Technical Report Documentation Page

1. Project No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/11/161127-1		

4. Title and Subtitle	5. Report Date
Understanding Emerging Commuting Trends in a Weekly Travel Decision Frame--Implications for Mega Region Transportation Planning	September 2011
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Ming Zhang and Binbin Chen	Report 161127

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Center for Transportation Research University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, TX 78701	11. Contract or Grant No. 10727

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Southwest Region University Transportation Center Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Supported by general revenues from the State of Texas.

16. Abstract

National transportation statistics have shown the rise of long-distance, trans-regional commute (LDC/TRC) in the US. Four societal factors contribute to the trend: increase in dual earner households, advance in information and communications technologies, new concept of arranging work time weekly, and people's changing attitude towards travel. In the field of urban transportation planning, commuting has been studied in individual metropolitan areas in a one-day time frame. LDC/TRC traverse multiple metros and the commuting behavior cannot be better understood without going beyond the one-day convention. Studying LDC/TRC corresponds to the growing interest worldwide in planning for megaregions. Up to date, the phenomenon of weekly commuting has been explored only by a few European researchers in the fields of geography and sociology.

This study analyzed LDC/TRC using national datasets available in the US. They are American Travel Survey, National Household Travel Survey, and Census Transportation Planning Package. Further detailed analyses were conducted for the Texas Triangle megaregion. The national travel surveys are helpful in portraying large pictures of LDC/TRC but limited in offering insights into LDC/TRC behavior. Based on the preliminary study, the next phase of the study will conduct qualitative research by interviewing selected LDC/TRC individuals in the Texas Triangle megaregion.

17. Key Word	18. Distribution Statement
Long-distance Commute, Travel Behavior, Transportation Planning, Texas Triangle, Megaregion	No restrictions. This document is available to the publich through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	67	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Understanding Emerging Commuting Trends in a Weekly Travel Decision Frame--Implications for Mega-Region Transportation Planning

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Sponsored by the
Southwest Region University Transportation Center

Research Report SWUTC/11/161127-1

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September 2011

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Acknowledgements

Dr. Daniel Yang (Project Monitor) at the Capital Area Metro Planning Organization (CAMPO), Austin, TX provided invaluable help to the project. Any errors remain the responsibilities of the authors.

The authors recognize that support for this research was provided by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the Southwest Region University Transportation Center, which is funded, in part, with general revenue funds from the State of Texas.

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Executive Summary

National transportation statistics have shown the rise of long-distance, trans-regional commute (LDC/TRC) in the US. Four societal factors contribute to the trend: increase in dual earner households, advance in information and communications technologies, new concept of arranging work time weekly, and people's changing attitude towards travel.

In the field of urban transportation planning, commuting has been studied in individual metropolitan areas in a one-day time frame. LDC/TRC traverse multiple metros and the commuting behavior cannot be better understood without going beyond the one-day convention. Studying LDC/TRC corresponds to the growing interest worldwide in planning for megaregions. Up to date, the phenomenon of weekly commuting has been explored only by a few European researchers in the fields of geography and sociology.

This study analyzed LDC/TRC using national datasets available in the US. They are American Travel Survey, National Household Travel Survey, and Census Transportation Planning Package. Results show that,

- Nationwide, the percentage of long distance commuters increased from 2.8% in year 2001 to 2.9% in year 2009. The South Census Region which Texas belongs to had the highest percentage of long distance commuters at 3.1% in 2009.
- Among long distance commuters, more than 80% traveled 50 to 100 miles to work, and less than 3% traveled over 300 miles to work. The main travel means for long distance commute was private car; more than 90% of long distance commuters drove private cars to work and more than 80% of them drove alone.
- The vehicle miles traveled (VMT) by the 3% of long distance commuter accounted for 16% of VMT by all commuters in 2001 and 13% in 2009, respectively. The decline in VMT suggests a shift in mode choice over time from driving to non-driving.
- Long distance commuters spent more time away from home, leaving home earlier and return home later than normal commuters. Male commuters tend to travel longer distances than female. If a person has options to work at home occasionally, he or she tends to commute long distance.
- In Texas, 70% of commutes with distance of 50 miles or longer was interregional, and more than 70% of the long distance commutes in Texas was within the Texas Triangle Area.

The national travel surveys are helpful in portraying large pictures of LDC/TRC but limited in offering insights into LDC/TRC behavior. Based on the preliminary study, the next phase of the study will conduct qualitative research by interviewing selected LDC/TRC individuals in the Texas Triangle megaregion.

1. Introduction

Travel demand analysis has focused conventionally on activities and trips performed by household members in a given survey day. Such a one-day focus is plausible because human activities, for example, commuting, schooling and sleeping, cycle in a one-day time span due to physiological and institutional reasons.

Many emerging commuting trends however cannot be better understood without going beyond the conventional one-day travel decision frame. One emerging trend is the increase of long-distance commute (50-100 miles each way) and specifically the increase of the extreme commute (one-way journey to work distance longer than 90 miles). In 2005, 3.4 million people in the US undertook extreme commute, doubling the number in 1990 (Naughton 2006). Studying multi-day travel, for instance, one week, would offer insights into the growing long-distance or extreme commute. Kitamusa (1988), among other scholars, has stressed the importance of using multi-day data to examine day-to-day variations in travel patterns in order to address the likely biased representation of travel behavior in the one-day data sets. Yet there have been limited studies along this line of inquiries mainly because of the limited availability of multi-day data.

Another trend pertains to telecommuting. Telecommuting has become a recognized mode of (virtual) travel. Although the total substitution of telecommuting for physical travel is unlikely for all occupations, partial substitution by telecommuting one or more days a week and traveling physically the rest of the week is increasingly popular (Collantes and Mokhtarian, 2003). Understanding the implications of telecommuting for physical travel requires a time unit of analysis longer than one day.

Commuting has served for the U.S. Census Bureau as an important indicator of economic integration in spatially delineating metropolitan areas. Much of the long-distance or extreme commute mentioned above involves trans-metropolitan travel—travelers living in one metropolitan area but working in another (Lang and Nelson 2007). A growing share of the long physical commute is coupled with telecommuting, the outcome of multi-day trip-making decisions. Anecdotal evidence from the Texas Triangle megaregion suggests that a growing number of people live in Austin and work in Houston (or vise versa) through a combination of telecommunicating and physical commuting on a weekly basis. Studying trans-metropolitan commuting provides evidence to support travel demand analysis and strategic transportation plan-making at the megaregion level.

The report presents a preliminary study for better understanding of the rising long-distance, trans-regional commute in a behavioral decision frame beyond the one-day convention. It is part of a broader effort to propose transportation planning strategies for megaregions. The report first reviews societal factors that influence long distance, trans-regional commute. It then synthesizes the literature on analytical methods and empirical evidence pertaining to trans-regional commute. Empirical analysis with use of national data on the Texas Triangle is presented next. Finally the report summarizes study findings and suggests directions for future research.

2. Societal Factors Influencing Trans-Regional Commute

Commuting to a large extend is derived from the demand for participating in socioeconomic activities. For instance, people commute to work not for traveling per se, but mainly for earning income from work. Hence understanding changes in socio-demographic characteristics of individuals and households helps better understand commuting trends. Advances in information and communications technologies enable individuals to arrange flexible work schedules or to make commuting time less wasteful (Mokhtarian and Salomon 2001). This section reviews four trends that have reshaped the social environment and people's daily life that in turn influence people's commuting. They include increase in dual earner households, advance in information and communications technologies, new concept of arranging work time weekly, and people's changing attitude towards travel.

2.1. Increase in Dual Earner Households

One important change in the American family in the past 40 years has been the increase in women's participation in the labor market. According to the US Bureau of Labor Statistics, the female labor force increased from 43% in 1970 to 60% in 2008, and women's share of work market increased from 38% to 47% during the same time period (US Bureau of Labor Statistics, 2009). As more women are earning college degrees, the number of career-oriented women has been rising. These higher educated women are more likely to continue pursuing their careers even after marriage. Consequently, the share of traditional one-earner households has been declining and dual- or two-earner households have been on the rise. In 2007, 62% of households had two earners compared to 24% of households with only one earner (US Bureau of Labor Statistics, 2009).

The growing number of dual-earner households raises challenges to the conventional interpretation of individual's commuting behavior, which assumes a single or main earner in a household and the household makes decision on residential location based on the household's housing needs and the single- or main earner's commute. However, the commuting decisions for two workers in a household are interdependent; and a dual earner household would attempt to minimize the overall commuting cost in terms of travel time, money and energy of two partners (Badoe, 2002). In reality, dual-earner households face more complex situations than single earner households in determining residence locations and accepting job offers since they have to make decisions on careers for both partners along with the considerations of family lives (Sultana, 2006). Living near the work place of one partner may cause a longer commute for the other (Hjorthol, 2000; Turner & Niemeier, 1997). In some other cases, journeys to work by couples in a two earner household may be jointly chosen to be longer or shorter due to the household preference of housing and neighborhood amenities (Plaut, 2006). Researchers have also found that dual earner households tend to move less than single worker households (J. N. van Ommeren, Rietveld, & Nijkamp, 1998). In the situation that the job market in one region cannot satisfy both partners, one partner may choose to commute a long distance in other regions (Green, 1997).

As more women participate in the job market, researchers have paid an increasing attention to the gender difference in commuting behavior. General findings suggest that women remain to bear more house work responsibilities than men, especially in households with children, despite they are playing a more and more important role in the workforce; women usually also receive relatively lower wages and returns to commuting then men. They typically take shorter commute time and distance than men (Clark, Huang, & Withers, 2003; Hjorthol, 2000; Plaut, 2006; Turner & Niemeier, 1997). In addition, women are more likely to use public transportation and have trip chains in the journey to work (Hjorthol, 2000; Rose, 2009). Although women usually dislike long distance commuting, they may attempt to "make a negative into a positive" by using the commuting trip as "a mental shift, contemplation and relaxation" (Blumen, 2000; Lyons & Chatterjee, 2008, p. 194, Rose, 2009).

While most partners in dual earner households are making great efforts to coordinate their work and family life, a "living apart together" (LAT) relationship has also emerged in many dual earner households in a way that the partners do not choose to cohabitate as the traditional family form does. LAT allows the couple to pursue careers in different regions with more employment options while maintaining a desired degree of interdependence (Levin, 2004). The LAT relationship brings women a greater sense of autonomy and leads to a more balanced division of household work. It helps both partners well divide work from leisure and increases the quality of their time together (Holmes, 2009). Not traveling on a daily basis, LAT partners tend to commute in long distances.

2.2. New Information and Communications Technologies

The emergence of LAT relationships benefits from the advance of Information and communications Technologies (ICTs) (Levin, 2004). With ICTs people become connected to each other when they are not physically together. ICTs includes five broad application categories; they are telecommuting, teleconferencing, teleservices such as teleshopping or telebanking, mobile communications, and electronic message transfer (Mokhtarian, 2002; Salomon, 1986). These applications could greatly affect people's face-to-face interaction and people's need for travel.

Researchers have long realized the connection between ICTs and transportation (Gold, 1979; I. Hardill & Green, 2003; Mokhtarian, 1990, 2002; Salomon, 1985, 1986; Walls, Safirova, & Jiang, 2007). The possible effects of ICTs on transportation include (1) substitution, the application of ICTs could reduce people's physical travel; (2) complementary, the application of ICTs could either stimulate people to travel more or could help people make travel more efficiently, and (3) modification, the application of ICTs could change the time when people decide to travel without either reducing or increasing the number or length of trips (Mokhtarian, 2002).

There has not been an agreement on the actual effect of transportation and ICTs. For example, based on several surveys in North America on teleconferencing, Gold (1979) concluded that teleconferencing would not facilitate a reduction in intercity travel in the 1980s, but it could eventually substitute some intercity trips if more ICT systems were provided. In contrast, by examining people's attitudes towards ICTs and travel for different purposes including work, shop and business, Salomon (1985) believed that people's desire of mobility would counterweight the

substitution of telecommunication for travel. A more recent nationwide survey conducted in Finland about the impact of telecommuting on commuting distance and frequency showed that the effects varied depending on the actual commuting distance (Helminen & Ristimaki, 2007). In addition, job types could also affect people's choice in telecommuting. Walls et. al. (2007) claimed that jobs in sales, education and training, and architecture and engineering appeared to be more likely to have telecommuters based on a survey in Southern California.

Despite the inclusiveness in the relationship between transportation and ICTs, both telecommunication and travel are believed highly likely to continue to grow in the future. Telecommunications do permit great flexibilities in making travel decisions such as whether, when, where, and how to travel (Mokhtarian, 2002). In terms of commuting, the option of telecommuting provides people the possibility to work in places other than the office and during the time other than regular working hours. Thus long distance commuting could become more acceptable when people have the choice to work at home for some time or even some days in a week.

