Sustainability Implications of Mass Rapid Transit on the Built Environment and Human Travel Behavior in Suburban Neighborhoods: The Beijing Case

by

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ABSTRACT

The sustainability impacts of the extension of the Mass Rapid Transit (MRT) system in suburban Beijing are explored. The research focuses on the neighborhood level, assessing sustainability impacts in terms of greenhouse gas emissions, air pollution, and energy consumption. By emphasizing suburban neighborhoods, the research targets the longest commuting trips, which have the most potential to generate significant sustainability benefits. The methodology triangulates analyses of urban and transportation plans, secondary data, time series spatial imagery, household surveys, and field observation. Three suburban neighborhoods were selected as case studies.

Findings include the fact that MRT access stimulates residential development significantly, while having limited impact in terms of commercial or mixed-use (transit-oriented development) property development. While large-scale changes in land use and urban form attributable to MRT access are rare once an area is built up, adaptation occurs in the functions of buildings and areas near MRT stations, such as the emergence of first floor commercial uses in residential buildings. However, station precincts also attract street vendors, tricycles, illegal taxis and unregulated car parking, often impeding access and making immediate surroundings of MRT stations unattractive, perhaps accounting for the lack of significant accessibility premiums (identified by the researcher) near MRT stations in suburban Beijing.

Household-based travel behavior surveys reveal that public transport, i.e., MRT and buses, accounts for over half of all commuting trips in the three case study suburban neighborhoods. Over 30% of the residents spend over an hour commuting to work, reflecting the prevalence of long-distance commutes, associated with a dearth of workplaces in suburban Beijing. Non-commuting trips surprisingly tell a different story, a

large portion of the residents choose to drive because they are less restrained by travel time.

The observed increase of the share of MRT trips to work generates significant benefits in terms of lowered energy consumption, reduced greenhouse gas and traditional air pollution emissions. But such savings could be easily offset if the share of driving trips increases with growing affluence, given the high emission intensities of cars. Bus use is found to be responsible for high local conventional air pollution, indicating that the current bus fleet in Beijing should be phased out and replaced by cleaner buses. Policy implications are put forward based on these findings.

The Intellectual Merit of this study centers on increased understanding of the relationship between mass transit provision and sustainability outcomes in suburban metropolitan China. Despite its importance, little research of this genre has been undertaken in China. This study is unique because it focuses on the intermediate meso scale, where adaptation occurs more quickly and dramatically, and is easier to identify.

Dedicated to My Family

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ACRONYMS AND ABBREVIATIONS

AEP	Aggregated Environmental Performance
AQG	Air Quality Guideline (Global Standards by WHO)
BDA	Beijing Development Area
BPTC	Beijing Public Transport City
BRT	Bus Rapid Transit
CBD	Central Business District
CE	Coal Equivalent
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CTOD	The Center for Transit-Oriented Development, USA
EPA	Environmental Protection Agency, USA
ER	Emergency Room
ERAU	Environmentally Responsible Architecture and Urban Design
ETDZ	Economic and Technology Development Zone
FDI	Foreign Direct Investment
GHG	Greenhouse Gas
HOV	High-Occupancy Vehicle
HTDZ	High-Tech Development Zone
MRT	Mass Rapid Transit
NOx	Nitrogen Oxides
O_3	Ozone
PM	Particulate Matter
PPP	Public-Private Partnership

RMB	Renminbi or Chinese Yuan
TCRP	Transit Cooperative Research Program, USA
TOD	Transit-Oriented Development
TSP	Total Suspended Particle
VKT	Vehicle Kilometers Traveled
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compounds
WB	World Bank
WHO	World Health Organization

Chapter 1

INTRODUCTION

1.1 Research Context

Research on sustainable urban development is flourishing, significantly driven by the threat of climate change, especially in terms of increased frequency of extreme weather, and limits to fossil fuel availability. In many East Asian cities, including Bangkok and Manila, urban transportation accounts for over half of greenhouse gas (GHG) emissions. How to meet human travel demand and to move people efficiently with minimum impact on the environment is a paramount issue for urban development, as the globe moves toward an equilibrium level of approximately 80% urbanized this century. East Asia is no exception to these dynamics. The future of urban transportation in China will contribute or detract significantly to the world's climate change mitigation efforts, since there will be 1 billion people living in China's metropolitan areas by 2030; and six new megacities (each with a total population of over 10 million) will emerge (Mckinsey Global Institute, 2009). Rapid urban growth exacerbates the conflicts between transportation supply and demand, creating problems such as severe traffic congestion, environmental pollution, and rapidly increasing energy demand. At the same time, cities are faced with institutional challenges, such as the lack of coordination between land use planning and transportation planning (Tsinghua-BP SUMO Project Team, 2007).

As the core (central) areas are being built out in large Chinese cities, new development is being added to the peripheries to accommodate increasing urban population. The periphery of major Chinese metropolis in the late 1980s and 1990s was largely driven by industrial relocation – dispersal to designated industrial zones (Douglas Webster, 2002). Although this process continues, it is likely to slow, with a relative slowing of China's "factory of the world" function. On the other hand, more recently residentially based suburbanization has become a more important driver of peripheral development in Chinese metropolitan regions. This suburbanization, which differs significantly from North American and European suburbanization, as explained in Chapter 2, is characterized by incremental outward development from the existing built-up area, both contiguous in some areas, and "leap-frogging" in others. Relative to suburbanization in the West, particularly North America and Australia, it is relatively high density (often more than 7 - 10,000 persons per square kilometer. This suburbanization is generally driven by major transportation links such as expressways and public transit, although in some cases, suburban developments are poorly served by transport linkages. Often rapid transit service becomes available after development is significantly underway; although in other cases transit service may be concurrent, or even precede, suburban development. The impact of the sequencing of suburban development vis-à-vis transit service is a theme pursued in this research. The well-known ring road (primarily expressways) structure of the Beijing Region facilitates such spreading style suburbanization by increasing accessibility within the periphery, in contrast to a radial road (expressway) system, which focuses activity, to a greater extent, on the core city.

Along with rapid suburban growth in the past decade, Beijing has witnessed surging housing prices resulting in significantly lower housing affordability. This has caused tremendous pressure on middle class households, especially the young, who are seeking to purchase an apartment. Data for January and February 2010 revealed that the average price of off-the-plan houses inside the 4^{th} Ring Road has exceeds 30,000 RMB/m^2 (about 408 US$/sq. ft.) (Duan, March 15, 2010). Even apartments outside the 6^{th} Ring Road are priced, on average, over 10,000 RMB/m^2. Other research indicates that the ratio of average housing prices to average annual household incomes has exceeded 50 in Beijing, as well as other large cities in China such as Shanghai and Guangzhou; the

World Bank recommends a ratio of 1.8 - 5.5 for developed countries, and 3 - 6 for developing countries (Ruan, April 22, 2010). Although the efforts made by the central government in 2011 effectively slowed rapidly growing home values, the average price is still beyond the average household's purchasing power. Such high housing prices are pushing households, especially members of the middle class, to locate to suburban neighborhoods, creating high traffic demand to central areas (the core within the fourth ring road – Beijing is not yet dominated by a single CBD) where most jobs are located. Meanwhile, the total number of registered private cars in Beijing Municipality has already exceeded 5 million in early 2012. For the first half of 2011, 32.7% of total trips in Beijing were by private cars, slightly lower than the share of public transport (40.9%). The average period of peak traffic congestion in Beijing has risen to 5 hours, leading to substantial losses in economic productivity, environmental degradation and quality of life.

At this stage, other than luxury villas (a niche product for celebrities, the rich – often as second homes, etc.; i.e., those who do not need to commute daily), suburbs are not preferable places for average living or working, because basic facilities and public services such as schools and hospitals are often inadequate. A formalized real estate market has been a major driving force for urban and suburban development since the late 1990s in China, a product of the emergence of land and property markets earlier in that decade (He et al., 2008). Property-led development shapes suburban growth in two ways. The first is redevelopment projects in the city core almost invariably cause relocation of the original residents to the periphery. The second driver is that development of "comprehensive" communities in the suburbs provides choice for urban households relative to possibly older or more cramped housing in the core. As noted, a major factor in the decision to locate in the suburbs is usually affordability. Often young or new households are attracted to the suburbs because of the availability and relative affordability of the housing there.

To a large extent, the development of Chinese suburbs is still considered secondary to the city center administratively and functionally (especially in terms of employment and public services), as compared to the US cities where suburbanization has created a polycentric spatial structure (Y. Zhou & Ma, 2000). In US metropolitan regions, “edge cities” have emerged with significant employment, public and private services, etc. (Garreau, 1991). In Beijing, major employment clusters are largely concentrated within the 4th ring road (China Academy of Urban Planning & Design, 2003). Suburban residents rely predominantly on the automobile or Beijing’s Mass Rapid Transit (MRT) system to make daily trips to work – often trips of considerable length. Fortunately, hosting the 2008 Olympic Games stimulated the intensive investment in the MRT system in Beijing, increasing the total length of lines from 54km (two lines) in 2001 to 200km (seven lines) in 2008. This prioritization of public rapid transit resulted in the announcement of a “Beijing Public Transport City (BPTC) 2015” plan in 2009 aiming at expanding the MRT system to a total length of 561km by 2015 to serve the city center more intensively and significantly extend service to the suburbs. The BPTC plan is designed to relieve current and future pressures on the road system and enhance resident quality of life by providing convenient and environmentally sustainable public transport option. It is estimated that at the end of 2015, the share of transit trips as a percentage of all journeys to central Beijing will increase to 45% (Beijing Daily, June 10, 2009). On December 30th, 2010, five new MRT lines were opened in Beijing at the same time with a total length of 108km, all of which are suburban lines (Z. Liu, December 31, 2010). In 2012, the total length of MRT system in Beijing is 336km, a quantum leap from the 2001 level.

Suburban residents are suffering from long commuting trips, overcrowded MRT trains, and severe road congestion. The *Annual Report on Urban-Rural Development of Beijing (2010-2011)* shows that the average commuting time in Beijing has increased to 45.04 minutes one way, an increase of 18.53% over 2005 levels (Beijing Academy of Social Sciences, 2011)[1]. While comparatively, it took the average worker in New York metropolitan area 33.54 minutes to go to work in 2010 (Roberts, Sep. 23, 2011). Of the 6,677 individuals sampled in a recent study by Meng, Zheng & Yu (2011), 22% spend more than 60 minutes to travel to work. Evidence also shows that: (i) Suburban neighborhoods have the longest commuting times, indicating that suburbs may have failed to provide locally accessible employment opportunities and that there is an urgent need to improve travel options (time, comfort, affordability) between these suburban neighborhoods and major employment destinations; (ii) Households in the four inner urban districts experience relatively long commuting times, averaging 37-42 minutes. Though not as long as their suburban counterparts, these travel times may be explained by heavy traffic congestion in the city center; (iii) The travel time of residents in two suburban district satellite towns is lower than the study's average, demonstrating the benefit of relocating to satellite towns with regard to commuting times; Finally, (iv) Yizhuang - where the national level Beijing Development Area (BDA) is located – has been planned for a mixed use of residential and industrial land uses, and, with a better jobs-housing balance than its conventional suburban counterparts, demonstrates commuting times close to the study mean. The experience of the satellite cities and BDA communities raise questions as to whether such alternative spatial constructs might be preferable in the Beijing extended urban region, compared with the more conventional suburbanization processes that are now dominant.

