. Under limitation of data set, there are three set of variables using in the model; location, transportation and socio-demographic variables. The location characteristics indicate the impact of transit neighborhood on mode choice selection. Travel time and cost indicate the importance of alternative-specific factors in explaining travel behavior. A change in the relative time or monetary costs of public transit relative to driving a car are likely to make it more attractive to commuters. However, a limitation of this analysis concerns the nature of the data available; in particular, information on alternative characteristics such as in-vehicle time and waiting time is simply not available. Lastly, socio-demographic attributes comprise income, the location of house and workplace, the presence of children, the number of workers and car ownership proportion showing the number of travelers and cars in household as shown in Table 5.1 above. The variable "car proportion" enables model to represent the effects of competition among household members for the use of the household's automobile. In particular, increase in the number of traveler in household, which cause decrease in the value of car proportion make it less likely that household's automobile will be available for commuting purposes.

5.3.3 The proposed model

The modes considered for modeling are only railway and car. Hence, a binary choice model is adopted to assess to what extent the travel choice behavior can be explained by these variables mentioned above. The decision to model mode choices binomially was based not only on sample-size considerations but also a desire to frame the analysis to best support public policy-making. Recent policy interest in transit oriented development (TOD) has focused almost exclusively on rail transit systems. And given that the main public benefit of TOD is transit riding, travel demand is best treated as binary as part of an integrated analysis of residential location and commute choice (Calthorpe, 1993; Cervero et al., 2002; Ewing, 1996). Furthermore, there are too few bus transit trips among those living near the rail stops to support a modal model of motorized commute choice. Thus, bus trips are excluded from the final analysis. This study therefore represents mode choice between rail transit and automobile (drive alone and shared-ride) alternatives.

The observable utility of each alternative is assumed to be a linear function of various independent variables and an error term. Following the convention in literature, the observable utility can be written in an addictive form for V_{ir} and V_{ic} as follows:

$$V_{ij} = X_{ij}\beta + L_i\alpha_j + Z_i\gamma_j + \varepsilon_{ij}$$

where

X_{ij} is the vector of transport mode variables; β is the vector of transport mode parameters,

L_i is the vector of location-specific variables; α_j is the vector of estimated parameters for the location-specific variables,

Z_i is the vector of individual-specific variables; γ_j is the vector of estimated parameters for the individual-specific variables,

ε_{ij} is the error term.

5.4 RESPONDENT AND TRAVEL CHOICE BEHAVIOR CHARACTERISTICS

The question who is the main passenger of the railway will be far more clearly understood. Of course, it can be expected that more station-area residents become the regular transit passengers than non-station-area residents. As the main research question is why the former mainly are not the regular users of the railway and why the latter become the regular railway passengers, there are two target groups of respondent to consider their travel choice behavior thoroughly. The first group is the station-area residents who do not use the rail for their work trip. The second one is the non- station-area residents who select the rail transit as their mode choice.

Table 5.2 shows the travel choice behavior of the station-area residents and station-area residents. The result is not consistent with expectations that residents those living and working near the railway line are significant more likely to choose this mode over those living far from the railway line. Private car is the most selected mode for all residents. Moreover, the proportion of transit users among the station-area residents is quite lower than that of car users. With respects to the two interesting groups mentioned above; the station-area residents obviously use their car to go to work no matter their workplace is located near the station or not. Even they both live and work near, 57% of them are car users. Unlike the station-area residents, most of non-station-area residents use the rail as one link for their work trip in case that their workplace is near the railway (47.21%). Of course, if their workplace is far from the train line, they scarcely choose it as their mode choice (0.05%). The question what kinds of the station-area residents and non- station-area residents characteristics are likely to be the transit users is continually investigated.

Only low and middle income residents those both living and working near the station become transit passengers rather than driver while high income and multi-car family residents mostly go to work by car even though their office is not far from the station (Table 5.3). Surprisingly, this group who has to leave home during the peak hour doesn't go to work by mode choice with no congestion like the rail transit. It can be concluded that the high income group that are the main group of car dependent no matter where they live or work. Conversely, the non-residents particularly low and middle income group will select the rail to go to work if they have to go to office near the station during the peak time as shown in Table 5.4. Moreover, most of them are not the multi-car family. They mostly have only one car in household. This means that one of the household members will use the car and let other travelers change to rail mode to go to work.

Table 5.2 Travel choice behavior of station-area residents and non-station-area residents

Place		Mode choice	
Origin (house location)	**Destination (workplace location)**	**Transit user (%)**	**Auto user (%)**
Station-area resident	Near station	42.94	57.06
	Far from station	35.96	64.04
	Total	40.21	59.79
Non-station-area resident	Near station	47.21	52.79
	Far from station	0.05	99.95
	Total	10.91	89.09
Grand Total		14.07	85.93

Table 5.3 Station-area residents' characteristics

Variables	Workplace Location				Total (%)
	Near station		Far from station		
	Transit user (%)	Car user (%)	Transit user (%)	Car user (%)	
Income					
Low	1.7	0.7	1.0	0.7	4.1
Middle	8.2	5.5	2.4	3.1	19.2
High	16.2	28.5	10.7	21.3	76.6
Car ownership					
Yes	26.1	34.7	14.1	24.7	99.6
No	0.4	0	0	0	0.4
Multi-worker household					
Yes	11.3	24.4	7.6	14.1	57.4
No	14.8	10.3	6.5	11.0	42.6
Household with child					
Yes	6.8	8.5	4.5	15.7	35.5
No	21.1	11.1	11.7	21.6	65.5
Total	26.1	37.4	14.1	25.1	100

Table 5.4 Non- station-area residents' characteristics

Variables	Workplace Location				Total (%)
	Near station		Far from station		
	Transit user (%)	Car user (%)	Transit user (%)	Car user (%)	
Income					
Low	1.2	0.4	0	2.8	4.4
Middle	2.1	1.8	0	11.1	15
High	7.6	10.0	0	63.0	80.6
Car ownership					
Yes	10.7	12.0	0	75.6	98.3
No	0.4	0	1.3	0	1.7
Multi-worker household					
Yes	5.1	6.8	0	51.8	63.7
No	5.8	5.4	0	25.1	36.3
Household with child					
Yes	5.6	9.6	0	35.2	50.4
No	8.1	11.2	0	29.3	48.6
Total	10.9	12.2	1.3	75.6	100

5.5 FACTORS INFLUENCING TRAVEL CHOICE BEHAVIOR: DISCRETE CHOICE MODEL

The model results can explain which factors influence the railway ridership. Table 5.5 shows the estimated values of the coefficients of the model. The coefficients are estimated by the maximum likelihood method using the data described above. For the case of Bangkok, there are various factors especially location attributes, socio-demographic attributes and transport related attributes influencing households on making decision. Among these typical factors, rather than transport utility characteristics, the built environment characteristics particularly the location of workplace are found to play a significant role in explaining the travel choice behavior of people.

The coefficients for the explanatory variables including travel time, travel cost, the location of house and workplace, low income, multi-worker household as well as the presence of children are clearly significant, while the other factors are not significant at $P < 0.05$. The signs of several of the estimated coefficients are worthy of attention. The negative signs of the coefficients of travel time, travel cost, car ownership proportion, household with multi-worker and children indicate that other things being equal, travel alternatives with high travel time and travel time and that involve having car, children and multi-earner tend to be less preferred than alternatives that have low travel times and travel time and do not involve these variables. On the other hand, the positive coefficient of low income, middle income, house and work location near the station implies that these groups are more likely to be the transit users, other things being equal.

Table 5.5 Estimated values of the model's coefficients

Independent variables	Coefficient	S.E.	Sig.	Odd ratio
Location characteristics				
House location proximity to rail station	.903	.172	.023*	2.468
Work location proximity to rail station	3.442	.182	.009**	29.250
Transport characteristics				
Travel time	-.009	.003	.001**	.991
Travel cost	-.048	.009	.032*	.953
Household characteristics				
Low income	1.227	.310	.044*	3.413
Middle income	.479	.188	.061	1.615
Multi-worker household	-.073	.164	.006**	.930
Car ownership proportion	-.169	.243	.487	.844
Household with children	-.296	.658	.016*	.744
Constant	-3.325	.639	.000	.036
-2 Log likelihood 1227.85				
Cox & Snell R Square .278				
Nagelkerke R Square .502				
No. of observations 600				

** Significant at 1% level;

* Significant at 5% level.

Among the significant predictors, the proximity to the station; both house and workplace, is thus the main determinant of mode choice selection corresponding with the previous studies that confirmed the higher share of transit trips in transit-based neighborhoods (e.g. Friedman et al., 1994; Handy, 1996a,b; Kitamura et al., 1997; Cervero and Gorham, 1995; Cervero and Radisch, 1995). It can be summarized that there is truly a connection between the characteristics of residential locations and travel behavior at high degree. However, rather than house location, workplace location is the best predictor of the rail users as shown by coefficients. The odds ratio value associated with work location is 29.25. Hence the householders are 29 more times likely to belong to the transit users. This mode will be one choice of all link trip of the worker those working near the train line as mentioned to the travel behavior of the non-residents. Their traveling mode from house to job location will shift from other modes to the rail.

Meanwhile, travel time and travel cost traveling, typical predictors in mode choice study, cannot be the influential factors of householder who decides to use the rail as alternative since they are found to be less potential predictors. It is implied that the drivers will not shift to take this mode if the traveling time can be reduced. This finding doesn't concur with previous findings which mostly found that the travel time and cost are the most important determinants of mode choice (Alpizar et al., 2003; Amador et al., 2005; Fosgerau et al., 2010; Henshe and Rose, 2010; Morera et al., 2004; Abuhamoud et al., 2011). Rather, the respondents are more sensitive to travel cost than travel time due to its higher value of coefficient. In this study, the individual might not seek to make the best use of the travel time on the chosen mode.

For home-based work trip, householder usually travels during morning and evening peak hours. Fundamentally, the private car is the most used mode consistently throughout the day whereas the public transit services use picks up during the morning and late afternoon peaks when congestion puts the greatest pressure on travel time and costs making the car comparatively less attractive during these periods. In comparison during the midday period when there are less traffic pressures and public transit services are not as frequent, the car use almost completely dominates among the transport modes. In this study, less significant of travel cost and travel time demonstrates that the public transit systems in the study area has lost market share for most trips to the private car even during peak time. It can be implied that the magnitude to which the railway usage increases relative to the car during the peak periods is not substantial.

Next, only low income is significantly meaningful to predict the transit passengers. This can be supported by the previous finding that the low income group tends to be more captive riders than the middle and high income group. They rely on the public transportation such as rail transit, bus and paratransit for their work trip. In contrast, the two other groups seem to be choice transit riders who have a vehicle but choose the transit for some trips. Also, the previous study stated that one main reason of the failure to attract ridership in this city is the incomplete and small networks that generally follow middle and high income residential areas (Charoentrakulpeeti et al, 2006)

Household composition also proves to be the significant determinant of transport mode choice for the journey to work. Compared to single worker households, multi-worker households are significantly less likely to choose the railway as alternative. Also, households with children are less likely to travel by the railway, compared with single adult households.

Lastly, there are two variables not statistically significant to predict the probability of mode choice selection including car ownership proportion and middle income. This means that they are no significant to the respondent's mode choices selection. Regarding to the car ownership in household, it can be summarized that householders basically use transit for their trips regardless of the ability to use the private car. This true choice rider characteristic will be the great chance to promote the number of public transit passengers in this city.

5.6 KEY FINDINGS

This study is set out to investigate the travel choice behavior of people who live near and far from the urban railway in Bangkok in order to examine factors influencing on their mode choice decision between the railway and private car. Evidently, the car is the most selection mode among the station-area residents who are expected to be the main group of the rail users.

From the hypothesis mentioned above, the study explores several potential factors for understanding the prospect of promoting transit ridership. Despite the limitations associated with using household survey data to examine modal choice decisions, the results highlight the importance of individual demographic and socio-economic characteristics, transit neighborhood taken home and work location into account as well as travel variables such as travel time and cost in explaining transport decision of Bangkok residents. The empirical results from the binary choice model indicate that the hypothesis is identified since the certain factors more important to predict the transit uses are finally found. Built environment concerning the proximity to the transit station can potentially explain the decision on allocation to the transit passenger or driver. Also, the study exhibits statistically significant factors such as income group, the household composition as well as transportation factors affecting the probability of the transit user.

Transit accessibility is evidently an important consideration, as shown by the highly significant railway proximity variable. The residents those living and working in the area which is well serviced by the railway are significantly more likely to choose to travel by the railway. In this study, the railway proximity can be the strongest predictor for householders' mode choice selection. The main condition of the station-area residents and non-station-area residents to use the rail as alternative depends on where they work. The distance between workplace and the railway affects their decision on travel modes. This result confirms the significant relationships between the size and extensiveness of employment centers and level of transit patronage in corridors leading to the employment centers (e.g. Arrington and Cervero, 2008; Badoe & Miller, 2000). Most previous studies found that concentrating jobs and housing where residents can be served by transit increases transit mode shares and reduces vehicle miles traveled (Transit Cooperative research Program, 1995). However, it can be noted that this condition is true particularly to the choice decision of low income group.

There are wide range characteristics of transit riders. In order to encourage more transit passengers, providing easy access for those individuals who use transit the most like the poor people is the potential means to success. The use of rapid transit should not beyond the means of most low income Bangkokians. The policies to encourage more low income group to live near the railway corridor should be promoted. The development of housing near transit that is affordable to a broader range of incomes should be carefully investigated. Furthermore, from the case study of Bangkok, the car ownership is no significant for the households' decision on their mode choices. Therefore, the hypothesis that it is expected to be significant factor to predict the volume of riders could be denied.

The challenges for further investigation are to find out the interplay between mode choice and location choice decisions as house and workplace location are the best predictor in this study. Residential location and work location are assumed as exogenous but it is possible that individuals make their housing and work location decisions on the basis of (preferred) travel arrangements. The data is also lacking information on alternative characteristics including in-vehicle time and out-vehicle time such as waiting time at station or walking time from home to station as well as information on other household members' travel patterns, such as the necessity of dropping second worker to workplace or children to school, which may influence the mode choice decision of an individual. The validity of findings in this chapter will be enriched by the further studies in order to make more clearly understanding on multi-relationship between the built environment concerning to transit proximity and travel choice behavior of resident those choose to live within the transit catchment area.

CHAPTER 6

INTEGRATED MODEL OF LOCATIONAL AND TRAVEL CHOICE BEHAVIOR

The previous chapter explains the importance of built environment taking account of residential and workplace location in explaining the travel choice behavior. It concludes that there is a connection between the characteristics of residential locations and travel behavior at high degree. From review literature, past studies claimed that one important aspect in assessing housing location decisions is its relation with travel choice. Hence, the questions whether people who choose to live near rail transit station will become regular railway users after moving is more investigated based on the assumption that there is the interplay between location and mode choice. People might simultaneously consider where to live and how to go to work. Integrated modeling of location and travel choice behavior is then proposed to evaluate how households consider transport characteristics in their residential location decisions.

Presently, household choices regarding employment and place of residence are often jointly made decisions. The interaction between household location and commuting decisions is more complex since each household decision may be conditioned by more than one member's workplace choice. Therefore, not only single-worker household but multi-worker family as well will be considered how they evaluate the overall utility of all working members when making decision on house location and travel mode for their work trip.

6.1 BACKGROUND

It has long been recognized that transport accessibility has a large impact on residential location choice decision; however, these effects have rarely been quantified, particularly in developing country. Changes in accessibility are likely to influence the relative attractiveness of a location. Given that residential land use occupies about two thirds of all urban land, and that home-based trips account for a large proportion of all travel, residential location is one of the most important household long-term choice decisions (Harris, 1996; Guo and Baht, 2002). Therefore, a renewed emphasis on location decisions is critical to examining the importance of accessibility for transportation and land development (Cho et al., 2008).

Much of the previous research has assumed that commuting time and cost are endogenous to people's decisions about where to live and work (Abraham and Hunt, 1997; Levine, 1998; Clark et al., 2003). Formal economic was based on the intuitive concept that the residential location choices of individuals are based on a trade-off between the increasing costs of commuting to work and the decreasing unit prices of housing and land that are associated with living further out from a central area of employment (Alonso, 1964; Mills, 1972; Muth, 1969 and Weisbrod et al., 1980). It could be assumed that, according to this theory, the poorest houses will be on the very outskirts of the city, as that is the only place that they can afford to occupy. However, in modern times this is rarely the case, as many people prefer to trade off the accessibility of being close to the CBD, and move to the edges of the settlement, where it is possible to buy more land for the same amount of money (as Bid Rent states). Likewise, lower income housing trades off greater living space for greater accessibility to employment. For this reason low income housing in many North American cities, for example, is often found in the inner city, and high income housing is at the edges of the settlement (Weisbrod et al., 1980).

Similarly, the bid-rent theories offer explanations of the apparent paradox that in Bangkok city, Thailand. Empirically, it seems like low-income households tend to locate on high-priced urban land to save their travel cost and time, while higher-income households choose suburban locations where land is cheaper. The explanation lies in the relative preference of high-income households for large residential lots and their greater willingness to pay for transportation over long distances to and from work (Weisbrod et al., 1980). However, these trends have been continually changing; the middle and high income have been moving back to inner area since the 47 km of rail transit system namely BTS and MRT began operation in 1999 and 2004 respectively. The introduction of the two rail networks is believed to have significantly changed in the both urban land development as well as the resident behaviors since the decade of its operation. The urban railway system has been the alternatives for residents those living near these mass transit routes to daily commute to workplaces and avoid heavy congestion (Sirikolkarn, 2008). Consequently, proximity to the railway systems is now one of the major concerns when resident choose the location to live as people value their time and cost saving from commuting to their workplaces.

The importance of transportation accessibility in explaining the residential choice is well recognized. For the case of Bangkok city, although no direct study was made with respect to home location choice preferences, it seems like the accessibility by the urban railway have been becoming one factor for Bangkok resident to select their house location. However, the extent to which transportation accessibility can be a main determinant of residential location choice decision is still not well understood. Therefore, this study originally aims to examine factors influencing on housing choices decision. In particular, it tries to investigate how much the transit neighborhood play a significant role in determining where people choose to live compared with other factors in disaggregate manner.

6.2 RESIDENTIAL LOCATION AND MODE CHOICE DECISION MECHANISM OF SINGLE-WORKER HOUSEHOLD

6.2.1 Research framework

The choices of residential location are enormous complex to realize. The definition of the term “residential location” could sensibly refer to the exact house or apartment that a household chooses. This study attempts to further concentrate on linking residential location with different modes and other travel choice behaviours. Much of research made significant on the interplay between residence location and mode choice selection (Eliasson and Mattsson, 2000; Krizek, 2006; Pinjari et al., 2008a). Likewise, in the context of Bangkok city where the car dependent rate is very high, it seems like the households simultaneously select mode choice to go to work as they choose where they will live. This means the choice of house location influences the choice of travel mode to work. For instance, people who live far away from the transit; the transit non-resident, are unlikely to choose to go work by the rail. On the other hand, some people may intentionally choose to live near the transit line because they want to go to work by the transit. In this case, the choice of mode to travel to work affects the choice of residential location. Therefore, the choice of residence location and work trip modes will be jointly determined in this study. The travel modes exclusively on home-based work trip that are presented in the model are categorized into two modes; rail and other modes. These two categories will minimize the complexity of the model and picture the real impact of transit on household’s decision.

In addition, many research suggested that workplace location can be a dominant determinant in explaining house location choice. These studies have examined commuting factors and the relations between the locations of residence and workplace (Clark and Withers, 1999; Waddell et al., 2008; Cho et al., 2008; Rivera and Tiglao, 2005). In reality, most residential choice location decisions are based on present location of workplace. Nevertheless, it should be made clear at the outset that the goal of this study is limited to better understanding the households’ location and related choices, and not the complete interplay between job and residence location. Thus, workplace is assumed to be exogenous to residential location decision-making in this study. Furthermore, workplace located near the station within 1 kilometre is assumed to be the potential workplace as it may be one reason for resident to live near the transit station and go to work by rail.

Considering these various impact factors on the residential location choice and travel behaviour, this chapter focuses on location attributes, the transport related attributes mainly comprising the travel cost and travel time and non-transport related attributes concerning socio-demographic attributes, while controlling for built-environment characteristics of house location. It is noted that the main goal here is to understand the household's location and another related choices of travel mode but not the whole interaction between employment and residence location. Then the main hypothesis is set. Among these typical factors, rather than transport accessibility, workplace location proximity to the transit station and the socio-demographic status particularly income and auto ownership level will play a significant role in explaining the residence location of single-worker households in this city.

6.2.2 Research methodology

1) Household travel survey data

Data was obtained from the household travel survey of Bangkok 2008 as mentioned in chapter 5. Data set includes the location of home and workplace, car ownership, the household's size and income, and the mode of travel to work, travel cost as well as travel time. The total of 600 household samples was specifically extracted according to model requirements of: 1) single-worker households and 2) households that moved after the first railway operation in 1999.

2) The proposed model

The analysis of residential location choice at the household level was largely enabled by the development of discrete choice modelling methods. The early applications by Lerman (1976) and McFadden (1978) on this subject paved the way for a generation of research on identifying different contributing factors and making connections with travel-related behaviours. Much of this work is centered on the utility maximization concept where housing choice is represented as a bundle of other associated choices. An advantage of the discrete choice approach is that it is based on microeconomic random utility theory, which states that households trade-off different location attributes when choosing their location that maximizes their utility (Sermons and Koppelman, 2001; Rivera and Tiglao, 2005). This study then creates to model utilizing random-utility theory in order to characterize the choice of home and travel mode of resident. Finally, multinomial choice model is adopted.

Suppose the railway influences the residents to select their house location, there are two location choices divided by the proximity to the railway; near and far from the rail stations. The house located within 1 kilometer and one located between 1-2 kilometers along the railway corridor are defined as living near and far from the station respectively. Also only two alternative modes; rail transit and other modes are used. Therefore, the alternative that integrates the choice of residential location and travel mode is divided into 4 broad categories illustrated in figure 6.1

The multinomial logit (MNL) formulation is widely used in practice and research. In the analysis, each household is assumed to select the alternative location which maximizes its utility. This utility is expressed as a function of attributes of the alternative and the attributes of the household itself. The observable utility can be written as

$$V_{ij} = X_{ij}\beta + L_i\alpha_j + Z_i\gamma_j + \varepsilon_{ij}$$

where

X_{ij} is the vector of transport mode variables; β is the vector of transport mode parameters,

L_i is the vector of location-specific variables; α_j is the vector of estimated parameters for the location-specific variables,

Z_i is the vector of individual-specific variables; γ_j is the vector of estimated parameters for the individual-specific variables,

ε_{ij} is the error term.

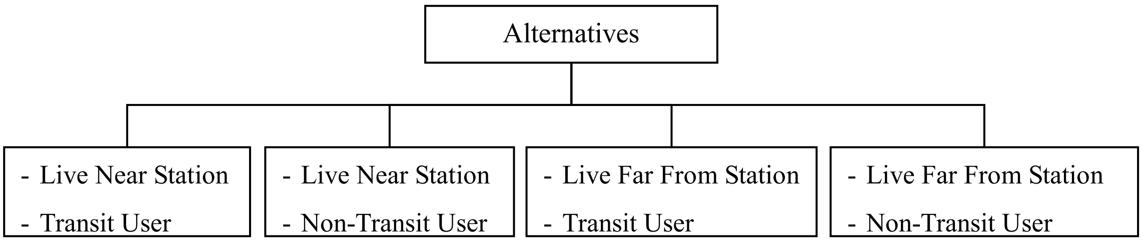


Figure 6.1 Integrated residential location and travel choice of single-worker household

3) Identification of Variable

The choice of residence of households generally involves trade-offs among several factors which give the household the highest possible utility. Fundamentally, consumers make personal choices regarding residential density and location based on a series of housing, neighbourhood, job, and transportation tradeoffs. Over the past decade, it has become increasingly clear that transportation is only one element of what has been termed the total activity system in which each household is involved. The previous research hypothesized that aside from house characteristics, the relative travel times and ease of access provided by roads and public transport systems present in a particular area contributes to the location's degree of attractiveness. The main determinants were included monthly house rent, travel time to work and proximity to rail. The study concluded that there exist two types of households when choosing a residential location: first, are those households that use public transport and believe that public transport influences the quality of the residential location while the second type are households who do not intend to use public transport and consider the degree of attractiveness of public transport insignificant to the location (Hunt et al., 1994; Rivera and Tiglao, 2005).

Besides transportation accessibility, however, there is a variety of other residential location attributes that may affect the housing and location choices of households. These may include the socio-demographic characteristics of householder such as age, household size and income or the characteristics of housing such as racial composition of neighbourhoods, residential density and the size, quality, condition, and price of the housing stock (Weisbrod et al., 1980). Many previous studies have examined the impact of socio-economic factors and the level of public services on the actual location decisions of households. These studies provide evidence for several conclusions(Mayo,1973; Friedman, 1975; Lerman, 1975 and Pollakowski, 1975); (1) The levels of community expenditures on police, fire, education, and recreation services are less important factors in location choice for most households than is transportation accessibility to work, (2) The effect of transportation access on location choice decisions is overshadowed by household income and size considerations, and (3) Household auto ownership level decisions are related to residential location decisions (Rivera and Tiglao, 2005).

In deciding which variables those are known and likely to influence the choices being modelled, it is necessary to take account of the behavioral and mathematical structure of the model, the intended use of model, and the data that are available for applying the model. There is a data set compatible with discrete choice models in the context of multinomial choice. Under limitation of data set, there are three set of variables using in the model; location, transportation and socio-demographic variables as previously mentioned in Chapter 5.

6.2.3 The characteristics of single-worker households

Table 6.1 summarizes the characteristics of household chosen as the samplings of this study. Most of the respondents are high income, car owner, single-person household and the householders those working near the stations. The housing provision towards housing affordability targets these middle-income and high-income earners as main buyers. Notwithstanding, by comparison with the high class, the middle class is more likely to be transit passenger as shown below in figure 6.2. Unlike the two income groups described above, living near the station tend to be less preferred than other alternatives for the low income people since the average price of condominium in this zone seems to be unaffordable price for low income residents. Even though they choose to live far from the transit corridors, they are the main group of the rail passengers as seen below in figure 6.3. This can be supported by the previous finding that the low income group tends to be more captive riders than the middle and high income group. They rely on the public transportation such as rail transit, bus and paratransit for their work trip. In contrast, the two other groups seem to be choice transit riders who have a vehicle but choose the transit for some trips.