While ICTs continue to advance, there are also new technological breakthroughs in passenger transportation technologies, such as higher fuel efficiency cars, electronic cars, and high-speed rail (HSR). HSR is noteworthy as one of the most significant new travel modes. HSR has a speed ranging from more than 100 mph to more than 300 mph. Since the beginning of year 2008, there have been about 10,000km of new HSR lines in operation around the world (Campos & Rus, 2009), most of them were distributed in Europe and East Asia. HSR is regarded as an effective transport mode for linking places that are 100 to 500 miles apart (Leinbach, 2004; Nash, 2003). Compared to the automobile, HSR has the advantage of being able to move passengers at a much higher speed and enables a far higher throughput of passengers per hour than roads. Compared to the air mode, HSR can free passengers from checking in and going through security screening at airports and is more flexible in expanding capacities than airplane (Nash, 2003). Additionally, HSR are believed to be more environmental friendly than auto and aircraft since it operates mainly on electricity and produces little CO2 emissions. It consumes about 17% and 21% less energy per passenger mile than aircraft or automobile respectively, and is specially designed for noise abatement to reduce negative impacts on sensitive habitats (Ross, 2008; Zaidi, 2007).

The advantages of HSR have attracted many supporters who consider HSR a mode with a great potential to serve the needs of megaregions, in which the typical distance between metropolitans falls in the ideal operating length range of HSR. In turn, HSR could also largely shape the interregional commuting images. For example, if HSR were implemented in the Texas Triangle connecting the four major metro areas at a speed of 430 miles per hour, it would reduce the travel time by more than 70%, enabling people to commute between any pair of cities in the Triangle Area within a reasonable daily commuting time (Zhang, et al., 2007). In such a scenario, both households and companies could enjoy the benefit of being able to access more opportunities and resources in the megaregional environment than those available in individual metropolitan areas.

2.3. New Concept of Arranging Work Time

In recent years, employers have begun to allow employees greater flexibilities in arranging their work times. In this case, employees do not have to follow a set "9-to-5" pattern but can vary the actual time they arrive and leave the office. In 1997, 27.6% of full-time workers, or more than 25 million workers in the US somewhat varied their work hours (Beers, 2000). This flexible work hour arrangement is more common for workers whose work can be conducted efficiently regardless of their start and end times, such as executive, managerial or professional occupations (Beers, 2000). As employees enjoy the flexibility work hours, they tend to work longer when the work time is not fixed (Irene Hardill, 2002). Furthermore, some employers have scaled down office facilities and equipped employees with laptops and ICT equipment to let them work from home, during travel or any places possible in order to reduce real estate costs (I. Hardill & Green, 2003).

Except varying the start and end work time daily, there is another type of work time arrangement different from the traditional work schedule - a compressed workweek (CW). CW allows workers to work fewer days in a week but a longer work day to compensate the hours lost because of the additional free days (Hung, 1996). For employees, CWs result in fewer commuting trips and better utilization of leisure time. Thus CWs are especially attractive for long distance commuters. Actually, some research has claimed that in the US most employees prefer CWs to the standard 5-day workweek (Hung, 1996; Ronen & Primps, 1981; Zhou & Winters, 2008). On the other hand, employers also benefit from CWs. Most US firms that implemented CWs reported increased morale and work efficiency (Hung, 1996).

As people gain more flexibilities in arranging work time and space, the day-to-day variability in commuting and work behavior could become enlarged. Then the "typical work day" picture that is used in the current travel demand analysis may not be able to capture the true activities of many workers. For example, a person may vary his or her work arrival time and departure time the first and last day of a week and keep a regular schedule the rest of a week; a person who adapts CWs will actually have a "typical work week" instead of a "typical work day". Thus, the concept of allocating time weekly should be discussed. Researchers have indeed realized the existence of longer than daily cycle of travel activities (Doherty, Miller, Axhausen, & Garling, 2002; Hanson & Huff, 1988; Hirsh, Prashkea, & Ben-Akiva, 1986; Jones & Clarke, 1988). Generally speaking, one-week time period could capture a proper collection of an individual's different daily patterns (Hanson & Huff, 1988; Hirsh, et al., 1986).

2.4. People's Changing Attitude Towards Travel

Travel has been traditionally deemed as "derived demand". That is, people travel in order to fulfill the need to engage in activities at various locations. For instance, the purpose of commuting is to get to the office and work. However, Mokhtarian & Salomon (2001) challenged this concept and argued that human has the intrinsic to travel and travel itself could be the actual demand. According to them, the positive utility of travel includes "the sensation of speed, the exposure to the environment and movement through that environment, the ability to control movement in a demanding and skillful way, the enjoyment of scenic beauty or other attractions of a route"(p. 699). Sometimes, the desire to travel may encourage people choose a longer route

to get to their destination, or even induce the demand for an activity. In their research, Mokhtarian & Salomon conducted a survey with more than 1900 samples in three communities in the San Francisco Bay Area and confirmed the positive utility of travel. More than half of the respondents reported having experience of traveling "just for fun of it" and agreed that journey itself was part of the good thing when traveling somewhere (Mokhtarian & Salomon, 2001).

Not only traveling itself brings enjoyment to people, people can also do many activities while traveling (Lyons & Urry, 2005; Mokhtarian & Salomon, 2001; Ohmori & Harata, 2008). The survey conducted by Mokhtarian & Salomon(2001) found that travel time was not generally considered only as wasted time. Rather, people can do a variety of things on a journey, such as sleeping, reading, listening to music, playing electrical games, and working while riding a bus or a train. The application of ICT further enriches the activities by enabling people to communicate with people in any other places and access the internet using mobile devices. An on board survey in Japan conducted on normal trains and high-grade rains, the "liner trains", which provide larger space and better services and privacy at an extra charge, indicated that people tend to pay more to be able to better utilize travel time on liner trains; the survey also found that passengers were engaging in numerous types of activities on the trains, and some passengers with flexible work hours used the journey as working time(Ohmori & Harata, 2008). Commuting time thus could become productive. In this case, public transportation would be valued higher than driving.

On the other hand, traveling offers people a period of "anti-activities", a period of purely relaxing and thinking, and a mental transaction between origin and destination activities (Lyons & Urry, 2005; Mokhtarian & Salomon, 2001). In term of commuting, some people may prefer the buffer created by the journey and having the time to switch roles from work to family life. Both the activities and the "anti-activities" brought by the commuting time lead some commuters to consider the long trips that "represent the only time for thinking or the chance to catch up on reading or other neglected but important tasks" (Mokhtarian & Salomon, 2001, p. 702).

3. Studies on Long-Distance Commuting (LDC) / Trans-Regional Commute (TRC)

LDC/TRC involve traveling a long distance to go to work, more often than not, across the boundary of a metropolitan region, either from one metropolitan to another or from/to non metro areas to/from metro areas. While some LDC/TRC commuters choose to commute daily, others may opt to live in a secondary home near work place and commute back to primary home weekly. This section first presents two economic theories explaining the residential or work location selections. Next it assembles the results of studies on intra- and trans-regional long distance commute.

3.1. Commuting and Job/Home Locations

Commuting is a necessity as long as there is a separation between residence and work place. Hence commuting behavior is highly related to residential and job locations. According to the neoclassical model of urban residential location (Alonso, 1964; Mills, 1972; Muth, 1969) households try to maximize their utility subject to their income constraints, and the decision of their residential locations is a tradeoff between housing cost and transportation cost. This residential location model was developed based on the monocentric urban setting, in which land density and housing prices are lower far away from a central business district (CBD) than those closer in. Thus, households may choose to live further from the CBD, the workplace, and commute longer in exchange of lower housing cost and better living condition. When a technological innovation decreases the transportation costs, or household income increases, the urban periphery will be expanded since households have more desire for land with higher income and are able to commute longer. The residential location theory provides a basic explanation for commuting behaviors.

However, the residential location model assumed a perfect market condition under which workers were fully informed and were always able to choose the optimal amount of commuting distance. On the contrary, another body of economic theory, the search theory, suggests that workers have to search for jobs and dwellings continuously in order to improve their current position (J. van Ommeren, Rietveld, & Nijkamp, 1997, 2000). From the point view of search theory, commuting behavior is "determined by chance - the probability of receiving a job or residential offer at a certain distance - and a decision-making process - the decision to accept the offer" (J. van Ommeren, et al., 1997, p. 404). Based on the search theory, long distance commuting is often compensated by higher wage. Yet, the current highly specialized workforce has created a situation in which labor markets cannot provide rich job options within a moderate distance thus forcing workers to commute a longer distance even when it is not fully offset by wages in order to avoid costly job or residence moving (Sandow & Westin, 2010; J. Van Ommeren & Rietveld, 2007).

3.2. Long Distance Commuting within One Metropolitan Area

Research examining long distance across-region commuting has been limited. Long distance commuting has often been studied as excess commuting within one metropolitan region. Excess commuting represents the deviation of the actual average commute and the theoretical smallest average commute given the spatial setting of residential and workplace sites in a metropolitan area (Horner, 2002; Ma & Banister, 2006). It is often used as an indicator of the overall geographical imbalance between jobs and housing in a city and is associated with the issue of unsustainable urban land use pattern.

One subset of literature in excess commuting is concerned with factors that contribute to the long distance commute, which can provide useful insight for this researc. Ma & Banister (2006) listed many factors examined by researchers since 1980s that could prevent workers from finding jobs near residential location in a comprehensive review of excess commuting research. According to this review, the most studied and proved factor was the increased number of two worker households since there exist more obstacles to an optimized commute for both workers in a household as mentioned in the earlier section; home owners tend to have higher level of excess commuting than renters; people who have relatively unstable jobs also tend to accept longer commutes; occupation variation and pay variation in a job market could be another factor induce excess commuting; transport subsidies such as parking allowance may encourage people drive more; in addition, the costs of moving and rapid job turnover, neighborhood amenities and family life, and imperfect labor market information have all been examined as possible influences on excess commuting (Ma & Banister, 2006).

Excess commuting is commonly deemed as inefficient and unnecessary, so most of the literature has been concentrated on finding solutions to reduce excess commuting. The redistribution of workers and encouraging mixed land use to achieve job and housing balance are the mainly suggested policy implications (Ma & Banister, 2006). However, the intricate causes of long distance commuting challenges the effectiveness of these policies; the continuing complex travel behavior of households and more advanced ICT applications could also weaken the power of policies that only focus on shortening journey-to work trips. Thus, it is not surprising to see more excess commuting emerging. Furthermore, Some researchers have argued from the psychological point view that humans prefer the switch buffer between home and work activities as well as the distinct territories of home and work created by commuting (Lyons & Chatterjee, 2008; Ma & Banister, 2006). Humans also have the natural desire for travel (Mokhtarian & Salomon, 2001). These psychological factors could contribute to the decision to commute long distances.

In terms of regional economic strength, the land use and transportation policies that attempt to balance job and work and reduce long distance travel pose another question, as described by Pisarski (2006, p. 150)

> *"if most workers actually work in their residence county[or other region unit], that would clearly be better for the transportation system in terms of congestion, but would it be better for the region as an entity? ...Isn't the strength-the hallmark- of a region based on its ability to provide a market in the millions? For example, an employer in a very specialized sphere locating in a large region has a market of prospective employees measuring in the millions. This is also true of an exotic restaurant, great art gallery, or*

any specialty store. This suggests that transportation policies that would suppress longer distance travel and encourage short-distance trips are destroying part of what makes a big region a greater region."

Except for generating problems such as congestion and a waste of energy, excess commuting might deliver a message to us that workers are demanding access to larger job markets or larger housing markets. When the needs exceed the boundary of one metropolitan area, interregional commuting is inevitable. Thus while on the one hand, it is important to provide better balance in job and housing in a particular region so that households have options to locate homes near work, on the other hand, long distance interregional commuting should be further examined, and solutions should be offered to workers who choose to take such commuting to do so in a more sustainable way thus creating a society in which people have more freedom to choose live and work where they want.

3.3. Long Distance Commuting across Regions

One relatively new study focused on the interregional long distance commuting in the US was conducted by Lee (Lee, 1995, 1996) in 1990s as his dissertation research. This research investigated the motivations of the long distance commuters who traveled from homes in California's San Joaquin Valley to work in the San Francisco Bay Area. The long distance commuting in this study was defined as journeys that were over 45 minutes one way and involved crossing a metropolitan area boundary. Based on the Census PUMS 5% data, Lee concluded that a white married male with a medium education level (but relatively higher level than other commuters in the San Joaquin valley) and worked in construction, communications or other public utilities field represented a typical long distance commuter between the Central Valley and the Bay area.

Since the Census data did not provide detailed answers for behavior questions, Lee further carried out four focus group discussions and in-depth interviews with 40 interregional commuters. The respondents were contacted through the Bay Area regional ridesharing agency. He discovered that the expensive housing price in the Bay area was an important reason why these people chose to reside in the San Joaquin valley where they could afford larger houses. Additionally, maintaining a better living environment was a common reason for households with small kids. There were also commuters who preferred rural lifestyle, and who did not mind driving. Although these commuters expressed some dislike to the driving, they all became used to it after a while and treated the long distance commuting as a long-term goal. Lee concluded that the "pull" power that attracted people to live in the valley had more influence on the decision to long-distance commuter than the "push" factors that repelled people from wanting to live in the city, such as high housing costs or crime.

Lee's research is quite similar to this study. Therefore it is noteworthy to compare the two cases. First, in the California case, the interregional commuting is between the San Francisco Bay area, a highly job concentrated place with high living cost and the San Joaquin Valley, a "bedroom" community. So the commuting has a fixed direction and more resembles the "suburb to CBD" commuting pattern. While in the Texas Triangle case, there is no clearly presumed commuting flow direction since the living cost in the four metro areas are not as dramatically uneven as the

California case. Second, the average commuting time in the California case was 90 minutes, and commuting was all done by workers on a daily bases, yet in the Triangle Area, the distance among the metropolitans are much longer, and commuting between them may become weekly. Third, Lee performed this research more than 10 years ago. Since then, the ICT has been rapidly advancing. This improvement could have large impact on the interregional commuting.