[1] By comparison, it took the average commuter in the New York metropolitan area 33.54 minutes to get to work in 2010 (Roberts, Sep. 23, 2011)

1.2 Research Objectives

Public transit is considered to be the most efficient way of moving large numbers of passengers within most metropolitan systems in terms of energy consumption per capita, road occupancy and reliable travel time (Bertaud et al., 2009; Reid Ewing et al., 2008; Kennedy et al., 2005; D. Li & Mao, April 13, 2010; Moavenzadeh & Markow, 2007). The awarding of the 2008 Olympic games to Beijing in 2001 encouraged intensive development of the MRT system, offering a unique opportunity for the city to transfer to a more sustainable future. It is expected that the extension of the MRT system will enable Beijing to continue suburbanizing, while improving quality of life and social equity for those suburban residents by offering an efficient and affordable travel option for both commuting and non-commuting trips. In other words, extensification of the MRT system should improve the efficiency of Beijing's suburbanization. However, it is still poorly understood whether the accessibility provided by MRT contributes to mixed use development in these suburban neighborhoods, i.e., outcomes displaying characteristics of Transit Oriented Development (TOD). To the extend TOD development is induced by MRT development, greater intra-neighborhood access to goods and services or even jobs is the expected outcome, potentially resulting in fewer trips outside the neighborhood. Many questions remain unanswered in the Beijing context. Firstly, to what extent does MRT availability switch people's travel mode from driving to using public transport in terms of commuting trips. Secondly, if mixed use (TOD) environments were induced around MRT stations, would this reduce out-of neighborhood trips? Certain Chines characteristics may factor into the foregoing question, for example, the best middle schools tend to be centrally located. Obviously many factors are interacting, creating challenges to urban researchers.

A key element of the research is to determine the extent of incremental sustainability benefits that will be generated by the availability of MRT service in particular suburban neighborhoods. Environmental improvement is measured against a variety of indicators, including GHG emissions, conventional air pollution, energy consumption, and social benefits.

The objectives of this dissertation are manifold:

i) To explore the interactive development of public transit facilities and the immediate built environment around these facilities on the neighborhood level by tracing historical changes of land uses from 2003 to 2010), over which time, the intensive investment in the MRT system in Beijing took place;

ii) To better understand how the accessibility of MRT services has changed people's travel behavior, both commuting and non-commuting trips, using before- and after comparative approaches;

iii) To develop an indicator system quantifying the sustainability benefits of improved MRT accessibility in terms of energy consumption, GHG emissions, conventional air pollution and human time savings, by comparing the Beijing's average travel mode share with that of the study neighborhoods;

iv) To provide institutional recommendations to support development of a more sustainable city, addressed to urban and transport planners, city management bureaus. These recommendations focus on built environment design and MRT service improvement.

Three suburban neighborhoods in Beijing, all located outside the 5th Ring Road, are selected as the context for study: Huilongguan (Chinese: 回龙观), Tiantongyuan

(Chinese: 天通苑) and Tongzhou Beiyuan (Chinese: 通州北苑). Map 5.1 shows the locations of these three neighborhoods. Both Huilongguan and Tiantongyuan are newer neighborhoods that began to be developed in the late 1990s, while Tongzhou Beiyuan has a longer history. On the other hand, both Huilongguan and Tongzhou Beiyuan enjoyed early MRT access in 2003/2004, while Tiantongyuan did not receive MRT access until 2007. These cases are selected to demonstrate any potential significance of the timing of MRT accessibility in the neighborhood development history.

1.3 Significance

By focusing on travel in suburban areas, this research project intends to target the longest daily trips in urban areas, which, of all commuting trips, presents the most potential to generate significant sustainability benefits. While other studies on sustainable urban transportation predominantly focus on the metropolitan scale, this research focuses on the intermediate level, to examine the most dynamic and fast-paced changes on the ground which have direct impacts on people's daily lives and their travel behavior patterns. In addition, as newly constructed urban fabric, suburban areas are where new forms of development can be deployed, and are relatively under-researched in China (Douglas Webster, 2011). The methodology triangulates analysis of urban and transportation plans, secondary data, time series spatial imagery, household surveys, and neighborhood observation / check lists.

The Intellectual Merit of this research is based on its contribution to increased understanding of the relationship between mass transit provision and sustainability outcomes in suburban metropolitan China. Despite the importance of the topic, little research of this genre has been undertaken in China. The research approach involves identification and analysis of i) key drivers of neighborhood development, and in particular the impact of MRT stations / service; ii) the role of MRT service timing and commencement (relative to the local built form development trajectory) and sequencing (announcements, construction, station openings) on the behavior of key stakeholders, such as urban planners and real estate developers; iii) key features of a neighborhood that impact people's decision regarding housing location and travel behavior; and iv) key measurements of sustainability performance of a neighborhood associated with changes in human travel behavior.

Given the size and global importance of Beijing, the research findings will garner a high profile and will have important implications for other cities, particularly in metropolitan East Asia. This research broadens and deepens academic theory, empirical knowledge, and literature on sustainable urban transportation, especially in regard to the relationship among the urban built environment, public transport systems and human travel behavior. In Chapter 2, particular areas where the research addresses gaps in theoretical and empirical understanding in the subject field are identified. Existing theoretical and empirical knowledge suggests that effective public transport is an important contributor to sustainable urban development, and that higher densities and more variability in density, including transit-oriented mixed use development near transit stations tend to result in shorter trip lengths, more use of non-automotive modes, and more use of public transit in particular. The implications are not trivial. This research not only fills the gap of research on the intermediate (neighborhood) scale that facilities the consideration of consumer preferences in terms of residential location and travel modes choice, but also pushes the research envelope in terms of quantifying sustainability benefits from human travel changes. This study adds a significant case to the current literature on sustainability and transportation in developing cities and offers a study methodology that can be duplicated in studies of other cities.

1.4 Dissertation Organization

This dissertation is organized as follows:

Chapter 1 introduces the research context and research objectives, and discusses the significance of this research.

Chapter 2 reviews the existing literature on: i) the relationship between different urban form and sustainability, ii) the relationship between trip characteristics of suburbanites (particularly mode choice) and sustainability; iii) assessment of sustainability benefit, especially as related to urban transportation; and iv) Chinese metropolitan suburbanization, particularly what differentiates Chinese metropolitan suburbanization from the Western model. The objectives of Chapter 2 are to frame the research methodology in the context of theoretical and empirical gaps in research activity in the subject field to date.

Chapter 3 demonstrates the spatial context of Beijing, laying the contextual background for the dissertation research.

Chapter 4 explains the methodology applied in this research. Research questions and hypotheses are presented. Data sources are identified and data analysis methods are explained. The household survey questionnaire used in the research is presented.

Chapter 5 introduces the three selected neighborhoods in terms of their development history and key stakeholders.

Chapter 6 analyzes changes in land uses in the case study neighborhoods since 2003, levels of provision of public services, and neighborhood development process. The relationship between housing prices and the distances to MRT stations is examined to generate evidence to better understand the interaction between MRT accessibility and the built environment. Institutional implications are discussed based on the analyses. Chapter 6 examines the case study neighborhoods through a comparative prism. Differing dynamics among the three case study neighborhoods in terms of the foregoing dynamics are flagged.

Chapter 7 focuses on the changes to people's travel behavior before and after the MRT service became available, based on household questionnaire surveys. Vehicle kilometers traveled (VKT) savings are quantified. Comparison is also performed between these suburban neighborhoods and the city's average VKT to assess whether and how suburban location is affecting people's travel choices. Findings are summarized in light of the beneficial changes brought about by the introduction of MRT service.

Chapter 8 assesses the sustainability benefits attributed to the availability of MRT service in the case study neighborhoods, focusing on GHG emissions, conventional air pollution, and energy consumption related to urban transportation. In undertaking this analysis, best estimate coefficients are utilized derived from the latest empirical findings and academic literature, particularly as related to energy, GHG, and emissions associated with different transportation modes. These applicable coefficients are applied to the case study results, then up-scaled to illustrate potential Beijing wide impacts associated with human transport behavior change (particularly mode change) to quantify the above benefits.

Chapter 9 summarizes the key findings of the research, and puts forward implications in terms of our understanding of the built form-human transport interface in major Chinese metropolitan areas. Implications in terms of urban and transport planning and policy are also put forward.

Chapter 2

THEORETICAL CONTEXT: LITERATURE REVIEW

This chapter reviews the existing literature, both in English and in Chinese, on: (i) the relationship between different urban forms and sustainability; (ii) the relationship between trip characteristics of suburbanites (particularly mode choice) and sustainability; (iii) assessment of sustainability benefits, especially as related to urban transportation, and, (iv) Chinese metropolitan suburbanization, particularly what differentiates Chinese metropolitan suburbanization practices from the Western model. The objective is to frame the research methodology in the context of theoretical and empirical gaps in research activity in the subject field.

2.1 Urban Form, Urban Transportation and Sustainability

The literature on urban form, urban transportation and the built environment is part of *Urban Form Theory*, which considers the city as a system composed of sub-systems including spatial configuration of land uses and densities, activity patterns, the physical environment, and connectivity (Robert Cervero, 2004a; Y. R. Jabareen, 2006; Xingshuo Zhao, 2010). There is already a rich body of English literature on the relationship between urban form and sustainability, drawn from international experience and theoretical exploration. The first systematic efforts to examine the interrelationship between transportation and urban spatial development were made in the 1950s by Hansen (1959), who argues that more accessible locations have a higher chance of being developed, and at a higher densities, than more isolated and less accessible locations. He also recognizes the nature of co-determination for trips and location decisions. The "land-use transport feedback cycle" (see Figure 2.1) was virtually universally accepted among American planners, which led to the advocacy of coordination between transport and land use planning (Hansen, 1959).

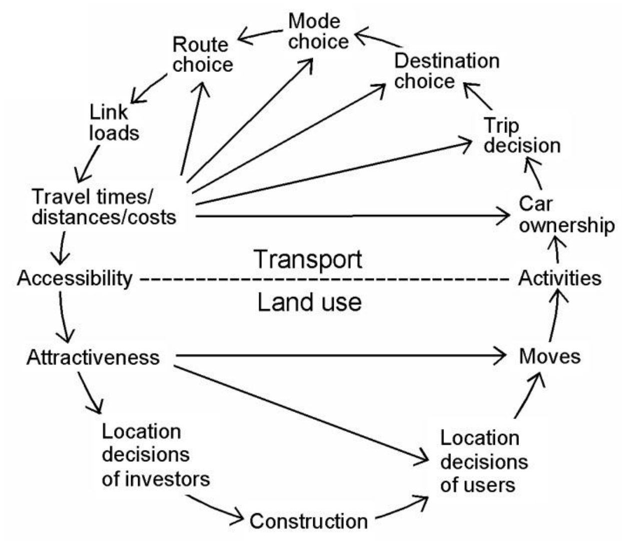


Figure 2.1: The Land-use Transport Feedback Cycle

Source: (Wegener, 2004).