Table 6.1 Summary of samplings' socio-economic characteristics

		Live Near station (%)	Live Far From station (%)
Income group	Low income	6.43	10.52
	Middle income	23.29	23.09
	High income	70.28	66.40
Car ownership	No	23.69	14.36
	Yes	94.38	85.64
Single-person family	No	94.38	87.75
	Yes	5.62	12.25
Workplace near station	No	39.36	86.12
	Yes	60.64	17.51
Rail passenger	No	69.88	95.49
	Yes	30.12	4.51

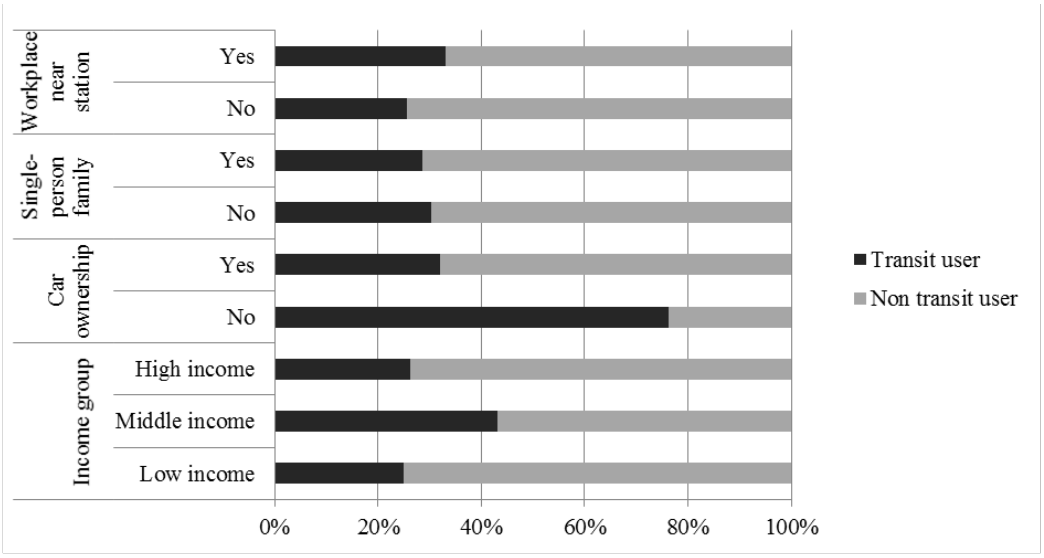


Figure 6.2 Characteristics of station-area residents

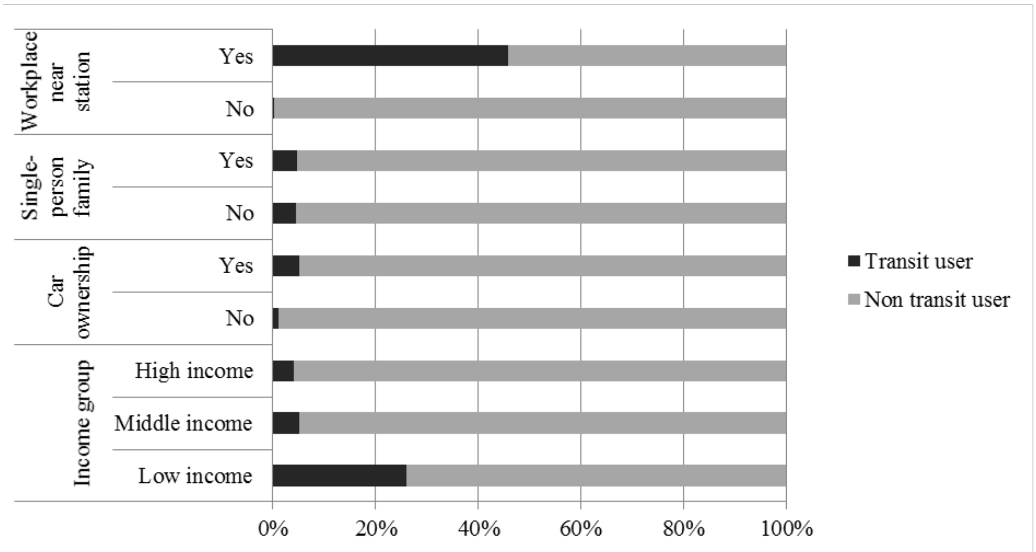


Figure 6.3 Characteristics of non-station-area residents

6.2.4 Factors influencing residential location and mode choice behavior of single-worker household

Table 6.2 shows the estimated values of the coefficients of the model. The coefficients were estimated by the maximum likelihood method using the data described above. The coefficients for the explanatory variables including commuting cost and time as well as middle income are clearly significant, while the other factors are not significant at $P < 0.05$. The signs of several of the estimated coefficients are worthy of attention. The negative signs of the coefficients of travel time, travel cost and car ownership indicate that other things being equal, the alternatives with high travel time, travel cost, and that involve having car tend to be less preferred than alternatives that have low travel times and do not involve these variables. On the other hand, the positive coefficient of low income and middle income implies that these groups are more likely to live near the transit route and go to work by the transit, other things being equal.

Table 6.2 Estimated value of the model's coefficients

Variables	B	S.E.	Wald	Sig.	Exp(B)
Intercept	-.843	.559	2.274	.000**	
Total two-way travel time	-.064	.022	8.661	.003**	.938
Total two-way travel cost	-.035	.009	15.244	.001**	.953
Low income	.234	.467	.252	.616	1.264
Middle income	.351	.359	.965	.011*	1.421
Single-person family	.392	.427	.843	.359	1.575
Car ownership	-2.521	.495	25.961	.998	0.080
Work location near rail station	3.570	.389	84.172	.000**	16.564.
Null log-likelihood	2016.834				
Final log-likelihood	1294.145				
Pseudo R-Square	.559				
No. of observations	600				

**p value of less than 1%

*p value of less than 5%

Among the significant predictors, due to magnitude of the coefficient, workplace location near the rail transit is the best predictor of residents' decision to live near the transit line. The station-area residents those working near the station will choose the rail for their mode choice. The odds ratio value associated with work location is quite high. When location is raised by 1 unit, the householders are 16 more times likely to belong to the station-area residents and transit user.

Comparison to other income groups, only middle income seems to be the main group of the station-area residents and regular passengers. Meanwhile, single-person family as well as car ownership cannot be the influential factors of householder who decides to live near the station and use this mode as alternative.

The main condition of householders to be the transit-based residents and use transit mode to go to work depends on their workplace location. The distance between workplace and the station affects their decision on house location and travel mode. This can be implied that the Bangkok residents rely less on a combination of alternative modes, ignoring any changing of modes. The convenience of one linked trip from home to work by the rail is preferable. It seems like there is a poor connectivity between the rail transit and other existing transportations in this city as the former study on mass transit in this city concluded that both rail transit systems have not yet achieved the main goals to reduce traffic congestion and attract more ridership. The two main reasons are the lack of connections to main transportations, and the difficulty in accessibility (Charoentrakulpeeti et al., 2006). These shortcomings dissatisfied commuters and led to low system performance and level of patronage. Besides expanding the mass transit network coverage, the future urban transportation plans should mainly consider on improving connectivity, both passenger accessibility and connection to the station as mentioned in the previous study (Tangphaisankun, 2010). However, as discussed above, it can be noted that the condition is true particularly to the choice decision of middle income group since this income group is significantly meaningful to predict the probability of transit residents and passengers.

In addition, the transportation variables; the travel cost and time, are found to be less potential predictors. It can be implied that the householders are less likely to move to live near the stations and use the transit if the travelling cost and time can be reduced. This finding concurs with previous findings which found that transportation factors are less important determinants in location and travel choice. Surprisingly, the car ownership has no significant impact on the household's decision on their house location and mode choice. Hence, the hypothesis of the good predictor of car ownership could be rejected. It can be summarized that the Bangkok residents basically select to live near the rail station line and use this mode for their trips regardless of the ability to use the private vehicles. This reveals the true choice rider characteristic. This characteristic will be the great chance to promote the number of public transit in this city.

In addition, the challenges for further study are to find out the interplay between job and house location as the workplace location is the best predictor in this study. For long-term predictions of household locational patterns it is important to examine both workplace location choice and home location choice (Abraham et al., 1997).Therefore, the choice of residence location, job location and work trip mode will be jointly determined in the future study. Special attention shall be given to two-worker households to give us an insight on how workers in the household assess each worker's disutility when relocating.

6.3 LOCATION AND MODE CHOICE DECISION MECHANISM OF MULTI-WORKER HOUSEHOLD

The study of location and travel choice behavior has captured the interest of scholars in a diverse range of disciplines. Studying these decisions can reveal a great deal about expectation of the city's residents on land use and transportation development. As the mechanism of households' decision-making plays an important part in the urban and transportation planning, it is worthwhile to study what makes people select their house and job location and travel mode, particularly in the household with more than one worker has profound effects on their decisions. Many new researchers pointed out that assumptions of single-worker households and exogenous workplace location should be reconsidered (Watterson, 1994; Simpson, 1987; Waddell, 1993; and Rivera and Tiglao, 2005). They discovered that a model comprised of workplace and residential location explains urban commuting distances better than models of residence or workplaces alone. Now, more than ever before, household choices regarding employment and place of residence are often jointly mode decisions (Montgomery and Curtis, 2006). Some studies have tried to improve model by including transport mode choice as part of household' location choice decision process.

Therefore, the objective of this part is to examine factors influencing on multi-worker households' choices decisions including the location and commuting pattern, with particular emphasis on the role of transport factors. For the case of Bangkok city, even though no direct study was made with respect to the interplay between location and travel choice preferences, general assumptions can be set that the accessibility by the urban railway have been becoming one factor for Bangkok residents to choose to reside near to the railway and they are regular railway users. Specially, how workers in the multi-worker household assess each worker's disutility when relocating should be considered. For this reason, this section try to investigate how much the transportation factors in terms of each worker's travel cost and time play a significant role in determining the decision mechanism of these households those living near the railway corridor compared with socioeconomic and demographic factors in disaggregate manner. Finally, it should be made clear at the outset that our goal is jointly considering households' location and related choices including the interplay between residence and job location as well as mode choice decision.

Residential location (and indeed workplace location) and travel choice are assumed as endogenous because it is possible that individuals make their housing and work location decisions on the basis of (preferred) travel arrangements.

6.3.1 Research framework

As TOD sustainability has been fostering in this city, two rail networks in Bangkok are believed to significantly change the resident behaviors. This study has been started with the question why multi-worker households choose to reside near to the railway and whether or not they are regular railway users. Specifically, sub research question is that how the determination of residential and job location choice (as proximity to the station) and travel behavior (i.e. mode choice) are controlled in terms of transport accessibility and socio-demographic factors. This means that it is wondered how transport accessibility is important in location and mode choice decisions.

In multi-income households, the presence of second worker's work location is hypothesized to have the influence on household's residential location choice and travel choice decisions. The main reason is that the decision mechanism of household choice selection basically involves trade-off among several factors which give the household the highest possible utility. Among workers in this type of households, there will be one worker's workplace that is the most important to consider than the other ones when relocating. One worker who will be defined as primary is typically the head of the household, if he or she is employed full time or has the highest income. Other workers are termed secondary. Accordingly, the utility of the primary worker is given more priority in the choices decision making. All workers' accessibility to work are jointly treated as a dependent variable with their house and workplace location in the study

6.3.2 Research methodology

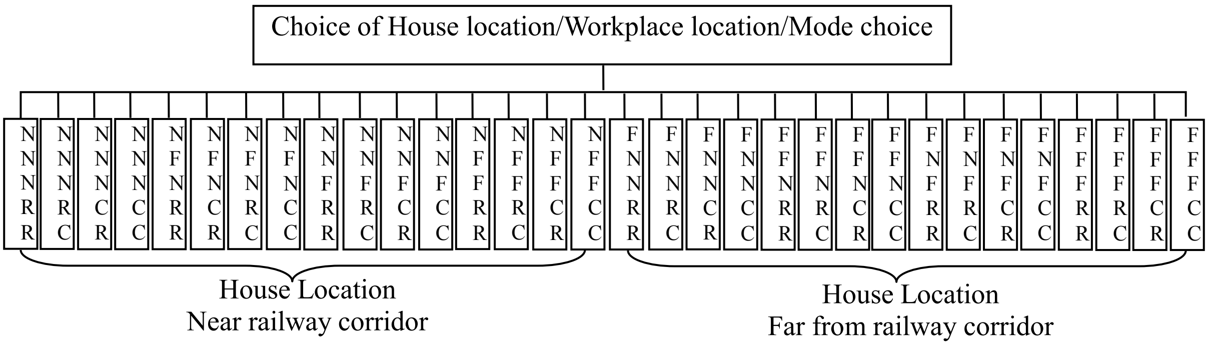
1) Data Collection

In this part, the household survey data is analyzed to assess the factors affecting the selection of residential and job location and mode choice. A total of 600 household samples of Bangkok household survey 2008 are extracted according to model requirements of: 1) multi-worker households and 2) households that moved after the first railway operation in 1999.

2) The proposed model

From the recommendation of previous studies, it has been proved that most residential choice location decisions are based on present location of workplace. However, for long-term predictions of household locational patterns it is important to examine both workplace location choice and home location choice. Hence, the residential location, workplace location and mode choice are jointly determined in this study.

There are two location choices divided by the proximity to the railway; near and far from the stations. Similarly, each worker's job location is defined. Also only two alternative modes; the rail transit and car are used. To minimize the complexity of analysis, two workers living in multi-worker household are assumed to jointly choose residential location, worker 1's workplace and worker 2's workplace to maximize utility. Therefore, the alternative that integrates the choice of residential location, job location and travel mode is divided into 32 broad categories as seen in figure 6.2.



Alternatives = (House location) x (Worker1's job location) x (Worker2's job location) x (Worker1's mode choice) x (Worker2's mode choice)

House / Workplace location — Mode choice

N = near railway corridor — R = Railway

F = far from railway corridor — C = Car

Figure 6.4 Location and Mode Choice of Multi-Worker Household

From previous studies, the basic model of multi-worker households' location choice and mode choice is disaggregate discrete choice model in the context of multinomial logit model. The distance linking the household's house to one of its workplace constitutes the main variable of this study. This choice determines the commuting cost and time of both workers. Utility (V) is defined as a function of attributes of the alternative and the attributes of the household itself. The function V is specified as

$$V = H + \sum_{w=1}^{2} M_w$$

Where,

H = Household characteristics

M= Transport mode characteristics

3) Identification of Variable

In this research, the influence of transport and household characteristic factors on the residential location and mode choice decisions will be examined with controlling for the effects of house and built-environment characteristic variables on these decisions. Firstly, as mentioned in Kim (1995) and Charron (2007) cited in Surprenant-Legault (2010), the transport factors in terms of the travel cost and travel time between house and workplace of each worker play a significant role in determining the decision mechanism of these households because they illustrate to which extent the commute distance associated with the household's choices and constraints is split between the all partners. This type of household minimizes commuting distances more than one-worker household. Notwithstanding constraints and the variety of factors or motivations affecting home to work distances, minimization of distances remains desirable for all households and is a tendency effectively reflected in commuting behavior. Lastly, which socio-demographic factors connect the location and travel behavior of workers living in the multi-worker household are decided. These factors concern the characteristics of this household type such as housing tenure, the presence of child, car ownership and household income. Rather than transport factor, factors particularly income and the presence of child are expected to have more influence on their choice decisions.

6.3.3 The characteristics of multi-worker households

Table 6.3 summarizes the characteristics of household chosen as the samplings of this study. Most of the respondents, both living near and far from the railway or zone 1 and zone 2, are high income, car owner, and households with children of school age.

Focusing on multi-earner households, the residential location and mode choice decisions of workers are based on their job location as both workers will apparently commute by the transit if their workplaces are located near the railway station. Conversely, they choose to travel by car in the case that their job locations are far from the station. Also, their job locations would be less accessible by other modes than the car. In addition, the primary and secondary workers have different trip modes and accessibility to workplaces. Evidently, the primary workers seem to have priority over the secondary workers to drive the car due to the higher proportion of their car using. As men account for approximately 90% of primary worker group, the car dependency of the primary earners originates from men's preference for driving car. The length of their trip is likely to increase more when the car is used instead of the transit mode. The secondary earners seem to be more constrained than the primary ones to reach the same level of accessibility to workplace.

They are less likely to drive the car, but they are more likely to be the car passenger or to take the public transit. They prefer to work in the job location that easily access by the railway than in the other job centers. Therefore, the household that has the worker 2's job location near the railway line mostly more selects the railway than the car as their travel choice to work.

Table 6.3 Summary of samplings' characteristics

	Variables	House location near station				House location far from station			
		W1Z1 W2Z1	W1Z1 W2Z2	W1Z2 W2Z1	W1Z2 W2Z2	W1Z1 W2Z1	W1Z1 W2Z2	W1Z2 W2Z1	W1Z2 W2Z2
W1 Mode choice	Railway	33.3	51.6	14.5	23.1	90.3	47.8	23.1	0.0
	Private Car	66.7	48.4	85.5	76.9	9.7	52.2	76.9	100.0
W2 Mode choice	Railway	50.0	9.7	90.0	15.4	66.7	47.8	42.3	10.3
	Private Car	50.0	90.3	10.0	84.6	33.3	52.2	57.7	89.7
Household income	Low income	10.0	15.5	10.0	5.3	19.1	22.0	13.8	15.3
	Middle income	25.8	33.7	10.0	7.7	33.3	18.7	15.4	17.2
	High Income	64.2	50.8	80.0	87.0	47.6	59.3	70.8	67.5
Presence of Child	No child	25.0	25.8	30.0	7.7	33.3	17.4	34.6	17.2
	Have child	75.0	74.2	70.0	92.3	66.7	82.6	65.4	82.8
House tenure	Rent	8.3	12.9	20.0	15.4	16.7	4.3	23.1	6.9
	Owner	91.7	87.1	80.0	84.6	83.3	95.7	76.9	93.1
Car ownership	No car	0.0	3.2	0.0	0.0	0.0	4.3	7.7	3.4
	Have car	100.0	96.8	100.0	100.0	100.0	95.7	92.3	96.6

W1 = Worker 1's Workplace location

W2 = Worker 2's Workplace location

Z1 = Workplace near station,

Z2 = Workplace far from station

For the railway resident, it can be expected at least one worker in this family opts to use the rail transit. However, both earners mostly use their car rather than rail transit for their work trip. Next section will explain why they don't commute by the railway and what kinds of households are most inclined to move to station areas and use the transit.

6.3.4 Factors influencing locational and mode choice behavior of multi-worker household

With an iterative procedure for model calibration, the best set of variables as necessary is finally obtained. It is also proved that there are no correlations among these variables. Table 6.4

shows the estimated values of the coefficients of the model. The coefficients are estimated by the maximum likelihood method using the data described above. The coefficients for the explanatory variables including workers' commuting cost and time, low income, middle income, and the presence of child are clearly significant, while the other factors are not significant at the 0.05 level. The signs of several of the estimated coefficients are worthy of attention. The negative signs of the coefficients of travel time and travel cost from home to individual's workplace, middle income, the presence of child, and house owner indicate that other things being equal, the alternatives with high travel time and travel cost of each worker's commuting to work, as well as that involve being middle income, having child and owning house tend to be less preferred than alternatives that have low travel cost and travel time and do not involve these variables. On the other hand, the positive coefficient of low income as well as long distance between workers' job location implies that they are more likely to live near the transit route and go to work by the transit, other things being equal.

Table 6.4 Estimated value of the model's coefficients

Variables	B	S.E.	Wald	Sig.	Exp(B)
Intercept	8.946	2.845	9.885	.002**	
Worker1's two-way travel time	-.087	.055	2.535	.018*	.917
Worker2's two-way travel time	-.046	.047	.973	.024*	.955
Worker1's two-way travel cost	-.073	.025	8.415	.004**	.930
Worker2's two-way travel cost	-.051	.022	5.681	.017*	.950
Distance between W1W2 workplace (Car user)	.200	.226	.784	.376	1.221
The presence of child	-2.932	3.271	.803	.015*	.053
Low income	.493	4.103	.014	.036*	1.637
Middle income	-.686	1.669	.169	.008**	.503
House owner	-1.053	1.193	.296	.075	.349
Number of observations	600				
Null log-likelihood	-1288.223				
Final log-likelihood	-893.541				
Pseudo R-Square	.544				

** Significant at 1% level;

* Significant at 5% level.

Even though all variables relating to transport factors are all significant below the 95% confidence level, the parameter estimates of travel cost and travel time variables for the worker1 and worker2 show that they are slightly less impact on the households' location and mode choice compared to other variables. It indicates that the householders are less likely to move to live near the railway line and use this mode to commute if the travel cost and time can be reduced. This finding concurs with the previous findings which found that transportation factors are less important determinants in location and travel choice behavior. Among two workers, all else being equal, they have different sensitivity to travel time and cost accessibility to individual's workplace. This implies that the households tend to locate themselves close to any one worker's work locations in order to save his/her travel time and travel cost rather than to live either longer or shorter for both workers. The utility of the primary worker is given more priority in the location choice decision because the coefficient of worker1's commuting time and cost is stronger than that of worker2's. Hence, the hypothesis that one worker's workplace will be more important to consider when relocating can hold true. Since most of the primary earners represent male, it can be said that the female work commute has less influence on the residential location choice than the male commute.

For car-owning households, the distance between the workplaces of the two workers have a positive impact on the choice preference of households being the railway residents and passengers although it was found to be not significant. This could mean a probability for two earners not to share riding for their work trip in case of long distance between two workplaces. Moreover, the negative and high coefficient value of the presence of children supports the idea that their child's school location becomes an additional location factor that has powerful effect on the household's choice decision. Logically, children's school trip traveling that is immaturity and dependency on adults will encourage car oriented mode of family mobility which directly affects to household travel patterns.

Considering income group, being low and middle income group is significant to predict who will become the station-area residents and the rail users. These income groups are more likely to choose their residence closer to the closest employment centre where they can commute to work by the rail, while they are also likely to live at locations which are close to the train station at the same time. Basically, both middle income and high income group account for the majority group of multi-worker households those living near the railway in this study. Notwithstanding, by comparison with the high class, the middle class is more likely to be transit passengers.

Although an average price of condominium along the railway route seems to be unaffordable price for low income residents, living near the station tends to be more preferred than other alternatives for the low income households if members' job location are located near the transit station. The model predicts that the odds of deciding to be the railway residents as well as the railway passengers are 1.637 times higher for the low income families than they are for other income groups. Along the railway lines, there are many transitional zones where the land use has been changing rapidly since the launch of the first railway system. The poor residents can live at the cheap apartment rental available in these zones and go to work by using the railway. They are willing to trade-off proximity to their workplace to the good quality of house. Although most of them choose to live far from the transit corridors, if there is at least one member working near the transit, the proportion of using the railway is explicitly high regardless of house location as mentioned above in table 6.3. This is the reason why they are expected to be the main group of the railway passengers. This can be supported by the previous finding that this income group tends to be more captive riders than the middle and high income group. They rely on the public transportation such as rail transit, bus and paratransit for their work trip. In contrast, the two other groups seem to be choice transit riders who have a vehicle but choose the transit for some trips. Therefore, in order to promote the more railway passengers, more people whom can be proved to be regular transit passengers like the poor people should be encouraged to have more chance to live near the railway corridor. The policies on development of housing near transit that is affordable to a broader range of incomes should be carefully investigated.

6.4 KEY FINDINGS

In this research, Bangkok city where the first urban rail transit system was introduced over past decade, but car use rate is still high, is employed as a case study in order to investigate the role of urban railway in determining location and mode choice decisions. Initial findings provide the better understanding on the mechanism of Bangkok resident's decision on residential location and travel behavior specially attention given to not only single-worker household but also multi-worker households who are more constrains in selecting house location, workplace location and travel choice. Two factors including transport factors and household characteristic factors are investigated in this research, while controlling for house and built-environment characteristics.

For location and mode choice analysis of one-worker family, the study explores several potential factors for understanding the decision-making on residential location. The empirical results from the multinomial choice model indicate that the hypothesis is identified since the certain factors more important to predict who will live near the transit line and travel by the rail transit are finally found. The study exhibits statistically significant factors such as work location, middle income group, the travel cost as well as travel time affecting the probability of the transit residents and passengers. Rather than transportation characteristics, households' explanatory characteristics can potentially explain their decision on allocation to the station-area resident or non- station-area resident as well as the transit users and non-users. Particularly, the workplace location proximity to transit can be the strongest predictor for householders' residential location and travel choice selection. Meanwhile the car ownership is not significant factor affecting the households' decision.

Focusing on location and mode choice analysis of multi-worker family, the result gives us an insight on how workers in the household assess each worker's disutility when relocating. Likewise, results from the multinomial choice model indicate that the hypothesis is identified since the presence of second worker's work location has the influence on residential location choice and travel choice in multi-worker households. There are different impacts of travel time on workers' choices decisions. The utility of the primary worker is given more priority in the location choice decision. Also, the certain factors more important to predict which household will live near the transit line and travel by the railway are finally found. The study exhibits statistically significant factors such as both workers' commuting cost and time, low income, middle income and the presence of child affecting the probability of being the station-area residents and rail passengers. Also, households' characteristics, particularly, the presence of children can be the strongest predictor for Bangkok residents' location and travel choice selection.

This research expects in contributing greater extra details on spatial choice behavior to better understand the likely measures that would have to be taken to encourage greater residential land use development and mass transit users. In addition, the challenge for further study is to find out more factors to assert the importance of the separation between the causal effect and the spurious relationship among built environment and travel behavior. Therefore, the inclusion of 'self-selection' effect in explaining the relationship between location choice and travel behavior should be continually examined.