More recent studies on long distance interregional commuting have been performed by researchers in Europe. According to the literature, the number of long distance commuters crossing municipal regions or even national boundaries has been steadily increasing in some European countries. Such commuting includes daily travel between home and work and weekly commute (Lyons & Chatterjee, 2008; Sandow & Westin, 2010). The literature that is concerned with this type of commuting can be grouped into two directions. One group studied the long distance commuting from travel behavior point of view and attempted to explain people's commuting decision using quantitative methods. However, research in this group did not specifically distinguish between daily and weekly commuting but rather *typically* defined long distance commuting as a work trip longer than 30 to 45 minutes. Another group paid a special attention to the weekly commuting phenomenon. Studies in this group were typically done by social/family life researchers and geographic researchers who devoted their effort to inspect the impact of weekly commuting on family life and the connection between migration and weekly commuting. In this section, the first group of literature will be reviewed, and the second group will be discussed in the later section.

A common method for studying long distance commuting is the utilization of secondary data developing regression models to scrutinize the causal effects of various factors on long distance commuting (Ohman, 2010; Sandow & Westin, 2010; Titheridge & Hall, 2006). One study also explored people's preferences and options of commuting through a survey (Sandow & Westin, 2008).

Titheridge & Hall (2006) inspected long distance commuting in the Greater South East Region, the "global mega-city region" (Hall & Pain, 2006) in England. The study focused on the East Corridor and the North Corridor radiating from London to the periphery of the region where rail service is available. Six models with dependent variables of commuting distance and different commuting modes were developed for each corridor for years of 1981 and 1991 based on the Census data. Titheridge & Hall concluded that a lack of job opportunities near one’s residence was a significant reason for workers to choose a longer commute. In addition, they found that higher social class people were the ones who travelled the longest distance.

Titheridge & Hall's finding about the association between long distance commuting with social classes was confirmed by Sandow & Westin (2008) who conducted a survey of 2,500 samples in 2004 in four municipalities in northern Sweden where the population density is only 2-15 inhabitants/km^2. Based on this survey, Sandow & Westin examined people's inclination and opportunities to commute in this relatively sparsely populated environment. Their results showed that people with a high level of education, especially males with a higher level of education working in the private sector, were more willing to accept longer commutes. The survey also revealed that 45 minutes one way was a common maximum that people deem feasible and tolerable for daily commuting. The 45-minute time limit has also been verified by some other researchers (Levinson & Wu, 2005; Ohman, 2010; Sandow & Westin, 2010; Van Ham &

Hooimeijer, 2009; J. van Ommeren, 1998), and when commuting is longer than 45 minutes, weekly commuting or migration may be preferred (Sandow & Westin, 2008).

Sandow & Westin (2010) later conducted another study using the 1995-2005 register data of Sweden to analyze the duration of long distance commutes. They found that most long distance commuters had been commuting long distances for many years, and economic incentive was important for them to sustain such long work trips. Sandow & Westin concluded that since longer commuting provided more opportunities for all members in a household and was often associated with higher income, it tended to be a long range mobility strategy rather than a temporary solution for households.

In the Netherlands, the determinants of long distance commute and intention for migration were examined by Van Ham & Hooimeijer (2009) used the 2002 Housing Demand Survey. Based on three logistic regression models, Van Ham & Hooimerjier further proved the importance of individual and household characteristics to the longer journey to work. For example, long distance commuters in the Netherlands commonly had higher income and higher levels of education. However, although they found that home owners were less willing to migrate for a job than renters, they could not use home ownership to explain long distance commutes.

Another long distance commuting study was also conducted in Sweden by Ohman (2010) based on the 1994 Sweden register data. The results of Ohman's model were quite similar to the conclusions of other long distance commuting studies. Yet Ohman addressed the importance of social ties, individual and social preferences and norms, and the accessibility and choice of transportation mode all would influence people's choice of longer commute although he did not includes these variables in his model. Moreover, Ohman distinguished three types of mobility patterns as "what individuals can, must and want to". What people can do depends on the technological level in transportation and communication of a society, and physical ability and income and information resources possessed by an individual. What people must do to make a living and utilize services depends on the spatial setting including workplaces, housing and shopping in a region, as well as social norms and values. What people want to do reflects people's freewill and preferences which might also be influenced by social norms. Then, long distance commuting becomes the result of combination of "can", "must" and "want to" mobility (Ohman, 2010).

3.4. Long Distance Weekly Commuting

After choosing to take long work trips, workers do have options to travel between home and work daily or to spend weekdays at the workplace followed by returning home during weekend, which is called long distance weekly commuting. When the distance between a workplace and a residence is beyond the feasible or tolerable daily journey to work, individuals have to commit to weekly commuting life when they need to or want to obtain opportunities far away from home without relocating. The literature on long distance commuting discussed above does not distinguish these two types of long distance commuting although some researchers have mentioned the issue (Ohman, 2010; Sandow & Westin, 2010). Long distance weekly commuters in the current society only represents a small group of population, and the current major travel survey typically assumes that individuals travel on a daily basis between a single fixed residence

and single fixed workplace (Green, Hogarth, & Shackleton, 1999a), which creates the major difficulty to separate weekly commuters for daily commuters. Most long distance weekly commuting research which will be reviewed below was performed based on small samples and conducted using qualitative methods.

The phenomenon of long distance weekly commuting has mostly been investigated by researchers in the fields of geography and sociology. These two bodies of literature have emphasized different aspects of the weekly commuting. In geography, weekly commuting is studied as a strategy to avoid migration with the consideration of the social and spatial contexts. In sociology, on the other hand, researchers focus on the impact of weekly commuting on family life and evaluate the satisfaction of such a lifestyle.

3.5. Migration vs. Commuting

Migration is defined as " any permanent or semi permanent change of residence, more meaningfully, a spatial transfer from one social unit or neighborhood to another, which strains or ruptures previous social bonds" (Zelinsky, 1971, p. 225). Generally, migration is highly related to local labor market conditions. For example, wage differences between regions may motivate people to migrate to areas with higher wage levels to improve their living conditions. Unemployment due to occupation imbalance, lack of enough information and uncertainty of job availability in a labor market may also force people to migrate (Oeberg, 1995). In addition, individuals' backgrounds and experience could influence their migration intentions. For instance, a high level of education could prevent people from changing job occupations but encourage people to move geographically (Borsch-Supan, 1990). On the contrary, a higher value of the physical infrastructure of a region, such as a diverse housing program, a sophisticated transportation system, or an excellent education system might discourage people from migrating to other regions (Oeberg, 1995).

According to Zelinsky (1971), our society has gone through five stages of mobility transition from the pre-modern stage in which society was mainly dependent on traditional agriculture and was sedentary to the middle stages, which was represented by a massive migration flow, and to the super advanced stages when migration flows were again absorbed by the modern ICT systems (Oeberg, 1995; Zelinsky, 1971). Today, on the one hand, various modern means of transport have provided people higher mobility; the advanced ICT system enables people access to information beyond geographical boundaries; a rising level of affluence and education increases people's desire to obtain better opportunities even further away. All these facts create a greater potential of higher geographical mobility. On the other hand, humans have accumulated a higher level of physical capitals thus making people tend to attach to a place more easily. Neighborhood amenities, schools, city welfare, local social networks and so on would hinder people from moving to different places. Thus long distance weekly commuting offers an additional option other than migration to resolve this dilemma (Eliasson, Lindgren, & Westerlund, 2003; Green, et al., 1999a; Sandow & Westin, 2008).

The cases of long distance weekly commuting between North East England and London were examined by the Policy Studies Institutes sequentially in mid-1980s and late 1990s (Green, et al., 1999a; Green, Hogarth, & Shackleton, 1999b; Hogarth, 1987; Hogarth & Daniel, 1988). Since

the late 1970s, a significant uneven employment distribution between north and south areas have emerged in England which resulted in a significant number of individuals who found jobs in the South East, but for a variety of reasons, principally lacked affordable accommodation, maintained their living in the North and commuted weekly to the South East region (Hogarth, 1987).

In the first study, Hogarth (1987) and Daniel (Hogarth & Daniel, 1988) estimated a total number of 10,000 long distance weekly commuters based on the national census, then they sent out questionnaires on coaches and trains leaving London on Friday evening for North-East England and found one hundred and five long distance weekly commuters, among whom they chose twenty five for further in depth interviewing. They also probed the opinions of partners of some of these weekly commuters and explored the attitudes of employers by surveying companies who had been advertising in North East England for professional employees.

More than ten year later, Green et al. (1999b) discovered over 200,000 employees in England who had their workplaces beyond the daily travelling distance of their homes. Using the same methods as Hogath and Daniel, Green et al. (1999b) surveyed one hundred and fifteen long distance weekly commuters and interviewed twenty five of them along with some partners, and surveyed 48 companies. Both surveys in the 80s and in the 90s related the increase of women in employment and the growth of dual earner households to the phenomenon of long distance weekly commuting. According to Hogarth & Daniel (1988) and Green et al (1999b), one group of weekly commuters were "pulled" into commuting because weekly commuting could provide them more prestigious employment opportunities and chances to further career prospects. In addition, weekly commuting could also allow them to retain their family home in the environment they felt more attractive, maintain their partners' career pursuits and children's education statuses. This group of commuters more enjoyed the benefit of such a life style and appreciated the uninterrupted working time during weekdays. Another group of weekly commuters were "pushed" into the lifestyle due to job secondment, or because the job opportunities were the only work available and could not afford the accommodation in South East England. Workers in this group deemed the long distance commuting as "necessary evil" which ensured the financial security of their family (Green, et al., 1999b). However, a majority of the weekly commuters regarded commuting as long term and not as temporary. Comparing the results of the two time periods, Green et al. (1999b) concluded that there were more "pull" factors in commuting in the 90s than in the 80s. At the same time, employers had become more willing to accept long distance weekly commuting employees and permitted more flexibility to these employees with the support of the ICT systems.

3.6. Commuting Couples - the Sociological & Psychological Perspectives

In the field of sociology, the phenomenon of long distance weekly commuting has attracted researchers' attention due to new family form and partner role that it created. The traditional couple relationship has implied cohabitation (Holmes, 2009), and members in a family had been treated as a single unit in which the husband was the head of the family (Gerstel & Gross, 1984). The historical reasons that separated couples typically involved men leaving home to work at sea, in the military, or in the oil and mining industries (Gerstel & Gross, 1984; Holmes, 2009). In more recent time, some careers such as sales man or politician also require frequent traveling.

Yet in most other cases when a husband needed to move for work reasons, the wife often followed becoming the "trailing spouse" (van der Klis & Mulder, 2008). However, as more women have begun to participate in the labor market, more households have to manage careers for both partners creating a new home format, called "commuting marriage" or "commuting couples".

One of the earliest studies in commuting marriage was conducted more than 30 years ago by Gerstel & Gross (1984), who defined the commuting marriage as "employed spouses who spend at least three nights per week in separate residences and yet are still married and intend to remain so"(p. 2). They challenged the suitability of nuclear families in the contemporary society in which the need for mobility in the labor market conflicts with the traditional pattern of a shared family home. Individuals had to find different ways to coordinate work and family life, and the commuting marriage became a solution to support the career pursuits of both partners (Gerstel & Gross, 1984; Holmes, 2009).

Since Gerstel & Gross's original study, a series of other research studies have further explored the incident. The main method used by these researchers was a qualitative investigation. These researchers typically searched for respondents by non-random and snowball sampling techniques and conducted in-depth interviews, through which researchers have been able to examine the rationales behind the commuting marriage life, explore the meaning of separated homes and family roles for commuting couples, evaluate the benefit and stress of commuting marriage, and make recommendations for improving the commuting life.

This body of literature found out that commitment to a commuting partnership always included the work domain (Holmes, 2004, 2006; van der Klis & Karsten, 2009a; van der Klis & Mulder, 2008). Most of the interviewees in these studies were professionals whose specialization in certain areas and education levels left them only small pools of job opportunities fitting their personal occupational demand (van der Klis & Mulder, 2008). Holmes (2004) in particular emphasized the difficulty facing academic couples - the limited number of universities within one area made commuting partnership highly likely, yet the flexibility of academic jobs counteracted the difficulty of such a relationship. Holmes (2006) also argued that professional jobs were necessary to maintain a commuting partnership due to the obligation of sufficient money and some flexibility to maintain two residences. In addition to the work domain, Van der Klis & Mulder (2008) also addressed the reasons from the residential domain including lifestyle preference and housing market conditions.

This group of researchers also looked into family issues in households with commuting couple. Van der Klis & Karstern (2009b) discussed the meaning of the commuter residence to workers by interviewing thirty commuter couplers in the Netherlands. They concluded that since it was difficult for a commuting partner to establish a strong social connection near the commuter residence, he/she would not consider the second residence as a true home, and he/she would totally separate the work life from the family life between the commuter residence and primary residence. Thus Van der Klis & Karstern argued, in contrast to Gerstel & Gross, that although more families were expected to commit to a commuter partnership in the future, the commuter partnership would not likely become an equal alternative to the nuclear family in the long run (van der Klis & Karsten, 2009b).