Urban form is the spatial configuration of the urban transport system and land use patterns (Rodrigue et al., 2009b). Human activities are performed within this framework, but also provide feedbacks to the system. It has been recognized that certain urban forms perform more efficiently than others, as measured by automobile usage (in terms of vehicle-km travelled (VKT)), energy consumption, emissions, travel cost and use of land (Kennedy, et al., 2005; Kenworthy, 2006).

A series of key urban form concepts and characteristics have been identified in light of critical sustainability thinking, including compactness, sustainable transport, mixed land use, density, diversity, innovative design for alternative energy, judicious use of green space, transit oriented development (TOD), nodality, urban and suburban sub-centers. By applying or emphasizing some of these concepts, different types of sustainable urban forms are proposed by a variety of researchers and advocates, e.g., neo-traditional development, urban containment, the compact city, and the eco-city (Yosef Rafeq Jabareen, 2006). All these urban forms have their advantages but also pose issues, many of which are still under debate. Tools for achieving sustainable urban development are also proposed, such as transit oriented development (TOD), public transit approaches, integrated land-use and transportation planning, etc.

A review of the literature in both languages, reveals a similarity in the choice of topics at a general level, including the trajectory and characteristics of land use changes and urban morphology, the environmental impacts of urban growth, the relationship between urban transport and urban form, the impact of urban form and transportation on people's travel behavior, and exploration of urban planning and management methods to improve urban sustainability. However, emphases vary between the two sets of literature. Scholars working in English-speaking, Western academia devotes substantial energy to understanding the role of urban compactness, urban transport, travel modes and pursue critical thinking in regard to the foregoing and sustainable urban development performance. Chinese literature, in contrast, allots a large amount of effort toward descriptive and explanatory studies of the evolution of urban morphology, and the interrelationship between urban transport development and urban form in terms of land-use change and the direction of metropolitan spatial growth in a region. A limited number of Chinese based studies discuss what sustainable urban form should be, but mainly re-introduce concepts or review findings, from the English language literature. The relationship between urban form and sustainability is less explored.

2.1.1 Evolution and Dynamics of Urban Form

Understanding the trajectory of urban form is important for promoting a more sustainable future. Urban form trajectory research is carried out at all scales, ranging from the megapolitan to neighborhood scales. Statistics, surveys, urban land use and transportation maps and plans, as well as remote sensing images are the main sources of data. Longitudinal statistical analysis and spatiotemporal analysis are the most often used methodologies, especially given the easy availability of remote sensed imagery and GIS spatial analysis (Y. Chen & Jiang, 2009; B. Huang et al., 2009; J. Luo & Y. H. D. Wei, 2009; Tang et al., 2008; Douglas Webster et al., 2010; F. Yang et al., 2009).

Governance restructuring in post-reform China after 1978 (see Chapter 3) was characterized by the central government ceding more autonomy to local governments, such as Beijing's municipal government, and the introduction of a land market, albeit land remaining state-owned, that sought to promote market-driven development. A secondary impact was that, the post-Reform period created a greater divide between the land use and urban transportation planning, creating further obstacles to the integration of land use and transportation strategies. Zhao, P., *et al.* (2009) argue that reform initiatives resulted in increased competition among local governments, and a jobs-housing imbalance (previously most people worked and lived in the same place, most typically residing in factory-provided dormitories known as " *danwei*" or "work units"[2]) which led to a dramatic decline in overall job accessibility and the quality of urban life. Yang and Mao note that the separation of transportation and land use planning made it difficult to achieve the high efficiencies possible from integrated infrastructure design (J. Yang & Mao, 2006).

In China today, plans at various spatial scales target different development objectives. Conceptual plans, applied at a vast regional scale, set the overall development strategy of a city within its region. For example, the Beijing-Tianjin corridor, which connects Beijing with Tianjin, a major port city of over 12 million people about 140 km to the southeast, is considered as a single agglomeration in the Jing-Jin-Ji Metropolitan

[2] Danwei, or work unit (Chinese: 单位), refers to the living and working habitat of employees during the planned economy period in China. These units not only provided employment, but also residences, public services, and other functions. In a Danwei unit, the employers are spatially and functionally attached to their employee by living close to where they work and being able to satisfy most of their daily needs (such grocery shopping) in the community.

Regional Planning Region. At the local level, development corridors, urban transport systems and green space are used to suggest the overall spatial structure of the city. At the inner city level, conservation plans for old city cores and redevelopment projects are proposed, and if implemented, can significantly reshape the core. (F. Li et al., 2008) has suggested that improving a city's environmental performance, given the different spatial scales (with differing objectives) applied to planning in Chinese cities, should involve injecting sustainability goals at each planning scale.

Both compactness and density are key characteristics of urban form, considered as widely accepted strategic metrics for improving land use and energy efficiency to achieve sustainable urban form (Jenks & Burgess, 2000). These two concepts are closely related to urban contiguity, which promotes containment in the development of new or existing areas. The result of compact development is inevitably higher density population and construction. A set of indicators have been identified to measure urban compactness (Burton, 2002).

Heated debates have been stimulated by the possible negative impacts of compactness on the environment, society, and economy if density is not well managed. For example, dense slums are often associated with negative implications of density. With recognized advantages and disadvantages of compact development, studies have been carried out to explore technical and management measures for achieving the positive outcomes while minimizing the negative influence. Tsou, Chow & Lam (2003) believe an Environmentally Responsible Architecture and Urban Design (ERAU) system can help promote and assess design and planning quality at the building and neighborhood levels in a terms of reducing negative environmental impact.

The level of compactness varies across countries and it is almost impossible to set universal criteria. In China, by US standards, cities are growing in a very compact way. However urbanization trends have begun to mirror American practices, if not at the scale and low density of American cities. Growing car ownership levels combined with increasingly segregated (single use) land use patterns have begun to pervade Chinese cities (Sadownik & Jaccard, 2002). There has been research exploring how to measure the compactness of Chinese cities, how to evaluate the impact of compactness on the urban environment, and whether there is an optimal level of density and compactness that optimizes benefits, while minimizing the negative outcomes.

Chen, Jia & Lau (2008) investigated the relationship between compactness and Aggregated Environmental Performance (AEP), using data from 45 core Chinese cities. Net population density, namely non-agricultural population density in built-up areas of the city, is used as the measurement of compactness. 16 indicators embedded in 5 categories are identified to measure the AEP. These categories are facility availability, infrastructure efficiency, public transport, domestic energy and resource consumption, and environmental externalities. Results suggest that high net population density may contribute to negative environmental externalities, such as air pollution, noise, and loss of green space, but reduce overall energy consumption and deliver positive results in terms of other indicators. Chen, Jia & Lau perform what they consider a "best-of-fit" analysis[3] to explore the nature of the relationship between compactness and the AEP and to search whether an urban density exists that maximize advantages but minimizes disadvantages. Their findings show that such an optimal density level does exist - about 168 persons per hectare. But such figures have not been seen or cited in other studies as a standard for dense development. Of all the cities studied, only Shanghai and Wuhan have population densities higher than this level, so their conclusion is that Chinese cities have the potential to absorb increasing population into existing urban areas.

[3] What the "best-of-fit" analysis is, and how the authors performed it, are not very clearly elaborated in the paper.

In the Chinese literature, major effort is devoted to exploring urban morphology, and the interrelationship between urban transport development and urban form (measured in terms of land-use change and the direction of metropolitan expansion). Socio-economic factors and infrastructure construction (transportation) are identified as the major driving forces of urban form. However, these studies are still largely empirical and descriptive, lacking critical reflection in regard to the relationship between urban form and sustainability.

TOD and bus rapid transit (BRT) are two notable planning and management tools discussed and implemented in the Chinese urban context. Over 10 cities in China have built, are building, or are planning to build, BRT systems. A significant number of studies evaluate the performance of BRT systems in China. Promoting alternative energy in the vehicle manufacturing industry is another effort that China has made to improve its environmental performance. Public-Private Partnership (PPP) plays a vital role in moving this agenda forward. From this perspective, practical work is ahead of academic work. In sum, innovation in urban transport is to a significant extent not being assessed by Chinese academics.

Exploring the evolution of the urban morphology of Chinese cities has been one of the areas that have attracted the most scholarly attention, particularly with the availability of remote sensing images and development of GIS technology. Wu's (1990) influential book on the structure, characteristics and evolution of the urban form of Chinese cities laid the ground for this type of research. The trajectory of change in urban form for a specific city, and overviews of change in urban morphology for Chinese cities overall for the past 20 years has become one of the most investigated topics (H. Chen, et al., 2008; Q. Chen et al., 2007; Shuhua Liu & Shen, 2006; Mu et al., 2008; X. Wang et al., 2005; Xiong, 2005; P. Zhao & Feng, 2003). These researchers attempt to identify the driving forces behind changes in urban form in the context of policy reforms and rapid urbanization. In general, findings are: i) urban industrial restructuring strengthens the central district and relocates industries to new industrial zones in the periphery; ii) redevelopment of old neighborhoods in the city center improves the infrastructure and makes way for a modern transport network integrating rapid transit, while relocating the original residents to the urban fringe; this creates new social and environmental challenges; iii) development zones transform the typical sprawl style of urban morphological development to a development axis style; iv) policy innovations introduce market forces into urban growth; v) the more frequent adjustment of administrative divisions tends to combine formerly smaller areas, creating larger entities for spatial expansion (G. Fang et al., 2009; Luan & Wang, 2008). While the contribution of these studies to outlining Chinese development practices are important – at least at understanding long term regional spatial growth – they suffer from a lack of in-depth, neighborhood-scaled analysis, or a proper understanding of the micro-scale workings of land development institutions (such as the unique Chinese land market system) and how individual developers are involved in redeveloping individual land parcels that is necessary for capturing the nuances of urban development. These practices, in the aggregate, may lead to the spatial growth patterns their regional studies detect.

2.1.2 Urban Growth and Its Environmental Impacts

Understanding urban growth and its environmental performance, as well as the carrying capacity of the urban environment is of importance to sustainable urban development (Güneralp & Seto, 2008). Studies show that for the past 50 years, there has been a positive linear relationship between urbanization in China and its ecological footprint, while a negative exponential relationship exists between urbanization and environmental quality (C. Fang & Lin, 2009). If Chinese cities continue to grow in the current pattern, the ecological environment will become seriously degraded over the next two decades. The main driving forces of urban development in China are identified as fast economic growth and rural-urban migration, whereas the expansion of cities causes the increase of transport distance in importing resources from outside of the city as well as the decline of sustainable resource use (Hu *et al.*, 2008).