CHAPTER 7

ROLE OF TRAVEL PREFERENCE IN TRAVEL CHOICE BEHAVIOR

Previous chapters illustrate factors influencing travel choice behavior choosing Bangkok as case study. The results reveal the causality relationship between built environment concerning to location choices close proximity to transit station and transit ridership. As location choices are assumed as exogenous variables in discrete choice modeling, they can potentially explain the decision on allocation to the transit passenger of transit resident. When assuming these choices as endogenous in travel choice modelling, the household characteristics become the strongest predictor for who will live near the station and become the rail passenger.

This chapter originally examines further why people choose to live near rail transit station, whether their decision is related to the decision to commute by rail and whether they become regular railway users after moving to live near the station are examined. Specifically, it takes residential self-selection into account in travel behavior research. Travel-related attitude is claimed by several studies that it indeed influence travel behavior both directly and indirectly through residential choice. Empirically, this chapter provides a better understanding of a complex relationship among built environment, travel, socio-demographic characteristics and attitudes.

7.1 BACKGROUND

Past studies on residential location and mode choice showed that people with a preference for traveling by public transport have a strong tendency to choose a residential location well-served by transit (Cervero and Duncan, 2002; Mokhtarian and Cao, 2008; Boarnet and Crane, 2001; Cao et al., 2006; Van Wee et al., 2002; Nurlaelaa and Curtis, 2012). These studies provided some empirical supports for the self-selection debate. They claimed that people do not always adjust their travel behavior in accordance with the opportunity available in selecting residential location, but many instead select the location that facilitates their travel preferences. For example, residents who prefer driving over using public transport may choose remote and spacious neighborhoods, while households with a preference for public transport may opt for more urban residential locations within walking or cycling distance of a railway station (Bohte and Van Wee, 2009)

It is important to note that the relationships between residential location and commute pattern could also be two-directional (Van Wee, 2009). For example, after people move to a location with good public transport access, they might experience the advantages of travelling by public transport, which might influence their attitudes. This means attitudes towards modes could influence residential choice, but a reverse relationship is also possible. For example, after moving to a dwelling near a station people could have more positive attitude toward using rail. The self-selection with respect to locations and with respect to travel modes and travel behavior are in some cases strongly related: self-selection with respect to location choices might be the result of preferences with respect to travel. And even the opposite can happen as in the example above: attitudes towards travel might be influenced by location-based experiences (Van Wee, 2009). Several residential self-selection studies explicitly including attitudes have shown that attitudes add to the explanation of travel behavior by built environment characteristics and socio-demographic variables (Kitamura et al., 1997; Schwanen and Mokhtarian, 2005; Næss, 2009). However, the definition, modeling and measurement of attitudinal variables vary considerably between studies, their results are hardly comparable (Bohte and Van Wee, 2009).

In general, researchers do not include these other preferences in their studies, and literature on these preferences is very scarce. If preferences are either not, or only partly, related to personal and household variables, ignoring these preferences results in an overestimation of the impact of proximity to railway station on travel choice behavior (Cervero and Duncan, 2002). The research objective is therefore to focus on these preferences, with the aim of answering the question whether the preferences for modes have played a role in travel choices decision indirectly through residential choice within the urban railway corridor area. The hypothesis is set. After relocating to live near the station, people with mode preference to travel by rail transit at the time of residential choice decision are more likely to commute by transit than others, all else being equal.

7.2 ANALYTICAL FRAMEWORK

The research framework covering three hypotheses is examined, i.e. (1) there is a relationship between residential location and mode choice decision; (2) the decision to live near the station is due to the decision to commute by rail (3) the travel pattern is partly a result of the decision where to live. The hypotheses of this study must have some connections with the theoretical background. Based on a literature review, this research basically hypothesizes that the complex relationship of location choice and travel behavior could be simplified fundamentally into three elements, i.e. travel-related attitudes, residential location choice and travel behavior as shown in figure 7.1.

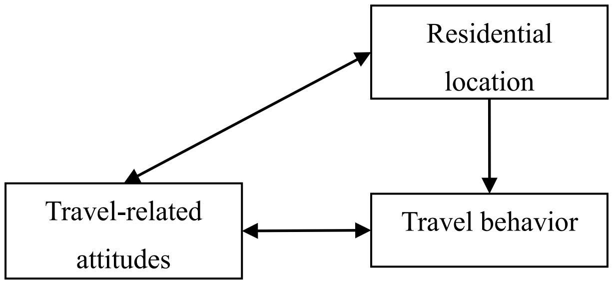


Figure 7.1 Multi-directional relationships between residential location and travel behavior

It can be assumed that travel-related attitudes affect residential location through the evaluation of housing alternatives when searching for a new house. It is thus assumed that residential self-selection takes place and that people select where to live according to the built-environment characteristics of a new house that at least to some degree conforms to their attitudes towards travel behavior. Secondly, and consequently, it is assumed that travel-related attitudes and built environment characteristics of the residential location influence travel behavior. Finally, it is assumed that attitudes towards travel behavior influence travel behavior indirectly through residential choice.

Firstly, Assumption that households select a residential choice complying with their travel-related attitudes at some degree is set. Secondly, people who have a positive attitude toward rail transit and have a preference for traveling by train will live closer to railway stations. Thirdly, after moving to a house near a station, attitude toward using rail will be more developed after people have experienced travelling by train.

In this chapter, the residential self-selection argument will be widened by considering the specificity of attitudes, travel behavior and built environment characteristics. The influence of travel attitudes at the time of residential choice is discussed. Attitudinal variables like preferences are included in model to analyze the role of travel attitudes on travel mode choices behavior. This chapter will use the broad definition by Eagley and Chaiken (1993) in that an attitude 'is a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor (Borte, 2010). The definition of evaluating refers to affective responses (e.g. I like using a train) (Bamberg, 2003). In this residential self-selection study, the specificity of travel-related attitudes is defined in general (e.g. attitude towards driving a car or using a rail transit).

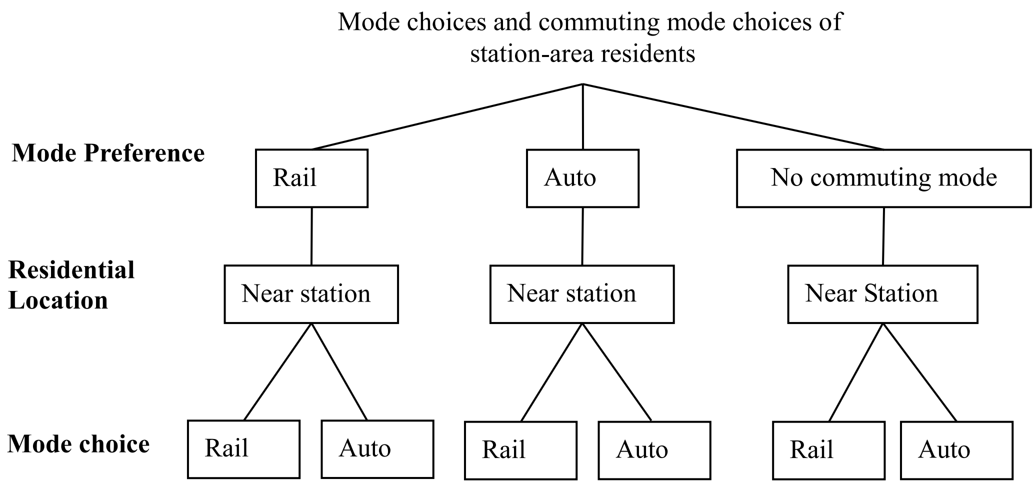


Figure 7.2 Conceptual framework of the influence of attitudes on travel behavior through residential self-selection

Figure 7.2 summarizes the assumed relationships investigated in this chapter. Mode choice is chosen normally just before the start of the trip. Commuting mode can be pre-determined just before the decision of residential location. It is differentiated from mode choices as normal meaning. Furthermore, some people predetermine the commuting modes but others not. In this context the first stage must have three categories such as 1) I would like to commute by rail hopefully, 2) I would like to commute by auto hopefully and 3) I am not considering about the commuting mode at the time of residential choice decisions. Then, after moving to live near the station 1) I will go to work by rail or 2) I will go to work by auto. Finally, a multidimensional approach is also offered to examine that relationship, i.e. involving several factors consisting of socio demographic, location characteristics, travel characteristics and attitudes factors affecting mode choice decisions.

7.3 RESPONDENT CHARACTERISTICS

The data using in this chapter is obtained from the station-area resident travel behavior survey 2003 phrase I (See also in chapter 3). The respondent characteristics are described in table 7.1. The typical characteristics of the station area-resident are female workers, single-persons, middle income, and car-owning households.

Table 7.1 Summary of respondent characteristics

Variables		% Mean	SD
Individual characteristics			
Sex	male	37.2	
	Female	62.8	
Household type	Living alone	54.6	
	married couple only	5.9	
	married couple with child	7.8	
	living with family	21.9	
	unrelated house sharers	9.7	
Education	low level	4.1	
	medium level	60.2	
	high level	35.7	
Income	low	3.7	
	middle	54.4	
	high	41.9	
Car ownership	no	23.4	
	yes	58.7	
Location characteristics			
Distance to nearest station		482.99	280.254
Move after 1999	no	3.3	
	yes	96.7	
Dwelling type	Condominium	84.4	
	Apartment	14.5	
Parking availability	no	35.8	
	yes	64.2	
Parking fee	no	26.8	
	yes	73.2	
Workplace near station	no	36.1	
	yes	59.9	
Two houses living	no	78.4	
	yes	21.6	
Travel-related attitude			
Mode preference	I would like to commute by rail hopefully	86.2	
	I would like to commute by auto hopefully	7.4	
	I am not considering about the commuting mode	6.3	
Travel behavior			
Frequency of transit use (per week)		3.54	2.230
Train total travel cost (Baht)		44.22	34.996
Train in-vehicle travel time (minutes)		25.32	14.479
Train out-vehicle travel time (minutes)		9.20	7.466

Variables		% Mean	SD
Car total travel cost (Baht)		111.12	48.884
Car in-vehicle travel time (minutes)		50.41	23.460
	N=469		

With respect to mode preferences, the respondents are categorized into 3 groups presenting the degree of a station-area resident self-selection, hereafter, SAR self-selection, following the research of Tsai (2008).

Group 1: Transit-driven SAR self-selection is composed of those who relocated into station area because they would like to use rail transit

Group 2: Mismatched SAR self-selection is composed of those who relocated into station area but they would like to use auto

Group 3: SAR self-selection is composed of those who relocated due to the preference for transit proximity, no mode choice preference before moving.

7.4 THE RELATIONSHIP BETWEEN TRAVEL ATTITUDES AND MODE CHOICES

This section explains the relationship between mode preferences, commuting choices, and respondents' characteristics using crosstab analysis method. It describes the existing situation on whether the Bangkok residents who move to live near train stations tend to be rail-commuters. The simple statistics of travel attitudes on Table 7.1 suggest that living near the rail transit has become the alternative choice for residents who would like to commute by rail at the time of residential choice decision. There are very few people who would like to commute by car or who did not decide on their choice. Figure 7.3 shows that rail transit has become the most popular commuting mode choice for the station-area residents. It is overwhelmingly selected as mode choice to go to work while the car is used nearly as half of the transit use. Particularly, the residents those had preference to travel by rail and those did not have preference for mode choice before moving house mostly choose to go to work by rail as seen in figure 7.4. Also, the residents those live in the condominium or apartment within 500 m from the station select rail transit more than car as their mode choice. On the contrary, car and paratransit such as motorcycle taxi are preferable among the residents living further away as seen in figure 7.5.

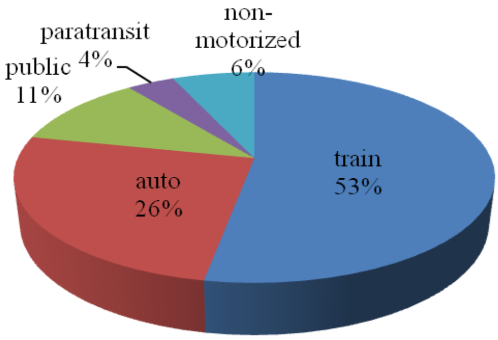


Figure 7.3 Mode shares of respondents

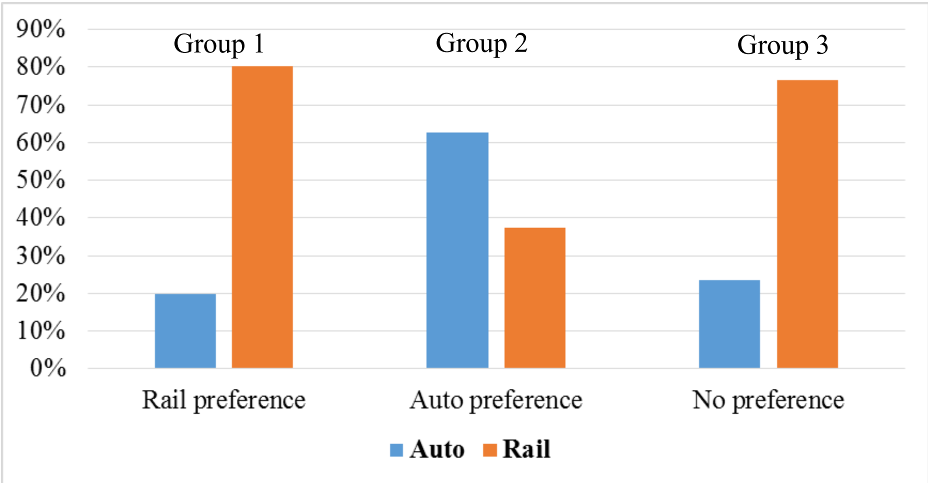


Figure 7.4 Mode share among mode preference groups

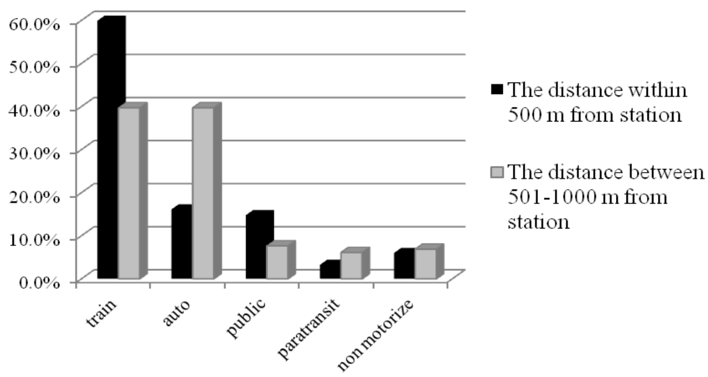


Figure 7.5 Mode choices of residents those living within and beyond 500 m ring of the rail station

Figure 7.6 explains that most of residents who have the preference for traveling by train choose to commute by rail after moving to reside near the rail except married couple both with and without children. They are auto users. Although there are very few low income respondents, all of them have the preference on rail and commute by rail. In contrary, nearly all residents who like to use auto highly select to travel by auto. But if they live closer to the station, they select rail transit as their commuting mode choice as seen in figure 7.7. Even though some of residents didn't decide on mode choice, they chose to be rail passengers after living near the rail stop. Nevertheless, the residents being men, being married couple with children, being car owner as well as working and living further become auto users rather than rail users as shown in figure 7.8. It is noted that there are very few respondents in some categories as mentioned in Table-1. Therefore, there are no respondents in some categories of crosstab table, for instance, the respondents of married couple with and without children as seen in Figure 7.7 and Figure7.8.

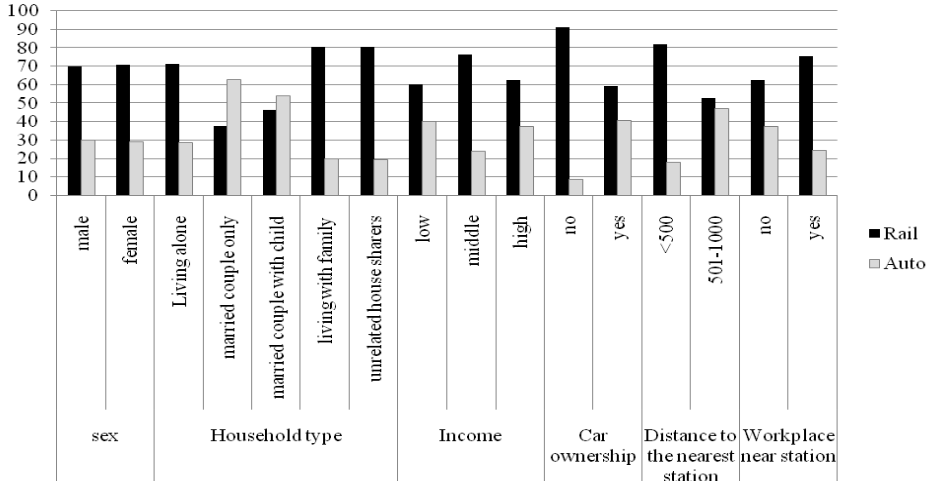


Figure 7.6 Mode choices of transit-driven SAR self-selection group

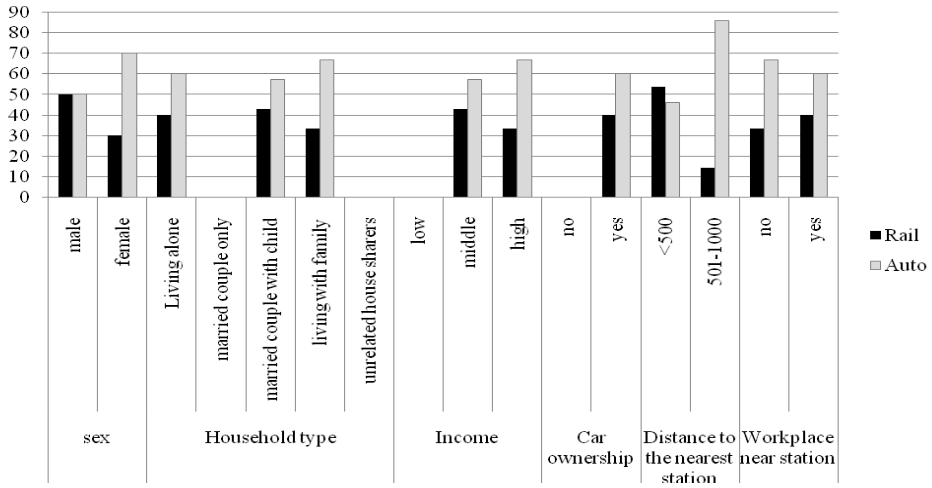


Figure 7.7 Mode choices of mismatched SAR self-selection group

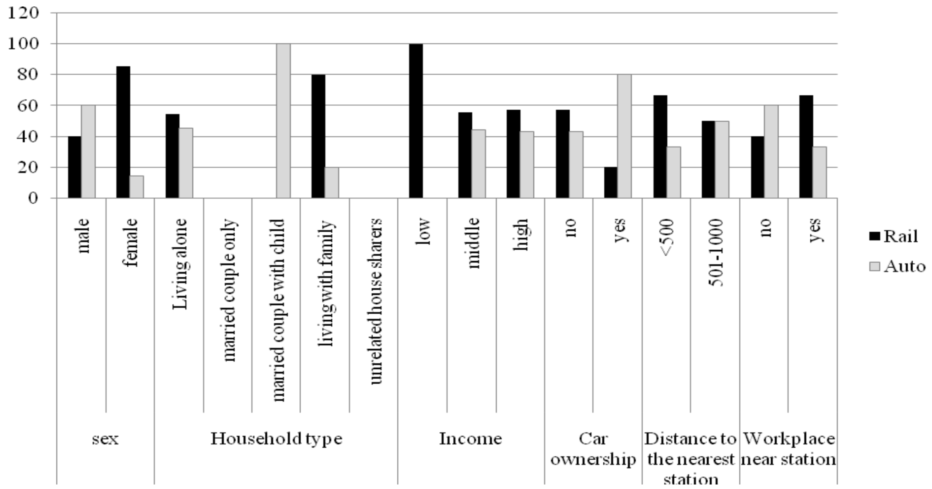


Figure 7.8 Mode choices of SAR self-selection group

7.5 LOCATION CHOICE BEHAVIOR AND RAIL COMMUTING OF THE STATION AREA-RESIDENTS

To analyze the relationship of residential choice and rail commuting, the existing situation on whether the Bangkok residents who move to live near train stations tend to be rail commuters is examined. It has been realized that households select a residential choice that complies with their travel-related attitudes. Their decision to live within the rail transit catchment area is related to the decision to commute by rail. However, to what extent the preference for traveling by train of the station-area residents has an impact on the rail commuting is still questionable. Discrete logit model in the context of binary logit is then employed to examine factors influencing transit ridership in this city. The best set of predictors is finally found.

Table 7.2 shows the estimated values of the model coefficients. All explanatory variables except income variable are clearly significant at $P < 0.05$. The signs of the estimated coefficients are worthy of attention. The negative sign of the coefficients of variables such as car ownership, married with children household, distance to the nearest station, travel cost, travel time and attitude toward car use indicates that other things being equal. The alternatives with high travel time, travel cost and distance as well as that involve having car, having child and having intention to use car tend to be less preferred than alternatives that have low travel cost, travel time and distance as well as do not involve these variables. On the other hand, the positive coefficient of variables such as low income, middle income, workplace near rail station, parking fee at workplace and attitude to use rail implies that these groups are more likely to commute by the transit, other things being equal.

Table 7.2 Model estimation of rail transit passenger

Variables	With influence of travel attitudes			Without influence of travel attitudes		
	Coefficient	Sig.	Odd ratio	Coefficient	Sig.	Odd ratio
Individuals attributes						
Low income	.499	.347	1.646	.508	.452	1.662
Middle income	.300	.452	1.350	.293	.460	1.341
Car ownership	-1.766	.002**	.171	-1.793	.001**	.167
Married with child	-1.003	.012*	.367	-.906	.037*	.404
Location attributes						
Distance to the nearest station	-.002	.000**	.998	-.002	.000**	.998
Workplace within 1 km of rail station	.556	.019*	1.743	.586	.014*	1.796
Parking fee at workplace	.053	.039*	1.055	.061	.023*	1.063
Transport attributes						
Total travel cost	-.001	.004**	.999	-.002	.007**	.998
Total in-vehicle travel time	-.066	.000**	.936	-.068	.000**	.934
Total out-vehicle travel time	-102	.013**	.903	-.196	.039*	.890
Attitudes						
I would like to commute by rail hopefully (Rail preference)	1.830	.009*	6.234	-	-	-
I would like to commute by car hopefully (Car preference)	-.748	.011*	.474	-	-	-
Constant	**1.550**	**.039***	**4.712**	**1.909**	**.020***	**6.748**
-2 Log likelihood			127.03			166.765
Cox & Snell R Square			.515			.417
Nagelkerke R Square			.708			.572

** Significant at .01 level

* Significant at .05 level

7.5.1 The role of mode preferences in mode choice modeling

As compared to model calibration without travel attitudes, the inclusion of travel attitudes in analysis model noticeably demonstrates the set of predictors with the stronger R squared values. There are two potential attitude factors for understanding the decision-making on rail commuting of the station-area residents. To start with the travel attitude to commute by rail, it is the strongest positive predictor for the rail passenger. The odds ratio value associated with train preference explain when attitude is raised by 1 unit; the householders are as much as 6.2 more times likely to belong to rail transit users. The more positive attitude they have the more rail passengers they tend to be. Empirically, individual characteristics are significantly related to the travel attitudes as mentioned in the previous section. Being women, being single-person household, being medium education level person as well as being the residents living closer to the station significantly have a more positive attitude towards rail use. The increasing of pro rail attitude may develop as the result of the good service of mass transit system. For this reason, it is crucial to improve the service of mass transit system based on commuter satisfaction to encourage more rail patronages.

Conversely, the attitude toward car use is strongly a negative effect on the transit ridership. The vast majority groups of car users are the station-area residents who have intention to use car before moving to live near station. It is difficult for mass transit system to induce people who are pro car attitude to shift from being car user to being rail user.

The inclusion of travel-related attitudes can significantly explain specific travel behavior such as using rail or driving to work. This illustrates that residential self-selection has taken place and there is a significant relationship between built environment, travel attitudes and travel choice behaviors. Travel attitudes have influence on travel choice behavior through residential choice. The decision to live near the station is due to the preference to commute by rail and travel pattern is partly a result of the decision where to live. The hypothesis is then identified since Bangkok households select their residential location close to the transit that conforms to their preference with respect to travel by the rail transit. The station-area residents with high level of preference for traveling by rail have a higher probability of transit commuting than those without this preference. Transit-driven SAR self-selection can definitely increase the probability of riding transit at a larger magnitude than that of SAR self-selection.

7.5.2 Factor influencing rail commuting of the station area-residents

1) socio-demographic characteristics

The significant effect of attitudinal variables shows that they play an important role in explaining the mode share of rail trips among the transit-based residents by socio-demographic characteristics. Socio-demographic characteristics and car availability together potentially explain travel choice decisions. Firstly, car ownership variable is the strongest negative impact on the transit ridership. Evidently, all people who have intention to use car and in turn choose the car as their mode choice belong to car-owning households. Thus, mass transit system is less attractive for those who have car and lesser for those who have pro car attitudes.

Secondly, being married couple with children household is significantly meaningful to predict transit passenger. This household type is more apt to be the car user than single-person household. The high negative coefficient value of the presence of children variable supports the idea that their children' school location becomes an additional location factor that has a powerful effect on the household's choice decision. Logically, travelling trips to school of young children with immaturity and dependency on adults will encourage car oriented mode of family mobility directly, which will affect household travel patterns. Therefore, the distribution of quality school seems to strongly affect the traffic condition in Bangkok.

Apart from significant variables, Bangkok residents select to use the rail transit for their trips regardless of their income level since income variable is not a significant predictor. However, the positive sign of coefficient of low and middle income states that they are most inclined to be regular rail passengers.

2) Built environment characteristics

The negative sign of coefficient estimation of access distance between house and station means that the probability of mass transit being chosen decreases as the distance increases. The low estimated coefficient of the distance factor reveals that it has less influence on travel choice behavior. The effect of living nearer the station area has low degree to increase the rail transit use.