Since commuting couples usually spend at least half of their lives separately, well balancing work and family life becomes an importance issue. Van der Klis & Karsten (2009a) distinguished two types of commuting families: the traditionalizing type in which the husband concentrates full time on paid work and the wife with no or a part time job who takes most of the responsibility for the housework, and the egalitarian type in which both partners participate in paid work and share the housework during weekend. The second family type actually reflects a changing role of women in the family life. Although Anderson (Anderson & Spruill, 1993) argued that wives in the commuting family still had more tasks than their husbands in household labor, other researchers believed that women have gain a greater level of autonomy within a commuting partnership (Irene Hardill, 2002; Holmes, 2004).

The commuting life has been found to have both rewards and strains (Bunker, Zubek, Vanderslice, & Rice, 1992; Gross, 1980; Irene Hardill, 2002; van der Klis & Karsten, 2009a). The most positive effects of such a life is the enlarged geographical scale of job locations while the most negative effect is the missing out on the daily family life for a significant time(van der Klis & Karsten, 2009a). The perception of the commuting partnership could vary among different individuals under different situations. For instance, by interviewing 43 spouses, Gross (1980)concluded that older couples, couples married longer or freed from childrearing responsibilities, and those among whom at least one partner had an established career might consider the lifestyle less stressful.

Furthermore, Bunker et al. (1992)compared the quality of life of 90 commuting couples with that of 133 single residence dual career couples. Their study demonstrated that commuting couples expressed less satisfaction with their partner relationship and family life, yet commuting couples, especially men were more satisfied with their work life and appreciated the additional time they could reserved for themselves.

4. Analytical Methods to Study LDC/TRC

4.1. Intercity Travel Demand Model

Intercity travel demand model has different types that focus on different geographic units including major intercity corridor, statewide, regional, and national models. The motivation of developing intercity travel model in addition to the urban travel model is that transportation researchers believe that people travel according to a different set of rules over longer distances and between metropolitan areas from inside a metropolitan region (TRB, 2006). The ability to analyze intercity travel demand relationships and forecast future intercity travel demand is important to assist public agencies and private carriers in making intercity transportation service decisions, such as investment in HSR technologies (Koppelman & Hirsh, 1986).

The earliest intercity model were developed in the 1960s, and in the 1980s, Rice et al. (1981) and Koppelman et al. (1984) conducted detailed reviews of intercity model development efforts. Yet, the intercity models were often associated with an academic exercise, making use of fewer, more carefully chosen origin-destination pairs and generally presenting situations that were a little more abstract in nature (TRB, 2006). The most implemented intercity travel models are those statewide models that developed by different state transportation agencies starting in the 1990s.

The existing intercity travel modeling approaches can be categorized into two major classes – aggregate approach and disaggregate approach. (Koppelman, et al., 1984; Rice, et al., 1981; TRB, 2006). The aggregate approach relied on aggregate data that describe the averages or totals of the socioeconomic status of a city or a region, such as population, employment, economic activity, while disaggregate approach introduced disaggregate data that go further exploring the behavioral motives and characteristics of individual trip makers.

4.1.1. Aggregate Approach

The examination of the Northeast Corridor initialed the intercity travel modeling effort in the 1960s. Most of the early intercity travel model applied the aggregate approach. These models can be further grouped into direct-demand model and sequential models in terms of their structures – a direct-demand model "calculates all of the desired travel information in one, singly calibrated step" (TRB, 2006, p. 79) while a sequential model divides the calibration process into multiple stages. The typical example of the sequential model is the traditional urban four-step model. As Koppelman et al. (1984) summarized, the direct demand model either focused on direct origin-destination traffic volume for one or all travel modes, or focused on modal share, and sequential models included both intercity traffic volume and mode share.

The early aggregate intercity travel mode revealed that variables that were statistically related to travel volume included city activity and attraction variables such as population, employment and average/medium income, as well as city pair level of service such as travel time, travel cost and service frequency, and it was important to segment intercity travel market by trip purpose (at

lease business and non-business) and trip distance (Koppelman & Hirsh, 1986; Koppelman, et al., 1984).

Quandt & Baumol (1966) developed one famous intercity travel model in the 1960s – the abstract mode model. In the abstract model, the choice of a mode by a traveler depended on the absolute performance level of the "best" mode on each criterion (i.e. travel time, travel cost, service frequency) and the performance level of each mode on each criterion relative to the "best" mode. The travel modes were defined in terms of the type of service they provided to the travelers but not in terms of the physical equipment they employed (i.e. whether it is airplane or railroad). The authors claimed the advantage of possibility to use the abstract model to predict travel on a new mode or a mode with no historical data. However, other researchers did not obtain ideal results when applying this abstract mode approach, and believed that the "the use of the best attribute approach representing competitive effects…[was] …a weak representation of intermodal competition" (Koppelman, et al., 1984).

The aggregate intercity models were criticized for lack of behavioral basis and hence insensitive to important policy variables, estimation bias caused by data aggregation, and unsuccessful functional form (Koppelman, 1989; Koppelman & Hirsh, 1986). These deficiencies led to poor model performance and encouraged researchers divert attention to the disaggregate approach.

4.1.2. Disaggregate Approach

The disaggregate approach analyzes intercity travel at the level of the decision marker – the individual or household. The most advantage of disaggregate approach is the inclusion of a wide range of policy-sensitive variables. Thus disaggregate model is regarded by researchers as more accurate in representing the behavioral response of travelers to changes in economic activities and to changes in intercity transport services (Koppelman, 1989).

Watson (1974) developed both a aggregate model and a disaggregate model using the same data from the Edinburg-Glasgow Area. The aggregate model contained 158 zone-to-zone pairs between the two cities, and the disaggregate model used a binary logit model (rail versus car) based on a sample of 2,546 individuals. Watson concluded that the disaggregate model provided a better statistical explanation of mode-choice behavior. In Watson's study, the predictions of modal split derived from the aggregate models were inferior to those obtained from the disaggregate models. Thus, Watson believed that disaggregate models have "extremely desirable performance characteristics".

Understanding the intercity passenger decision-making process is an important step to develop disaggregate intercity travel model. Koppelman & Hirsh (1986) constructed a intercity travel behavioral framework as show in Figure 1.

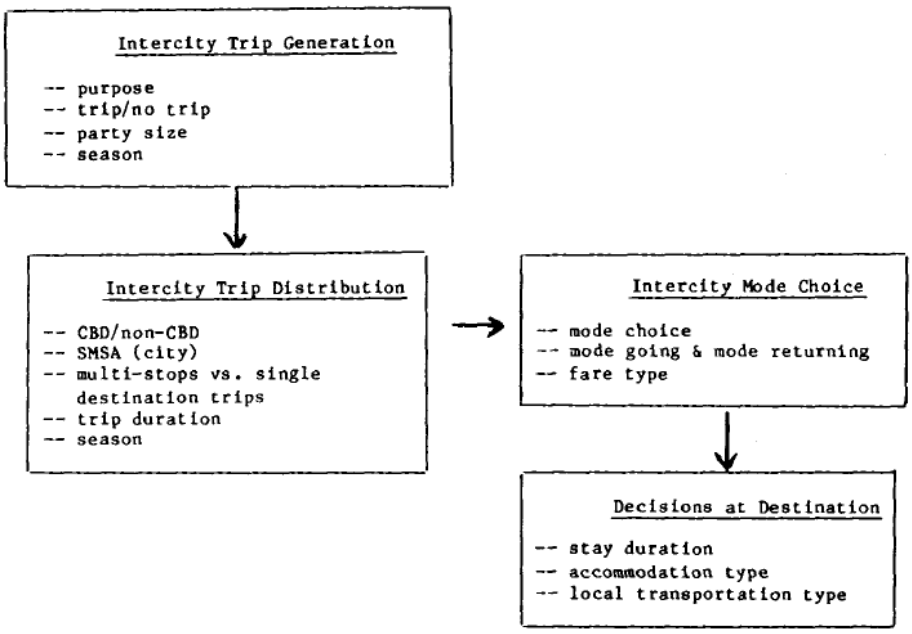

Figure 1: Intercity Decision Making
(Source: Koppelman & Hirsh, 1986)

Koppelman (1989) then developed a multidimensional model system for intercity travel choice behavior. Koppelman's model used the 1977 NTS data which contained l00 miles or more trips during a 3-month period for randomly selected households in 34 metropolitan areas. Seven cities (Atlanta, Baltimore, Boston, Buffalo, Chicago, Los Angeles, and Washington, D.C) were selected as either origin or destinations of city pairs to limit the number of city pairs and hence reduce the burden of collecting intercity level-of-service data. Thus 130 city pairs were chosen and information of travel time, fare and service frequency was obtained for available modes and fare classes between these city pairs.

This model system contained four sequential disaggregate models: the choice of trip frequency, destination, mode, and for fare/service class for air travel. The trip frequency model applied a linear regression method to predict the expected trip frequency for each traveler, and the other three models applied multinomial logit method to predict the possibility that the traveler will choose each alternative in the available choice set. Koppelman described the four steps of decision making as an interrelated process which can be reflected in a hierarchical structure. In the hierarchy, each choice decision is made conditionally on the higher level choices and influenced by the lower levels choices. For example, the choice of travel mode is based on the selection of the selected city, and a traveler will make decision about service class only after he/she decides to travel by air. This hierarchical structure was realized by a nested logit model approach.

Koppelmand reported the importance of level of service variables and demographic variables were supported by the significance of the corresponding parameters; the hierarchical mode structure was also supported by the estimation results for the composite variables. Moreover, Koppelman pointed out since this model system relied on travel service data obtained from

published schedules rather than actual performance, and access travel time and cost were excluded from the model due to lack of precise origin and destination locations, his approach was not a fully disaggregate approach that would produce even better predicted results.

Based on the hierarchical model framework proposed by Koppelman, Yao & Morikawa (2005) developed an integrated intercity travel model for the Tokyo – Nagoya – Osaka corridor in Japan to forecast the travel need of a proposed HSR project. Yao & Morikaw's model included trip generation, destination choice, mode choice, and route choice. In addition to applying the nested logit model structure to capture the relationship between each choice, Yao & Morikawa introduced an accessibility measure to capture the short term induced travel. Since this model is to evaluate a proposed HSR project, in the mode choice step, Yao & Morikawa constructed three sub-models using the revealed preference data, stated preference data, and aggregate Origin/Destination trip data. They estimated there is a general preference for the HSR service relative to other modes, and by 2020 when the HSR would be put into operation, the induced travel accounted for 16.5% of the travel demand.

4.2. Mode Choice modeling

The mode choice modeling represents the single most critical component of the overall intercity demand forecasting process (Miller, 1992), and the disaggregate approach is most applied and developed in modeling intercity travel mode choice. The choice among a set of mutually exclusive available intercity travel mode including auto, bus, rail, air, and/or HSR is referred as discrete choice. Discrete choice analysis is commonly used to model such choice based on principles of utility maximization – travelers are assumed to select the mode with the highest utility. The utility of a choice contains a deterministic portion which can be explained by a set of variables including characteristics of travelers and the transport mode, and a random component which represents the unknown or unobservable effect (Ben-Akiva & Lerman, 1985). The distribution of the random component of the utility largely decides the functional structure of the mode choice model.

The most widely used operational intercity passenger mode choice model is the multinomial logit (MNL) model, which assumes the random term is Gumbel distributed. The MNL model has the advantage of a closed form mathematical structure to simplify computation in both estimation and prediction (Koppelman & Wen, 2000). Stephanedes et al. (1984) calibrated a MNL model for business travel in the Twin Cities-Dulutn, Minnesota Corridor considering the bus, auto and plane mode in the 1980s. Stephanedes et al. defined this model as "fully" disaggregate comparing to the previous models which were only partially disaggregate because of the utilization of average values for travel time/cost and level of service variables for each trip mode and corridor. This model used data from non-random observation of 90 intercity travelers at the Twin Cities air and bus terminals and outlying gas stations. In order to ensure full data disaggregation, the researchers estimated the out-of-vehicle trip characteristics for the non-chosen alternatives.

The MNL model is based on the assumption of independence of irrelevant alternatives (IIA) of random term, which implies the alternatives being considered in the model are independent of each other and have the same variance. This assumption represents the biggest weakness of the MNL: the cross elasticity of one mode to all other modes remains constant, which means improvement in one mode, or introducing a new mode will result in trip diversions to the changed mode/new mode in fixed proportions from all other modes. When the reality violated such condition, the MNL model will results in incorrect predictions.

The weakness of the MNL can be strengthened by relaxing the IIA assumption. The first and the most widely used relaxation of the IIA assumption is the nested logit (NL) model by grouping similar alternatives into nests (Ashiabor, et al., 2007). Other models that relaxed the IIA assumption include cross-nested logits, ordered generalized extreme value model, paired combinatorial logit (PCL), generalized nested logit (GNL), and mixed logit (Ashiabor, et al., 2007), etc. Figure 2 (Koppelman & Sethi, 2005) summarized a conceptual overview of the different random utility based discrete choice models. In this report, the PCL model (Koppelman & Wen, 2000), the heterogeneous GNL(Koppelman & Sethi, 2005), and mixed logits model (Ashiabor, et al., 2007; Srinivasan, et al., 2006) will be reviewed.