Private car ownership has been increasing dramatically with fast economic growth, and is closely associated with energy consumption and air pollution. A study of Beijing's vehicle use shows that its external economic, social and environmental costs, both on the local and global levels, are equivalent to 7.5-15% of the city's total GDP (Creutzig & He, 2009). Externalities related to land use inefficiency and human time cost are not included in this study. A road charge system is argued by the author to be the appropriate approach to addressing congestion and yielding environmental benefits.

Foreign-direct investment (FDI)-driven peri-urbanization and its social and environmental impacts: the development of peri-urban area (PUA) in Shanghai was largely driven by FDI in manufacturing, causing dispersed development and deterioration of the environment. Moreover, this area accommodates a large number of urban poor, emerging as a potential threat for the society and economy (Jiaping Wu, 2008).

Assessment of urban environmental performance is also carried out at the national level and identifies geographical divides across the country (L. Liu, 2009). This study covers a wide selection of cities, including 72 model cities, 113 key cities and the 43 most polluted Chinese cities. Model cities refer to those that meet State Environmental Protection Administration (SEPA) standards on urban sustainability, as designated by SEPA in 2008. SEPA also selected 113 key cities that need to improve their environmental performance – the key cities. Findings show that model cities tend to evolve along China's eastern coast, which also have better economic achievements whereas the most polluted cities tend to be in western China, which runs contrary to the argument made by Fang & Lin as discussed above. The relationship between growth and environmental impacts is not as simple and linear as Fang & Lin suggest. If China had the same level of growth and was predominantly rural instead of urban, the ecological footprint would have been even greater. Additionally, environmental spending does not seem to have a strong relationship with the city's environmental performance, except for the level of sulfur dioxide (SO_2) emissions.

Assessment of urban sustainability is a complex task, given its association with complicated and intertwined social, economic and environmental factors. Le *et al*. (2009) develop a comprehensive evaluation index from an indicator system that include 52 indicators that represents economic growth and efficiency, ecological and infrastructural construction, environmental protection, and social and welfare progress. A Full Permutation Polygon Synthetic Indicator (FPPSI) method is applied. A major drawback of the FPPSI method is that it requires a large amount of data; meaning the indicator system may not be replicable for a full range of cities.

Academic publications by Chinese scholars on sustainable urban form or sustainable development are still at an early stage of discussion compared with Western academia. Thus many key concepts are in early stages of introduction in China. The concepts now being explored by Chinese scholars include compact city, smart growth, new urbanism, rational growth, green transport, etc. The definition of sustainable urban development is generally understood in China as balanced development of the economy, society and environment, consistent with the Western definition. Accordingly, a sustainable urban form should be one that recognizes the importance of physical, social and spatial activity structures / processes in a manner that promotes sustainable development (Bai et al., 2006; Ding & Meng, 2007; Han & Qin, 2004; Lin et al., 2006; Y.

Ma, 2007; Punter et al., 2005; Ye, 2008; Ming Zhang et al., 2005). Other research methodologies such as space syntax are also being introduced (T. Yang, 2008).

Based on the theories developed in the Western context, Chinese researchers have developed their own indigenous operable models of sustainable development practice. Guolian Dong, director of a privately owned architecture and urban research center in Shenzhen, created the “land-saving model”, or the “JD model” (JD is the initial of Chinese for “land-saving”), (Dong & Zhang, 2006). The JD model is based on a vertical transport system which separates pedestrian and vehicle traffic. In this model, there are four independent spaces: i) ground traffic without pedestrian or cyclists, ensuring through traffic; ii) ground parking space – it is estimated that 35% of the ground space will be enough for all parking needs; iii) a pedestrian system above the ground parking spaces, to ensure safety; iv) outdoor spaces, which include elevated parks and ground green space. One pilot project has been carried out in the Xinzhou delta area in Changsha, in Hunan province. Under this vertical development model, the designated FAR increases from 2.0 to 2.8 which increase the development intensity by 40%, equivalent to a land-saving of 58.62 ha. The total construction area increased by 1.2 million m^2, as compared to the traditional development model, and reached 4 million m^2. The ratio of green space was improved from 30% to 50%.

2.2 Suburban Travel Characteristics and Sustainability

2.2.1 The Relationship between Urban Transport and Urban Form

The advancement of transport technologies has increased people’s mobility greatly, creating spatial segregation patterns between residence and employment, and contributing to increases in travel demand (S. Zhou & Yan, 2005). Considerable academic effort explores the relationship between urban transport and the urban form. On the supply side, transportation infrastructure forms the skeleton of a city and in turn has important impacts on shaping the urban form. The design of the transport network determines the evolution of urban spatial structure to a significant extent. On the demand side, urban spatial structures determine the location of different land use types, creating certain travel patterns among households, which ultimately can have an effect on the long-range development of metropolitan transport systems.

The opening of a transit line not only brings new travel options to the residents along the corridor, especially those living relatively close to stations, but also functions as a magnet for certain high value and/or time sensitive activities, while deterring others because of increased land costs. The key concept underlying the relationship between MRT and urban form is accessibility. The improved accessibility reduces travel cost in terms of money and time, giving advantages to activities along the transit corridor and around the stations as compared to areas not served by MRT lines. *Classical location theory* and *land economics* hold that business and residents cluster around transit stations to capitalize on the accessibility of a fast, reliable, convenient and green travel mode (Robert Cervero, May 1999). Business and offices rely on *agglomeration and localization economies*. Given the value of accessibility, theorists expect real estate markets around the transit stations to display a price premium, faster absorption rates, and lower vacancy rates compared with properties farther away from the stations.

Accessibility, coupled with the amenities of transit-designed development, such as improved walkability and mixed land use, tend to increase residential and commercial values and rents within walking distance from the stations (Benjamin & Sirmin, 1996; Hess & Almeida, 2007). Hedonic model has been developed and applied to estimate the contribution of property and location characteristics, such as floor space, distance to CBDs or to the nearest rapid transit stations, and the quality of nearby schools, to predicting property values. .

In the US context, a summary of studies on rail transit impacts reviewed by the Transit Cooperative Research Program (TCRP) suggests that the values of apartment properties located within a few block from transit service could increase up to 45%, while some office and retail facilities more than doubled in value for being located near transit stations as compared to similar properties without proximity to transit services (TCRP, 2010). Such accessibility premiums are found to be a little smaller for single family residential (up to 32%) and condominiums (up to 18%) by the Center for Transit Oriented Development (CTOD, November 2008). Variances in property premium across cities have been recognized. Based on a review on studies since late 1980s, Cervero (2004b) found that average housing price premiums associated with the proximity to a transit station are 6.4% in Philadelphia, 6.7% in Boston, 10.6% in Portland, 17% in San Diego, 20% in Chicago, 24% in Dallas, and 45% in Santa Clara County.

Asian practices show a smaller accessibility premium for properties to locate in proximity to transit services. Cervero and Murakami (2009) find that a property within walking distance from a transit station has a price premium between 4.7% and 15.7%. Such premium is found to be 4-9% in Singapore for every 0.3km of increase in distance from a transit station (Sue & Wong, 2010). Studies on Chinese cities show even lower accessibility premiums. Evidences from MRT Line 8 in Shanghai suggest that a property located within 0.5km from a transit station has a 3% price premium as compared to a property more than 4km away; and the premium for a property located between 0.5 and 1 km from the station is 1.3% (L. Wang, 2010). The main reason for this lower accessibility premium is that the impacts of transit access is compounded by other factors such as development densities, clustering effects of businesses, and shortened distances to the CBD provided by the transit network. With other factors controlled, the direct impact of MRT access on housing prices is limited.

Accessibility provided by rapid transit services supports mixed land use development with higher densities. Improved accessibility raises the demand for residential and commercial properties in the immediate area around the rapid transit stations, leading to higher development densities (Bertaud & Richardson, 2004). However, land values and densities could fall if the MRT station area is not well designed, or regulated, and this may cause negative impacts such as congestion, chaos or noise. The relationship between rapid transit stations and density depends on many external factors such as the extent to which residents and tenants value proximity to rapid transit, zoning, land use regulations and incentives for dense development (Kolko, 2011).

Contemporary rail-based urban transit systems have the potential of developing land uses more intensively and efficiently, shaping the urban structure in the form of transit stations as urban centers, lines as development axes. Chen, Liu, & Shi (2006) examines the north part of MRT Line 13 in Beijing and the development of land use in its vicinity in details. The findings suggest that in the area from Longze station to Huoying station (three stations in total), there are large residential community developments with high densities at the site scale, while the development of other land use types is largely neglected. While rapid transit has, in this case, spurred development, the singularly residential nature of the developments have raised travel demand and, moreover, concentrated travel to peak hours, with lightly used service in off-peak times. The imbalance of travel demand, both in time and the direction of travel, has reduced the efficiency of providing public transit services. Chen, Liu, & Shi (2006) suggest balancing current land use structures by adding more commercial or industrial uses in areas adjacent to transit to even out travel flows in both directions during peak hours and to even out the spread of travel demand away from highly concentrated peak hours. These authors cite the successful case of the Koshien area in Hanshin, Japan. Construction of entertainment facilities, namely the Hanshin Koshien Stadium and the Hanshin Earthquake Memorial Park, have increased the travel flow in off-peak times and contributed 12.3% of the income of the Hanshin Electric Railway Co.

Transportation infrastructure on the periphery of an urban region has significant impact on land use development in its vicinity areas and directs urban expansion to certain sections of the region, especially during times of fast economic growth, when much is in flux. This dynamic is supported by evidence from Shenzhen (J. Mao et al., 2008; L. Xie & Sit, 2007). When the Special Economic Zone could not accommodate a rapid inflow of FDI with corresponding demand for more production sites, activities expanded along major transport lines throughout the municipality. The urban spatial structure was inevitably transformed from a monocentric core city to one where intra-metropolitan sub-centers predominated at major transport junctions.

Some studies evaluate the spatial fit between transport networks and urban forms. Wang, Chen, & Ma (2008) propose three indices to measure the spatial fit of rail transit network configuration and urban form, namely the fit between the median point of the urban rail transit network and the city's center of gravity, the consistency index of their fractal dimensions, and the orientation similarity index. A composite index is calculated by multiplying these three indices. Wang *et al* apply this index system to assess four candidate plans of the urban transit network in Xi'an. The index that matches the urban form the best (i.e. the one with the highest value on the composite index) is considered the best plan. However, the underlying criteria behind the indices are put forward as self-evident in this study, without being argued or tested.