Confirming with the previous studies, workplace location is the significant predictor to predict who is most inclined to be a rail passenger. Destination's proximity to transit tends to encourage the likelihood of rail commuting. As mention above in figure 7.4, the respondents keep commuting by car if their house is beyond the acceptable walking distance (500m) and workplace location is further than the transit catchment area respectively. While longer distance to access is related to inconvenience where more effort is needed to reach mass transit station. As a result, the car-availability travelers would keep using a car rather than shifting to mass transit as the distance to station increase significantly. It is because they might highly value the convenience aspect of using mass transit comparing to using car. Therefore, it is more effective to encourage infrequent users who have car availability but have positive attitude toward rail use to shift from being car user to rail user than to convince people with car use preference.

Next, parking fee at workplace has positive influence on rail use decision significantly. The car park availability along the corridor seems to be the key explanation of not using transit. Some of respondents keep using car even their house and workplace are located within catchment area of the transit station. There is high percentage of car park availability at workplace among car user group. Therefore, car parking policies along the transit corridors should be carefully considered as the critical issues to control car use and encourage transit use.

3) Transport factors

The model results reveal to what extent the transportation factors in terms of travel cost and time influence on the decision mechanism of households living near the railway corridor. The time in the model was associated with the total in-vehicle travel time and out-of-vehicle travel time while the cost is referred to the total of out-of-pocket cost. In the case of Bangkok, the total travel time has slightly more impact on rail commuting as compared to the total travel cost. The transit mode is preferable due to its advantage in the term of time saving for the pair of origin and destination within transit corridors. In addition, the total cost of rail transit use is not too much cheaper than of auto use because the travelers particularly those living and working beyond walking distance to the station mostly rely on paratransit such as motorcycle taxi to access the station. Unfriendly environment conditions such as narrow road without footbath or hot and humid weather condition diminish the non-motorized mode such as walking and bicycling to access the station. They are willing to pay more travel cost in order to save the travel time. Transit system can take advantage of the existing paratransit. The previous study suggested that introduction of paratransit as a feeder for mass transit system is one of the solutions to improve mass transit patronage. The improvement policies regarding paratransit service must be carefully drawn with the purpose of enhancing the performance of mass transit (Tangphaisankun, A. et al., 2009)

The important lesson learnt from this chapter is that people are more sensitive about out-of-vehicle travel time than in-vehicle time to make their decision on mode choice. Lesser out-of-vehicle time or waiting time is preferable for the rail users. The passengers want to minimize their out of vehicle time due to hot weather. Although the in-vehicle time of traveling by rail is fixed, the out of vehicle time is less reliable during rush hours. At present, BTS services surpassing 600,000 passengers on average per day, with the number peaking at 715,000, and is upgrading to a fleet of 35 four-car trains on the Sukhumvit line to accommodate more passengers during peak hours. Also, MRT approximately services 200,000 passengers per day. The standard capacity of BTS and MRT are 8 passengers per square meter, totally 1,490 passengers per fleet (4 cars) and 886 passengers per fleet (3 cars) respectively. The frequency of BTS and MRT are 2.40 minutes and 3.15 minutes during the peak hours 06.00 - 09.00 and 16.30 - 19.30 respectively[31), 32)]. At peak hour, the trains sometimes depart without being able to take all waiting passengers. The passengers inevitably spend more time waiting for the next train due to the overcapacity of passengers at the main stations at peak hours, particularly at the main interchange stations. This problem can reduce the positive attitude toward rail transit use.

7.6 KEY FINDINGS

All the discussions above explain the existing situation of residential location and travel behavior of Bangkok residents after the first railway system was introduced in the city. As transit-based housing is rapidly expanding along railway lines, this chapter examines whether the residents choosing to reside near the railway station mainly are regular users of the railway. From location and travel behavior survey by using self-selection question, the simple statistics shows most of the station-area residents would like to commute by rail at the time of making residential choice and in turn choose to go to work by the rail transit after moving. This summarizes that people who have a positive attitude toward rail transit and have a preference for traveling by train will live closer to railway stations. The hypothesis is then identified since Bangkok households select their residential location close to the transit that conforms to their preference with respect to traveling by the rail transit.

Research on self-selection can shed light on the kinds of households most inclining to move to station areas and becoming regular transit passengers. Binary logit model was employed to estimate the probability of the station-area will commute by rail transit. From model calibration, the results show the influence of travel attitudes on travel choice behavior through residential choice. The model with the inclusion of travel attitudes shows higher Rho-squared values (R^2), that is a measure of goodness of fit. It is fair to say fits the data better. Mode preferences can significantly explain specific travel behavior such as using rail or driving to work. The parameter estimation results indicate householders who have preference on rail use and whose workplace are well-served by transit are thought to be drawn to transit-based residences and in turn become regular transit users. This illustrates that the so-called self-selection has taken place and there is a significant relationship between residential location choice, travel attitude and travel choice behavior. The strongest positive impact of mode preferences and the low estimated coefficient of the distance factor depict that the ridership bonus assigned to transit-oriented living is due to the nature of people who are inclined to live in such neighborhood rather than spatial proximity. Some station-area residents might still be riding transit even if they live away from the station.

Finally, as workplace location potentially influence on rail commuting of the station-area resident, whether or not the station-area residents those working near the station will use the transit to reach their workplace will further examine in next chapter.

CHAPTER 8

IMPACT OF SELF-SELECTION ON TRAVEL CHOICE BEHAVIOR

Chapter 7 tentatively concluded that travel attitudes have a powerful influence on travel choice behavior indirectly through residential choice. The station-area residents with high level of preference for traveling by rail have a higher probability of transit commuting than those without this preference. It implies that residential self-selection exists among transit-based residents. This chapter further examines the complex relationships among built environment, travel, socio-demographic characteristics, and household attitudes. The issue of residential self-selection is then continued to investigate a more complicated assumption of a sequential decision process on location and travel choice. It is assumed that people hierarchically select to live in the location that complies with their travel preferences before choosing their commuting choice for work trip. Therefore, the originality of this research is to develop multi-dimensional nested logit model by integrating mode preference together with locational and travel choice behavior.

8.1 BACKGROUND

The research at neighborhood and station-area scale indicates that significant transit trip generation rates from residential development proximate to rail stations, especially for systems and regions in which both housing and employment are found adjacent to transit. However, there is no clear evident whether residents those have both origin and destination within the transit catchment area are regular railway users. To what extent the ridership bonus assigned to transit-oriented living is due to spatial proximity or the nature of people who opt to live in these settings should be clear identified. As noted by Cao et al. (2009), very few studies provide conclusions on the relative effect of the built environment compared to the effect of residential self-selection. This research aims to examine factors influencing on mode choice decision of residents those living and working near the transit stations. Suppose that people have preferences for travel modes (especially car or rail transit), apart from their personal characteristics. The preferences for travel modes may be correlated to residential choice: people with a preference for traveling by train will, on average, live closer to railway stations.

A challenge is an attempt to model the relationship between travel-related attitudes, residential location and mode choice decisions within a behavioral analysis framework, focusing on the self-selection question. These choices behavior of station-area residents is examined in order to explain the hidden or underlying mechanisms affecting their decisions. Self-selection is argued to hold keys to a better explanation of people's location choices that are relevant for travel behavior. Self-selection with respect to residential location refers to as "the tendency of people to choose locations based on their travel abilities, needs and preferences" (Mokhtarian and Cao, 2008). The preferences for travel modes may be correlated to residential choice: people with a preference for traveling by train will, on average, live closer to railway stations. Ignoring this preference generally leads to an overestimation of the impact of the distance to railway station on travel behavior (Van Wee et al., 2003). Specifically, by controlling built environment and location choice characteristics, the impact of residential self-selection concerning the distance to the rail station on the rail commuting of the residents within rail transit area should be investigated.

8.2 ANALYTICAL FRAMEWORK

This chapter originally proposes multi-dimensional nested logit model which takes account of sequential process in modeling the complex connection between travel preferences, location choices and commuter modes decision mechanism (figure 8.1). The assumptions are set the same as mentioned in Chapter 7, except that location choices according to house and workplace location are controlled in this model. Only the locations of origin and destination within the transit catchment area are considered. Attitudinal variables like preferences accounting for residential self-selection are included as endogenous in model that analyzes the relation between the built environment concerning the distance to the rail station and travel mode choices behavior.

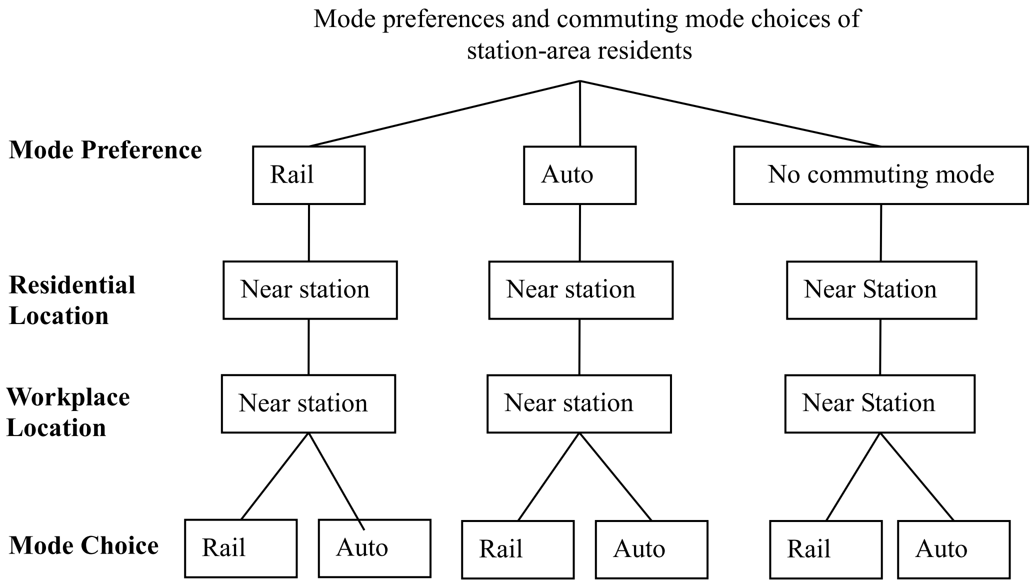


Figure 8.1 Conceptual framework of the influence of attitudes on travel behavior through residential self-selection

The analytical framework in this chapter is set as same as described in chapter 7. Attitudinal variables like attitudes toward travelling by each mode are included in model to analyze the influence of residential self-selection concerning to residential and workplace close proximity to transit stations on travel mode choices behavior. A conceptual four-tiered model of travel attitude, residential as well as workplace sorting, and mode choice is shown in Figure 8.1. In this four diagram, travel attitude is expressed in ternary terms: rail preference, car preference and no mode preference. The attitude in turn influences residential choice, controlled in the figure: only one lives near (i.e., within 1 km) of a rail station. The lowest level of the tree, mode choice, is represented as a product, in part, of location choice. This nested model structure is hierarchical and sequential, treating the influences of on mode choice as indirect – i.e., channeled through the proximity to transit. The hypothesis is set. Given their both origin and destination located close proximity to transit increases workers' probability of commuting by transit.

8.3 MODEL STRUCTURE: NESTED LOGIT MODEL

A parsimonious two-tiered hierarchical model shown in figure 8.2 suggests a sequential selection process based on the assumption that travel attitudes affect travel behavior indirectly through residential choice. It is estimated with the upper tier gauging the ternary choice of whether to prefer traveling by rail, car, or not considering on mode choice and whether or not rail is routinely taken to work. Nested logit estimation occurred by weighing lower-level factors influencing rail mode choice in the estimation of upper-level travel attitude choice. Nested estimation acknowledges that the subset of utilities of mode alternatives is not independent of the utilities that explain mode preferences.

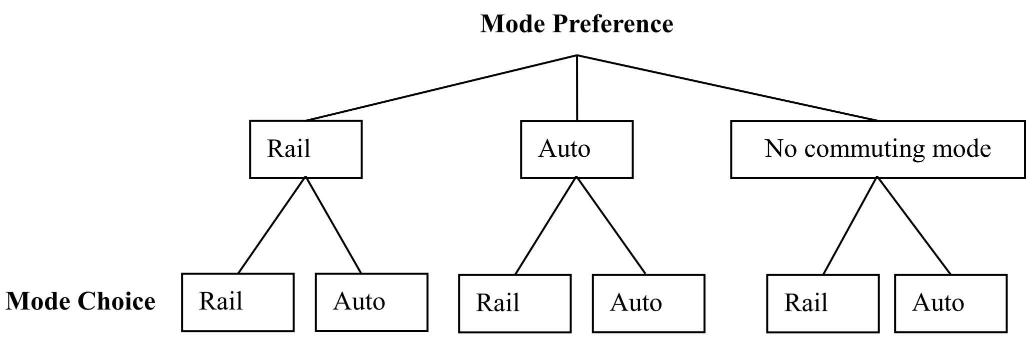


Figure 8.2 Two-tiered nested choice structure: mode preference and commuter mode

The two-tiered nested logit model used in this analysis takes the form:

$$P_{n,i|k} = \exp(V_{n,i|k})/[\Sigma_{j\in C_n} \exp(V_{n,j|k})] \quad (1)$$

$P_{n,k} = \exp(V_{n,k} + \lambda_k I_k)/[\Sigma_{j\in Cn} \exp(V_{n,j|k} + \lambda_k I_k)]$ (2)

where, for the k^{th} branch of the upper tier, the inclusive term, I_k, is:

$I_k = \ln \Sigma_{j\in Cn} \exp(V_{n,j|k})$ (3)

$P_{n,i|k}$ = probability person n chooses mode option i (e.g., rail) given mode preference choice k (e.g., rail preference)

$P_{n,k}$ = probability person n chooses mode preference choice k

C_n = choice set available to person n

$V_{n,j|k}$ = measurable component of utility for person n choosing mode option i given preference choice k

$V_{n,k}$ = measurable component of utility for person n choosing mode preference k

λ_k = estimated coefficient on inclusive term for preference choice k.

The expression $\lambda_k I_k$ captures feedback between the lower level (commute mode choice) and upper level (mode preference choice) of the nested model, where feedback is presumed to occur simultaneously. The inclusive value parameter, lambda (λ), measures the correlation among the random errors due to unobserved attributes of commute-mode choice.

8.4 RESPONDENT CHARACTERISTICS

1) The station-area resident

The data using in this chapter is obtained from the station-area resident travel behavior survey 2003 phrase II (See also in chapter 3). The respondent characteristics are described in table 8.1. The typical characteristics of the respondents are being young single female worker, educated, middle to high income, and carless households. As housing market has been gradually changing to promote smaller-sized room condominiums along the railway corridors, the size and cost of their dwelling are lesser as compared to prior house. This new trend for city condominium living is also creating a new type of owners who wish to live in condominiums only on weekdays. They can save commuting cost and time for daily work trip and live in another single detached house located far from transit line with family on holidays.

2) Mismatched of transit proximity and travel mode choice

Respondents mismatched with respect to transit proximity are those who attached importance to the distance from residence to the nearest station and claimed they were 'not satisfied' with the current distance on a scale that also included the categories 'neutral', 'unsatisfied' and 'very unsatisfied'. Table 8.2 shows the percentage of respondents who are mismatched in relationship to the station proximity. The respondents those live beyond 500 meters are unsatisfied with their location corresponding with their commuter mode to use car rather than train. It may be caused by the travel characteristics of Bangkokian that prefer short walking distance due to hot weather condition.

Table 8.1 Summary of respondent characteristics

Attributes	Characteristics	Percent
Gender	*Male*	33.8
	Female	66.2
Age	*15-20*	9.5
(Years old)	*21-30*	60.2
	31-40	18.9
	41-50	8.5
	51-60	2.5
	More than 60	0.5
Household income	*Low income (<20,000)*	12.9
(Baht per month)	*Middle income(20,001-60,000)*	43.8
	High income (> 60,001)	43.3
Car ownership	*Yes*	40.3
	No	59.7
Education	*Diploma*	10
	Undergraduate	66.7
	graduate	23.4
Household type	*Live alone*	38.3
	Live with friend	18.9
	Couple without child	27.4
	Couple with child	6
	Unrelated house shares	9
House tenure	*Buy*	**34.3**
	Rent	**65.7**
Property type	*Condominium*	**56.2**
	Apartment	**36.8**
	Others	**7**
	Total	**100**

Table 8.2 Percentage of mismatched respondents per distance to the closest station and consequences for their travel behavior

Distance	% Mismatched	%Mismatched auto use instead of rail use
1-250 m	10.7% (n=56)	14.3% (n=8)
251-500 m	17.9% (n=60)	16.9%(n=11)
501-750 m	1.8% (n=51)	90.0% (n=9)
751-1000 m	32.1% (n=68)	53.6% (n=8)

8.5 RELATIONSHIP BETWEEN TRAVEL ATTITUDES AND MODE CHOICES

The existing situation on whether the Bangkok residents who move to live and work near train stations tend to be rail-commuters is described. Firstly, the travel behavior before moving house is shown in figure 8.3. Obviously, some of them once used the rail to go to work. This concludes that the decision of relocation was partly driven by their past travel experience.

Concurrently, the simple statistics of travel attitudes suggest that living near the rail has become the alternative choice for the residents who would like to commute by rail at the time of residential choice decision as seen in figure 8.4. Most of them had a plan to use this mode after they move to live close proximity to the station. There are very few people who would like to commute by car or who did not decide on their choice. This states that households select a residential choice that complies with their travel-related attitudes. Their decision to live within the rail transit catchment area is related to the decision to commute by rail. Theoretically, there are three causes for moving into station areas, i.e. the preference for traveling by transit mode, built environment characteristics of the station and non-transit-related relocation, for example, preferred school districts, however, only individual transit preference could affect personal transport mode choice, given transit proximity and all being equal.

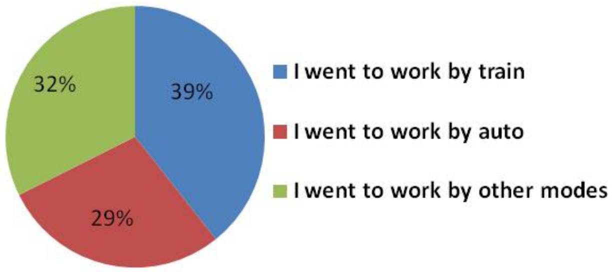


Figure 8.3 Respondents' previous mode choices before moving to live near transit station

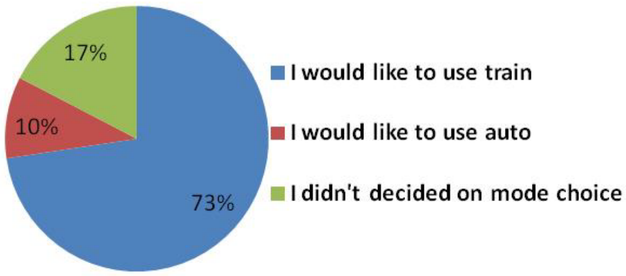


Figure 8.4 Respondents' mode preferences before moving to live near transit station

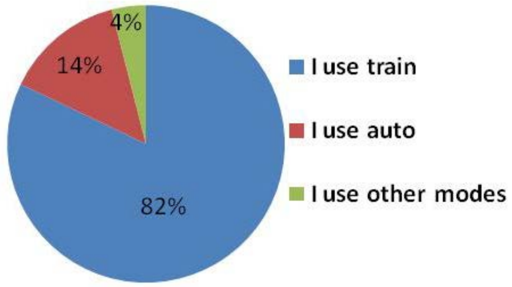


Figure 8.5 Respondents' present commuting choices

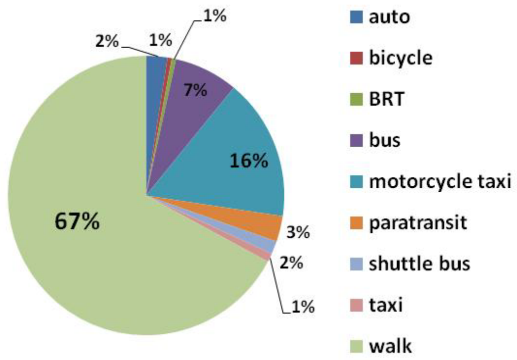


Figure 8.6 Respondents' access choices to transit station

Figure 8.5 shows that rail transit has become the most popular commuting mode choice for the station-area residents. It is overwhelmingly selected as mode choice to go to work while the car is used very less. As compared to their previous travel modes, the number of car user has fallen nearly as half after their relocation. This implies that having both origin and destination in the catchment area of the stations can decrease automobile dependent. Moreover, the increasing of transit ridership from 39 percent to 82 percent exhibits that, after people had experienced using train, they wanted to move to live closer to the station so as to reduce travel cost or travel time. Hence, walking is the regular choice for the station-area residents to access to the station as seen in figure 8.6.

Next section explains the linkages between mode preferences, commuting choices, and respondents' characteristics using crosstabulation analysis method. First of all, table 8.3 shows the proportion of rail passengers and car users within each mode preference. From the result of Chi-Square Tests, the p-value is <0.01 which means that it can reject the null hypothesis of no association between mode preference and mode choice. Rail is considerably selected as commuting choice among the station-area resident who had intension to go to work by this mode before relocation. Interestingly, 37.50% of rail passengers with auto preference as well as 76.56% of ones with no preference on mode choice imply that they could develop more pro rail attitudes after experiencing travel by train after living near the rail stop.

Table 8.3 Crosstabulation of mode preferences and mode choices

Mode preference	Commute mode choice		
	Auto	Rail	Total
Rail preference	19.70%	80.30%	100%
Auto preference	62.50%	37.50%	100%
No preference	23.44%	76.56%	100%
Total	**22.73%**	**77.27%**	**100%**

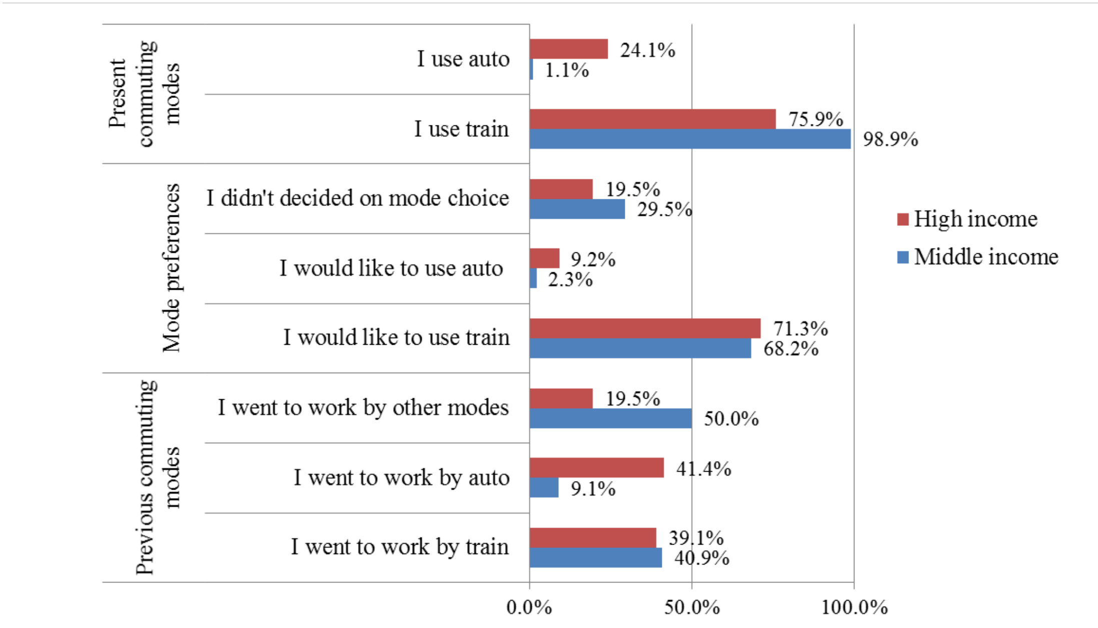


Figure 8.7 Mode preferences and choices comparing between middle income and high income

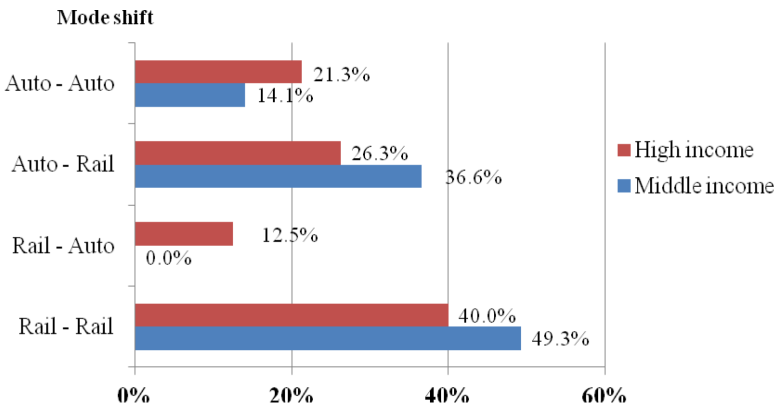


Figure 8.8 Modal shift between rail and auto after moving house comparing between middle income and high income

Next, as the transit housing provision towards housing affordability targets middle to high income earners as main buyers, the young single middle-class and high-class have been becoming the new generation of TOD residents in Bangkok. They are expected to be the regular transit user. As mentioned in table 8.1, they are the majority group of respondents. Therefore, travel characteristics between the middle-income and high-income residents are accordingly compared.

Figure 8.7 and Figure 8.8 state that middle-class residents are mainly regular rail commuters whereas high-class residents are car lovers and car users regardless of house location. The former has been more successful in reducing automobile dependency since their percentage of modal shift from auto users to transit users is quite higher than the latter. As well, none of them switches to car use. Moreover, figure 8.9 confirms that this group have stronger attitude toward using transit.