The primary difference between the NL model and the PCL model is how they represent similarity between pairs of alternatives: in the NL model all pairs of alternatives in a common group have the same similarity as all other pairs, while in the PCL model each pair of alternatives can take on a similarity relationship that is independent of the similarity relationship between other pairs of alternatives (Koppelman & Wen, 2000). Koppelman & Wen (2000) calibrated the MNL, NL, and PCL models for the same study areas. The study is to estimate the demand for HSR in the Toronto-Montreal corridor, and used data from observations of 2769 travelers who chose air, train or car to travel in the corridor. The NL model contains train-car nest and air-car nest; the PCL model contains train-car similarity, air-car similarity, as well as train-car and air-car similarity. The model containing similarity parameters for air and car and for train and car represents the specialty of the PCL model structure which cannot be realized by the MNL or the NL models. It also yields the highest loglikelihood, and hence demonstrates the statistical and structural superiority of the PCL model (Koppelman & Wen, 2000).

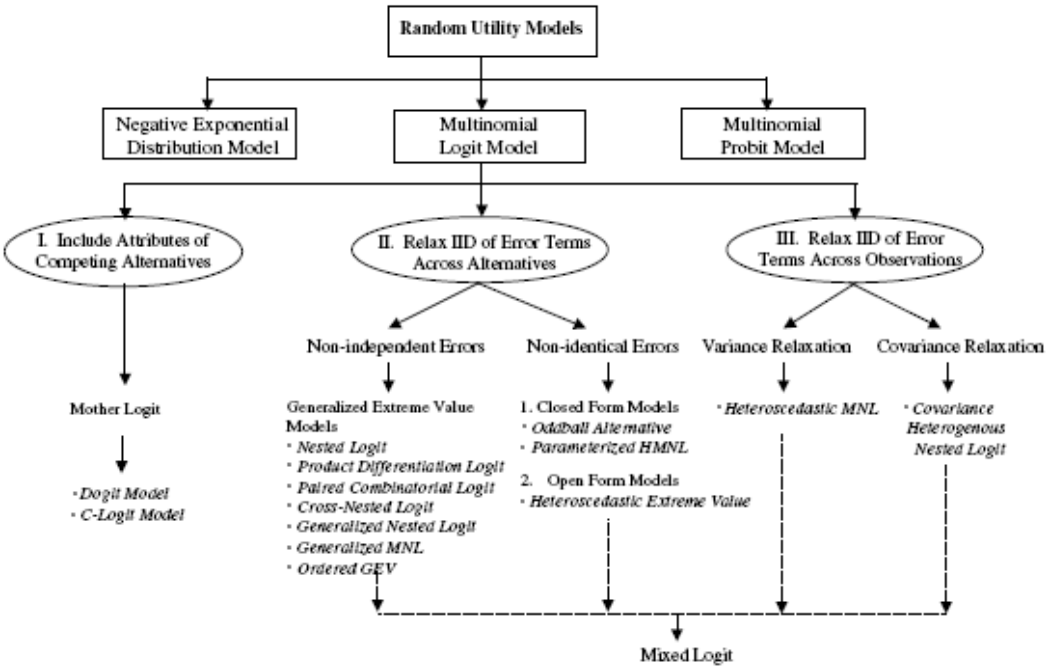

Figure 2: Overview of different random utility models (Source: Koppelman & Sethi, 2005)

Koppelman & Sethi (2005) developed a Heterogeous GNL model which combined the GNL model that allows for non-independent errors, the Heteroscedastic MNL which allows non-constant errors across observations, and the Covariance Heterogeneous NL model which allows for non-constant correlation structure across observations. This combination of three model structure enhances the model's ability to represent the complexity of intercity travel choice decision making. This study used data from a Stated Preference survey of both existing rail users and travelers using other intercity travel modes but not rail to analyze rail service class choice. Koppelmand & Sethi developed the model in four stages starting from the simple MNL structure and sequentially relaxed some of its restrictive assumptions to realize more flexible models.

Both NL and GNL models relax the identical distribution assumption of the IIA, another model structure, mixed logit, was recently developed to relax both the identical and independence assumption simultaneously. Ashiabor et al. (2007) compared a NL model structure and a mixed logit model structure. The two models were developed to study national-level intercity travel market share among automobile, commercial airline and a possible new mode – small aircraft transportation system (SATS) in the U.S. In this analysis, the 1995 ATS data served as the source of traveler information supplemented with a random survey of 2000 samples conducted by the authors. The automobile trips included all trips between any pair of counties and the air trips included all trips between any pair of airports in the U.S. The models were separately calibrated for business and non-business trip purpose. The NL and the mixed logit model included the same variables which are travel time, travel cost, household income and location of the trip origin or destination (whether it is inside MSA or not). The differences between the two model structures are the time coefficient is no longer fixed in the mixed logit model which also

does not have nests. Ashiabor et al. found that all variables in the models were significant, and the mixed logit model always had a better fit than the NL model.

Srinivasan et al. (2006) calibrated a rank-ordered mixed logit model to evaluate the impact of security perceptions on intercity mode choice is the aftermath of the event of September 11, 2001. The study used data collected in New York City from October 2003 to May 2004. The survey asked respondents to rank-order four travel modes for a business trip under different scenarios for one of six intercity corridors in the Northeast and Midwest region. Ten scenarios were defined by varying the values of variables including time-of-day departure, travel time, airplane inspection and boarding time, and travel cost. In addition, the survey asked questions on the individual's security perceptions and the travel characteristics of respondents in their assigned travel corridor. Srinivasan et al. concluded from the model results that the success of the strategies applied to improve aviation security to sustain air users depends on the passengers' perception of the measures implemented and the inspection times.

4.3. Application Example: Intercity Bus Transportation

Intercity bus represents a very small intercity travel market segment. Yet, intercity bus transport provides a critical role for smaller communities or rural areas where air or passenger rail options are not available, and for population who cannot afford other higher-cost transport modes (TRB, 2002). The Texas Department of Transportation conducted an on-board intercity bus survey in the state of Texas in the early 1980s (Urbanik, et al., 1982). Urbanik et al.(1982) summarized the survey results and compared the results to an on-board survey conducted in Michigan in 1977. They found that low-income persons were a significant part of intercity bus riders, and having no automobile was an important reason why people chose riding intercity bus. However, they also found that the loss of bus service would appear to leave only a small number of persons without an alternative travel mode. In addition, Urbanik et al discovered that the younger passengers represented more of a captive market than the elderly. Overall, they concluded the Texas intercity bus rider did not appear to be significantly different from those in other parts of the U.S; they also suggested improvement in intercity bus service should be focused on safety, on-time performance and comfort based on respondent's attitudes.

After the regulatory reform on the intercity bus industry, another study was conducted by Fitzpatrick et al (1996) to produce data necessary to define the status of the intercity bus industry in Texas in the 1990s. The study revealed that the number of communities served by the intercity bus in Texas decreased from 1,106 in 1970 to 596 in 1992. The study included a household survey mailed to Texas residents to gather data about demographics, information about intercity bus use and people's attitude to the intercity bus system. Based on the responses of 545 households, it appears that the intercity travel users had similar characteristics to that in the early 1980s in spite of the service drop: intercity bus riders were generally a lower-income group and to visit friends or relatives; express bus service, better bus station locations, increase in air and train fares, as well as bus safety and comfort are major factors that affected people's decision in taking intercity bus.

4.4. Application Example: Forecast Ridership for New Mode (HSR)

Decision in investment of HSR is an important concern of intercity transportation policy. The approaches used to forecast ridership of the HSR can be classified into two major groups. The first approach starts the forecast from projecting total travel and then uses the discrete choice model to determine the share, based on which predict the future HSR ridership. The second approach starts from projecting trips that would be made by each existing mode and then determining with separate mode choice model to shift to the new HSR mode (or other new mode) as a function of relative factors (Brand, et al., 1992; Peeta, et al., 2008). The argument for the second approach lies in that different mode users exhibit different behavior when confronted with the choice to use HSR.

Brand et al. (1992) applied the second approach to forecast the HSR ridership for the proposed Texas TGV. The forecasting process was divided into two steps. In the first step, the total trip volumes by each existing modes were estimated based on population in origin/destination cities, income of intercity travelers and the level of service of each mode between the origins and destinations. In the second step, the share of total trips by trip purpose (business and non-business) that were expected to divert to HSR was estimated for each existing mode based on the comparison between the access, egress and line-haul time/cost and service frequency of the existing mode and those of HSR. The third step estimated induced travel by the new HSR service by incorporating the mode choice model utility function into the total demand model of the first step.

Because HSR does not exist in the U.S., it is not possible to use revealed preference (RP) data to estimate the HSR market share. Then, stated preference (SP) data are often utilized by researchers in studying a non-exist travel mode. The SP method was originally developed in marketing research in the early 1970s and received increasing attention in transport research since the 1980s (Kroes & Sheldon, 1988). Compared to RP method, the SP method has advantages of easier control of variables, more flexibility and capability to explore non-existing situation. Yet, it also has several limitations for travel demand modeling: respondents may respond differently in a real situation from what they indicate in the survey; they may not understand the explained scenarios in the survey, or too detailed explained scenarios will lead to a very long questionnaire (Peeta, et al., 2008). The uncertain reliability of SP data often leads to the question about the validity of the forecasting results only based on the SP data. Thus, to forecast HSR ridership, researchers often choose to combine RP data and SP data. In their HSR forecasting study, Morikawa et al (1991) and Yao & Morikawa (2005) developed RP and SP models separately and then combined RP/SP estimator by maximizing the joint log-likelihood function.

The Bay Area HSR ridership and revenue study (Cambridge Systematics Inc., 2006) was reviewed at the end of this report to serve as a practical case of studying intercity travel demand. The HSR ridership forecasting model followed the framework of the California Statewide model, which contains four components: urban travel, interregional travel, external travel and trip assignment. This report will only focus on the interregional travel model component. The interregional trips were defined “as all trips with both ends in California and whose origin and destination are in different urban areas (or different counties outside the urban areas) having proposed HSR stations” (Cambridge Systematics Inc., 2006, pp. 1-3). The interregional trips

were further segmented into short trips that were less than 100 miles and long trips that were longer than 100 miles.

In order to calibrate the models, intercept survey and household surveys were conducted to obtain RP and SP mode choice data from air, rail and auto trip passengers. The air passenger survey (1,234 samples) was conducted at six key airports throughout California. The rail passenger survey (430 samples) was conducted both as an on-board self-administered survey and as a telephone survey among qualified existing rail users. The auto passenger survey (1,508 samples) was conducted as a household telephone survey using a stratified sampling approach.

The interregional models consist of four model components: trip frequency, destination choice, main mode choice, and access/egress mode choice. The market segmentations in the models were defined by trip purposes as business, commute, recreation, and other, as well as trip length as short trip (less than 100 miles) and long trip (longer than 100 miles). The trip frequency model treated "person-day" as the decision unit and applied the MNL structure. The model results showed that intraregion accessibility, travelers' living location, and travelers' household characteristics including income, auto ownership, number of workers and household size all affected the frequency of trip making. The destination choice model also applied the MNL structure. The model considered travel impedance, distance, area type, region, location interaction, and the amount of activities that occurs at destinations, yet the location interaction variables were tested as insignificant.

The access/egress mode choice model and the main mode choice mode all applied the NL structure. The access/egress model produced probabilities that each access and egress mode will be chosen for each origin-destination pair given the specific transportation characteristics and demographic characteristics of that travelers (Cambridge Systematics Inc., 2006, pp. 3-27). Driving including drive/park, drop off and rental car, and non-driving are the fist level of choices; taxi, transit and walk/bike are nested in the non-driving option. The main mode choice model contains auto and no auto options while air, conventional rail and HSR are nested in the non-auto option. The final model results indicate a higher HSR share due to the attractiveness of the time and cost. It should be noted that the trip frequency, destination choice and mode choice models all utilize accessibility or impedance measure as inputs.

5. Empirical Studies with National Datasets

5.1. The 1995 American Travel Survey (ATS)

The 1995 ATS represents the most current comprehensive survey on the long-distance travel of persons living in the United States. The ATS interviewed approximately 80,000 households beginning in April 1995 and ending in March 1996. Sample households were interviewed four times during this period at about three-month interval. The survey population consisted of persons resident in households and in group dwellings such as dormitories. The ATS data include basic social and economic characteristics of travelers including age, sex, education, income, etc, and detailed information about each trip including trip purpose, means of transportation, origin, destination, intermediate stops, travel dates and duration, number of nights away, and types of lodging used.

The 1995 ATS defined a long-distance trip as at least 100 miles one-way. The ATS (BTS, 1997) reveals that during the one year period, American households made 685 million long-distance trips (1 billion of personal trips), over 95% of which were to destinations within the United States. Of the trips with destinations inside the U.S., 45% were to destinations inside the traveler' home state. Personal use vehicle (PUV) was heavily used for long-distance travel. The total long-distance PUV trips were about 505 million from 1995 to 1996, resulting in over 280 billion vehicle miles of travel (VMT) on the nation's highways. The PUV were most used for shorter trips – 37% of the PUV were less than 300 miles round trips and 68% of the PUV trips were less than 500 round trips. On the contrary, commercial air was mostly chosen for longer trips – 72% of commercial airplane trips were 1,000 miles or more round trips.