Because Chinese cities must accommodate significant population growth as well as rapidly growing living standard expectations, with a limited supply of developable land, Hong Kong provides an instructive example for how to effectively plan middle class, livable communities while utilizing scarce land resources very effectively. As Loo & Chow (2008) discuss, Hong Kong has successfully integrated its land use and land development patterns with regional transportation strategies. The privatization of Hong Kong Mass Transit Railway (MTR) Company and extremely dense mixed-use integrated development aligned with transit stations are the main reasons accounting for Hong Kong's globally rare profitable transit system (Robert Cervero & Murakami, 2009).

On the other hand, some scholars point to evidence that rapid transit's effects on urban form are slow to accrue, especially if the area is already built up. Giuliano (1995) found that the impact of Bay Area Rapid Transit (BART) expansion in the San Francisco Bay Area on land uses after 5 years of operation was not significant. Transit access was rarely considered in job location choices of individuals, while it was only of minor importance in determining residential location decisions. When employers considered where to locate, site availability, price, and proximity to other firms were more important factors than transit access. Miller et al. (1999) argue that rail transit facilitates development but does not create development. In other words, MRT is an important but not sufficient condition for development to occur.

Potential exists, at some strategic locations, to create sizable and dense centers/sub-centers, even in traditionally lower density US cities. An in-depth study of the San Francisco BART system by Cervero and Landis (1997) reveals that land-use changes associated with the BART system have been largely localized, creating a multi-centered regional spatial structure. This is a theme I pursue in this research, hypothesizing that Beijing's MRT system has local impacts, but does little to affect the overall spatial distribution of employment and residence in the Beijing metropolitan Region. For the few land-use changes that did occur, Cervero and Landis attribute them to either neighborhood opposition or a vibrant local real estate market.

Finally, parking supply and management are also tools that may impact transit usage in two ways. First, the increase in parking spaces in a densely developed area will reduce the attractiveness of transit services. Secondly, the availability of park and ride facilities at transit stations in less dense areas or suburban areas will increase the transit boardings while at the same time increase the service catchment area of the station.

2.2.2 The Impact of Urban Form and Density on Travel Demand and Travel Mode

The choice of transportation mode used to travel to work (hence: mode share and/or mode choice) has attracted a lot of scholarly attention since it is closely related to public transport ridership and use of private cars. Households determine mode share, and therefore, aggregate societal energy consumption and the quality of the environment in urban areas. Mode choice is the result of a complex mix of individual factors ranging from a person's socio-economic status, to the availability and accessibility of different types of travel in a locale, to personal travel preferences. The built environment is not the only factor, but it "does influence travel behavior, at least in some crude manner" (Crane, 2000). The outcomes of these factors are shown in private car ownership and use levels, as well as ridership levels of public transit, and alternative modes of travel.

Studies on the relationship between urban form and travel mode are offered from both the supply side perspective (development of transport infrastructure and provision of alternative travel options) and demand side (generation of travel demand and people's travel preferences). Researchers have focused their efforts on predicting travel flows under different built environment conditions to evaluate impacts of interventionist measures on environmental quality. Studies are carried out to investigate how travel patterns can be changed by manipulating certain aspects of urban form. This activity analysis has attracted an increasing attention in recent years (Czado & Prokopenko, 2008; Z. Guo & Ferreira Jr., 2008; Horner, 2007; Rodriguez & Joo, 2004; Ming Zhang, 2005).

As a result, the questions that are asked are primarily urban design-focused and include how to better integrate public transit stations with neighborhoods, and how to improve the local street configurations to encourage walking and cycling. Good urban design integrating transit facilities, especially the stations, with surrounding built environment, encourages pedestrian access to public transit (Bertaud, 2002; Boarnet et al., 2011; Loutzenheiser, 1997). The Central district of Hong Kong is a successful example of transit oriented urban design in an area with its high densities. Transit stations are well incorporated into the underground structure of office buildings and shopping centers. Extensive elevated and covered pedestrian passages connect buildings and separate pedestrians from ground traffic, providing convenience and walking safety. Some buildings put their lobbies on the second floor to connect to these elevated passages, further encouraging transit and walking.

High residential density generates high aggregate demand for travel. With more and diverse activities concentrated in a small area, nodal centers become attractive destinations where people can access their desired services and potentially combine their trips. High density also increases vehicle congestion and parking availability and costs, encouraging people to use non-motorized travel modes, such as MRT, cycling and walking (Litman, 2011). Jobs-housing balance is a concept derived from the mix of land use types, which is defined by the ratio of jobs to residences in an area. Communities with high jobs-housing balance have been studied by Chinese scholars (J. Yang & Mao, 2006; P. Zhao, B. Lü, et al., 2009). A large range of jobs suitable for community residents located within reasonable walking distance of the housing stock is theorized to reduce long-distance commuting. The jobs-housing balance concept has been critiqued because of the difficulty of attracting the range of businesses and activities demanded by a populace within walking distance, and because employees who work in an area may not be able to afford nearby housing. However, jobs-housing balance is desirable in terms of encouraging bidirectional traffic flows during peak periods, and channeling high percentage of trips to inter-nodal routes. This does not imply a dispersal of employment to places which are poorly served by public transit; the policy implication is that nodes should be developed around transit stations.

With the introduction of land markets in China, the work unit (*danwei*) complexes have been gradually dismantled and employment and housing has become much more physically separated for the vast majority of the population. A study on the jobs-housing relationship in Beijing shows that the commuting distances and the use of motorized travel modes normally increase as employees move from *danwei* housing to market housing (D. Wang & Chai, 2009a), suggesting that the introduction of land and property markets has increased travel demand in Chinese cities, effectively having a negative impact on land use efficiency. Growing affluence under a market economy is associated with a rise in car ownership, decline in walking and cycling, and increased VKT. Because all land, including urban land in China is under public ownership, in principle the central government has more potential than its Western counterparts to implement spatial strategies to manipulate urban form and, hence, to achieve desired travel pattern outcomes. So far, however, the state has chosen not to act decisively to improve land use efficiency.

Pan, Shen, & Zhang (2009) use the concept of green transport, referring to non-motorized travel, in their survey (n=1,709) on the influence of urban form on travel behavior. A survey of travel behavior was done in four neighborhoods, chosen for their historic developmental character, in Shanghai. One of the neighborhoods was built in the 1930s-1940s in Li Long style which represents a typical traditional, mixed use, human-scale neighborhood in Shanghai; two of them were a neighborhood work unit (residential blocks built by work-units in the 1970s and 1980s), the other one was privately developed in the 1990s in the Pudong area and characterized by high rise buildings and spatially separated from where the residents work. Regression modeling techniques are applied in the analysis. Results show that the traditional densely built neighborhood has much lower car ownership rates[4]. A strong correlation exists between the physical environment of a neighborhood and the motorized travel since walking or cycling friendly environments help to reduce the need for a private car. It is argued that changes in urban form may not be able to reverse the increasing trend of car ownership associated with increasing incomes, but it may help slow down the growth rate of motorization.

In light of the trends in travel behavior in urban China, determining how to build a sustainable urban transportation system has attracted a significant amount of scholarly attention. However, this is a complex process and the solutions are not clear due to the involvement of multiple stakeholders, uncertainties in securing funding for infrastructure construction, difficulties in integrating land use and transport planning, and many other socio-economic factors. Kennedy *et al.* (2005) argues that there are four important components to establish a more sustainable transportation system: (1) effective governance of land use and transportation; (2) fair, efficient and stable funding sources, (3) strategic infrastructure investments, and (4) attention to neighborhood design. Due to the complex nature of sustainable urban transportation systems, a wide range of analytical approaches need to be applied in research and design, including descriptive statistics, spatial mapping, travel preference functions, regression analysis, etc. (Black et al., 2002; Fedra, 2004b; Lo & Wong, 2002). Accordingly, a mix of management, operational and planning tools are proposed to achieve more sustainable transport

[4] Low car ownership could be the result of denser and more walkable environments in these traditional neighborhoods, or because the residents are usually poorer who are not able to afford a car. In addition, lack of neighborhood parking spaces may be another factor. It is often argued to be one of the reasons for Shanghai having a lower level of motorization, despite being richer.

systems, such as Transit-oriented Development (TOD), Bus Rapid Transit (BRT), intelligent management systems, neo-traditional neighborhood design, etc. (Goldman & Gorham, 2006).

Studies on sustainable urban transportation in Chinese cities focus less on theoretical explorations and more on whether the above tools fit China's context, as well as how to apply the tools in practice to improve current transport efficiency. The concepts most common in Chinese literature include TOD, BRT, and neighborhood design. But such academic studies are still at an early stage, and there are challenges in having research and design findings implemented.

Transit-oriented Development (TOD) is a synergistic strategy that attempts to balance transportation and land use developed in the U.S. context; it has emerged from the neo-traditional planning literature. Its principles include incorporating a mix of land uses, constructing defined town centers that are positioned around transit stations, pedestrian friendliness and walkable designs, with 18 hours of activity and a complete range of community services (Lai, 2007). A successfully-designed and constructed TOD project should: i) encourage travel by transit and reduce motorized trips; ii) improve environmental quality; iii) provide a sense of community; and iv) increase the value of the land and property.

The successful implementation of TOD requires integrated land use and transportation planning. This may pose challenges in China because the bureaus responsible for land use planning and transportation planning have always been separately administered. However, the tremendous increase in travel demand and motorization levels in China makes it critical to develop more mass rapid transit. Efforts are also being made to encourage walking and biking by offering bike rentals immediately adjacent to some MRT stations, according to Beijing's Public Transport City

Plan 2015 (Beijing Daily, June 10, 2009). Many Chinese cities are expanding at a relatively fast pace, both demographically and in terms of land conversion. Thus, "a transit-based corridor-nodal urban pattern is believed to be more desirable (Ming Zhang, 2007)". In this sense, TOD represents an ideal model (Robert Cervero & Day, 2008b). Zhang also argues that the TOD principles as developed in the U.S. are valid, although not operationally applicable to Chinese practice. After exploring the experiences of transit-centered development in Hong Kong, Taipei, and mainland Chinese cities, Zhang summarizes conceptual TOD framework as five-D's squared (5D2)[5] and labels it as "the Chinese edition of TOD": i) Differentiated Density: There should be a difference of density inside and outside of the TOD community. There should also be a differentiated density profile upward sloping toward the station, the center of the community; ii) "Dockized" District - an idea borrowed from seaport or airport design. The key to the success of a TOD community is people's willingness to walk. In the airport or seaport terminals, there are numerous moving walkways that passengers pass through to the boarding gates. These walkways are normally flanked by activities such as shopping and dining spaces; iii) Delicate Design: the emphasis here is on achieving high standards and fine detail in environmental design, which promotes pedestrian friendliness. High design standards also help to increase the property value; iv) Diverse Destination: this feature has dual intentions – mixed use at the local scale and access to diverse urban services and functions at the regional scale. Based on this principle, the concept of job-housing balance plays a key role. Zhang advocates matching the right types of jobs with the right types of housing within 30-45 minutes' travel time by transit; v) Distributed Dividends: this is associated with the economic sustainability of public transit. Currently, transit operations in China are dependent on subsidies from the government. But with the "value

[5] As oppose to the 5D's proposed by Bob Cervero and Kara Kockleman: Density, Diversity, Design, Destination Accessibility and Distance to Transit (Robert Cervero & Murakami, 2008).

capture" mechanisms, it is possible to realize sustainable financing through transfer from the private to public sector.