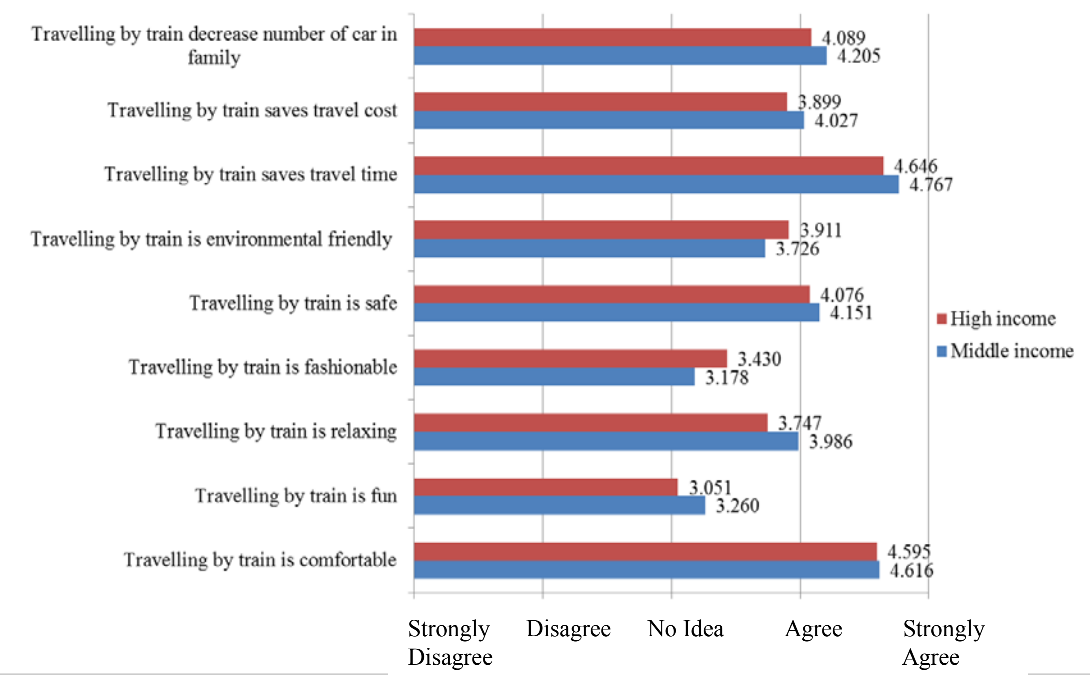


Figure 8.9 Attitudes toward using train comparing between middle income and high income

8.6 THE IMPACT OF RESIDENTIAL SELF-SELECTION ON RAIL COMMUTING

To analyze the connection between SAR self-selection and rail commuting, whether or not people those have origin and destination within transit catchment area opt to be regular rail passengers are empirically examined. From the descriptive statistics, the decision to live within the rail transit catchment area is related to the decision to commute by rail. However, to what extent the SAR self-selection has an impact on the rail commuting is still questionable. It is the first attempt to employ the hierarchical two-tiered nested model to examine the influences of travel attitude on mode choice selection indirectly though location choice. The unmet SAR self-selection respondents were excluded from the modeling since the degree of their SAR self-selection could not be measured. The total 418 samples were used in the model. In order to assess the impact of SAR self-selection on travel choice behavior, transit proximity in terms of the straight-line distance from residence to the nearest station was adopted in the modeling.

Table 8.4 Nested logit model results for rail preference choice (upper nest) and rail commute choice (lower nest)

Factors	Upper Nest		Lower Nest	
	Mode Preference: Rail Preference		Rail Commute Choice ¦ Rail Preference	
	Coefficient	P-Value	Coefficient	P-Value
Attitude attributes				
Attitude toward travel time saving	0.258	.049*	-	-
Attitude toward travel cost saving	0.037	.041*	-	-
Attitude toward comfortable	-0.025	.001*	-	-
Locational attribute				
Straight-line distance from residence to the closest station (m)	-	-	-0.0001	.012*
Parking availability at workplace (0-1)	-	-	1.322	.032*
Transportation attributes				
Out-of-vehicle time (rail)	-	-	-0.110	.036*
Travel time	-	-	-0.006	.021*
Travel cost	-	-	-0.005	.181
Household attributes				
Past experience on rail traveling (0-1)	1.814	.001**	-	-
Own residence (0-1)	-0.125	.004**	-0.524	.145
Middle income household (0-1)	0.730	.177	0.591	.020*
Car ownership (0-1)	-0.698	.032*	-1.503	.039*
Single-person household (0-1)	1.641	.124	1.262	.001**
Inclusiveness Factor (λ)	0.523	.012*		
Constant	1.712	.008**		

No. of observations	418
Mean log-likelihood	-0.79124
Rho-Square: 1-LL(1)/LL(0)	0.425

Table 8.4 shows the nested logit model results for rail preference choice (upper nest) and rail commute choice (lower nest). Firstly, the estimated log-sum coefficient is .523. As the correlation is approximately .47 (1-0.523), there is a moderate degree of correlation in unobserved factors over alternatives within each nest. The hypothesis that the log-sum coefficient equals 1(the value that it takes for a standard logit model) is tested by t-test. The t-statistic is (1-.523)/.215=2.22. The critical value of t for 95% confidence is 1.96. Thus, the hypothesis that the

true model is standard logit can be rejected. This confirms nested logit model is significantly appropriate in this analysis.

8.6.1 Mode preference model

With respect to mode preferences, the respondents are categorized into 3 groups presenting SAR self-selection degree including transit-driven SAR self-selection, mismatched SAR self-selection and SAR self-selection as mentioned in Chapter 7.

The upper-level model, shown on the left-hand side of table 8.4, predicts who is likely to be the transit-driven SAR self-selection. The model results reveal that attitudes toward travel cost and time saving as well as comfortable are selected as determinant variables to predict train preference. Among these attitudes, the preference on the shortest travel time has the strongest impact on the station area resident's preference on mode choice. It could be the severe traffic congestion during peak hours in Bangkok that discourages the car use among the transit residents. Also, the transit mode is preferable due to its advantage in terms of cost saving for the pair of origin and destination within the transit corridors. In addition, the total cost of rail transit use is much cheaper than that of auto use because most of the regular transit passengers use a commuting card for their daily work trip. Its minimum price is about 22 Baht or 0.67 US dollar per trip for the payment within 50 trips. Actually, the travelers within walking distance to the station mostly walk to access the station to reduce the cost. This argument could be supported by the fact that 67% of the transit residents access to station by walk. The increasing of pro rail attitude may develop as the result of the good service of mass transit system in terms of travel cost and time saving. However, attitude toward travel cost saving has slightly less impact on rail preference as compared to the attitude toward total travel time saving. Lastly, more attitude toward comfortable decrease the odds of train preference. Most auto users prefer traveling by only one mode choice between origin and destination such as house and workplace. The negative sign of coefficient expresses that train lose its competitiveness to auto due to its lesser comfortable from user's point of view. This might partly be one reason that the station-area residents who dislike driving consciously have an intension to use transit and choose to live near the station.

In addition, if past travel experience affects current travel behavior, thus, this variable was included in the model. Apparently, this variable has a strong impact on the preference for transit mode. Informed by prior part, most of rail commuters have pro rail attitude because of their good experience with traveling by train before moving house. In term of household characteristics, the model suggests that car-owner household discourage transit preference, all things being equal.

People in a carless household significantly increased the odds of rail lover. They much more often have a preference for cars (70%) compared to those not owning a car (9%). Interestingly, house ownership decreases the odds of commuting by rail transit. The reason might be that the auto is more a mode choice of the high class people who tends to buy their house rather than rent.

8.6.2 Commute mode choice model

The lower tier of the nested structure in figure 8.2 was estimated sequentially for those traveling by transit, included the distance to the nearest station, car ownership, conventional predictors of mode choice like travel-time and cost and personal attributes of trip-makers. The right-hand side of the nested logit model from Table 8.3 shows the results of commute mode choice, stratified by those who have preference on rail and those who do not, controlling for residential location and working in close proximity to transit.

Firstly the distance to the nearest station significantly affected the odds of rail commuting. The negative sign of coefficient suggests a gradient effect, with the likelihood of rail-commuting lesser for house located further from the station. Longer distance to access is related to inconvenience where more effort is needed to reach the station. As a result, the car-availability travelers would keep using their car rather than shifting to mass transit as the distance to the station increases significantly. However, its low degree coefficient implies that residential self-selection has taken place but has limited impact in explaining mode choice behavior in the case study of Bangkok.

Secondly, the model results reveal to what extent the transportation factors in terms of travel cost and travel time influence on the commute mode decision mechanism. The time in the model is associated with the total in-vehicle travel time and out-of-vehicle travel time while the cost is referred to the total of out-of-pocket cost. Inconsistent with mode-choice theory, travel time are not the strongest single predictor of whether one commutes by rail transit whereas travel cost are not significant factors to predict rail passenger. As compared to in-vehicle time, out-of vehicle time much has much greater impact on the mode choice decision.

Lastly, the results show that personal attributes also influence mode choice. Most important was the availability of car, which tended to deter rail commuting. Evidently, all people who have intention to use car and in turn choose the car as their mode choice belong to car-owning households. They would keep using the auto rather than shifting to mass transit. It is because they might highly value the convenience aspect of using mass transit comparing to using car. Mass transit system is less attractive for those who have car and lesser for those who have pro car attitudes. The vast majority group of car users is the station-area residents who have intention to use car before moving to live near station. It is difficult for mass transit system to induce people who are pro car attitude to shift from car user to rail user. Thus, it is more effective to encourage infrequent users who have car availability but have positive attitude toward rail use to shift from being car user to being rail user than to convince people with the car preference.

Also, parking availability at workplace has negative influence on rail use decision significantly. The car park availability along the corridor seems to be the key explanation of not using transit. Some of the rich residents keep using car even their house and workplace are located within catchment area of the transit station. There is high percentage of car park availability at workplace among car user group. Therefore, car parking policies along the transit corridors should be carefully considered as the critical issues to control car use and encourage transit use.

Among the station-area residents, the likelihood of rail commuting tended to be higher for middle-income workers and those who live alone. Being single-person household is more apt to be the rail user than multi-person household because the number of travelers becomes an additional location factor that has a powerful effect on the household's choice decision.

It is noted that standard logit model could be used to model choice sets at each branch of the tree – i.e., commute mode choices. According to the young middle income and high income residents are the new generation of transit-based residents in Bangkok, the model estimations were calibrated separately between these two income groups. As noted previously, living near station tends to be less preferred than other alternatives for the low income people due to an unaffordable housing price for low income household. Therefore, they are excluded from model calibration.

The lower tier of the nested structure in figure 8.2 was estimated separately for middle-class and high-class household. Discrete logit model in the context of binary logit was then employed to examine factors influencing their mode choice behavior. Mode preferences were added as exogenous in the model. The coefficients were estimated by the maximum likelihood method. By using stepwise method with PIN 0.25 and POUT 0.3, the best set of predictors was finally found. Table 8.4 shows the estimated values of the model coefficients comparing between the middle-class and high-class residents. All explanatory variables except gender are clearly significant at $P < 0.05$.

First of all, preference for rail mode at the time of residential choice has strongly a positive impact on the decision to commute by rail, all else being equal. The more positive attitude toward rail use the residents have the more rail passengers they tend to be. Theoretically, the definition of residential self-selection, in this case, is a mix of transit driven SAR self-selection of individual. Among residents residing at the same distance from a transit station, those with individual transit-driven SAR self-selection will be more likely to be transit commuters than those without it. Conversely, the attitude toward car use has powerfully a negative effect on the transit ridership. Empirically, the degree of transit-driven SAR self-selection among middle-income household is considerably higher than high-income household. Moreover, more negative coefficient of transit proximity among the high-class group means that their probability of mass transit being chosen more decreases as the distance increases than another group. They are more sensitive about the access distance between house and station.

Table 8.5 Binary logit model estimation of rail transit passenger among middle and high income residents

Variables	Middle income				High income			
	Coefficient (B)	Standard Error	Sig.	Odds ratio Exp(B)	Coefficient (B)	Standard Error	Sig.	Odds ratio Exp(B)
Mode preferences			.015				.003	
Group 1 : Rail preference	1.545	.870	.046	4.688	.376	.532	.018	1.457
Group 2: Car preference	-.793	.846	.039	.453	-.855	.498	.026	.425
Locational Characteristics								
Straight-line distance from residence to the closest station	-.0000143	.000036	.009	1.000	-.000572	.000364	.016	1.001
Parking availability at workplace	-.526	.373	.009	.591	-.872	.409	.033	.418
Transport characteristics								
Out-vehicle time	.039	.034	.034	1.040	-.052	.030	.004	.949
Travel cost	-.003	.005	.027	0.996				
Socio-Economic characteristics								
Car Ownership	-1.162	.392	.003	.313	-.872	.409	.033	.418
Male	-0.417	0.329	.081	.659	1.410	.667	.034	4.094
Single-person household	2.591	1.039	.013	13.34	-.526	.373	.079	.591
Constant	1.115	.670	.006	3.050	-.706	.908	.017	.493

	Middle income		High income	
	Number of cases	238	Number of cases	180
	-2 Log likelihood	185.605	-2 Log likelihood	187.772
	Cox & Snell R Square	.239	Cox & Snell R Square	.216
	Nagelkerke R Square	.403	Nagelkerke R Square	.397
	% of Cases correctly predicted	83.2	% of Cases correctly predicted	81.7

In the case of the middle-class households, interestingly, only travel cost significantly affects their decision on rail commuting. This is the reason why some transit passengers have to move to live closer to the station because they want to reduce the total cost by cutting the additional cost to access the station. They shift from using bus or paratransit such as motorcycle taxi to non-motorized mode or walking. However, this variable doesn't affect the commuting choice decision of the high income households. Their choice decision depends on out-of-vehicle time. This implies that higher travel cost doesn't affect their commuting choice selection. They are willing to pay more travel cost in order to save the total travel time.

The important lesson learnt from this research is that the rich people are more sensitive on out-of-vehicle travel time than in-vehicle time in selecting their mode choice. The choice with lesser out-of-vehicle time or waiting time is preferable for them. Although the in-vehicle time of traveling by rail is fixed, the out of vehicle time is less reliable during rush hours. The frequency of BTS and MRT are 2.40 minutes and 3.15 minutes during the peak hours 06.00 - 09.00 and 16.30 - 19.30 respectively. At peak hour, the trains sometimes depart without being able to take all waiting passengers. The passengers inevitably spend longer time waiting for the next train due to the overcapacity of passengers at the main stations at peak hours, particularly at the main interchange stations.

8.7 KEY FINDINGS

By controlling the residential and workplace location close proximity to rail stations, rail transit is overwhelmingly chosen as mode choice among the station-area residents. The complicated relationship among built environment, travel, socio-demographic characteristics, and household attitudes is finally clarified. The originality of this research in integrating mode preference together with locational and travel choice behavior in nested logit model is statistically approved. The model was set based on the assumption of sequential process that the decision to live near the station is due to the preference to commute by rail and travel pattern is partly a result of the decision where to live. Empirically, the inclusion of residential self-selection can significantly explain specific travel behavior such as using rail or driving to work.

From model calibration, how residential self-selection with respect to the distance to the nearest station influences on travel pattern can be disentangled. The low degree coefficient of transit proximity reveals that it has limited impact on transit ridership in Bangkok. The effect of living nearer the station area has low degree to increase the rail transit use. Personal characteristics such as car ownership, family type and income can better explain the transit-driven SAR self-selection and rail commuting than transport characteristics. First, the past experience with traveling by train has the greatest impact on the transit-driven SAR self-selection. Secondly, the availability of car is still the potential factor to discourage not only transit preference but also transit ridership. Thirdly, as opposed to high-income workers, middle-income earners have higher degree of transit-driven SAR self-selection and ridership. Lastly, considering transport factors, the tendency of those with a predisposition toward transit to reside in areas well-served by transit can be occurring for the reasons of travel cost saving more slightly than that of travel time saving. However, only travel time can be predictor of whether one commutes by rail transit.

CHAPTER 9

CONCLUSION AND POLICY RECOMMENDATION

This dissertation mainly aims to provide an appropriate framework that can guide the urban and transport planning practice in developing countries that are investing in mass transit systems and implementing TOD. This chapter concludes the key findings derived from the previous chapters including the assessment of TOD sustainability, causal relationship between built environment and travel behavior, the integration of locational and travel choice model, the inclusion of travel attitude in travel choice behavior, the influence of residential self-selection on rail commuting. The proper policy concerns of enhancing the TOD sustainability are then recommended. Lastly, the future prospects for further research are discussed.

9.1 SUMMARY OF KEY FINDINGS

9.1.1 TOD sustainability of outcomes

Sustainability of the TOD based on empirical aspect of outcomes is examined whether or not Bangkok city has achieved the TOD goals for sustainable development to reduce over-reliance on private automobile and to promote more transit ridership. Firstly, from travel behavior survey of condominium residents along the BTS line in the well-known residential area namely "Sukhumvit" zone, high potential zone of TOD development, most of condominium residents in this zone are well-education and high-income people who own a car. There is no low income in this zone because its main characteristic exclusively serves for the rich people. Considering transit ridership, most of respondents are non-transit user. This means private vehicles is the most selected mode. Notwithstanding, a middle-class worker accounting for the major group of car occupancy tends to be transit user more than that high class that is mostly auto-reliance. This area is finally proved to be unique from other residential zones because most of the residents are the elite high income people and foreigners who are car dependent. Due to its uniqueness, therefore, the TOD outcomes have not yet achieved the main goals to increase attractiveness of transit despite it has enormous potential for TOD due to high density and mixed land use.

Apart from the Sukhumvit zone mention above, the travel behavior survey data in 2008 reveal that the station-area residents obviously use their car to go to work. Focusing on multi-worker household, the primary and secondary workers have different trip modes and accessibility to workplaces. Evidently, the former those is mostly male are the car users whereas the latter those is female is more likely to be the car passenger or to take the public transit.

From travel behavior survey data in 2013, the situation of transit ridership among the station-area has been dramatically changing. Obviously, rail transit has become the most popular commuting mode choice for the station-area residents. It is considerably selected as mode choice to go to work while the car is used less than nearly a half of the transit use, corresponding with the high proportion of carless-household among the station-area residents. Particularly, the residents those both live and work near the station overwhelmingly choose this mode to reach their workplace. Rationally, an increasing in ridership among the transit-based residents demonstrates the great opportunity for the TOD enhancing in this city.

9.1.2 Factors influencing transit ridership

The interrelated findings between chapter 5, 6, 7 and 8 are summarized as presented in figure 9.1. Also the result of discriminant analysis in chapter 4 is integrated in the conclusion which factors can potentially explain travel choice behavior.

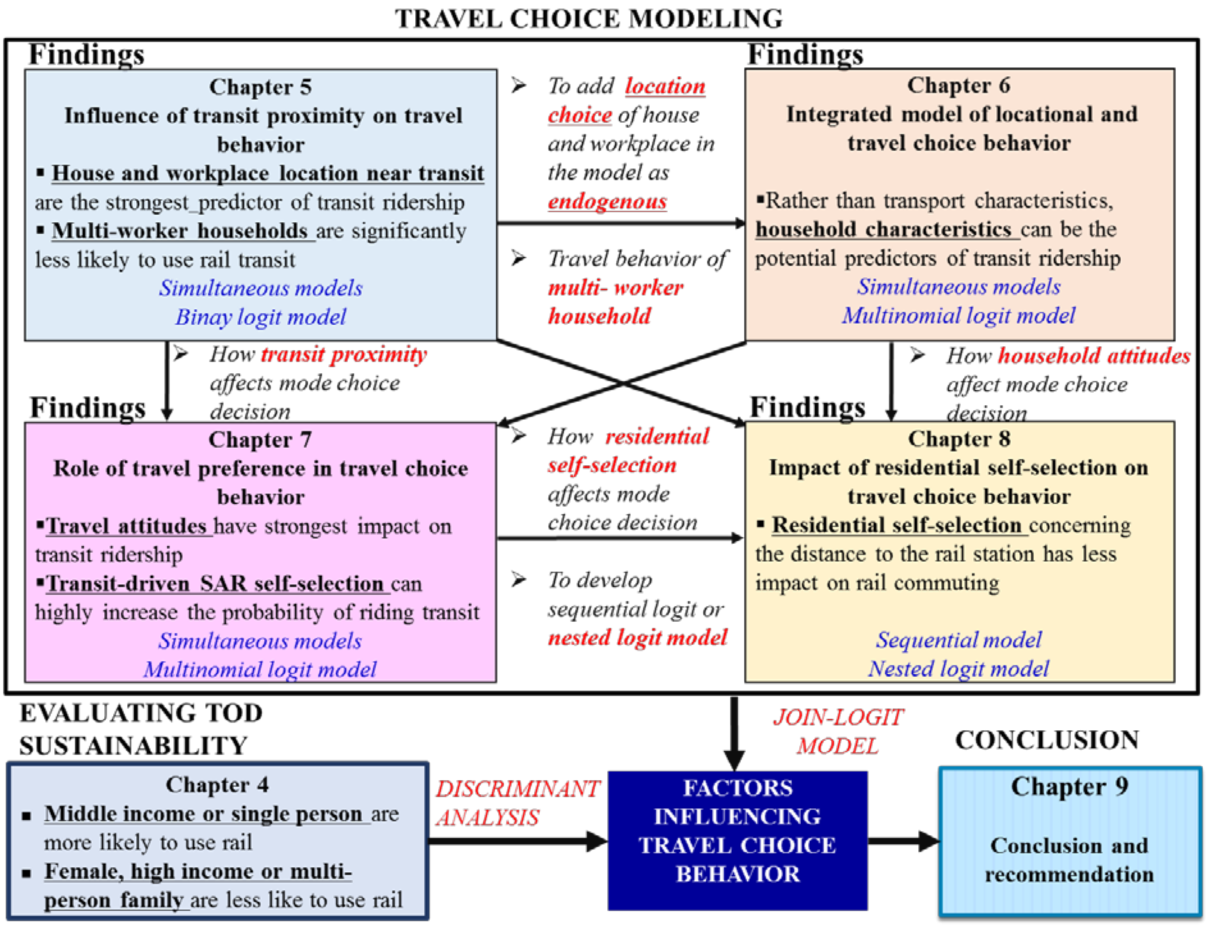


Figure 9.1 the interrelated findings of travel behavior modeling in each chapter.

From discrete choice modeling estimated results, several significant factors affecting the transit ridership are finally presented as summarized in Table 9.1.

1) Built environment: transit proximity

The empirical results from the binary choice model indicate that built environment concerning the proximity to the transit station can potentially explain the decision on allocation to the transit passenger or driver. Residential and workplace location within mass transit catchment area are the main determinants of mode choice selection corresponding with the previous studies that confirmed the higher share of transit trips in transit-based neighborhoods (e.g. Friedman et al., 1994; Handy, 1996a,b; Kitamura et al., 1997; Cervero and Gorham, 1995; Cervero and Radisch, 1995). However, rather than house location, workplace location is the best predictor of the rail users. Destination's proximity to transit tends to encourage the likelihood of rail commuting.

Next, the research applies multinomial logit model to integrate the locational and mode choice behavior. The model estimation also confirms the causal relationship between the built environment and travel behavior. The main condition of householders to be the transit-based residents and use transit mode to go to work depends on their workplace location. The distance between workplace and the station affects their decision on house location and travel mode. This can be implied that the Bangkok residents rely less on a combination of alternative modes, ignoring any changing of modes. The convenience of one linked trip from home to work by the rail is preferable.

2) Travel attitudes

By controlling the built environment of residential location close proximity to the station, the inclusion of travel attitudes in analysis commuting choice model noticeably demonstrates the set of predictors with the stronger R squared values. The attitudes such as attitude towards using rail transit or driving can significantly explain specific travel behavior such as using rail or driving to work. As compared to other significant factors in the model, preference for transit mode choice is the strongest positive predictor for the rail passenger. The more positive attitude the station-area residents have the more rail passengers they tend to be. Conversely, the attitude toward car use is strongly a negative effect on the transit ridership. The vast majority groups of car users are the station-area residents who have intention to use car before moving to live near station. It is difficult for mass transit system to induce people who are pro car attitude to shift from being car user to being rail user.

3) Socio-demographic characteristics

The empirical results from the discrete choice model and the discriminant analysis together indicate that travelers' explanatory characteristics can potentially explain their decision on allocation to the transit passenger or non-passenger. Socio-demographic characteristics and car availability potentially explain travel choice decisions. Firstly, car ownership variable is the strongest negative impact on the transit ridership. Evidently, most of car users belong to car-owning households. Thus, mass transit system is less attractive for those who have car. Moreover, parking fee at workplace has positive influence on rail use decision significantly. The car park availability along the corridor seems to be the key explanation of not using transit. Some of respondents keep using car even their house and workplace are located within catchment area of the transit station if the car park is available at destination with cheap cost or no fee.

Secondly, income is significantly meaningful to predict the transit passengers. The low income group tends to be more captive rider than the middle and high income group. In contrast, middle-income and high-income groups seem to be choice transit riders who have a vehicle but choose the transit for some trips. However, only middle income seems to be the main group of the station-area residents and regular passengers as compared to other income groups.

Lastly, household composition also proves to be the significant determinant of transport mode choice for the journey to work. As compared to single worker households, multi-worker households are significantly less likely to choose the railway as alternative. Female can be the strong predictor of using car as the alternative. They tend to be auto-reliance rather than transit passenger and non-motorized. But they are more likely to take the public transit if they are the second worker in multi-worker family. Also, households with children are less likely to travel by the railway, compared with single adult households. Being single-person household is more apt to be the rail user than multi-person household because the number of travelers becomes an additional location factor that has a powerful effect on the household's choice decision. While the high negative coefficient value of the presence of children variable supports the idea that their children' school location becomes an additional location factor that has a powerful effect on the household's choice decision.

4. Transport factors

The discrete choice model results reveal to what extent the transportation factors in terms of travel cost and time influence on mode choice decision mechanism. The time in the model was associated with the total in-vehicle travel time and out-of-vehicle travel time while the cost is referred to the total of out-of-pocket cost. They are finally found to be less potential predictors. This finding concurs with previous results which found that transportation factors are less important determinants in location and travel choice. The important lesson learnt from this research is that people are more sensitive about out-of-vehicle travel time than in-vehicle time to make their decision on mode choice. Lesser out-of-vehicle time or waiting time is preferable for the rail users.