Of all personal trips made during the survey year, 23% were for business, 30% were for leisure activities, one third were to visit friends or relatives, and 15% were for personal business such as attending wedding or funerals, or participating in school-related activities. The ATS also revealed the temporal pattern of long-distance trip making – the largest share of travel in 1995 occurred during the third quarter, July through September. It should be noted that household in Texas made more long-distance trips than the national average – the 1995 ATS data show that in Texas, about 87% of household took one or more long-distance trips to a destination 100 or more miles away, comparing to 80% of household in the nation.

The 1995 ATS has been used and analyzed by researchers for understanding intercity travel. Many of the work were presented in the 1999 "Personal Travel: The Long and Short of It" conference held at Washington, D.C., and published in the *Transportation Research E-Circular* (E-C026). Several researchers concluded based on the ATS dataset that income is an important factor affecting intercity travel behavior including travel frequency and mode choice (Addante, 2001; Chin & Hwang, 2001; Georggi & Pendyaly, 2001; Hwang, et al., 2001; Mallett, 2001). Mallett ((2001) compared the long-distance travel behavior of low-income people to the entire population. He found that Low-income people made much less long-distance travel than the entire population (1.6 per year vs. 3.9 per year) in 1995; for low-income people, one of the most important limiting factors is vehicle availability since air travel was beyond the means of most poor family. In addition, business and leisure trips are much more sensitive to income than those

to visit friends and relatives or personal business. Georggi & Pendvaly (2001) conducted similar research analyzing long-distance travel (trip frequency, trip purpose, trip mode, trip distance, trip duration, and travel party size) across age groups and income groups, in considerable detail for the elderly and the low income. Their findings confirmed the conclusion that the low income (along with the elderly) had significantly lower log-distance mobility when compared to other segments of the population.

Based on the 1995 ATS data, Chin & Hwang (2001) assigned person vehicle trips and household vehicle trips between metropolitan areas to major highways to identify major passenger corridors in the U.S. They identified such corridors by different trip purposes, income levels, as well as private vehicles and buses. They found the most traveled highway corridors were concentrated on east and west coast and there was no significant east-west cross-country corridor. In addition, pleasure trips including recreation and visiting family and friends as well as trips made by the middle-income household group dominated the long-distance highway travel in 1995. They also indicated that business trips showed concentration between nearby metropolitan areas while non-business travel showed distinct northeast and Pacific coastal corridors. In Chin & Hwang's research, the most prominent corridor to Mexico was identified as starting from the Dallas and Houston areas passing through San Antonio and entering Mexico via the border of city of Laredo. Moreover, Chin & Hwang pointed out that information on travel between cities that are less than 100 miles apart was missing from the ATS, which could lead to some incomplete understanding about long-distance travel.

The 1995 ATS data were also used to analyze intercity air travel. Addante (2001) studied the air travel market in the New England region. He revealed for air travel, the business and non-business split was about the same, yet for all mode travel, the split was about 30% to 70%, and the most significant class of air travelers were well educated, high income, married male with children. Hwang et al. (2001) evaluated the relationship between the accessibility of the air transportation system and the demographic and socioeconomic status of travelers. They found that higher income households were more likely to choose air travel; more than half of all out-bound air passenger drove to the airport and parked their vehicles at the airports, and the majority of travelers were either picked up by private vehicle or used a rental car to get from the airport to their final destination. Moreover, business travelers were more likely to drive to the airport and park and pleasure travelers were more likely to be dropped off at the airport.

The 1995 ATS data is a rich resource for intercity travel model development. O'Neil & Brown (2001) used the ATS data to develop a long-distance, non-business trip generation model using a cross-classification approach. The authors estimated the cross-classification trip rate for metropolitan and non-metropolitan areas separately based on household income and household type. The trip rates were defined by income level (low, medium, and high) and by household types (married with kids, married without kids, single parent with kids, family or non-family without kids, and non-family not living alone). It should be noted that the results of this research showed that whether there are kids or not would affect the long-distance travel decision. The authors also pointed out the ATS data have about half sample in metro areas and half in non-metro areas. Then the nearly equal sample size of households in metropolitan and non-metropolitan raised concerns that the metropolitan long-distance trips might not be well represented in the survey.

Another research done by Thakuriah et al. (2001) applied a gravity model to estimate patterns of demand between 50 metropolitan areas using the ATS data. The authors estimated the cost parameters by Maximum Likelihood and estimated the origin and destination parameters using a variant of Iterative Proportional Fitting. They defined different scenarios in which different cost variables including only distance, only time and combination of distance and time were used and concluded that model with the variable of combination of distance and time had slightly better result. The authors highlighted challenges associated with estimating inter-city demand from the ATS data – the need for better cost data since the cost data needed for model are not directly available from the ATS data set and need to be constructed from exogenous sources.

Richardson & Seethaler (2001) worked on the survey method for long-distance trips, specifically the selection of the period of observation for long-distance travel. The selection of the period of observation for long-distance travel has more difficulties than daily travel because of the infrequency and irregular characteristics of long-distance travel – too short period will not be able to catch enough long-distance travel while too long period will bring recall errors or put too much burden to respondents who make frequent long-distance travel. The typical long-distance travel survey defines a two-three month window and used retrospective recall methods while the 1995 ATS used prospective recording where respondents were given a diary in advance of the period and asked to record trips as they occurred. The authors proposed the "most recent trip survey method" for long-distance trip, which does not restrict a time period, but ask respondents the most recent long-distance trip they made no matter when. One of the most difficulties of using data obtained from such survey is how to calculating trip rate. The authors also proposed a probability method to calculate the trip.

Other than the 1995 ATS, the 1995 National Person Travel Survey (NPTS) also asked respondents questions about their long-distance travel. Hu & Young (2001) compared these two long-distance data sets. They summarized several major differences: The NPTS used residential telephone numbers as sample frame while the ATS used an address-based sampling frame (the ATS could capture more low-income household); The NPTS defined 75 miles (one way) as long-distance while the ATS defined 100 miles (one way) as long-distance; The NPTS had a 2-week window while the ATS had a 12-month window; The NPTS excluded college students and individuals younger than 5 years old while the ATS included all of them; ATS trip distances were calculated based on real route distance and from zip code centroid to zip code centroid while NPTS trip distances were calculated based on the great circle distance (22% shorter) and from MSA centroid to MSA centroid.

5.2. Census Transportation Planning Package (CTPP) and National Household Travel Survey (NHTS)

The two other most comprehensive travel data currently available to public include the Census Transportation Planning Product (CTPP) and the NHTS. The CTPP is a set of special tabulations derived from the decennial Census long form questionnaire which was sent to approximately one in six households containing all of the questions on the short form plus additional detailed questions relating to the social, economic, housing characteristics of each individual and household. In the long form questionnaire, six questions related to the journey to work were asked to survey respondents who worked at least 1 hour during the "last week" before the survey

date. The CTPP data include three parts containing residence end data, place of work data and journey-to-work flow data, respectively. The long form questionnaire has been stopped after the 2000 Census.

The NHTS is a nationwide travel survey sponsored by the Bureau of Transportation Statistics (BTS) and the Federal Highway Administration (FHWA) to collect data on daily travel by the American public. The NHTS survey obtained information of individual travel for a single day across all days of the survey year, and the people traveling, their household and their vehicles. Compared to the decennial Census, the NHTS has a smaller number of samples; about 1 out of 1500 households in 2001 NHTS and 1 out of 750 households in 2009 NHTS were represented. Yet, the NHTS data include the work trip distance reported by respondents, by which commuters can be easily grouped; the NHTS data also contain detailed personal and household information of individual travelers, which allows a thorough search of factors that influence long distance commuting decisions.

Base on their particular characteristics, the two datasets have been studied separately with different emphases. Since the CTPP has a larger sample coverage and contains journey-to-work flow data, in this proposed research, it was used to map the inter-metropolitan work flow in the Texas Triangle area. The NHTS data were then used to summarize the general characteristics of long distance commuters and long distance commuting trips, as well as to examine the relationship between socioeconomic characteristics of commuters and long distance commuting decisions. Due to the relatively small sample size of long distance commuters, the NHTS data were mainly analyzed at the national scale.

LDC/TRC commuting in this research should have two basic characteristics. First, the commute crosses the boundary of a metropolitan area; second, the length of the commuting trip should be at least 50 miles.

The criteria of long distance commuting vary among studies and there is no consensus on the minimum distance that constitutes long distance commuting. The US Census Bureau defines 90 minute one-way work trip as extreme commuting, and the US NHTS defines 50-mile one-way travel as long distance trip. Several European countries also defined long distance commuting based on survey results which varied between 15 kilometers and 100 kilometers (Sandow, 2011). Commuting trips with one-way distance at least 50 miles are defined as long distance commuting in this research following the US NHTS's long distance trip concept. According to the NHTS, the average commuting distance in the US is about 12 miles, 50-mile commute is about four times of that distance.

The LDC/TRC commuting can be conducted daily or weekly when the distance between residences and work places exceeds the tolerable daily commuting length. Weekly commuting involves staying in a secondary residence near work place one or several nights each week. Weekly commuting cannot be accurately distinguished from others in the NHTS data. For this analysis, 50-mile commute is considered as long-distance commuting. When the commute reaches 100 miles, approximately 2-hour drive, it is assumed that people will start weekly commuting. When the commute reaches 300 miles or more, it is assumed that weekly commuting is no longer feasible for driving, and people would prefer flight or reduce travel frequencies to residence.

5.3. The Analysis of the CTPP data

The 1990 and 2000 CTPP journey-to-work flow data were used to monitor the changes in the commuting flows between the four major metropolitan areas during the ten-year period.

The results are presented in Table 1. From 1990 to 2000, changes in the total number of commuters and the number of inter-metropolitan commuters within the Texas Triangle Area varied in the four major metropolitans. Although the number of commuters who lived in counties outside the four major metropolitan areas only increased 15%, the number of commuters who commuted to the four major metropolitan areas increased 91%. The huge difference between the two growth rates signals strong social-economic activities within the four major metropolitans in the Triangle Area. In both Houston and San Antonio regions, the growth of the inter-metropolitan commuters was much faster than the growth of the total commuters, which indicates that more commuters traveled outside of their residence metro regions to work. Then, the detailed commuting flows between regions presented in Table 1 show that for San Antonio region, the largest group of inter-metropolitan commuters were commuting to the Austin region, with the percentage increased from 59% to 74% from 1999 to 2000. The changes in the total number of commuters and the number of inter-metropolitan commuters from 1990 to 2000 in the Dallas-Fort Worth region were about the same. And Austin is the only region where the growth of the total number of commuters were much faster than that of the number of inter-metropolitan commuters from 1990 to 2000; meanwhile Austin region attracted more inter-metropolitan commuters from all other areas in the Texas Triangle during the ten-year period, especially commuters from San Antonio.

Table 1: Percentage Changes of Total and Interregional Commuters from 1990 to 2000

Residence Location	**Work Location**	**Year**		**Change**
		1990	2000	
Houston	Total	1,759,277	2,054,374	17%
	Outside Houston Metro	9,571	13,498	41%
Dallas-Fort Worth	Total	2,005,468	2,458,325	23%
	Outside Dallas-Fort Worth	8,284	10,136	22%
Austin	Total	414,695	614,275	48%
	Outside Austin Metro	9,565	11,530	21%
San Antonio	Total	587,886	706,685	20%
	Outside San Antonio	7,776	14,208	83%
Other Counties	Total	389,253	445,820	15%
	Four Metros	17,781	33,944	91%

Table 2: Commuting Flow between Regions in the Texas Triangle Area (1990)

		Destination				
		Houston	Dallas-Fort Worth	Austin	San Antonio	Other Counties
Origin	Houston	-	26%	11%	12%	51%
	Dallas-Fort worth	39%	-	14%	9%	37%
	Austin	16%	13%	-	35%	36%
	San Antonio	18%	13%	59%	-	9%
	Other Counties	45%	32%	19%	4%	-

Table 3: Commuting Flow between Regions in the Texas Triangle Area (2000)

		Destination				
		Houston	Dallas-Fort Worth	Austin	San Antonio	Other Counties
Origin	Houston	-	25%	14%	9%	52%
	Dallas-Fort Worth	32%	-	17%	9%	42%
	Austin	15%	15%	-	38%	31%
	San Antonio	10%	10%	74%	-	6%
	Other Counties	36%	26%	35%	3%	-

The strongest message delivered by the CTPP data is the rapid growth of commuters from other counties to the four metropolitan regions, and the increasingly tightened connection between Austin and San Antonio.

5.4. The Analysis of the NHTS data

The 2001 and 2009 NHTS data are used to examine the long distance commuting patterns in the US. The most current NHTS data (2009 data) were collected in year 2008. There are a total of 150,147 household samples (324,184 persons) in the survey, among which 22,255 household samples (49,172 persons) were collected in Texas. Prior to the 2009 NHTS is the 2001 NHTS. In the 2001 NHTS, 69,817 household samples (160,758 persons) were collected nationwide with 5543 household samples (12,938 persons) in Texas.

The analysis was concentrated on two geographical levels - national level and Texas level. The variable of reported distance to work was used to identify long distance commuters. Since the NHTS data do not provide detailed origins and destinations of each commute, it is difficult to distinguish interregional commute from commutes within one region. Yet, the 50-mile one-way distance can be used as the criterion to identify commutes across the boundary of a metropolitan region. In addition, the NHTS does not include survey questions to distinguish weekly commuters, thus, in this analysis, weekly commuters were separated out by assuming that workers who travel 100 miles or more to work will commute weekly. At the national level, a descriptive analysis of the two NHTS data (2001 and 2009) were performed, and binary logit models were developed for commuters who traveled at least 50 miles and 100 miles, respectively. At the Texas level, detailed work flow directions were examined based on the home and work address that respondents reported.