Residential relocation caused by urban redevelopment creates potential for TOD to make rapidly suburbanizing Chinese cities more sustainable. Cervero & Day (2008a) explore the relationship between relocation and commuting behavior based on survey data from Shanghai. Massive urban redevelopment of the old city centers in China turns traditional human-scale neighborhoods into modernist communities, and forces the original residents to relocate to the periphery. This direct result is reduced job accessibility for those who have no other choice but to move to the designated housing. Cervero & Day also show that these practices resulted in a 10-15 minute increase in the commuting duration. Some more affluent households, however, are able to select more accessible locations by themselves. On the other hand, those households that are relocated to neighborhoods within 1 km of a transit station (instead of 500-800 meters as suggested from Western experiences) experience a significant improvement in access to work. The conclusion is that with systematic planning and design, TOD can serve these people's daily commuting needs in a more sustainable way.

2.2.3 Trip Characteristics of Suburbanites (Particularly Mode Choice) and Sustainability

Theories and evidence have been amassed to understand the trip characteristics of suburbanites, mostly from US studies. In metropolitan areas of the US, a sprawling pattern of incremental development is common and is often blamed for high dependency on automobile travel, and environmental problems (Handy et al., 2005). Burchell et al. (2002) define the key characteristics of sprawl as low-density, outward expansion and leapfrog-style development. Studies on suburban travel behavior in U.S. metropolitan areas show that the built environment has a greater impact on trip lengths than trip frequencies, and socio-economic characteristics of the travelers or households affect travel mode choice as much as the built environment. Evidence suggests that there is a small but statistically significant impact of the built environment on vehicle miles traveled (VMT) (R. Ewing & Cervero, 2001).

Alonso's (1964) bid-rent theory describes how housing price decreases and demand preferences for real estate changes as the distance from the CBD increases, based on a concentric zone model. Residents tend to move to the suburbs for larger living space and lower housing price, hence higher affordability. Such behavior is the result of the cost – space trade off activity, or often refer to as "drive till you qualify" by the real estate industry (Osland & Thorsen, 2008). The freedom to move, individualism, fondness of larger living space and proximity to nature have been major forces for driving suburban development in the U.S., fostering a unique suburban culture (Muller, 1982).

In investigating land use and travel behavior studies in suburban areas, several travel behavior variables are tested in various studies. These variables include measurements of trip generation, travel mode choices, and trip distances (or VMT). Findings suggest that land use has a larger impact on trip distance (or VMT) than mode choice. Land use also has statistically significant impact on trip generation, but the magnitude is small, and evidence shows that socio-economic and demographic characteristics have the most significant effects on predicting travel behavior decisions (Boarnet et al., 2003; Boarnet & Sarmiento, 1998; R. Ewing & Cervero, 2001).

Travel decision making is a complex process that involves factors like destination locations, travel times, routes, and modes of travel. Travel decisions are also related to the types or purposes of trips. They can roughly be divided into commuting (going to and from work) and non-commuting trips. Or, more specifically, they can be divided into four types, as argued by Næss (2005): i) bounded trips which are fixed by location and time, such as work trips; ii) non-bounded trips which are flexible in both time and spatial, such as going to watch a movie at a theatre; iii) intermediary trips refer to those trips with one flexible aspect but fixed on another, such as gym trips, which are bounded by the location but not necessarily the time; iv) semi-bounded trips with some flexibility but also demonstrate some regularity, such as trips to the supermarket for food.

Discrete choice theory is frequently used to explore the relationship between the urban form and socio-demographic factors and travel decisions. It is suggested that an individual makes a logical decision on travel mode choice after considering the utility of that choice relative to other choices (Ben-Akiva & Lerman, 1985). Such utility could be measured in different ways based on individual preferences, such as monetary costs (including gasoline price, transit fares, tolls, and parking fees), time costs (including time lost to congestion, transfer and waiting time for transit, etc.) and the cost of convenience. In-depth understanding of the factors that determine individual mode choice decisions can help policymakers find preferable mechanisms to gear individual travel behavior towards non-motorized options. An individual's activity space, travel cost (time and money), personal preferences, affordability, the built environment, and opportunity cost are important factors when people make their travel decisions. Individual mode choice decisions in discrete choice models are theorized to take place under rational choice and are made after evaluating and balancing all variables.

Suburbs in Chinese cities are being developed at similar densities to central cities. The dynamics of suburbanization in China are different from U.S. cases (refer to section 2.3). Travel behavior studies are often based on surveys that cover the whole city while limited efforts have been made to focus specifically on suburbs (D. Liu et al., 2009; Meng, et al., 2011; M. Zhao et al., 2009).

2.3 Measuring Sustainability Impacts (Related to Land Use Changes and Transportation)

The evaluation of outcomes of land use changes associated with urban public transit development can be measured in terms of economic, social and environmental impacts. I will review current research on the economic and environmental impacts in this section while putting emphasis on the environmental impacts, because it is the focus of my assessment of the sustainability impacts of MRT development in Beijing.

2.3.1 Economic Impacts

The economic impacts of land use changes and urban transportation can be divided into three areas: economic productivity of locales, public investments, and individual costs.

It is argued that transit-accessible areas that incorporate transit-friendly building and public space designs enable more efficient economic activity and innovation due to the *agglomeration effects* of development in these communities. Additionally, Bettencourt et al. (2007) argue that densely developed neighborhoods with mixed activities and good accessibility facilitate cooperation and interaction among people and businesses (Bettencourt et al., 2007). However, due to the different scales and combinations of economic activities, it is difficult to measure these impacts. Research estimates that such impacts appear to be significant (Anas et al., 1997; Sohn & Moudon, 2008).

More compact and accessible locations also tend to increase the number of employment opportunities and land/property values, leading to more successful development (IEDC, 2006). Population density is found to have positive impacts on economic productivity. Rosenthal and Strange (2004) find that if the population density of a city doubles, its economic productivity increases by 3% - 8%. The benefit may appear to be small. But if only service industries are examined, doubling the population density will result in a significant increase in productivity by 10% - 20%, demonstrating the importance of density to service industries (Morikawa, 2008). Service activities, particularly high-end serves, appear to benefit more from density than other types of urban economic activity.

Public investments, including unit infrastructure costs and public service provision, are more cost effective at rapid transit-accessible locations with high development densities, by reducing road and utility lines and travel distances for some local trips (Blais, 2010; R. Burchell et al., 2002). Canada Mortgage and Housing Corporation (2008) developed a model to estimate the costs of residential public services, demonstrating how capital costs increase with decreased development density. However, this model does not include the economics of public service provision, such as hospital emergency responses and school buses. The *Plan-it* program of the City of Calgary (IBI Group, 2009) compares the impacts of alternative urban development patterns on infrastructure costs and finds that the neighborhoods with more compact land use saved 33% in capital costs and about 14% in operating costs (see Table 2.1).

Table 2.1 Public Services Capital and Operating Costs, Calgary Canada

	Public Services Capital Costs (Billions)			Public Services Operating Costs (Annual Billions)		
	Dispersed	Compact	Difference	Dispersed	Compact	Difference
Roadways	$17.6	$11.2	$6.4 (-36%)	$0.23	$0.19	$0.04 (-18%)
Transit	$6.8	$5.2	$0.6 (-9%)	$0.30	$0.30	$0.00 (0%)
Water & Wastewater	$5.5	$2.5	$3.0 (-54%)	$0.06	$0.03	$0.03 (-50%)
Fire Stations	$0.5	$0.3	$0.2 (-19%)	$0.28	$0.23	$0.05 (-18%)
Recreational Centers	$1.1	$0.9	$0.2 (19%)	$0.23	$0.19	$0.04 (-18%)
Schools	$3.0	$2.2	$0.8 (-27%)	-	-	-
Totals	$34.5	$23.3	$11.2 (-33%)	$0.99	$0.86	$0.13 (-14%)

Source: (IBI Group, 2009)

2.3.2 Environmental Impacts

There have been a number of studies that evaluate the environmental and ecological impacts of urban transportation. An inventory approach is often adopted to consider all the parameters that contribute to emissions and consumption, including all sources of emitters and consumers, vehicle fleets, intensity of use, VMT/VKT (Vehicle Miles Traveled or Vehicle Kilometers Traveled), energy generation methods, etc. Empirical studies offer insights into the sustainability impacts of different travel modes.

Emission simulation models are frequently used to facilitate the quantification of major emissions of urban transport to explore characteristics of a well-balanced integrated transport system. For example, as part of its work, the Sustainable Urban Transportation (SUTRA: http://www.ess.co.at/SUTRA/) project developed an emission model for road traffic named the Transport and Environment Reporting Mechanism (TERM) based on local data for transportation characteristics such as vehicle fleet (including engine type and capacity), driving conditions, and average travel speeds. Additionally, carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), volatile organic compounds (VOC), carbon dioxide (CO_2), and particulate matters (PM) are incorporated in the TERM model, as major transportation pollutants (Fedra, 2004a). This model contributes significantly to both methodological and substantive research on the environmental impacts of urban transportation.

Of all the forms of atmospheric emissions, greenhouse gases (GHG) receive the most scholarly attention because climate scientists link them to global climate change. While there are a large number of sources of GHG emissions in the cities, they can be divided into three categories: buildings, transportation-related emissions and industrial emissions. Transportation is a key factor in economic growth, but also a significant and fast growing emitter of GHG. In 2005, 23% of total CO_2 emissions from fossil fuel combustion were attributed to the transportation sector. From 1990 to 2003, emissions from transportation grew by 31% worldwide (Bertaud, et al., 2009). Bertaud *et al.* argues that it is important to understand the links between urban transport, labor mobility and city productivity if reducing GHG emissions by transportation, while improving urban productivity is a national goal, which it is in China. To quantify the CO_2 emissions by road transport, researchers led by Bertaud build a model incorporating trip types (commuting, non-commuting and freight), share of trips taken by various "modes" (categorized as private motorized, private non-motorized, and public transit), and variables for each travel mode (average travel distance, CO_2 emission intensity per VMT and load factors). This model is applied to New York City; yielding an estimates that if the proportion of regional trips taken by transit increases from 36% to 46%, by shifting car travelers to transit travelers, GHG emissions will be reduced by 13%. Bertaud *et al.*'s findings demonstrate significant reductions in GHG emissions by shifting individual travel decisions toward public transit.