9.1.3 The influence of residential self-selection on rail commuting

Whether residential self-selection exists or not is examined using standard and nested logit model. With respect to sequential process decision mechanism, multi-dimensional nested logit model is developed. The originality of this research is to model the complex relationship between built environment and travel behavior by integrating mode preference together with locational and mode choice modeling.

1) Standard logit model

Discrete logit model in the context of binary logit is to examine to what extent the residential self-selection concerning mode preference has an impact on the rail commuting of the station-area residents. The powerful determinant of mode preferences mentioned above illustrates that residential self-selection has taken place and there is a significant relationship between built environment, travel attitudes and travel choice behaviors. Travel attitudes have strong influence on travel choice behavior through residential choice. The decision to live near the station is due to the preference to commute by rail and travel pattern is partly a result of the decision where to live. With respect to a strong positive impact of preference for rail mode on the decision to commute by rail, the definition of residential self-selection is theoretically a mix of transit-driven SAR self-selection of individual. Transit-driven SAR self-selection would highly increase the probability of riding transit. Among residents residing at the same distance from a transit station, those with individual transit-driven SAR self-selection will be more likely to be transit commuters than those without it. Finally, the low estimated coefficient of the distance factor depicts that the ridership bonus assigned to transit-oriented living is due to the transit-based resident characteristics rather than spatial proximity.

2) Nested logit model

The issue of residential self-selection is then continued to investigate a more complicated assumption of a sequential decision process on location and travel choice, controlling for residential location and working in close proximity to transit. It is assumed that people hierarchically select to live in the location that complies with their travel preferences before choosing their commuting choice for work trip. From the nested logit model calibration, the estimated log-sum coefficient confirms this model is significantly applicable. The model results reveal that attitude toward travel cost and travel time saving significantly influence rail preference In addition, past travel experience has a strong impact on the preference for transit mode. Most of rail commuters have pro rail attitude because of their good experience with traveling by train before moving house. In term of household characteristics, car availability tends to deter transit preference, all things being equal.

The results of commute mode choice, stratified by those who have preference on rail and those who do not, illustrate the distance to the nearest station significantly affects the odds of rail commuting. However, the low estimated coefficient of the distance factor reveals that it has less influence on travel choice behavior. The effect of living nearer the station area has low degree to increase the rail transit use. It implies that residential self-selection concerning the distance to the rail station has limited impact on transit ridership in Bangkok.

Table 9.1 Summary of factors influencing transit ridership

Built environment: transit proximity	**Travel attitudes**	**Socio-demographic characteristics**	**Transport factors**	**Residential self-selection**
Discriminant analysis :	**Discrete choice model: Joint logit**	**Discriminant analysis :**	**Discrete choice model: Joint logit**	**Discrete choice model: Joint logit**
- **Distance between home and the station** are no significant for the respondent's decision on their mode choices.	By controlling the built environment of residential location close proximity to the station, - **Preference for transit mode choice** is the strongest positive predictor for the rail passenger.	**Car ownership** is no significant for the decision on their mode choices **Middle income office worker and family size** have negative impacts on transit ridership **Female** has a negative impact on transit ridership	**Total in-vehicle, out-of-vehicle travel time and the total travel cost** are finally found to be less potential predictors	**1) Standard logit model** **Transit-driven SAR self-selection** can highly increase the probability of riding transit **2) Nested logit model** **Residential concerning the distance to the rail station** has limited impact on transit ridership
Discrete choice model: Joint logit **Residential and workplace location** are the main determinants of mode choice selection **Workplace location** is the best predictor of the rail users **Distance to the nearest station** has less influence on travel choice behavior		**Discrete choice model: Joint logit** **Car ownership,car parking, middle income, multi-worker, the presence of child** have negative impacts on the transit ridership. **Female, single-person and single-worker household** tend to be rail users		

9.2 POLICY DEVELOPMENT

The findings in this research could provide an appropriate framework to enhancing the TOD implementation and future urban land use and transportation planning for sustainable development in transit cities in developing countries. There are several critical issues that must be taken account to provide better understanding of TOD implementation. Recommendations for creating more TOD sustainable cities range from macro-level strategies that influence land development and governance at the metropolitan scale to micro-level policies, such as TOD, which can radically transform development patterns at the neighborhood level. This research originally focuses at individual-level initiatives, such as travel choice behavior taking into account residential self-selection, which can throw light on the kinds of households who are most inclined to move to station areas and become the patronage of transit services. Therefore, three main policies and strategies level can be summarized as follows:

1. Urban railway corridor development policies

The outcomes of the research can initially assist the policy makers in solving the strategic issues of transit planning, including the future development of the railway corridor. The research suggested that having residences and jobs in close proximity can reduce the vehicle-trips. This finding is partly supported by the empirical research that living and working closer to rapid rail transit stations (i.e., residential and workplace transit proximities) increase the probability of their riding rapid transit to work. In addition, the effect of bringing workplaces nearer to transit stations is better than locating residences nearer. Certainly, locating both residences and workplaces closer to transit works is the best alternative.

- The destination accessibility reflecting the proximity or ease of access to regional trip opportunities such as employment is the most important aspect of the built environment affecting transport mode share of journey to work. Some measures to attract workplace in catchment area of rail transit stations such as relaxation of land use regulation will be effective for the accumulation of workplace near the stations.
- With respects to common traits of TOD, the application of diversity basically focuses on not only mixed land use but also on extensive choices of housing and commutating, mixed-income transit-oriented neighborhoods. The mixed-income housing supports the increasing in ridership by providing easy access for those individuals who use transit the most. The development of housing near transit

that is affordable to a broader range of household types should be carefully investigated.

- Limitations in the housing market at the time of residential choice mean households cannot self-select. It is recommended that the spatial and temporal dimensions involved in building residential areas should be expanded, because this will increase the opportunities for households to self-select. It has been already proved in this research that the young single middle-class has been becoming the new generation of the TOD residents and they are most inclined to be the regular transit users. There has been the main problem due to a lack of affordable house for middle class families with children. The room size of new condominium along the transit corridor has been decreasing to the studio room size. Therefore, the policy to provide rooms not only for single-person households and couples without children but also for such families is also important for TOD sustainability.
- There is high percentage of car park availability at workplace among car user group. Therefore, car parking policies along the transit corridors should be carefully considered as the critical issues to control car use and encourage transit use. Now that the transit systems are maturing and market for TOD has strengthened, local planners should team up with transit agencies and developers to ensure that the parking policies will support high transit ridership.

2. Mass transit services improvement policies

The outcomes of the research are able to present some observable facts that might be useful in giving more understanding how to make mass transit work effectively. As people's positive attitude toward using rail transit maybe caused by the good services of rail transit, improvement rail transit system may improve their attitudes. This research suggested that the increasing of pro rail attitude may develop as the result of the good service of mass transit system in terms of travel cost and time saving. Policies on the improvement of transit accessibility by increasing the walkable environment or adding more feeder modes to access station can reduce out-of-vehicle time for the TOD residents.

- Reducing out-of-vehicle time can be an important strategy to increase more transit users by increasing more frequency of service during peak hours and improving connection to station (such as providing shelter or better footpath) as well. Increasing the quality of walking environment within acceptable walking distance could be an important strategy to make walking to station more attractive.

- This thesis found that shorter distances to railway stations lead to a decrease in the share of car trips, through the positive effect on attitudes towards public transportation, meaning that more accessible public transportation may seduce people into reducing their car use. Rail transit would be more attractive to gain more ridership by adding more feeder mode for longer distance to access station. It could be combined with providing exclusive shuttle bus to connect condominium to station because some of the station-area residents are infrequent users who own an automobile but have a good attitude toward rail and choose the transit for some trips.

3) Transit ridership enhancing policies

An understanding of the factors affecting the choice decision of such target groups is essential to the promotion of more sustainable behavior and the achievement of the city's transport targets. This research reveals to what extent the ridership bonus assigned to transit-oriented living is due to not only spatial proximity but also the nature of people who opt to live in these settings.

- Mass transit system is less attractive for those who have car and lesser for those who have pro car attitudes. The vast majority group of car users is the station-area residents who have intention to use car before moving to live near station. It is difficult for mass transit system to induce people who are pro car attitude to shift from car user to rail user. Thus, it is more effective to encourage infrequent users who have car availability but have positive attitude toward rail use to shift from being car user to rail user than to convince people with the car preference.
- Mass transit can offer additional services for particular target groups, for example, providing lady cars for female passengers during peak hours as they are more likely to be the regular passengers of mass transit.

9.3 IMPLICATION FOR DEVELOPING COUNTRIES

This research draws lesson from case example of transit-oriented metropolis of Bangkok that has direct relevance to cities in developing countries and elsewhere that are currently introducing mass transit and implementing the TOD. Empirically, the TOD is being implemented in different forms in different parts of the world. The research findings could provide valuable ideas to enhancing the TOD implementation, future urban land use and transportation planning for sustainable development in developing countries where the number of transit ridership has been lower than expected level. Basically, the TOD is a modern-day version of traditional urban development driven by all these policy concerns, shifting demographics, and lifestyle preferences. Therefore, spatial planning that aims to influence travel behavior will be most successful if it takes into account differences between specific groups of the population in terms of their preferences for housing and neighborhood characteristics and their travel-related attitudes.

There are wide range characteristics of transit riders. For the riders with certain level of self-selection, the policies should allow them to move closer to the stations in order to extend the number of transit passengers. The results of this thesis show that travel-related attitudes are significantly related to socio-demographic characteristics; therefore these individual and household characteristics can be used to divide the population into segments that can be used in spatial policy. Recommendations for creating more TOD sustainable cities at individual-level initiatives taking into account residential self-selection can throw light on the kinds of households who are most inclined to move to station areas and become the patronage of transit services.

This research originally expresses the idea who should be promoted to be TOD residents. Theoretically, for TOD implementation, low income group is supported to be the TOD residents as appeared in the previous chapters. But in reality, it seems like being the transit residents is beyond the means of most low income group due to unaffordable housing price along the transit corridors. It is undeniable on the negative side of TOD that proximity to rail transit often increases property values , the only people who can afford to live in the TOD are wealthier people - and wealthier people do not take transit as much. If the TOD accommodates mixed income housing and provides housing for higher income levels, people live in those housing may prefer living in the TOD areas for other reasons but not use transit. And if the TOD is developed with housing only for certain income groups, it may avoid others using transit. This dilemma requires a careful research before planning for the TOD implementation in developing world.

9.4 FUTURE PROSPECTS

This study has introduced the preliminary research on travel behavior addressing residential self-selection that explicitly include attitudes as mediating factor to understand the true relationship between built environment and travel choice behavior. However, the relationship between the built environment and travel behavior is very complex, and there are other mediating factors addressed in such relationships. Whether or not self-selection exists, it is essential to explore an alternative approach where some of the confounding factors are controlled for (such as self-selection in residence, accessibility and generalized transport costs) in explaining the true relationship between built environment and travel behavior. To avoid either overestimate or underestimate the influence of the built environment on travel behavior, further studies or spatial planning should take into account the other important mediating factors.

It is important to acknowledge that this study found only limited evidence of a role being played by residential self-selection in the relationship between the built environment and travel behavior by using cross-sectional data. And it has only considered the influence of attitudes on behavior. Based on Bohte (2010), this research proposed that there is a reverse relationship between built environment, travel pattern and travel attitudes as mentioned in social-psychological theories and some travel behavior studies. They suggest that travel-related attitudes not only influence travel behavior and residential choice, but also that travel behavior and the characteristics of the built environment of the residential location will also influence peoples' travel attitudes. Consequently, there has not completely understood the relationship between attitudes and behavior as the influence of behavior on attitudes may be also important. If built environment characteristics can affect changes in travel attitudes, thus, they can change travel behavior not only directly but also indirectly through influencing these attitudes. This influence of behavior and built environment characteristics on travel-related attitudes implies that attitudes change over time. Therefore the research on residential self-selection studies should measure peoples' travel attitudes at present time as well as the attitudes held at the time of residential choice if changes in the built environment which are the result of residential relocation can change their attitudes. It is important for further study to employ longitudinal data in order to determine the 'exact' role of self-selection. This research arena expects in contributing greater extra details on location behavior, travel pattern, and attitudes to better understand the likely measures that would have to be taken to encourage greater mass transit use.

Lastly, from a development point of view, transport planning should take the needs of different income and social groups into account, for example, to distinguish target groups on the basis of gender. Different cultural factors affect the pattern of each target groups' activities and destination of their traveling. These variables are important to understand the different needs with respect to the use of transport in order to plan transport effectively. The validity of the research findings will be enriched by the further studies in order to expedite the advancement of urban and transportation development in the developing countries.

REFERENCES

Abraham, J.E. and Hunt, J.D. (1997) Specification and estimation of nested logit model of home, workplaces, and commuter mode choice by multiple worker households. Transportation Research Record 1606. TRB, National Research Council, Washington, D.C., pages 17-24.

Abuhamoud, M.A.A., Rahmat, R.A.O.K. and Ismail, A. (2011) Modeling of Transport Mode in Libya: a Binary Logit Model for Government Transportation Encouragement, Australian Journal of Basic and Applied Sciences, 5(5): 1291-1296, ISSN 1991-8178

Ajzen, I. (1991) The theory of planned behaviour, Organizational Behavior and Human Decision Processes, 50 (2), pp. 179-211.

Ajzen, I., and M. Fishbein (1977) Attitude-behavior relations: A theoretical analysis and review of empirical research, Psychological Bulletin, 84, pp. 888-918.

Alonso, W. (1964) Location and land use: Toward a general theory of land rent. Harvard University Press, Cambridge, MA.

Alpizar, F. and Carlsson, F. (2003) Policy implications and analysis of the determinants of travel mode choice: an application of choice experiments to metropolitan Costa Rica. Environment and Development Economics 8, p. 603–619

Alvinsyah, Soehodho, S. and Nainggolan, P.J. (2005) Public transport user attitude based on choice model parameter characteristics, (case study: Jakarta bus way system). Journal of Eastern Asia Society for Transportation Studies, 6, 480-491

Amador, J.A., Gonzalez, R.M., and De Dios Ortuzar, J. (2005) Preference heterogeneity and willingness to pay for travel time savings. Transportation, 32, 627-647

Anable, J., and Gatersleben, B. (2005) All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes. Transportation Research Part A: Policy and Practice Positive Utility of Travel, 39(2-3), 163-181

Arrington, G., & Cervero, R. (2008). Effects of TOD on housing, parking, and travel: TCRP Report 128. Washington DC: Transportation Research Board. Published online. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf

Aruna S. Reddi (2010), Transit Oriented Development: An Integrated Land Use & Transportation Alternative for Sustainable Development. Dept. of Architecture & Regional Planning. Indian Institute of Technology. Kharagpur.W.B India.

Badoe, M., & Miller, E. (2000). Transportation – land-use interaction: empirical findings in North America, and their implications for modeling. Transportation Research Part D, 5, 235-263.

Bagley, M.N. and P.L. Mokhtarian (2002) The impact of residential neighborhood type on travel behaviour: a structural equations modeling approach, Annals of Regional Science, 36 (2), pp. 279-297.

Bamberg, S., I. Ajzen and P. Schmidt (2003), Choice of travel mode in the theory of planned behavior: The roles of past behavior, habit, and reasoned action, Basic and Applied Social Psychology, 25 (3), pp. 175-188.

Barrow, L. (2002) School choice through relocation: Evidence from the Washington, D.C. Area. Journal of Public Economics, 86(2), 155-189.

Ben-Akiva, M. and Bowman, J.L. (1998) An integration of an activity-based model system and a residential location model. Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

Ben-Akiva, M. and Lerman, S.R. (1985) Discrete Choice Analysis (Cambridge:MIT Press).

Ben-Akiva, M., J. Walker, A.T. Bernardino, D. Gopinath, T. Morikawa and A. Polydoropoulou (1999) Integration of choice and latent variable models, Proceedings of 8th International Conference on Travel Behavior. Austin.

Bernick, M. and M. Carroll, (1991) A Study of Housing Built Near Rail Transit Stations: Northern California. Berkeley: Institute of Urban and regional Development, Work Paper 624.

Best, H., and Lanzendorf, M. (2005) Division of labour and gender differences in metropolitan car use: An empirical study in Cologne, Germany. Journal of Transport Geography, 13(2), 109-121

Bhat, C.R. and J.Y. Guo (2007) A Comprehensive Analysis of Built Environment Characteristics on Household Residential Choice and Auto Ownership Levels, Transportation Research Part B, 41 (5), pp. 506-526.

Boarnet, M. and Crane, R. (2001), Travel by Design: The Influence of Urban Form on Travel. New York: Oxford University Press.

Boarnet, M. G., and Sarmiento, S. (1998): Can Land-use Policy Really Affect Travel Behavior? A Study of the Link between Non-work Travel and Land-use Characteristics. Urban Studies, 35(7), 1155 – 1169

Bohte, W., K. Maat and B. van Wee (2009) Measuring attitudes in research on residential self-selection and travel behaviour; A review of theories and empirical research, Transport Reviews 29 (3), pp. 325-357.

Borte, W. (2010) Residential self-selection and travel; The relationship between travel-related attitudes, built environment characteristics and travel behavior. The series of sustainable urban area, Delft University Press.

Braun M. (2011) Bangkok Public Transport Accessibility Levels, Master thesis, International Economics and Business: Urban, Port and Transport Economics, Erasmus University Rotterdam.

Brian D. Taylor and Camille N.Y. Fink (2003) The factors influencing transit ridership: A review and analysis of the ridership literature, UCLA Department of Urban Planning.

Brownson, R., & Boehmer, T. (2004). Patterns and trends in physical activity, occupation, transportation, land use and sedentary behaviors. In TRB Special Report 282: Does the built environment influence physical activity? Examining the Evidence. Washington DC: Transportation Research Board.

Burbidge, S.K. (2008) Identifying the Impact of Active Infrastructure Development on Active Travel Behavior and Overall Physical Activity. Dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy. Department of Geography, University of California, Santa Barbara.

Burning, E. R. et al (1985) Segmentation Analysis of Domestic Airline Passenger Markets, Journal of the Academy of Marketing Science, Vol.13, No.1, pp.17-31

Calthorpe, P. (1993) The Next American Metropolis: Ecology, Community and American Dream, New York: Princeton Architectural Press.

Canepa, B. (2007). Bursting the bubble: determining the transit-oriented development's walkable limits. Transportation Research Record, 1992, 28-34.

Cantwell, M., Caulfield, B. and O'Mahony, M. (2009) Examining the Factors that Impact Public Transport Commuting Satisfaction, Journal of Public Transportation, Vol. 12, No. 2

Cao, X. (2008). Exploring causal effects of neighborhood design on travel behavior using stratification on the propensity score. Paper 09-0115 on the Transportation Research Board 88th Annual Meeting CD-ROM. Washington, DC.

Cao, X., Mokhtarian, P. L., and Handy, S. L. (2005) The impacts of the built environment and residential self-selection on nonwork travel: A seemingly unrelated regression approach. Paper 06-1595 on the Transportation Research Board 85th Annual Meeting CD-ROM. Washington, DC.

Cao, X., Handy, S. and Mokhtarian, P.L. (2006) The influences of the built environment and Residential Self-Selection on Pedestrian Behavior', Transportation, 33(1), pp. 1-20

Cao, X., P.L. Mokhtarian and S.L. Handy (2008) Examining the impacts of residential self-selection on travel behavior: Methodologies and empirical findings, Research Report UCD-ITS-RR-06-18 (Davis: Institute of Transportation Studies, University of California), November.

Cao, X., P.L. Mokhtarian and S.L. Handy (2007) Do Changes in Neighborhood Characteristics Lead to Changes in Travel Behavior? A Structural Equations Modeling Approach, Transportation, 34 (5), pp. 535-556.

Cao, X., P.L. Mokhtarian and S.L. Handy (2009) Examining the impacts of residential self-selection on travel behavior: A focus on empirical findings, Transport Reviews, 29 (3), pp. 359-395.

Center for Transit-Oriented Development (2007) The Case for Mixed-Income Transit-Oriented Development in the Denver Region, March.

Cervero, R. (1994) Transit-Based Housing in California: Evidence on Ridership Impacts. Transport Policy 1, 3: 174-183.

Cervero, R. (1996) Mixed land uses and commuting: Evidence from the American housing survey, Transportation Research Part A, 30(5), 361–377.

Cervero, R. (2003). Growing smart by linking transportation and land use: Perspectives from California. Built Environment, 29 (1), 66-78.

Cervero, R. and R. Gorham (1995) "Commuting in Transit Versus Automobile Neighbourhoods," Journal of the American Planning Association, Vol. 61, pp. 210-225.

Cervero, R. and C. Radisch (1996) "Travel Choices in Pedestrian Versus Automobile Oriented Neighbourhoods," Transport Policy, Vol. 3, pp. 127-141.

Cervero, R. and K. Kockelman (1997) "Travel Demand and the 3Ds: Density, Diversity, and Design," Transportation Research D, Vol. 2, No. 3, pp. 199-219.

Cervero, R. and K.L. Wu (1998) Subcentering and Commuting: Evidence from the San Francisco Bay Area, 1980-1990, Urban Studies, Vol. 35, No. 7, pp. 1059-1076.

Cervero, R., and Duncan, M. (2002) Residential Self Selection and Rail Commuting: A Nested Logit Analysis. Working Paper, University of California Transportation Center, Berkley, California.

Cervero, R., & Duncan, M. (2003). Walking, bicycling, and urban landscapes: Evidence from the San Francisco Bay area. American Journal of Public Health, 93(9), 1478-1483.

Cervero, R. & Duncan, M. (2006). Which reduces vehicle travel more: Jobs-housing balance or retail housing mixing? Journal of the American Planning Association, 72 (4), 475-490.

Cervero, R., and Murakami, J. (2010) Rail and property development in Hong Kong:Experiences and extensions, Urban Studies, 46, 2019–2043.

Cervero, R., et al. (2004) TCRP Report 102: Transit Oriented Development in the United States: Experiences, Challenges, and Prospects. Transportation Research Board of the National Academies, Washington, D.C.

Cervero, R., Ferrell, C., and Murphy, S. (2002) Transit-Oriented Development and Joint Development in the United States: A Literature Review. Research Results Digest. Washington, D.C., Transportation Research Board, Transit Cooperative Research Program, No. 52.

Chalermpong, S. (2007) Rail Transit and Residential Land Use in Developing Countries:Hedonic Study of Residential Property Prices in Bangkok, Thailand, Transportation Research Record: Journal of the Transportation Research Board, Vol. 2038, 111-119.

Chalermpong, S. (2011) Differences in high-density residential development rate along Bangkok's rail transit corridors. International Transportation & Economic Development Conference. May 3, Charleston, W.V.

Chalermpong, S. and Wibowo, S. (2010), Characteristics of Mode Choice within Mass Transit Catchments Area, Journal of the Eastern Asia Society for Transportation Studies, Vol.8.

Chapin, F.S. (1978) Human time allocation in the city, in: Carlstein, T., D. Parkes and N. Thrift (Eds.), Human activity and time geography, pp. 13-26 (New York: Halstead Press).

Charoentrakulpeeti et al. (2006) Middle-class Travel Patterns, Predispositions and Attitudes, and Present-day Transport Policy in Bangkok, Thailand. Transport Reviews, Volume 26, Issue 6, 693 – 712.

Chapple, K & Weinberger, R 2000, 'Is shorter better? An analysis of gender, race, and industrial segmentation in San Francisco bay area commuting patterns'. University of California, Berkeley.

Charron, M. (2007) From excess commuting to commuting possibilities: More extension to the concept of excess commuting. Environment and Planning A, 39(5), 1238-1254.

Chen, C. et al. (2008). Role of the built environment on mode choice decisions: Additional evidence on the impact of density. Transportation, 35,285-299.

Chia-Nung Li1 and Tsung-Yu Lai (2006) Sustainable Development and Transit-Oriented Development Cities in Taiwan, The 12th Annual International Sustainable Development Research Conference.

Cho, J.E. et al. (2008) The role of employment subcenters in residential location decisions. Journal of Transport and Land Use 1:2 (Fall 2008) pp. 121–151.

Clark et al. (2003) Does commuting distance matter? Commuting tolerance and residential change. Regional Science and Urban Economics 33: 199–221.

Clark, W.A.V. and F. M. Dieleman (1996) Households and housing: Choice and outcomes in the housing market. New Brunswick: Centre for Urban Policy Research.

Clark, W.A.V., Withers, S.D. (1999) Changing jobs and changing houses: mobility outcomes of employment transitions. J. Regional Sci. 39, 653–673.

Crane, R., 2000. The influence of urban form on travel: an interpretative review. Journal of Planning Education and Research 15 (1), 3–23

Curtis and Montgomery (2006) Housing Mobility and Location Choice: A Review of the Literature. Impacts of Transit Led Development in a New Rail Corridor. Working Paper No. 2. http://urbanet.curtin.edu.au/

Curtis, C., and Olaru, D. (2010) The relevance of traditional town planning concepts for travel minimization. Planning Practice and Research 25 (1): 49-75.

Davis, JS 1993, 'The commuting of exurban home buyers', Urban Geography, vol. 14, no. 1, pp. 7-29.

Dieleman F. M. (2001) Modelling residential mobility; a review of recent trends in research. Journal of Housing and the Built Environment 16: 249–265

Dieleman, F., Dijst, M. and Burghouwt, G. (2002) Urban form and travel behavior: micro-level household attributes and residential context. Urban Studies, Vol. 39, pp. 507-527.

Digambar, A.P. and Mazumder, T. (2010) Residential Location Choice: A Study of Household Preferences for the City of Nagpur. Institute of Town Planners, India Journal 7 - 3, 01 - 19, July – September.

Dunphy, R., Myerson, D, Pawlukiewicz, M. 2004. Ten Principles for Developing Around Transit, Developing Around Transit: Strategies and Solutions That Work, R. Dunphy, et al., eds. Washington, D.C.: Urban Land Institute, Chapter Seven.

Eagly, A. and S. Chaiken (1993), The psychology of attitude (Fort Worth: Harcourt,Brace & Jovanovich)

Eliasson, J. and Mattsson, L. (2000) A model for integrated analysis of household location and travel choices. Transp.Res. A 34, 375–394.