Table 4: Percent of Trips (long-distance) by Trip Purpose

Mode	**Trip purpose**					
	Business	**Commute**	**Pleasure**	**Personal Business**	**Other**	**Total**
Personal vehicle	79.3	96.4	90.4	89.3	96.6	89.5
Air	17.8	1.5	6.7	4.7	1.9	7.4
Bus	0.8	0.5	2.2	5.6	0.5	2.1
Train	1.6	1.7	0.5	0.3	<0.1	0.8
Other	0.5	0.0	0.2	0.1	1.0	0.2
Total	100	100	100	100	100	100
% By Purpose	15.9	12.7	55.5	12.6	3.4	100.0

Table 5: Percent of Trips (long-distance) by mode for One-way Travel Distance

Mode	One-way distance				
	50-499 Miles	500-749 miles	750-999 miles	1,000-1,499 miles	1,500+ miles
Personal vehicle	95.4	61.8	42.3	31.5	14.8
Air	1.6	33.7	55.2	65.6	82.1
Bus	2.1	3.3	1.5	1.5	1.4
Train	0.8	1.0	0.9	0.7	0.8
Other	0.2	0.1	0.1	0.7	1.0
Total	100	100	100	100	100
% by Distance	89.8	3.1	2.0	2.3	2.8

Table 6: Percent of Trips (long-distance) by mode for Household Income Groups

Mode	Income			
	Less than $25K	$25K-$49K	$50-$74K	$75K+
Personal vehicle	92.2	93.3	91.7	83.9
Air	3.0	3.8	5.3	13.7
Bus	3.8	2.1	2.0	1.5
Train	0.7	0.6	0.8	0.8
Other	0.3	0.1	0.3	0.2
Total	100	100	100	100

Table source:
http://www.bts.gov/publications/america_on_the_go/long_distance_transportation_patterns/

Since the 2001 NHTS is a national survey, it collected data from a nationally representative sample of households to derive statistically reliably travel estimates at the national level. The nationwide sample data will not be adequate to provide statewide, or area-specific estimates. Yet, the NHTS provided an "add-on" program, which allowed a state or a local jurisdiction which wants to develop travel estimates for a specific area to purchase additional households in their jurisdiction to be interviewed and included in the NHTS. The state of Texas participated in the "add-on" program in the 2001 NHTS to add more than 3,000 samples in Texas, which can serve as a rich resource for understanding the intercity travel in Texas.

5.5. Long Distance Commute in the Nation

The NHTS data show that from 2001 to 2009, the total number of workers in the US increased 4% while the total number of workers in Texas increased 13% during the same period. In the US, 2.8% of all workers were long distance commuters in 2001, and the percentage increased to 2.9% in 2009. As shown in Table 7, Northeast and West regions had higher percentage of long distance commuters than other regions in 2001, but the percentage dropped to below other regions in 2009. On the contrary, the percentage of long distance commuters increased from 2001 to 2009 in Midwest and South regions. In 2009, the South region had the highest percentage of long distance commuters.

Table 7: Percentage of Long Distance Commuters

Year	Northeast	Midwest	South	West
2001	3.1%	2%	2.9%	3.1%
2009	2.9%	2.9%	3.1%	2.5%

Table 8 and Table 9 present the composition of long distance commutes in 2001 and in 2009. Overall, among the long distance commutes, more than 80% of the commutes were shorter than 100 miles one way and less than 3% of the commutes were longer than 300 miles. The long distance commute composition varied among the four Census regions. The South region had the highest share of commute with distance between 100 miles and 300 miles, although this share dropped from 17% in 2001 to 13% in 2009. The Northeast region had the second highest share of commute with distance between 100 mile and 300 miles but had the lowest share of commute with distance longer than 300 miles. The long distance commute composition in the Midwest region remained stable during the approximately 10-year period, and the share of commute with distance less than 100 miles were highest in the US in both years. In the West region, the share of commute with distance less than 100 miles experienced the largest drop from 2001 to 2009 while the share of commute with distance between 100 and 300 miles increased the most.

Table 8: 2001 Long Distance Commute Composition

Distance (Miles)	Northeast	Midwest	South	West	Nation
50-100	87.17%	92.17%	78.17%	91.91%	85.9%
100-300	12.59%	6.68%	17.12%	5.72%	11.52%
>300	0.24%	1.15%	4.72%	2.37%	2.58%

Table 9: 2009 Long Distance Commute Composition

Distance (Miles)	Northeast	Midwest	South	West	Nation
50-100	86.61%	91.09%	84.12%	88.30%	86.98%
100-300	12.78%	6.44%	13.42%	8.38%	10.73%
>300	0.61%	2.48%	2.46%	3.32%	2.29%

The main travel means for long distance commuters was private car. As shown in Table 10, more than 90% of long distance commuters drove private cars to work and more than 80% of them drove alone.

Table 10: Long Distance Commuting Mode Share

Year	Auto mode share	Drive alone share
2001	91.3%	80.0%
2009	91.5%	83.0%

Because of the long commute distance, long distance commuters need to spend longer time on road. Table 11 compares the percentage of long distance commuters who left home before 7am and returned home after 6pm to that of shorter distance commuters. More than 50% of long distance commuters left home before 7am and returned after 6pm while less than 30% of short distance commuters left home before 7am and less than 40% returned home after 6pm.

Table 11: Leave Home and Return Home Time

Year	Commuting Distance	Leave home before 7am	Return home after 6pm
2001	<50 miles	29.2%	37.4%
	>=50 miles	56.4%	56.6%
2009	<50 miles	28.9%	36.2%
	>=50 miles	56.0%	59.6%

The NHTS data also show that the Vehicle Mile Traveled (VMT) by the 3% long distance commuters accounted for 16% of VMT by all commuters in 2001 and 13% in 2009. Table 12 lists the VMT for commuting in 2001 and 2009. The overall VMT by commutes drops 0.05%; VMT by short distance commuters increased 2.8% while VMT for long distance commuter decreased 15%.

Table 12: Long Distance Commute VMT

Region	VMT for commuting (billion miles)					
	2001			2009		
	All	<50 miles	>=50 miles	All	<50 miles	>=50 miles
Northeast	106.9	91.4	15.4	112.4	96.9	15.6
Midwest	154.1	137.6	16.5	147.8	130.8	17.0
South	259.7	211.4	48.3	264.3	227.4	36.9
West	146.6	121.6	25.0	142.5	122.7	19.8
Total	667.3	562.0	105.3	667.0	577.8	89.2

Binary logit models were developed separately for long distance commute with trip length of more than 50 miles and trip length more than 100 miles, and for year 2001 and 2009.

Table 13 lists variables included in the models.

Table 13: Variables in Models

Variable	Model 1	Model 2	Model 3	Model 4
	DISTTOWK>=50 (2001)	**DISTTOWK>=100 (2001)**	**DISTTOWK>=50 (2009)**	**DISTTOWK>=100 (2009)**
Gender	Male/Female			
Income	1=<$25,000; 2=<$60,000; 3=<$100,000; 4=(>=100,000)			
Education	1=High school and lower; 2=Some college; 3=Bachelor; 4=Graduate		1=Lower than college; 3=Bachelor; 4=Graduate	
Occupation	1=Sales or service; 2=Clerical or administrative; 3=Manufacturing, construction, maintenance, or farming; 4=Professional, managerial or technical; 5=Other			
Life cycle	With children under 5/Not with			
Number of workers in household	1-10			
House ownership	Own/Rent			
Census region	1=Northeast; 2=Midwest; 3=South; 4=West			
Home location	1=Second city; 2=Rural; 3=Suburban; 4=Town; 5=Urban		1=Second city; 2=Suburban; 3=Town and country; 4=Urban	
Work at home option	Work at home in past two month/Not		Has option working at home/No option	
Internet use	Access to internet in past 6 month/No access		Access to internet in past month/No access	
View on price (Gas, Toll, etc.)	-		Is a problem/Not a problem	

The results of the models, as shown in Table 14, contain findings within expectation as well as surprises. Five variables have consistent effects in all four models. The first variable is gender. As found by other researchers, these models also prove that males are more likely to commute long distance than female. The second variable is income. The models show that workers with highest level of salary are more likely to commute long distance, which is expected since higher level of pay is an incentive for long distance commute and is often needed to compensate the cost associated with long distance travel. The third variable is number of workers in a household. The models indicate that individuals are less likely to commute long distance when the number of workers in a household increases. This result brings a little surprise. Several researchers have found that having two earners in a household can encourage long distance commute since there exist more obstacles to an optimized commute for both workers in a household (Ma & Banister, 2006). Yet, the result can also be explained because people may have more time to search for job opportunities closer to home with financial support of other household members. The fourth variable is home location. The models found out that workers living in urban areas are less likely to commute long distance. This result is as expected since urban areas provide more jobs. The last variable consistently affects the four models is the option of working at home. When people have the option to work at home occasionally, the probability of conducting long distance

commute increases. This result indicates that flexible work policy would encourage people to travel further for better job opportunities.

Then, surprisingly, education, occupation, and house ownership are not significant for all four models. Based on literature in long distance commuting, the hypothesis for these three variables is that workers with higher level of education, workers in professional fields, and workers who own a house tend to commute long distance. However, the hypothesis is not supported by the NHTS data.

In additional to the above mentioned variables, other variables show different effects across models. The hypothesis about life cycle is that workers with small children are less likely to commute long distance, which is supported by the models for 2009, but not by the models for 2001. Then, workers in different Census regions exhibit different tendency for long distance commute in the first three models. Moreover, internet use has a negative effect on long distance commuting in model 1. It can be explained by the assumption that internet brings more local job information to people and thereby reduces long distance commute, even though internet technology provides people the opportunity to work remotely and may encourage people to take jobs far away. Finally, people's views on travel price exhibit a positive effect on long distance commute, that is people who have concerns over travel cost tend to commute long distance. The result sounds controversial. However, it seems that this variable is more of an effect of long distance commuting instead of a cause - people who commute long distance are more concerned about travel price.

Table 14: Model Results

Variable	Model 1	Model 2	Model 3	Model 4
	DISTTOWK>=50 (2001)	**DISTTOWK>=100 (2001)**	**DISTTOWK>=50 (2009)**	**DISTTOWK>=100 (2009)**
Gender	Male is more likely to commute long distance			
Income	Workers with income more than 100,000 are more likely to commute long distance			
Education	Not significant			
Occupation	Not significant			
Life cycle	Workers with small children are more likely to commuter long distance	Workers with small children are less likely to commuter long distance (Not significant)	Workers with small children are less likely to commuter long distance	
Number of worker in household	Workers who have other people work in the household are less likely to commute long distance			
House ownership	Not significant			
Census region	Workers in Midwest are less likely to commute long distance than works in Northeast and West	Workers in South are more likely to commute long distance then workers in West	Workers in West are more likely to commute long distance then workers in Midwest and South	Not significant
Home location	Workers who live in urban areas are less likely to commute long distance			
Work at home option	Workers who can work at home are more likely to commute long distance			
Internet use	Workers with internet access are less likely to commute long distance	Not significant		
View on price (Gas, Toll, etc.)	-		Workers have concerns about gas (and other charges) are more likely to commute long distance	

5.6. Long Distance Work Flow Directions in Texas

The next step of this study is to narrow the geographical scope and focuses on the state of Texas, which is the largest state in the South region where the percentage of long distance commuting is the highest in 2009. In this step, the origins and destinations of long distance commutes were mapped based on the home and work locations respondents reported.

Figure 3 and 4 are two illustrations of long distance commuting flows in Texas in 2001 created using different methods. The origins and destinations were located at the tract level of reported home and work locations. In Figure 3 the long distance commuting were identified by the

reported distance to work of 50 miles or longer; in Figure 4, the long distance commuting were identified by the calculated commuting distance based on the reported home and work locations. TrasCAD GIS was used to calculated the distance between home and work based on FAF3 network. The second method has captured more long distance commuting.

By examining the detailed work flows, it proves that 50-mile is a good criterion to capture LDC/TRC commuting. About 70% of the commutes with distance of 50 miles or longer were interregional. In addition, it can also be found that the Texas Triangle area is the core which attracted LDC/TRC commuting in Texas. More than 70% of the long distance commuting destinations were located within the Texas Triangle area.