The performance of vehicle fleets, cleaner energy, and higher emission requirements, all play an important role in reducing pollutions. A study on vehicle emissions in Beijing conducted by Oliver et al (2009) collected vehicle usage data and performed on-road emissions tests for light-duty passenger vehicles, making a comparison between the performance of Beijing's fleet of vehicles with that of neighboring Tianjin. The findings suggest that, although the fleet size and total VMT in Beijing are 4.4 times those of Tianjin, the total emissions of CO, Total Hydrocarbon (THC), NOx, and PM in Beijing are only 2.1, 2.2, 1.4, and 0.7 times those of Tianjin. Tianjin's superior performance was attributed to the Tianjin Municipality's taking aggressive measures to controlling vehicle emissions since the early 2000s, including implementing more stringent emission standards for new vehicles, requiring cleaner fuels, phasing out older and high emitting vehicles faster, and enforcing a more rigorous inspection and maintenance program. At the same time, Beijing has been putting intensive investment in building a convenient and affordable public transportation system, while providing incentives (such as subsidies for transit fares) to encourage public transportation usage. Reducing vehicle emissions in Beijing has become a higher priority in the past decade, reflected by an improved performance in terms of environmental impacts.

An IFEU[6] (2008) study that puts an emphasis on comparing the energy consumption and CO_2 emissions from different travel modes, evaluated the performance of urban rail transit and passenger cars in Shanghai in 2005. This study revealed that urban rail transit was about 5 times more energy efficient per passenger kilometer than private cars, and 4 times more efficient than conventional buses. . In the same study it was also shown that emissions from urban rail transit were only one fifth the emissions of a private car per passenger kilometer (see Table 2.2) (ibid).

Table 2.2 Shares of CO_2 Emissions vs. Passenger Performance for Different Travel Modes in Shanghai in 2005, per passenger km traveled.

	Share of CO_2 Emissions	Share of Passenger Performance	Ratio (CO_2 Emissions per Passenger Performance)
Urban Rail Transit	4%	11%	0.36
Buses	15%	33%	0.45
Private Cars	50%	30%	1.67
Taxis	12%	23%	0.52

Source: (IFEU, May 2008).

Ma *et al.* (2011) utilize Structural Equation Modeling (SEM), Path Analysis and Confirmatory Factor Analysis (CFA) techniques to simulate the CO_2 emissions from daily travel in Beijing, based on a daily activity survey of 1,048 residents from 10 selected neighborhoods of Beijing in 2007. Findings suggest that both travel distance and mode

[6] IFEU: Institute for Energy and Environmental Research, Heidelberg

choices have different but significant impacts on CO_2 emissions. Also, urban form plays an important role in deciding travel behavior and hence CO_2 emissions. *Danwei* communities in Beijing have significantly lower travel demand and travel distances, with higher shares of non-motorized travels, and therefore produce much lower CO_2 emissions than the municipal average. On the contrary, residents in affordable housing communities are observed to travel longer distances and to choose private cars as their mode of choice. While not necessarily the particular development model advocated in this study, it is interesting to note that *danwei* communities bear many similarities with the higher density, compact and mixed-use development models that New Urbanists advocate.

However, alternative views have emerged on the effectiveness of urban form in yielding sustainable energy and emission outcomes. Significant increases in development density were found in a scenario study by the National Research Council (NRC, 2009) to result in only moderate short-term transport-related reductions in energy consumption and CO_2 emissions. More specifically, in a less ambitious[7] scenario developed in the same report, residents were projected to drive 12% less, resulting in only a 1% reduction in fuel consumption and CO_2 emissions by 2030, with a long-term reduction of between 1.3% - 1.7% in fuel and emissions by 2050. Some researchers have used similar findings to question whether it is worthwhile to direct significant resources aimed to mitigate climate change and reduce energy consumption to compact and mixed-use development when the environmental benefits appear trivial.

Besides GHG emissions, air pollution, and energy consumption, the environmental impacts of urban transport also include impacts on hydrology and aquatic habitats, farm land preservation, scenic beauty, and protection of special natural places, etc. This set of literature is not reviewed, because it is not central to this dissertation.

[7] The less ambitious scenario envisioned that assumes that only 25% of a city's housing stock would be built/replaced with more compact style neighborhood development.

2.3.3 Impacts of Air Pollution on Public Health in Beijing

China is considered to have the world's highest number of deaths attributed to air pollution. In 2007, the World Health Organization (WHO) estimated that 656,000 Chinese died prematurely annually from ailments caused by air pollution (Platt, July 9, 2007). While a study conducted by the World Bank and China's national environmental agency related 350,000 to 400,000 deaths to outdoor air pollution (Kahn & Yardley, August 26, 2007). Based on measurements of PM_{10} concentrations in 111 Chinese cities in China, Zhang et al. (2008) estimated that the total economic cost caused by PM10 pollution was about US$ 29,179 million in 2004.

Air pollution in Beijing is of major concern for the Chinese government as the concentrations of health threatening air pollutants have reached alarming levels (China Realtime Report, January 23, 2012). For example, the annual average $PM_{2.5}$ concentration in urban Beijing from 2005 to 2007 varied between 84.4 and 93.5$\mu g/m^3$, which was about six times the air quality standard recommended by the US Environmental Protection Agency (15 $\mu g/m^3$) and nine times the WHO Global Air Quality Guideline (AQG) (10 $\mu g/m^3$) (X. Zhao et al., 2009).

The health impacts of air pollution are significant and can be divided into short-term and long-term effects. More studies have been conducted on the relationship between public health and the routinely monitored air pollutants (NO_2, SO_2 and PM_{10}) than the more recently available pollutants ($PM_{2.5}$, CO and O_3).

The short-term impacts include both mortality, often measured by deaths, and morbidity, often measured by Emergency Room (ER) visits. Based on a multi-pollutant regression analysis, Chang et al. (2003) found that every 10 $\mu g/m^3$ increase of SO_2 corresponded with 0.4% increase of respiratory mortality and 0.4% increase of cardiovascular mortality. On the other hand, every 10 μ g/m3 increase of Total

Suspended Particle (TSP) was associated with 0.3% increase of respiratory mortality and 0.1% increase of cardiovascular mortality. As few cities in China have established a city-wide morbidity reporting system, recent studies have used health insurance system data or ER visits of a single hospital to investigate the short-term correlation between air pollution and hospital visits (J. Cao et al., 2009; Y. Guo et al., 2009). Cao et al. (J. Cao, et al., 2009) found out that a 10μg/m^3 increase in $PM_{2.5}$, SO_2, and NO_2 was statistically significantly correlated to hospital ER visits for cardiovascular diseases, with odds ratios of 1.005, 1.014 and 1.016 respectively.

On the other hand, long-term effects of air pollution are reflected in inducing or accelerating the progress of chronic diseases, and indirectly deteriorating the urban ecological system. There are fewer studies in China examining these long-term effects. Meanwhile, urban travelers are exposed to the air pollutants differently according to their choices of transport modes, such as subways, buses and taxis. Du et al. (2011) examined personal exposure to $PM_{2.5}$ and NO_2 in Beijing and found out that taxi drivers are exposed to both the highest $PM_{2.5}$ concentration and the highest NO2 concentration, while subway riders are also exposed to high $PM_{2.5}$ concentration. A comparison between Beijing and other cities of $PM_{2.5}$ exposure levels suggest that citizens in both Beijing and Mexico City are faced with high public health risks from $PM_{2.5}$ (see table 1). Considering that subway riders are also the victims of $PM_{2.5}$, and on-road vehicles contribute about 20% of the total mass of $PM_{2.5}$ in Beijing (China National Coal Association, Feburary 8, 2012), the reduction of car driving should be encouraged whenever possible.

Table 2.3 Comparison of $PM_{2.5}$ exposure levels in different cities, μg/m^3.

Reference	City	Taxi driver	Non-subway rider	Subway rider
(Du, et al., 2011)	Beijing	93.1	83.5	91.9
(Pfeifera et al., 1999)	London	33.36	24.02	36.77
(Tovalin-Ahumada et al., 2007)	Mexico City	125.9	85.0	–

Source: (Du, et al., 2011).

2.4 Chinese Suburbanization

This section reviews the driving forces and new trends in suburbanization in Chinese cities, demonstrating considerable differences in comparison with U.S. cities.

2.4.1 Driving Forces

The suburbanization process in Chinese cities has been closely related to the changes in government policies, industrialization and land/property market reforms. Urban researchers recognize that suburban development in China has gone through three stages since 1949. From 1949 to 1979, population movement was strictly controlled through the household registration system. Development in the inner suburbs of cities was mostly driven by limited state-led industrialization. The launch of the "Open and Reform" policies in 1978 stands as a "watershed" in the trajectory of suburbanization in Chinese cities. In the 1980s, local governments gained power (decentralization) by economic reforms, including the establishment of land and property markets. Less expensive suburban and peri-urban land became an incentive for industries to relocate to the suburban areas, affecting the residential choices of their employees. At the same time, local government launched urban renewal programs, which also contributed to suburbanization growth, often through forced relocation programs when large parts of the inner city areas were cleared for redevelopment. The third stage, since the 1990s, has been driven by multiple interwoven driving forces including the development of "commodity housing", which can be purchased freely on the market, as well as industrial restructuring associated with the emergence of large-scale Economic (ETDZs) and High-tech industrial parks (HTDZs) typically sited in suburban or peri-urban areas. Global capital (FDI) operating in close cooperation with both the public and private sectors in China has enabled these development forms to take root on a large scale. The unique institutions involved in land sale have reinforced these development forms. As explained in Chapter 3, Chinese municipal governments control the sale of land and have set up a land sale system that generates revenues directly to government coffers. Therefore, there is a profound incentive for municipal governments to sell land for (re)development (Feng et al., 2008; F. Wu & Phelps, 2008; L. Xie, 2007).

Suburbanization in Chinese cities went from a completely government-led process to a market-driven development but with significant state interests involved. This approach is termed "Chinese transitional cities" (Gaubatz, 1995). It is considered a "gradualist" approach, as the Chinese government has been implementing reformist policies since 1978 to gradually introduce market forces, while maintaining political stability. Such a transition has been a main research theme in the late 1990s and early 2000s for urban scholars (Bian & Logan, 1996; Gaubatz, 1995; Gu et al., 2005; Naughton, 1995; Nielsen et al., 1995; Sit, 2000; F. Wu, 1995, 1997, 2002; Yeh & Wu, 1996; L. Zhang, 2003).

2.4.2 Research on Chinese Suburbanization

The development of Geographical Information System (GIS) and remote sensing technologies has facilitated another major theme in the study of Chinese suburbanization, i.e. spatiotemporal and statistical analysis of population distribution and land use changes, modeling the spatial movement of urban households and rural-urban land conversion through GIS-based methods (Shenghe Liu et al., 2002; Walcott & Pannell, 2006; F. Wang & Zhou, 1999; Q. Wu et al., 2006; Y. Xie et al., 2007; L. Zhang et al., 2004). Most of these studies are conducted at the macro level (i.e., the city level). An earlier study conducted by Wang & Zhou (1999) models urban population densities in Beijing from 1982 to 1990 to capture the commencement, and characteristics of suburbanization, and its causes. Results confirm that the city center was losing population while suburban areas gained population over the study period. The density distribution fits the negative exponential function. Improvement of infrastructure and services in the suburban area is considered to be an important stimulus. Xu *et al.* (2007) employed sector analysis methods to document the spatial distribution and quantities of major land use types in Shanghai from 1979 to 1992. Findings suggest that the pace of urban expansion started to speed up from 1988, indicating the influences of land market reforms. More land has been converted to commercial uses in the urban core under the market regime. Residential uses have expanded outward rapidly since 1993, while industrial land tends to be clustered.