Ewing, R., Haliyur, P., Page, G.W., (1994) Getting around a traditional city, a suburban planned unit development, and everything in between. Transportation Research Record 1466, 53–62.

Ewing, R. & Cervero, R. (2010) Travel and the Built Environment - A Meta-Analysis. Journal of

the American Planning Association, vol. 76, no. 3, pp. 265-294.
Ewing, R. (1996) Best Development Practices. Chicago: Planners Press.
Ewing, Reid, and Cervero, R. (2001) Travel and the built environment: A synthesis, Transportation Research Record, 1780, 87–114 (FHWA).
Fosgerau M., Hjorth K. and Lyk-Jensen S.P. (2010) Between-mode-differences in the value of travel time: self-selection or strategic behavior?, Transportation Research Part D, vol. 15, pp. 370-381
Frank, L. et al. (2008). Urban form, travel time, and cost relationships with tour complexity and mode choice. Transportation, 35, 37-54.
Freedman, O. and Kern, C.R. (1997) A model of workplace and residence choice location in two-worker households. Regional Science and Urban Economics. Vol. 27, pages 241-260.
Friedman, J. (1975) Housing location and the supply of local public services. PhD dissertation, Department of Economics, University of California, Berkeley.
Friedman, J. (1981) A Conditional Logit Model of the Role of Local Public Services in Residential Choice, Urban Studies, vol. 18, pp. 347-58.
Friedman, B., Gordon, S.P., Peers, J.B., (1994) Effect of neotraditional neighborhood design on travel characteristics. Transportation Research Record 1466, 63–70
GH Bank Housing Journal (----) Mass - transit - influence on housing development, Thailand.
Giuliano, G. (1995). The weakening transportation – land use connection. Access, 3-11.
Golledge, R.G., and R.J. Stimson. (1997). Spatial Behavior: A Geographic Perspective, Guilford Press, New York, USA.
Gordon, P., Kumar, A., & Richardson, H. W. (1989) Gender differences in metropolitan travel behavior. Regional Studies, 23(6), 499-510.
Goulias, K. G. (2000) Travel Behavior and Values Research for Human Centered Transportation Systems. From Transportation in the New Millennium: State of the Art and Future Directions, Perspectives from Transportation Research Board Standing Committees Washington D.C.: Transportation Research Board.
Green, A.E. (1997) A question of compromise? Case study evidence on the location and mobility strategies of dual career households, Regional Studies, vol. 31, no. 7, pp. 641-57.
Guo J.,and Baht, C. (2002) Residential Location Choice Modeling: Accommodating Sociodemographic, School Quality and Accessibility Effects. Department of Civil Engineering, ECJ 6.8 University of Texas at Austin, Austin.
Guers, K. T. and van Wee, B. (2004) Accessibility evaluation of land-use and transport strategies:

review and research directions, Journal of Transport Geography, Vol. 12, 127-140.

Guevara, C. A. and Ben-Akiva, M. (2006) Endogeneity in residential location choice models. Transportation Research Record: Journal of the Transportation Research Board, 1977, 60-66.

Handson, S. (1995) The Geography of Urban Transportation, The Guilford Press, New York.

Handy, S.L., (1996) Urban form and pedestrian choices: Study of Austin neighborhoods. Transportation Research Record 1552, 135–144

Handy, S., Mokhtarian, P., Buehler, T., and Cao, X. (2004). Residential Location Choice and Travel Behavior: Implications for Air Quality. Research Report, UC Davis – Caltrans Air Quality Project, University of California, Davis, June. Available at http://aqp.engr.ucdavis.edu/Documents/Final_report_editted_updated1.pdf.

Handy, S.L., X. Cao and P.L. Mokhtarian (2005) Correlation or causality between the built environment and travel behavior? Evidence from Northern California, Transportation Research Part D, 10 (6), pp. 427-444.

Handy, S.L., X. Cao and P.L. Mokhtarian (2006) Does self-selection explain the relationship between built environment and walking behavior? Empirical evidence from Northern California, Journal of the American Planning Association, 72 (1), pp. 55-74.

Hanson, S. & Johnson, I. (1985) Gender differences in work trip length: explanations and implications. Urban Geography, 3: 193-219.

Hanson, S & Pratt, G 1991, 'Job search and the occupational segregation of women', Annals of the Association of American Geographers, vol. 81, no. 2, pp. 229-53.

Harris, B. (1996) Land use models in transportation planning: a review of past developments and current practice,

Hayashi, Y., Doi, K., Yagishita, M., and Kuwata, M. (2004) Asian trend, problems and policy practices, European Journal of Transport and Infrastructure Research.

Hayes, N. (1993). Principles of Social Psychology, Lawrence Erlbaum Associates Ltd., Publishers, East Sussex, England.

Hoshino, T. (2011) Estimation and analysis of preference heterogeneity in residential choice behaviour. Urban Studies, 48(2), 363-382.

Hoang, HP & Wakely, P 2000, 'Status, Quality and the Other Trade-off: Towards a New Theory of Urban Residential Location', Urban Studies,vol. 37, no. 1, pp. 7-35.

Hong, J. et al. (2013) How do built-environment factors affect travel behavior? A spatial analysis at different geographic scale. Transportation. Published online

Hunt, J.D., McMillan, D.P. and Abraham, J.E. (1994) A stated preference investigation of influences of the attractiveness of the residential locations. Transportation Research Record 1466. TRB, National Research Council, Washington, D.C., pages 79-87.

Inoa I. A. et al. (2013) Intra-household Decision Models of Residential and Job Location. THEMA Working Papers, THEMA (THéorie Economique, Modélisation et Applications), Université de Cergy-Pontoise.

Ioannides, Y. M. (1987) Residential mobility and housing tenure choice. Regional Science and Urban Economics, 17(2), 265-287.

Jayme, J.L.L. and Chalermpong S., (2013) Travel Behavior of Condominium Residents near Urban Rail Transit Stations: Case of Metro Manila. Proceedings of the Eastern Asia Society for Transportation Studies, Vol.9.

Kawada, M., Okamoto, N., Ishida H. and Tsutsumi, M. : Effects of Tsukuba Express Project on the Residents' Travel Behavior, Journal of the Eastern Asia Society for Transportation Studies, Vol.8, 2010.

Kenworthy, J., & Laube, F. (1999). Patterns of automobile dependence in cities: An international overview of key physical and economic dimensions with some implications for urban policy. Transportation Research Part A, 33, 691-723.

Khattak, A. J. and Rodriguez, D., (2005) Travel behavior in neo-traditional neighborhood developments: A case study in USA. Transportation Research Part A 39 pp. 481–500

Kim, S. (1995) Excess commuting for 2-worker households in the Los Angeles Metropolitan Area. Journal of Urban Economics, 38(2), 166-182.

Kim, J. H., Pagliara, F., and Preston, J. (2003) An analysis of residential location choice behaviour in Oxfordshire, UK: A Combined Stated Preference Approach. International Review of Public Administration, 8(1), 103-114

Kitamura, R., Mokhtarian, P.L. and Laidet, L. (1997) A micro-analysis of land use and travel in five neighbourhoods in the San Francisco Bay Area, Transportation, 24, pp. 25-158

Knight Frank Research Report (2010) www.knightfrank.com, (Accessed in March, 2012)

Krizek, K. (2003a) Residential relocation and changes in urban travel: does neighborhood-scale urban form matter? Journal of the American Planning Association, 69(3), pp. 265–281.

Krizek, K. (2003b) Planning, household travel, and household lifestyles, in: K. G. Goulias (Ed.) Transportation Systems Planning: Methods and Applications, chap. 6 (Boca Raton, FL: CRC Press).

Krizek, K.J. (2006) Lifestyles residential location decisions and pedestrian and transit activity.

Transp. Res. Record 1981, 171–178.

Lee, B. and Waddell, P. (2010) Residential mobility and location choice: A nested logit model with sampling of alternatives. Transportation, 37(4), 587-601.

Lerman, S. (1975) A disaggregate behavioral model of urban mobility decisions. Center for Transportation Studies Report no. 75-5, Massachusetts Institute of Technology, Cambridge.

Lerman, S.R. (1976) Location housing automobile ownership and mode to work: a joint choice model. Trans. Res.Record 610, 6–11

Levine, J.C. (1998) Rethinking accessibility and jobs-housing balancing. Journal of the American Planning Association 64 (2): 133–149.

Li, Z., Hensher, D.A. and Rose,J.M. (2010) Willingness to pay for travel time reliability in passenger transport: A review and some new empirical evidence. Transportation Research Part E: Logistics and Transportation Review, 46: 384-403.

Lin, J. and Shin, T. (2008) does transit-oriented development affect metro ridership: Evidence from Taipei, Taiwan. Journal of the Transportation Research Board, 2063, 49–158.

Litman, Todd A., 2005. Land use impacts on transport: how land use factors affect travel behavior. Victoria Transport Institute. <http://www.vtpi.org/landtravel.pdf> (accessed May 20, 2013).

Litman, T. (2008) Valuing Transit Service Quality Improvements. Victoria: Victoria Transport Planning Institute. Retrieved from http://www.vtpi.org/traveltime.pdf.

Luce, R. D. (1959) Individual Choice Behavior: A Theoretical Analysis," John Wiley, New York.

Mackett, R. (1994) Land use transportation models for policy analysis. Transportation Research Record, 1466. TRB, National Research Council, Washington, D.C.

Madden, J. F. (1980) Urban land-use and the growth in two-earner households. American Economic Review, 70(2), 191-197.

Madden, J.F. (1981) Why women work close to home, Urban Studies 18, 191-194.

Malaitham S. et al. (2013) An Analysis of Residential Location Choice Behavior in Bangkok Metropolitan Region: An Application of Discrete Choice Models for the Ranking of Alternatives. Journal of the Eastern Asia Society for Transportation Studies, Vol.9, 2013

Morrow-Jones, H. A. and Kim, J. H. (2009) Determinants of residential location decisions among the pre-elderly in Central Ohio. Journal of Transport and Land Use, 2(1), 47-64.

Matsuyuki M., Wakamiya R., Leeruttanawisut K. (2013) Study on Lifestyle Transformation under the Influence of Rail Transit in Bangkok -Focusing on Condominium Development along

Rail Transit. Proceeding of the Eastern Asia Society for Transportation Studies. Taipei, Taiwan

Mayo, S. (1973) Local public goods and residential location: an empirical test of the Tiebout hypothesis. Washington DC: Metropolitan Governance Committee, Resources for the Future.

McFadden, D. (1974) Conditional Logit Analysis of Qualitative Choice Behavior. In Zarembka, P. (ed.) Frontiers in Econometrics. New York: Academic Press, 1974.

McFadden, D. (1978) Modeling the choice of residential location. Spatial Interaction Theory and Planning Models. North Holland, Amsterdam, pages. 75-96.

Mills ,E.S. (1972) Studies in the structure of the urban economy. Washington DC: Resources for the Future.

Mokhtarian, P.L. and Cao X. (2008) Examining the impacts of residential self-selection on travel behavior: a focus on methodologies. Transportation Research Part B 42 (3), 204-228

Molin, E. and H. Timmermans (2003) cited in Bohte, W., K. Maat and B. van Wee (2009), Accessibility considerations in residential choice decisions: accumulated evidence from the Benelux. Paper presented at 82nd Annual Meeting of the Transportation Research Board, Washington D.C., 12 16 January 2003

Morera, F.J.A., Marrero, R.M.G. and Dios Ortúzar de J. (2004) Preference heterogeneity and willingness to pay for travel time. DOCUMENTO DE TRABAJO, 12.

Muconsult (2000), Mobility starts at the front door. The effect of the residential area on mobility and modal choice (Mobiliteit begint bij de woning. Het effect van de woonomgeving op de mobiliteit en de vervoerwijzekeuze), Delft: Connect

Muth, R. (1969) Cities and housing. Chicago: University of Chicago

Næss, P. (2009) Residential self-selection and appropriate control variables in land use – travel studies. Transport Reviews

Nicola, C. and Anne, N. (2009) Car Ownership and Mode of Transport to Work in Ireland, ESRI Working paper No.310, Provided in Cooperation with: The Economic and Social Research Institute (ESRI), Dublin.

Nurdden, A., Rahmat, R.A. and Ismail, A. (2007) Effect of transportation polices on modal shift from private car to public transport in Malaysia. Journal of Applied Sciences, 7 (7), 1013-1018.

Nurlaelaa, S. and Curtis, C. (2012) Modeling household residential location choice and travel behavior and its relationship with public transport accessibility, Curtin University of

Technology, Perth, Western Australia.

Office of Transport and Traffic Policy and Planning (2010) Mass Rapid Transit Master Plan in Bangkok Metropolitan Region: M-MAP, Ministry of Transport, Thailand.

Olaru, D. et al., (2011) Residential location and transit-oriented development in a new rail corridor, Transportation Research Part A 45 (2011) 219–237.

Parkany, E., R. Gallagher and P. Viveiros (2004) Are attitudes important for travel choice?, Transportation Research Record 1894, pp. 127-139.

Pickup, L., S.W. Town (1983), Commuting patterns in Europe: an overview of the literature, In: TRRL Supplementary Report 796, Berkshire: Transport and Road Research Laboratory

Pikora, T. et al. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. Social Science and Medicine, 56, 1693-1703.

Pinjari, A.R. et al. (2008a) Joint model of choice of residential neighborhood and bicycle ownership: accounting for self-selection and unobserved heterogeneity. Transp. Res. Record 2082, 17–26.

Pinjari, A.R., C.R. Bhat and D.A. Hensher (2009) Residential Self-Selection Effects in an Activity Time-use Behavior Model, Transportation Research Part B, 43 (7), pp. 729-748.

Pinjari, A.R., R.M. Pendyala, C.R. Bhat and P.A. Waddell (2007) Modeling Residential Sorting Effects to Understand the Impact of the Built Environment on Commute Mode Choice, Transportation, 34 (5), pp. 557-573.

Pinjari, A. R., Pendyala, R. M., Bhat, C. R., and Waddell, P. (2011) Modeling the choice continuum: An integrated model of residential location, auto ownership, bicycle ownership, and commute tour mode choice decisions. Transportation, 38(6), 933-958.

Plaut, P. O. (2006) The intra-household choices regarding commuting and housing. Transportation Research Part a-Policy and Practice, 40(7), 561-571.

Pollakowski, H.O. (1982) Urban Housing Markets and Residential Location. Lexington Books, Lexington, MA.

Pollakowski, M. (1975) A conditional logit model of residential choice. Presented at winter meetings of the Econometric Society (December).

Pushkarev, B., & Zupan, J. (1977) Public transportation and land use policy. Bloomington: Indiana University Press

Renne, J. L., Wells, J. S., and Bloustein, E. J. (2005) Transit-Oriented Development: Developing a Strategy to Measure Success, National Cooperative Highway Research Project 20-65(5), Washington, D.C.: Transportation Research Board.

Rivera. M.A.I. and Tiglao, N.C.C. (2005). Modelling residential location choice, workplace location choice and mode choice of two-worker households in metro Manila. Proceedings of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1167 – 1178.

Rouwendal, J 1998, 'Search theory, spatial labor markets and commuting', Journal of Urban Economics, vol. 43, pp. 1-22.

Rouwendal, J & Meijer, E 2001, 'Preferences for housing, jobs, and commuting: a mixed logit analysis', Journal of Regional Science, vol. 41, no. 3, pp. 475-505.

Rouwendal, J & Rietvald, P 1994, 'Changes in commuting distances of Dutch households', Urban Studies, vol. 31, no. 9, pp. 1545-57.

Sakpongsatorn, W. (2010) Travel Behavior of Residents in Condominiums along Bangkok Mass Transit System Sky train on Sukhumvit Road. Master thesis submitted to the Urban and Regional Planing department.

Salomon I. and Mokhtarian P. L., (1998) "What Happens When Mobility-Inclined Market Segments Face Accessibility-Enhancing Policies?" Transportation Research D 3(3), 129-140.

Singell, LD & Lillydahl, JH 1986, 'An empirical pattern of the commute to work patterns of males and females', Urban Studies, vol. 2, pp. 119-29.

Schwanen, T. and Mokhtarian, P.L. (2005), What if you live in the wrong neighborhood? The impact of residential neighborhood type dissonance on distance travelled, Transportation Research Part D, 10(2), pp. 127-151

Schwanen, T. and P.L. Mokhtarian (2005a) What if you live in the wrong neighborhood? The impact of residential neighborhood type dissonance on distance travelled, Transportation Research Part D, 10 (2), pp. 127-151.

Schwanen, T. and P.L. Mokhtarian (2005b) What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods?, Journal of Transport Geography, 13 (1), pp. 83-99.

Schwanen, T. and P.L. Mokhtarian (2007), The Role of Attitudes toward Travel and Land Use in Residential Location Behavior: Some Empirical Evidence from the San Francisco Bay Area, Housing Policy Debate, 18 (1), pp. 171-207.

Sermons, M.W. and Koppelman, F.S. (2001) Representing the differences between female and male commute behavior in residential location choice models. Journal of Transport Geography. Vol. 9, pages 101-110.

Singleton Jr., R. A. and Straits, B. C. (2005) Approaches to Social Research, 4th edn (New York:

Oxford University Press).

Simpson, W. (1987) Workplace location, residential location, and urban commuting. Urban Studies, 24(2), 119-128.

Sirikolkarn, P. (2008) The Effect of Mass Transit Systems on Price of Condominium in Bangkok. Undergraduate Honor Thesis, Department of Economics University of California Berkeley.

Schutt, R. K. (2004) Investigating the Social World: The Process and Practice of Research, 4th edn (Thousand Oaks, CA: Pine Forge Press).

Srinivasan, S. (2000) Linking Land Use and Transportation: Measuring the Impact of Neighborhood-scale Spatial Patterns on Travel Behavior. Doctoral thesis submitted to the Department of Urban Studies and Planning, MIT, Cambridge, MA.

Sultana, S. (2006) What about dual-earner households in jobs-housing balance research? An essential issue in transport geography. Journal of Transport Geography, 14(5), 393-395.

Sung, H. (2011), Transit-oriented development in a high-density city: Identifying its association with transit ridership in Seoul, Korea, The Korea Transport Institute, 2311 Daewha-dong, Ilsanseo-gu, Goyang-si, Gyeonggi-do 411-701, Republic of Korea.

Surprenant-Legault, J. (2010) The spatial patterns affecting home to work distances of two-worker households, In partial fulfillment of the Masters of Urban Planning Degree School of Urban Planning McGill University April

Suzuki, H. et al. (2013) Transforming Cities with Transit: Transit and Land-Use Integration for Sustainable Urban Development. The World Bank, Washington, DC.

Tabachnick B. G. and Fidell L.S. (1996) Using Multivariate Statistics. California State University, Northridge.

Tangphaisankun, A. (2010) Paratransit: Urban transportation planning challenges in developing countries, Journal of International City Planning, Intenational Symposium on City Planning.

Tangphaisankun, A. et al. (2009) Influences of Paratransit as A Feeder of Mass Transit System in Developing Countries Based on Commuter Satisfaction. Journal of the Eastern Asia Society for Transportation Studies, Vol.8, 2009

TCRP (Transit Cooperative Research Program) (1995) An Evaluation of the Relationships Between Transit and Urban Form. Research Results Digest. Washington DC: Transportation Research Board.

TCRP (Transit Cooperative Research Program) (2007) Chapter 17: Transit oriented development.

In Report 95: Traveller response to transportation system changes. Washington, DC: Transportation Research Board.

Timmermans, H, Borgers, A, Dijk, J & Oppewal, H 1992, 'Residential choice behavior of dual earner households: a decompositional joint choice model', Environment and Planning A, vol. 24, pp. 517-33.

Tkocz, Z & Kristensen, G 1994, 'Commuting distance and gender: a spatial urban model', Geographical Analysis, vol. 26, pp. 1-14.

Trans Link (2010) Transit-Oriented Communities: A literature review on the relationship between the built environment and transit ridership. Published Online

Train, K. (2009) Discrete choice methods with simulation. Cambridge University Press, New York.

Tsai, Y.-H. (2008) Impacts of self-selection and transit proximity on commute mode choice: evidence from Taipei rapid transit system, Springer-Verlag, May 1st .

Van Ommeren, JN, Rietvald, P & Nijkamp, P 1998, 'Spatial moving behavior of two earner households', Journal of Regional Science, vol. 38, pp. 23-41.

Van Wee, B. (2009) Self-selection: a key to a better understanding of location choices, travel behavior, and transport externalities? Paper presented at the BIVEC-GIBET research day, May 27th, 2009, Brussels, Vrije Universiteit.

Van Wee, B. et al. (2002) Preferences for modes, residential location and travel behaviour: the relevance for land-use impacts on mobility. European Journal of Transport and Infrastructure Research, 2, no. 3 / 4 pp 305-316

Van Wee, B. et.al.(2003) Preferences for modes, residential location and travel behavior: the relevance for land- use impacts on mobility. EJTIR,2, no.3/4(2002),pp 305-316

Vega, Amaya & Reynolds-Feighan, Aisling, (2009) A methodological framework for the study of residential location and travel-to-work mode choice under central and suburban employment destination patterns. Transportation Research Part A: Policy and Practice, Elsevier, vol. 43(4), pages 401-419, May.

Vichiensan, V. et al. (2007) Land Use/Transportation Interaction in Bangkok: Impact of Urban Rail Transit and Pilot Model Development. Compendium of Papers, the 86th TRB Annual Meeting, January 2007, Washington D.C., USA.

Vichiensan, V., Miyamoto K., Sato K., and Kitazume K. (2003) Introduction of Land Use Model to Improve Travel Demand Forecasting in a Metropolitan Area: A Case of TRANUS Application to Sapporo, Journal of the Eastern Asian Society for Transportation Studies, Vol.5, No.6, pp.

Vichiensan, V., Miyamoto K., Sato K., and Kitazume K. (2009) Integrated Approach to Analyze Land-Use Transport and Environment in Bangkok: Case Studies of Railway Impact and TRANUS Application.

Waddell, P. (1993) Exogenous workplace choice in residential location models: Is the assumption valid?. Geographical Analysis, Vol. 25, No. 1.

Waddell, P. (1996) Accessibility and Residential Location: The Interaction of Workplace, Residential Mobility, Tenure, and Location Choices', in Taxation, Resources and Economic Development Conference, Lincoln Land Institute.

Waddell, P. et al. (2008) Modeling interdependence in household residence and workplace choice. Transp. Res. Record 2003, 84–92.

Waddell, P., Bhat, C., Eluru, N., wang, M. and Pendyala, R.M. (2006) Modeling the Interdependence in Household Residence and Workplace Choices. Submitted for Presentation and Publication to the Transportation Research Board.

Wasoontarasook, V., Nakamura, K., Kato, H., Hayashi, Y. (2012) Transit Oriented Development Perspectives for Low-Carbon City in Bangkok, Thailand

Watterson, W.T. (1997) Dynamics of job and housing locations and the work trip: Evidence from the Puget Sound Transportation Panel. Transportation Research Record 1463. TRB, National Research Council, Washington, D.C., pages 1-9.

Weisbrod G (1978) Determinants of residential location demand: implications for transportation policy, MS thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge

Weisbrod, G., Ben-Akiva, M. and Lerman, S. (1980) Tradeoffs in residential location decisions:Transportation versus other factors. Transportation Policy and Decision-Making, Vol.1, No.1. pp. 13-26.

White, M., (1986) Sex differences in urban commuting patterns, American Economic Review, Papers and Proceedings, 76, 368-372.

Website

The National Statistical Office of Thailand, www.nso.go.th, (Accessed in March, 2012)

Bureau of Transport Statistic http://www.bts.gov/other/MFD_tmip/papers/landuse/compendium/dvrpc_appb.htm (Accessed in May, 2013)

Bangkok Mass Transit System Public Company Limited (BTSC), http://www.bts.co.th (Accessed in May, 2014)

BTS Group Holdings Public Company Limited, http://bts-th.listedcompany.com/bts_ridership.html (Accessed in January, 2014)

BTS Group Holdings Public Company Limited. BTS annual report 2010/2011 http://bts.listedcompany.com/misc/ar/20102011_en.pdf (Accessed in May, 2013)

Bangkok Metro Public Company Limited (BMCL), http://www.bangkokmetro.co.th (Accessed in March, 2014)

Discrete Choice Methods with Simulation: a complete on-line course with textbook, videotaped lectures for web-viewing, problem sets, and links to relevant articles, http://eml.berkeley.edu/~train/ (Accessed in February, 2014)

Mass Rapid Transit Master Plan in Bangkok Metropolitan Region http://en.wikipedia.org/wiki/Mass_Rapid_Transit_Master_Plan_in_Bangkok_Metropolitan_Region (Accessed in February, 2014)

Transport Data and Model Center (TDMC) http://www.otp.go.th/doc/project/tdmc%20V/EXECUTIVE%20SUMMARY%20REPORT_Eng.pdf (Accessed in January, 2014)

The Real Estate Information Center's (REIC) statistics, http://www.reic.or.th/ (Accessed in January, 2014)

RESEARCH PUBLICATIONS

1) Sanit, P., Nakamura, F., Okamura, T., and Wang, R. (2012) Evaluating Transit-Oriented Development along Urban Railway in Bangkok, Thailand. International Symposium on City Planning 2012 Journal, pp.111-123.

2) Sanit, P., Nakamura, F., Tanaka, S., and Wang, R. (2013) Residential Location Choice Analysis along the Urban Railway Corridor in Bangkok, Thailand. Proceeding of 13th World Conference on Transport Research (WCTR), Rio de Janeiro, Brazil.

3) Sanit, P., Nakamura, F., Tanaka, S., and Wang, R. (2013) Location and Mode Choice Decision Mechanism Analysis of Multi-Worker Household in Bangkok, Thailand. Journal of the Eastern Asia Society for Transportation Studies Vol. 10.

4) Sanit, P., Nakamura, F., Tanaka, S., and Wang, R. (2013) Analysis of Location Choice Behavior and Urban Railway Commuting of Bangkok's Households. International Symposium on City Planning 2013 Journal.