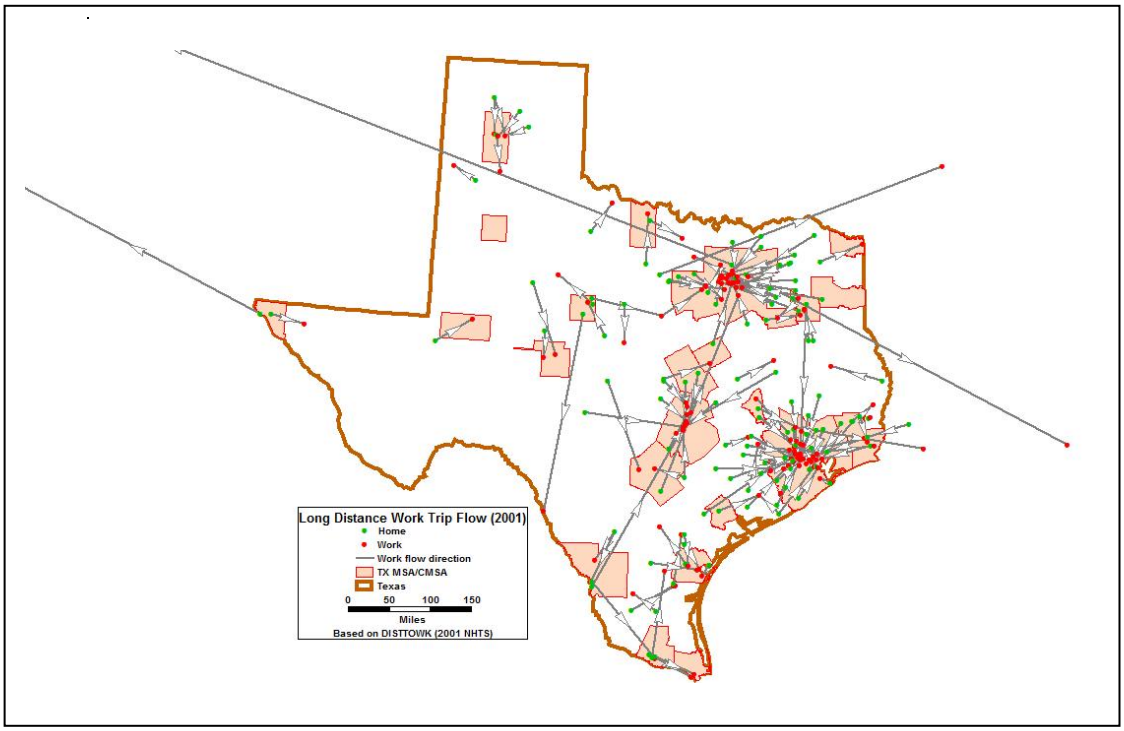

Figure 3: Long Distance Commute Flow Directions in Texas (2001a)

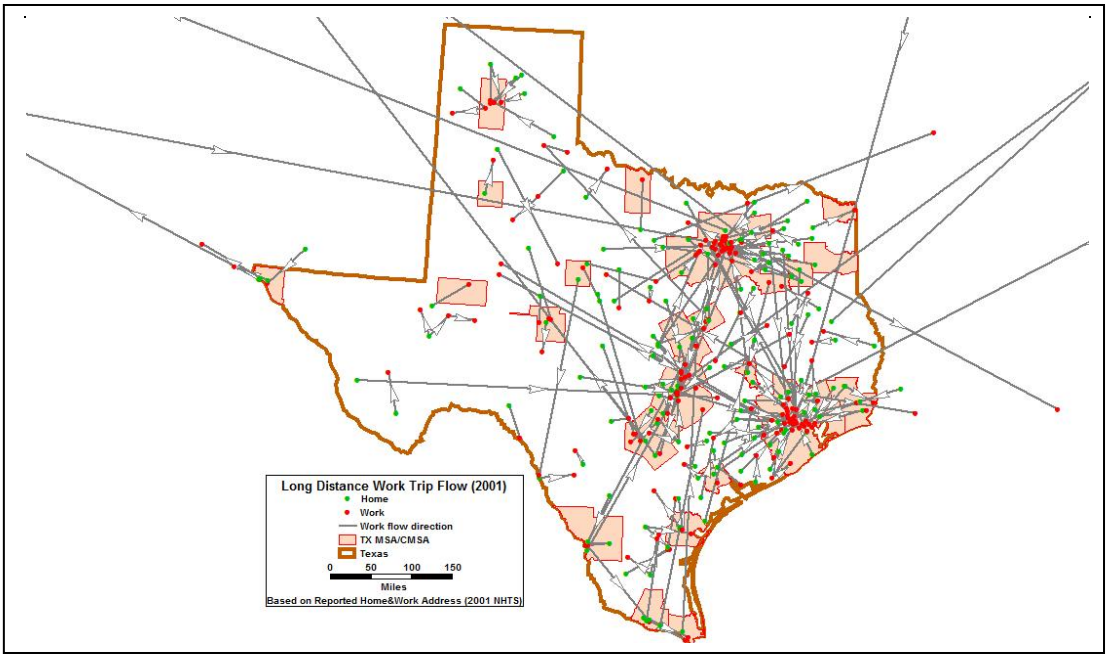

Figure 4: Long Distance Commute Flow Directions in Texas (2001b)

The long distance commuting flows were also mapped for 2009 using the first method, as shown in

Figure 5. As the sample size increased in the 2009 NHTS, a clearer "Triangle Pattern" that represents the commuting flows between the four major metropolitans in the Triangle area can be seen. In 2009, more than 60% of the commutes with distance of 50 miles or longer were interregional, and about 80% of the long distance commuting destinations were located within the Texas Triangle area.

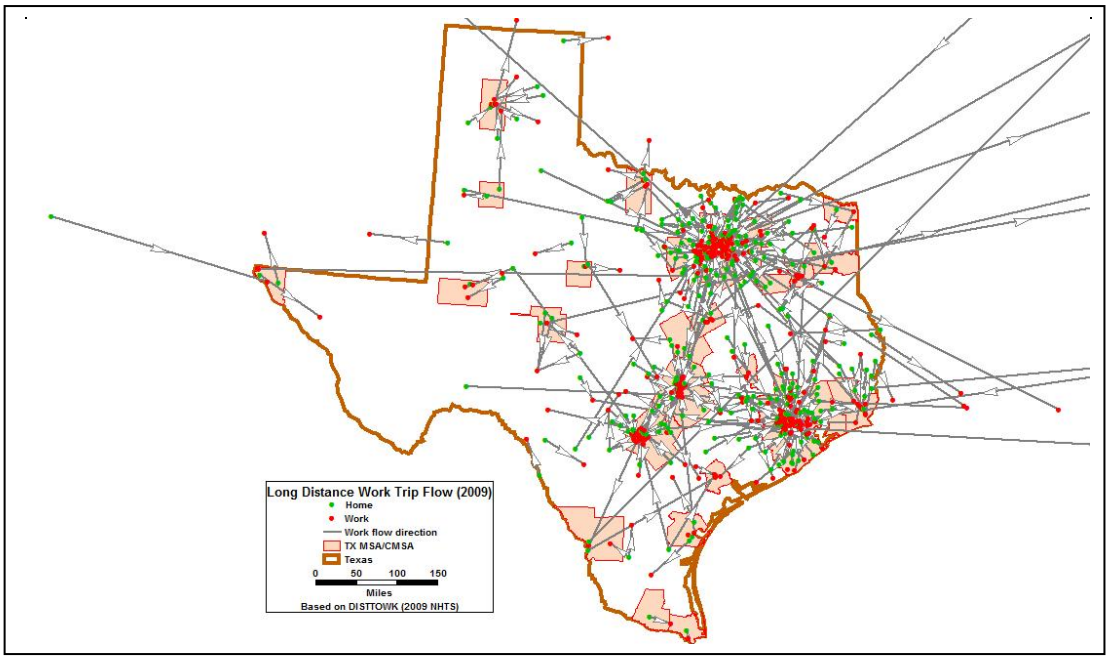

Figure 5: Long Distance Commute Flow Directions in Texas (2009)

5.7. Limitation of Using Secondary Travel Survey Data

Analyzing the CTPP data and the NHTS data is the first step in this research to gather knowledge about the LDC/TRC commuters and their work trips. The results generate an overall awareness of the interregional commuting flow patterns in the Texas Triangle Area, the long distance commuting changes across the nation, and some basic characteristics of the long distance commuters. However, the survey questions on journey-to-work trip in the Census survey and in the NHTS, as well as the characteristics of survey data limit their ability to clearly answer the questions asked in this research.

In the Census survey and the NHTS, the basic assumption on commuting is that individuals commute on a daily basis between a single fixed residence and a single fixed workplace. Thus LDC/TRC commuting that is often done less frequently than daily or weekly may not be well captured by the surveys. From the information provided by the two datasets, the identified interregional commuting based on home and work locations, as well as long distance commuting based on reported work trip distance cannot truly represent the research subject although they share some attributes of LDC/TRC commuting. Moreover, considering the special characteristics of the LDC/TRC commuting, more information especially "stories" behind the phenomenon is needed in order to answer the research questions.

6. Summary and Future Research

6.1. Summary of Preliminary Study

National transportation statistics have shown the rise of long-distance, trans-regional commute (LDC/TRC) in the US. Four societal factors contribute to the trend: increase in dual earner households, advance in information and communications technologies, new concept of arranging work time weekly, and people's changing attitude towards travel.

In the field of urban transportation planning, commuting has been studied in individual metropolitan areas in a one-day time frame. LDC/TRC traverse multiple metros and the commuting behavior cannot be better understood without going beyond the one-day convention. Studying LDC/TRC corresponds to the growing interest worldwide in planning for megaregions. Up to date, the phenomenon of weekly commuting has been explored only by a few European researchers in the fields of geography and sociology.

This study analyzed LDC/TRC using national datasets available in the US. They are American Travel Survey, National Household Travel Survey, and Census Transportation Planning Package. Results show that,

- Nationwide, the percentage of long distance commuters increased from 2.8% in year 2001 to 2.9% in year 2009. The South Census Region which Texas belongs to had the highest percentage of long distance commuters at 3.1% in 2009.
- Among long distance commuters, more than 80% traveled 50 to 100 miles to work, and less than 3% traveled over 300 miles to work. The main travel means for long distance commute was private car; more than 90% of long distance commuters drove private cars to work and more than 80% of them drove alone.
- The vehicle miles traveled (VMT) by the 3% of long distance commuter accounted for 16% of VMT by all commuters in 2001 and 13% in 2009, respectively. The decline in VMT suggests a shift in mode choice over time from driving to non-driving.
- Long distance commuters spent more time away from home, leaving home earlier and return home later than normal commuters. Male commuters tend to travel longer distances than female. If a person has options to work at home occasionally, he or she tends to commute long distance.
- In Texas, 70% of commutes with distance of 50 miles or longer was interregional, and more than 70% of the long distance commutes in Texas was within the Texas Triangle Area.

6.2. Future Research

The national travel surveys are helpful in portraying large pictures of LDC/TRC but limited in offering insights into LDC/TRC behavior. Based on the preliminary study presented above, the next phase of the study will conduct qualitative research by interviewing selected LDC/TRC individuals in the Texas Triangle megaregion.

The research subject includes commuters who reside inside the Texas Triangle area and commute at least 50 miles to a work place which is not located in the metropolitan region of his or her residence. Residents who live in non-metro area but commute to metro regions also qualify.

Non-probabilistic sampling techniques will be applied to recruit respondents. These techniques include convenience sampling, snowball sampling, and self-selection sampling.

The first step to recruit LDC/TRC commuters is by asking friends, family, and chance acquaintances, the so-called convenience sampling. Convenience sampling is a type of sampling in which the samples are obtained simply because "they are convenient" sources of data for researchers (Battaglia, 2008). Convenience sampling is easy to carry out. It requires little cost but can help researchers to gather useful data and information that would be difficult to collect using probability sampling method. In the preliminary study stage, five samples have been determined using convenience sampling method. The five samples include a financial manager who commutes between Austin and Hallettsville three times a week to maintain a preferred lifestyle; a transportation planner who commutes between Austin and Dallas weekly because of work arrangement; another transportation planner who commutes between Austin and Houston weekly to continue her education; a travel demand modeler who commutes between Houston and Austin to fulfill client's requirement; and a saleswomen who commutes to west Texas weekly from Austin for her work.

Convenience sampling provides a quick and easy access to some research subjects, it often suffers from selection bias. By convenience sampling, samples are often drawn from a certain group of people, and unable to represent the whole target population. The sample size obtained by this method is often insufficient. Then, recruiting more LDC/TRC commuters will be further realized by applying the self-selection sampling method. Self-selected sampling allows sampling units to determine whether to participate on their own accord, and are most common when "rare, difficult-to-locate demographic subpopulations are sampled"(Sterba & Foster, 2008). Self-selected sampling involves steps of publicizing the research need and checking the relevance of units to either invite or reject them (Web page, 2009). By solicitation, more LDC/TRC commuters could be attracted to this research. The respondents who volunteer to participate in the research are also more likely to share their experience and insight into the phenomenon being studied (Web page, 2009).

In order to attract attention from a maximum range of potential research subjects, it is important to propagate the research need to a large population. In this research, four types of medium will be selected to publicize the invitation for participating in the research: local newspaper, community classified and discussion forums, university student organizations and listserv, and professional organizations and listserv.

In addition to convenience sampling and self-selected sampling, snowball sampling will also be used to increase the sample size. Snowball sampling is a technique that is commonly applied to study members of a rare population. It begins with distinguishing one or more members of a rare population, from whom the names of additional persons in the same/rare population are obtained (Chromy, 2008). LDC/TRC commuters are more likely to know other LDC/TRC commuters through two channels. First, they may share the same travel means, such as car-pool or taking same flight; second, they may pay more attention to other LDC/TRC commuters around them to share feelings and experiences. Each LDC/TRC commuter found through convenience sampling and self-selected sampling will be asked questions about other LDC/TRC commuters they may know.

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