5) Sanit, P., Nakamura, F., Tanaka, S., and Wang, R. (2013) Assessing Impact of Residential Self-selection on Travel Choice Behavior in Bangkok, Thailand. Japan Society of Civil Engineers. *(Under review)*

6) Sanit, P., Nakamura, F., Tanaka, S., and Wang, R. (2012) Travel Choice Behavior Analysis of Urban Railway Residents in Bangkok, Thailand. Proceedings of 46th Infrastructure Planning Conference, Japan Society of Civil Engineers, CD-ROM, November 2-4, 2012, Saitama, Japan.

APPENDIX A

QUESTIONNAIRE SHEET FOR THE FIRST FIELD SURVEY

Yokohama National University, Japan
Transportation laboratory
Graduation School of Urban Innovation
79-5 Tokiwadai Hodogaya
Yokohama 240-8501, Japan
Tel/Fax : +81-45-339-4039
Website: http://www.cvg.ynu.ac.jp/G4/english/lab4-e.html

Questionnaire on Travel Behavior and Residential Choice Decision

The questionnaire is part of a study in assessing impact of residential self-selection on travel choice behavior in developing countries, a case study of Transit Oriented Development in Bangkok. The researcher is PhD student of transportation Laboratory, Institute of Urban Innovation, Yokohama National University, Japan

The main objective is to investigate the existing situation on travel choice behavior of residents living close proximity to mass transit as well as to examine what factors are significantly influencing on their mode choice decision. This questionnaire consists of 3 pats including residential location characteristics, travel behavior characteristics, and individual data.

The data on travel behavior and residential location choice will be useful for Transit Oriented Development sustainability in order to expedite the advancement of urban and transportation development in the city. Our research team would like to thank you for all support and the data will be use only for research purpose

Thank you very much

Professor Fumihiko NAKAMURA
Advisor

Associate Professor Shinji TANAKA
Co-Advisor

Peamsook Sanit
PhD Student

Survey team

For Staff only
Name (..) Sampling No. (..........)
Place (...) Date(.........................)
Station (………………………………………………..) Time (..........................)

Target groups
1. Permanent resident of condominium/apartment (NOT including short period stay)
2. Worker or student (university level) (ONLY work trip or school trip)

Please mark √ in the blank below

Example *When did you move to the present house?* ☑ *Before 1999* ☐*After 1999*

PART 1 : Residential Characteristics

1. Is your house located near BTS/MRT station? (Within 1 km distance ring of the nearest station)
   ☐ Yes Station…………………………….
   Distance between home and station…………………meters
   ☐ No
   Location……………………………......................................……………
2. When did you move to the present house? ☐Before 1999 ☐After 1999
3. What is the type of your house? ☐Condominium ☐Apartment ☐Others..................................
4. What is the type of house occupancy ☐Buy………………….Baht ☐Rent…………………Baht pet month ☐Others.................................
5. How many persons are there in your house?...persons
6. What is the type of family ☐Live alone ☐Couple without child ☐Couple with child ☐Parent/sibling ☐Roommate/friend ☐ Others.........................
7. Do you live with children under 15 years old? ☐Yes ☐No
8. The size of your house…………………m^2
   Total room…………rooms
9. Is there parking area at your building? ☐Yes ☐No
10. Is there parking fee ☐Yes……….baht per month ☐No
11. How many days in a week do you stay in this house?
    ☐every day ☐Only weekdays ☐Only holiday ☐Only……………...
12. If you don't live in this house every day, where is another place located?
    ……………………………………………………………………………………………
13. Which places is your house close proximity to?
    ☐Shopping center ☐Park ☐School ☐market
    ☐Hospital ☐Entertainment/Complex ☐ Others………………..
14. Accessibility level
    - The shortest distance to bus stop………………..meters
    - The shortest distance to main road………………..meters
    - The shortest distance to express way………………..meters
15. Was your previous house located near BTS/MRT station? (Within 1 km distance ring of the nearest station)
    ☐ Yes Station…………………………….
    Distance between home and station…………………meters
    ☐ No
    Location……………………………......................................……………
16. What was the type of your previous house?
    ☐Condominium ☐Apartment ☐Single detached house
    ☐Others...........................

17. **Please mark √ in the blank that best corresponds with your opinion**

	Reasons for moving house	**Yes**	**No**
1.	I graduated/ started getting job		
2.	I got married		
3.	Increasing of members		
4.	I/other members changed the workplace/school location		
5.	I/other members changed from single detached house to live in condominium/apartment		
6.	I/other members want to have our own house		
7.	I/other members want the better neighborhood		
8.	I/other members want to live near shopping center		
9.	I/other members want to live near school/workplace		
10.	I/other members want to travel by BTS/MRT		
11.	Others (…………………………………………………………………………)		

18. Do you make decision to buy/rent this house by yourself? If no, who makes decision?

☐Yes ☐No(…………………..) Move to Question No. 19

19. **Please mark √ in the blank that best corresponds with your opinion**

	Reasons for choosing this location	**Yes**	**No**
1.	Affordable price		
2.	Good design		
3.	High level of accessibility		
4.	I/other members can to go work/school comfortably		
5.	I/other members want to use BTS/MRT		
6.	Near school/workplace		
7.	Livable neighborhood		
8.	Near shopping center		
9.	Near my relatives, friends or family's house		
10.	Others (…………………………………………………………………………)		

20. After relocating, please explain the changing of the following list below (If you live alone, please answer only the question mentioned to you)

- My workplace/school location ☐ Change ☐ No change
- Other members' workplace/school location ☐ Change ☐ No change
- My travel time ☐ Decrease ☐ Same ☐ Increase
- Other members' travel time ☐ Decrease ☐ Same ☐ Increase
- My travel cost ☐ Decrease ☐ Same ☐ Increase
- Other members' travel cost ☐ Decrease ☐ Same ☐ Increase
- My frequency of using BTS/MRT ☐ Decrease ☐ Same ☐ Increase
- Other members' frequency of using BTS/MRT ☐ Decrease ☐ Same ☐ Increase
- My frequency of using car ☐ Decrease ☐ Same ☐ Increase
    - Other members' frequency of using car ☐ Decrease ☐ Same ☐ Increase
    - The number of car occupancy ☐ Decrease ☐ Same ☐ Increase
    - Others (……………………………) ☐ Decrease ☐ Same ☐ Increase

Part 2: Travel behavior characteristics

Before moving How did you go to work/school?

☐ **BTS/MRT**
☐ **Auto (car/motorcycle)**
☐ **Other modes**(………………….)

Before moving Did you have a plan or preference on mode choice for your work/school trip

☐ Yes, I preferred using —Please specific→ ☐**BTS/MRT** ☐**Auto (car/motorcycle)** ☐**Other modes**(………………….)

☐ No, I haven't decided on mode choice

After moving How do you go to work/school now?

☐ **BTS/MRT** → Please answer ONLY questions no. 1-10

☐ **Auto (car/motorcycle)** → Please answer ONLY questions no. 11-21

☐ **Other modes**(…………….) → Please answer ONLY question no. 22

1. How often do you travel by BTS/MRT?
   1.1 Work trip/school trip How often? ☐ Everyday ☐ Sometimes ☐ Only……....
   1.2 Shopping trip How often? ☐ Everyday ☐ Sometimes ☐ Only...........
   1.3 Others……………….. How often? ☐ Everyday ☐ Sometimes ☐ Only..........
2. How you access to the nearest station
   ☐ Walk……..minutes ☐ Motorcycle taxi………minutes ☐ Bicycle…..Minutes
   ☐ Car/Motrocycle……minutes ☐ Taxi………minutes ☐ Vanpool… Minutes
   ☐ Other(…………)………minutes
3. Is your workplace located near BTS/MRT station? (Within 1 km distance ring of the nearest station)
   ☐ Yes Station…………………………….
   Distance between home and station…………………meters
   Have you ever go outside of you workplace by BTS/MRT at lunch time?
   ☐ Often ☐ Sometimes ☐ never

   ☐ No
   Location……………………………......................................…………….
4. Do you have to pick up/drop off someone when you go to work/ back home?
   ☐ Yes ☐ No
5. How many travelers (students or workers) are there totally in your house? ………………Persons
6. Do they travel by BTS/MRT for their work /school trip?
   ☐ Yes …………….. Persons
   ☐ No

7. Please write down the itinerary trip data on your work/school trip

For example

Location/Segment		*Transport mode/ Others*	*Total Time Consumed (minutes)*	*Fare or Out of Pocket (Baht)*
From (Origin)	*To (Destination)*			
Home	*Phayathai BTS station*	*walk*	*5*	*0*
		Waiting for train	*5*	*0*
Phayathai BTS station	*Siam BTS station*	*BTS*	*5*	*20*
Siam BTS station	*Chulalongkorn university*	*Motorcycle taxi*	*5*	*20*
Total			*20*	*40*

Please write down your data

Location/Segment		**Transport mode/ Others**	**Total Time Consumed (minutes)**	**Fare or Out of Pocket (Baht)**
From (Origin)	**To (Destination)**			
Total				

8. **<u>ONLY CAR OWNER</u>** Have you ever gone to work/school by your own auto?

   ☐Yes Total travel cost......................Baht Total travel time.................. Minutes

   **Private car: Travel cost = fuel charge+express way cost (If you have) + parking cost (if you have)*

   *** In Bangkok Fuel charge = 4 Baht/ Km OR Gasoline= 2 Baht/ Km*

   ☐No

9. Have you ever gone from to work/school by taxi?

   ☐Yes Taxi cost......................Baht Total travel time ....Minutes

   ☐No

10. Will you continue using BTS/MRT if the ticket cost increase? ☐Yes ☐NO

Question for CAR USER

11. Is your workplace located near BTS/MRT station? (Within 1 km distance ring of the nearest station)

   ☐ Yes Station…………………………….

   Distance between home and station…………………meters

   Have you ever go outside of you workplace by BTS/MRT at lunch time?

   ☐ Often ☐ Sometimes ☐ never

   ☐ No

   Location……………………………..…………….

12. Do you have easy pass card of express way? ☐Yes ☐No

13.Does your company pay for your parking cost? ☐Yes ☐No

14.Is there a parking area at your workplace/school? ☐Yes ☐No

15.Do you have to drop-off or pick-up anyone else somewhere? ☐Yes ☐No

16.Apart from your workplace, do you have to go to other places? ☐Yes ☐No

17.**<u>Question for people who does NOT LIVE ALONE</u>**

- Are there other members in your house to travel by BTS / MRT ☐Yes ☐No
- Are there other members in your house to travel by auto ☐Yes ☐No

18. How long do you spend on traveling to workplace/school? ....minutes
19. How much do you spend on traveling to workplace/school? ....Baht

**Private car: Travel cost = fuel charge+express way cost (If you have) + parking cost (if you have)*

*** In Bangkok Fuel charge = 4 Baht/ Km OR Gasoline= 2 Baht/ Km*

20. If you must to go to work/school by BTS/MRT, please explain your itinerary trip data

For example

Location/Segment		*Transport mode/ Others*	*Total Time Consumed (minutes)*	*Fare or Out of Pocket (Baht)*
From (Origin)	*To (Destination)*			
Home	*Phayathai BTS station*	*walk*	*5*	*0*
		Waiting for train	*5*	*0*
Phayathai BTS station	*Siam BTS station*	*BTS*	*5*	*20*
Siam BTS station	*Chulalongkorn university*	*Motorcycle taxi*	*5*	*20*
Total			*20*	*40*

Please write down your data

Location/Segment		**Transport mode/ Others**	**Total Time Consumed (minutes)**	**Fare or Out of Pocket (Baht)**
From (Origin)	**To (Destination)**			
Total				

21. **Please select reasons why you go to work/school by your own car**

☐Workplace location is far from station

☐Public transport is not safe

☐Public transport is more expensive

☐Pick-up/drop-off

☐Car is more comfortable

☐Prefer 1 mode choice traveling

☐Public transport spends more time traveling

☐Public transport is not reliable

☐Heavy bag

☐Others...

Question for OTHER MODE USER

22. How do you go to work/study? How long does you spend traveling?

☐Walk____min. ☐Bicycle____min. ☐Bus ____Min ☐Boat____min

☐Motorcycle taxi____min ☐Taxi/Tuk Tuk____min ☐Van pool____min

☐Songtaew______min ☐Shuttle bus of workplace/school_____min

☐Shuttle bus of condominium/apartment______min ☐Others……………

Part 3: Personal data

1. Sex ☐Male ☐Female
2. Age ☐Less than 15 ☐15-20 ☐21-30 ☐ 31-40 ☐41-50 ☐51-60 ☐60-80 ☐More than 80
3. Education ☐Lower than undergraduate ☐Under graduate ☐Graduate
4. Occupation ☐Public officer ☐Employee ☐Business owner ☐Hirer ☐Student ☐Unemployment ☐Others...............................
5. Car ownership ☐Yes Totally number of car...................... ☐No
6. Driving license ☐Yes ☐No
7. Monthly income (Baht/month) *(**In case of student income= parent's income)*
8. ☐Less than 10,000 ☐10,001-20,000 ☐20,001-30,000 ☐30,001-40,000 ☐40,001-50,000 ☐50,001-60,000 ☐60,001-70,000 ☐70,001-80,000 ☐80,001-100,000 ☐More than100,000
9. Household income (Baht/month) *(* Total income of all members)*
   ☐Less than 10,000 ☐10,001-20,000 ☐20,001-30,000 ☐30,001-40,000 ☐40,001-50,000 ☐50,001-60,000 ☐60,001-70,000 ☐70,001-80,000 ☐80,001-100,000 ☐More than 100,000
10. ***ONLY worker who do not live alone***
    How many workers does your family have? ....persons
    Do you have the highest income ☐Yes ☐No

Thank you very much

APPENDIX B

QUESTIONNAIRE SHEET FOR THE SECOND FIELD SURVEY

Yokohama National University, Japan
Transportation laboratory
Graduation School of Urban Innovation
79-5 Tokiwadai Hodogaya
Yokohama 240-8501, Japan
Tel/Fax ：+81-45-339-4039
Website: http://www.cvg.ynu.ac.jp/G4/english/lab4-e.html

Questionnaire on Travel Behavior and Residential Choice Decision

The questionnaire is part of a study in assessing impact of residential self-selection on travel choice behavior in developing countries, a case study of Transit Oriented Development in Bangkok. The researcher is PhD student of transportation Laboratory, Institute of Urban Innovation, Yokohama National University, Japan

The main objective is to investigate the existing situation on travel choice behavior of residents living close proximity to mass transit as well as to examine what factors are significantly influencing on their mode choice decision. This questionnaire consists of 6 pats including travel behavior and attitude on urban railway mode choice, on auto mode choice as well as other mode choices, factors on mode choice selection, attitude on residential location choice and individual data.

The data on travel behavior and residential location choice will be useful for Transit Oriented Development sustainability in order to expedite the advancement of urban and transportation development in the city. Our research team would like to thank you for all support and the data will be use only for research purpose

Thank you very much

Professor Fumihiko NAKAMURA
Advisor

Associate Professor Shinji TANAKA
Co-Advisor

Peamsook Sanit
PhD Student

Survey team

For Staff only	
Name (...)	Sampling No. (..........)
Place (..)	Date(.........................)
Station (……………………………………………..)	Time (..........................)

Target groups 1. Permanent resident of condominium/apartment (NOT including short period stay)
2. Worker or student (university level) (ONLY work trip or school trip)

Please mark √ in the blank below

Example *After moving how do you go to work/school* ☑ BTS/MRT ☐Auto

House location	☐	Near BTS/MRT station within 1 km Station……………………………. Distance between home and station…………………meters
	☐	Far from BTS/MRT station (beyond 1 km) Location………………………………………………
Workplace location	☐	Near BTS/MRT station within 1 km Station……………………………. Distance between home and station…………………meters
	☐	Far from BTS/MRT station (beyond 1 km) Location………………………………………………….

Before moving How did you go to work/school?

☐ **BTS/MRT**
☐ **Auto (car/motorcycle)**
☐ **Other modes**(………………….)

Before moving Did you have a plan or preference on mode choice for your work/school trip

☐ Yes, I preferred using (Please specific) → ☐**BTS/MRT** ☐**Auto (car/motorcycle)** ☐**Other modes**(………………….)

☐ No, I haven't decided on mode choice

After moving How do you go to work/school now?

☐ **BTS/MRT**	→ please answer ONLY	1 4 5
☐ **Auto (car/motorcycle)**	→ please answer ONLY	2 4 5
☐ **Other modes**(…………….)	→ please answer ONLY	3 4 5

Part 1 Travel behavior and attitude on urban railway mode (BTS/MRT)

1. Do you have smart pass card of BTS/MRT (Rabbit Card)? ☐Yes ☐ No
2. Does your company pay for your traveling cost? ☐Yes ☐ No
3. How many times do you travel by BTS/MRT in one week?

☐Everyday ☐ 3-4 Days per week ☐1-2 Days per week

☐Only……………..

Question for people who does NOT LIVE ALONE

4. Are there other members in your house to travel by BTS / MRT ☐Yes ☐ No

5. Please write down the itinerary trip data on your work/school trip

For example

Location/Segment		*Transport mode/ Others*	*Total Time Consumed (minutes)*	*Fare or Out of Pocket (Baht)*
From (Origin)	*To (Destination)*			
Home	*Phayathai BTS station*	*walk*	*5*	*0*
		Waiting for train	*5*	*0*
Phayathai BTS station	*Siam BTS station*	*BTS*	*5*	*20*
Siam BTS station	*Chulalongkorn university*	*Motorcycle taxi*	*5*	*20*
Total			*20*	*40*

Please write down your data

Location/Segment		**Transport mode/ Others**	**Total Time Consumed (minutes)**	**Fare or Out of Pocket (Baht)**
From (Origin)	**To (Destination)**			
Total				

6. **ONLY CAR OWNER** Have you ever gone to work/school by your own auto?

☐Yes Total travel cost......................Baht Total travel time.................. Minutes

**Private car: Travel cost = fuel charge+express way cost (If you have) + parking cost (if you have)*

*** In Bangkok Fuel charge = 4 Baht/ Km OR Gasoline= 2 Baht/ Km*

☐No

7. Have you ever gone from to work/school by taxi?

☐Yes Taxi cost......................Baht Total travel time ....Minutes

☐No

8. Will you continue using BTS/MRT if the ticket cost increase? ☐Yes ☐NO

Part 2 Travel behavior and attitude on auto mode (car/motorcycle)

1. Do you have easy pass card of express way? ☐Yes ☐No
2. Does your company pay for your parking cost? ☐Yes ☐No
4. Is there a parking area at your workplace/school? ☐Yes ☐No
5. Do you have to drop-off or pick-up anyone else somewhere? ☐Yes ☐No
6. Apart from your workplace, do you have to go to other places? ☐Yes ☐No
7. **Question for people who does NOT LIVE ALONE**

7.1 Are there other members in your house to travel by BTS / MRT ☐Yes ☐No

7.2 Are there other members in your house to travel by auto ☐Yes ☐No

8. How long do you spend on traveling to workplace/school? ....minutes
9. How much do you spend on traveling to workplace/school? ....Baht

**Private car: Travel cost = fuel charge+express way cost (If you have) + parking cost (if you have)*

*** In Bangkok Fuel charge = 4 Baht/ Km OR Gasoline= 2 Baht/ Km*

10. If you must to go to work/school by BTS/MRT, please explain your itinerary trip data

For example

Location/Segment		*Transport mode/ Others*	*Total Time Consumed (minutes)*	*Fare or Out of Pocket (Baht)*
From (Origin)	*To (Destination)*			
Home	*Phayathai BTS station*	*walk*	*5*	*0*
		Waiting for train	*5*	*0*
Phayathai BTS station	*Siam BTS station*	*BTS*	*5*	*20*
Siam BTS station	*Chulalongkorn university*	*Motorcycle taxi*	*5*	*20*
Total			*20*	*40*

Please write down your data

Location/Segment		**Transport mode/ Others**	**Total Time Consumed (minutes)**	**Fare or Out of Pocket (Baht)**
From (Origin)	**To (Destination)**			
Total				

Part 3 Travel behavior and attitude on other mode choices

1. How do you go to work/study? How long does you spend traveling?

☐Walk____min. ☐Bicycle____min. ☐Bus ____Min
☐Boat____min ☐Motorcycle taxi____min ☐Taxi/Tuk Tuk____min
☐Van pool____min ☐Songtaew______min
☐Shuttle bus of workplace/school______min
☐Shuttle bus of condominium/apartment_______min ☐Others……………

2. From question no. 1, why do you choose to travel by this mode?

	Please circle on the choice you think	Strongly disagree	Disagree	no idea	Agree	Strongly agree
Example	*Travelling by BTS/MRT is expensive*	1	2	3	4	5
2.1	House is too far from station	1	2	3	4	5
2.2	It is cheapest cost	1	2	3	4	5
2.3	It is fastest	1	2	3	4	5
2.4	Workplace/school is too far from station	1	2	3	4	5
2.5	Prefer one mode traveling / Dislike changing mode	1	2	3	4	5
2.6	BTS or MRT are too congested during peak hours	1	2	3	4	5
2.7	There is low accessibility to station	1	2	3	4	5

Part 4 Factors on mode choice selection

1. Attitude on selecting mode choice to go to workplace/school

	Please circle on the choice you think	Strongly not important	Not important	no idea	Important	Strongly important
Example	Prefer only on mode choice from house to workplace/school	1	2	3	4	5
1.1	Prefer shortest travel time	1	2	3	4	5
1.2	Prefer cheapest travel cost	1	2	3	4	5
1.3	Prefer only one mode choice from house to workplace/school	1	2	3	4	5
1.4	Prefer shortest waiting time	1	2	3	4	5
1.5	Prefer reliable time schedule	1	2	3	4	5
1.6	Prefer owning own car and travel by car	1	2	3	4	5
1.7	Prefer vehicle that is environmental friendly					

2. Attitude on using BTS/MRT

	Please circle on the choice you think	Strongly disagree	Disagree	no idea	Agree	Strongly agree
Example	*Travelling by BTS/MRT is comfortable*	1	2	3	4	5
2.1	Travelling by BTS/MRT is comfortable	1	2	3	4	5
2.2	Travelling by BTS/MRT is fun	1	2	3	4	5
2.3	Travelling by BTS/MRT is relaxing	1	2	3	4	5
2.4	Travelling by BTS/MRT is fashionable	1	2	3	4	5
2.5	Travelling by BTS/MRT is safe	1	2	3	4	5
2.6	Travelling by BTS/MRT is environmental friendly	1	2	3	4	5
2.7	Travelling by BTS/MRT saves travel time	1	2	3	4	5
2.8	Travelling by BTS/MRT saves travel cost	1	2	3	4	5
2.9	Travelling by BTS/MRT decrease number of car in family	1	2	3	4	5

3. Attitude on using auto

Please circle on the choice you think		Strongly disagree	Disagree	no idea	Agree	Strongly agree
Example	*Travelling by car is comfortable*	1	2	3	4	5
3.1	Travelling by car is fast	1	2	3	4	5
3.2	Travelling by car is comfortable	1	2	3	4	5
3.3	Travelling by car is fun	1	2	3	4	5
3.4	Travelling by car is relaxing	1	2	3	4	5
3.5	Travelling by car is fashionable	1	2	3	4	5
3.6	Travelling by car is safe	1	2	3	4	5
3.7	Travelling by car is environmental friendly	1	2	3	4	5
3.8	Travelling by car saves travel time	1	2	3	4	5
3.9	Travelling by car saves travel cost	1	2	3	4	5
3.10	Owning car represents high income					
3.11	House is too far from station	1	2	3	4	5
3.12	Workplace/school is too far from station	1	2	3	4	5
3.13	Prefer one mode traveling / Dislike changing mode	1	2	3	4	5

Part 5 Attitude on residential location choice

1. Do you make decision to buy/rent this house by yourself? If no, who makes decision?
   ☐Yes ☐No(…………………..)
2. When did you move to the present house? ☐Before 1999 ☐After 1999
3. What is the type of your house? ☐Condominium ☐Apartment ☐Others..................................
4. What is the type of house occupancy ☐Buy ☐Rent ☐Others...................
5. What is the type of family ☐Live alone ☐Couple without child ☐Couple with child ☐Parent/sibling ☐Roommate/friend ☐Others...................
6. Is there parking area at your building ☐Yes ☐No
7. Do you stay only this house ☐Yes ☐No
8. Please circle on the choice you think

		Strongly not important	Not important	no idea	Important	Strongly important
Example	*The importance distance to shopping area*	1	2	3	4	5
8.1	The importance distance to BTS/MRT station	1	2	3	4	5
8.2	The importance distance to workplace/school	1	2	3	4	5
8.3	The importance distance to shopping area	1	2	3	4	5
8.4	The importance distance to public facilities	1	2	3	4	5
8.5	The importance distance to green area	1	2	3	4	5
8.6	The importance distance to child's school *(ONLY couple with child)*	1	2	3	4	5

Personal data

1. Sex ☐Male ☐Female
2. Age ☐Less than 15 ☐15-20 ☐21-30 ☐ 31-40 ☐41-50 ☐51-60 ☐60-80 ☐More than 80
3. Education ☐Lower than undergraduate ☐Under graduate ☐Graduate
4. Occupation ☐Public officer ☐Employee ☐Business owner ☐Hirer ☐Student ☐Unemployment ☐Others..............................
5. Car ownership ☐Yes Totally number of car..................... ☐No
6. Driving license ☐Yes ☐No
7. Monthly income (Baht/month) *(**In case of student income= parent's income)*
8. ☐Less than 10,000 ☐10,001-20,000 ☐20,001-30,000 ☐30,001-40,000 ☐40,001-50,000 ☐50,001-60,000 ☐60,001-70,000 ☐70,001-80,000 ☐80,001-100,000 ☐More than100,000
9. Household income (Baht/month) *(* Total income of all members)*
   ☐Less than 10,000 ☐10,001-20,000 ☐20,001-30,000 ☐30,001-40,000 ☐40,001-50,000 ☐50,001-60,000 ☐60,001-70,000 ☐70,001-80,000 ☐80,001-100,000 ☐More than 100,000
10. ***ONLY worker who do not live alone***
    How many workers does your family have? ....persons
    Do you have the highest income ☐Yes ☐No

Thank you very much