Spatial econometrics forms another stream of suburbanization studies. These scholars use regression models with geographical information to capture the characteristics of spatial growth of suburbs (Cheng & Masser, 2003; J. Luo & Y. H. Wei, 2009). Proximity to local arterial roads and highways is considered to have the strongest effect on land conversion in the suburbs. Densities of the already built-up area tend to promote urban expansion further into the suburban area. Distance to major city centers exerts more significant impacts than the distance to suburban centers (J. Luo & Y. H. Wei, 2009).

Other studies focus more on social aspects of suburbanization. Zhou & Ma (2000) reveal that development in the suburbs is still very much subordinate to the city center administratively and functionally, as compared to US cities where suburbanization has created a polycentric spatial structure, characterized by “edge cities”. The job-housing relationship has been a hot topic in recent years, especially in the Chinese literature, as severe traffic congestion and air pollution have become a pressing challenge of large cities in China. Before the 1978 reforms, *danwei* were the basic unit of economic, social and spatial organization in cities (Björklund, 1986). These self-contained developments not only provided salaries and comprehensive services for its employees, but also provided residences, kindergartens/schools, and shopping facilities (Bray, 2005). At that time, demand for intra-city travel was minimized and congestion was virtually non-existent. The market-oriented development since the 1980s has broken down this socialist style close spatial correlation between job and housing. The responsibility of housing provision was officially removed from the *danwei* in 1998, since then, people have to buy or rent their residences from the market, and thus have freedom to choose where they want to live, subject to availability and affordability. The literature indicates that imbalanced job-housing opportunities causes long commuting trips (Robert Cervero, 1989, 1996; Meng, 2009; Vandersmissen et al., 2003). Cervero (1989) finds out that suburban residents in the US travel farther than ever to work despite the fact that the number and proportion of jobs in the suburbs has been growing. He attributes this outcome to housing undersupply, housing costs that exclude many workers from local residential market, and demographic changes such as career shifts and dual earner households. This pattern has emerged in Chinese cities too, especially since 2000.

There has been strong criticism about the theoretical validity of job-housing balance, because in reality many socioeconomic or external factors prevent people from living close to their workplaces. Cervero argues that such balance between job and housing should not be planned, but be left to market forces to reduce the imbalance (Robert Cervero, 1996). Opponents of this argument point out that job-housing balance does not necessarily advocate that workers live near their workplace, but emphasizes that sub-centers, either in the urban core or in the suburbs, should consist of balanced number of jobs and housing to avoid overwhelming one-direction travels at peak hours, and to increase the likelihood of using rapid transit, which is likely to connect multiple nodes. Unbalanced one-direction commuting trips that have been both extended in terms of distance and time as a result of suburbanization are one of the major causes of congestion on roads and in public transit in Chinese cities, such as Beijing (Meng, 2009). Meng's findings indicate that commuting time has been increasing over time in Beijing. Job-housing imbalance is becoming a serious challenge for the city, in Beijing this imbalance is very severe in the suburbs compared with the urban core; the suburban imbalance is much worse than in most non-Chinese cities.

2.4.3 New Trends and Issues

Since the new millennium, new trends in Chinese suburbanization have been identified. First, suburbanization and peri-urbanization, in relative terms, is less driven by industrial investment (ETDZs or HTDZs). On July 18, 2003, the State Council announced the policy of terminating approval for any kind of new industrial zones/parks[8], including Economic and Technology Development Zones (ETDZ), High-Tech Development Zones (HTDZ), Commercial Development Zones, Software Parks, Logistics Parks, etc. Real estate development started to become the major driving force of suburbanization; suburbanization was significantly driven by these supply side dynamics.

In terms of real estate development, a comprehensive "Chinese" style has been adopted for large scale neighborhood development projects, which provide housing, shopping, entertainment facilities, public services, and amenity elements but ignore demands for employment opportunities. This development style, often branded as the "New City style", is a development model preferred by most real estate developers who generally earn more for residential development. On the other hand, specialized industry clusters create concentrations of employment in other segregated areas. The result is that clusters of employment and residential are becoming more spatially disparate in Chinese metropolitan regions. In the case of Beijing, centripetal commuting trips are the norm

[8] Official Documents can be reviewed at: http://www.law-lib.com/law/law_view.asp?id=80962 (in Chinese)

(Meng, 2009). Such “New City” style neighborhoods are inducing long commuting travels, causing increased VMT especially for those neighborhoods not connected by public transport.

New suburban development in China tends to mimic the urban core, in terms of density and building form. As a result, peripheral development in China is less physically distinguishable from the urban core than is the case in Western cities.

2.4.4 Differences from the Western Model

The Western model of suburbanization emerged at the end of the Second World War, with the US defining the phenomenon. Although US Suburbs originally started as “bedroom” communities with little employment, employment began to develop in the suburbs by the late 1950s. Since the 1950s, the employment gains in the suburbs have tended to outpace that of their central cities. And, in many metropolitan areas, the central city has recorded an absolute loss of jobs (Weaver, 1975). As early as the late 1950s, Vernon (1959) observed that the outward movement of population in American cities was being matched by an outward movement of jobs. Retailing followed the movement of the middle class population, and the movement of jobs reinforced the movement of population. Social trends such as the increase of private car use, and the preference of homebuyers for larger living spaces were key driving forces explaining American suburbanization.

While relatively rare phenomena such as segregated land uses and emerging ‘villa’ style developments suggest that there are some growing similarities between Chinese and U.S. models of suburban development, the two countries are, on the whole, vastly dissimilar in terms of suburban development approaches. In China, jobs do not necessarily follow an outward movement of the population, while central cities remain thriving locations that are desired by the affluent. Housing styles in Chinese suburbs do not take the form of detached, single-family houses but rather of 6-storey mid-rises and high-rise developments, all multifamily in nature. Car ownership has been increasing largely due to economic growth along with household income. But, while the share of trips taken by car has been increasing, the automobile is not nearly the dominant travel mode for suburban residents as it is in the U.S.; in China public transit alternatives are almost always offered and both the accessibility opportunities and the riderships are growing (W. Wu, 2010; Yao, 2011).

Compared to the "suburban culture" in the US, which defines an entirely different lifestyle, composed of different and unique cultural and political affiliations of suburbanites compared to their central city counterparts, what are the distinguishing social and physical attributes of Chinese suburbs? Do distinct suburbs really exist in China? Such questions are not yet well answered by the literature, but will be examined in my research.

2.5 Knowledge Gaps in the Literature

Neighborhood level research is underrepresented in the existing literature: Most research examining the relationship between land use/transport and sustainability performance is being undertaken at the metropolitan scale. One benefit of neighborhood level research is the ability to closely examine changes in the built environment and better understand the factors that immediately impact on people's travel behavior. The second benefit, as hypothesized in this dissertation, is that sustainability benefits are much more the result of micro (neighborhood, district) level change than the macro spatial reordering of cities.

Another gap in the literature on land use/transport and urban form is related to **the timing of MRT (rapid transit) accessibility relative to the development trajectory of city neighborhoods / districts**. I hypothesize in this dissertation that the timing of MRT accessibility relative to local development trajectories is a key factor in mode choice, and hence sustainability performance.

Thirdly, and related to the previous point, only limited attention has been paid to **suburbanization in China**, and **suburban neighborhood development, in terms of mode choice and sustainability performance.** Yet suburbs are growing rapidly in population and are characterized by the longest commuting trips; thus, potentially the largest benefits in terms of sustainability impacts of urban transportation could be realized in suburbia, given the right policies.

I hypothesize that travel behavior in China is different from that in Western countries, because of different values, traditions, and preferences. More needs to be known in regard to the preference structures of Chinese urban travelers.

Environmental, health and energy outcomes are the most important and direct impacts of urban transport. The **quantification of the sustainability outcomes** of changing travel behavior over time can play a significant role in justifying transit development and leveraging policy decisions. Virtually no rapid transit systems worldwide (with the exception of Hong Kong) yield a positive financial return, thus knowing the value of externalities is very important in calculating economic returns and making investment decisions. **The sustainability benefits of** MRT development, including environmental, human and energy impacts is not yet well understood, especially in China. Over time, Chinese MRT lines are increasingly serving the suburbs, thus externality data related to travel to/from suburban locations is especially important.

China is the largest market for automobiles and consumer of energy, but **the usage of urban transport and its relationship to urban form is** not yet well studied overall. Because of the sheer quantitative magnitude of Chinese urban travel, even small gains in sustainability performance, translate into large macro gains. Thus studies are needed to better determine system characteristics, including case studies dealing with specific cities or areas of cities.

This study aims at contributing to the above gaps in the current understanding of the relationship between urban land use/transport and sustainability performance by examining an important city, i.e. Beijing, the capital, which has experienced intensive investment in its MRT system over the past 10 years, offering a time compressed real world laboratory and opportunity to understand the dynamics between urban form / transport and sustainability performance, related to system shocks related to large scale MRT investment.

Chapter 3

THE SPATIAL EVOLUTION OF BEIJING: ROADS, TRAINS AND SUBURBS

This chapter sets the Beijing context with an emphasis on spatial and transportation development. The spatial evolution of the built-up area is summarized, with reference to transitioning city building processes. The development history of the road network and MRT subway lines is presented with an emphasis on their impacts on the overall land use changes and people's travel behavior. A time line of regional transportation development is presented chronicling changes since the construction of the second ring road and first subway line. The suburbanization process of Beijing during the same time period is illustrated from a perspective of transport network and residential/industrial development.

Beijing is over 3000 years old, and was both the capital of the Yuan (starting from the fourth year of Yuan, or 1267-1368), Ming (1368-1644) and Qing (1644-1912) dynasties. Accordingly, much of modern Beijing's spatial structure has evolved from the layout first surveyed by Qing and Ming dynasty builders, as well as major city-building projects initiated since the People's Republic of China was founded in 1949. The development of Beijing had been mainly contained within the city walls until 1953 when the wall started to be torn down and the 2nd Ring Road was built on its site. The year 1978 marked a turning point in China's political and economic practices when the "Open and Reform" policies (Chinese: 改革开放) were implemented. Under the leadership of Deng Xiaoping, the country transitioned from a planned economy to a market economy. The "Open and Reform" policies also had a significant impact on future city building practices since a land market system was established. Because of the lagging effect of policy changes (L. Xie, 2007), I will examine the evolution of Beijing's spatial structure since the 1980s in this chapter.

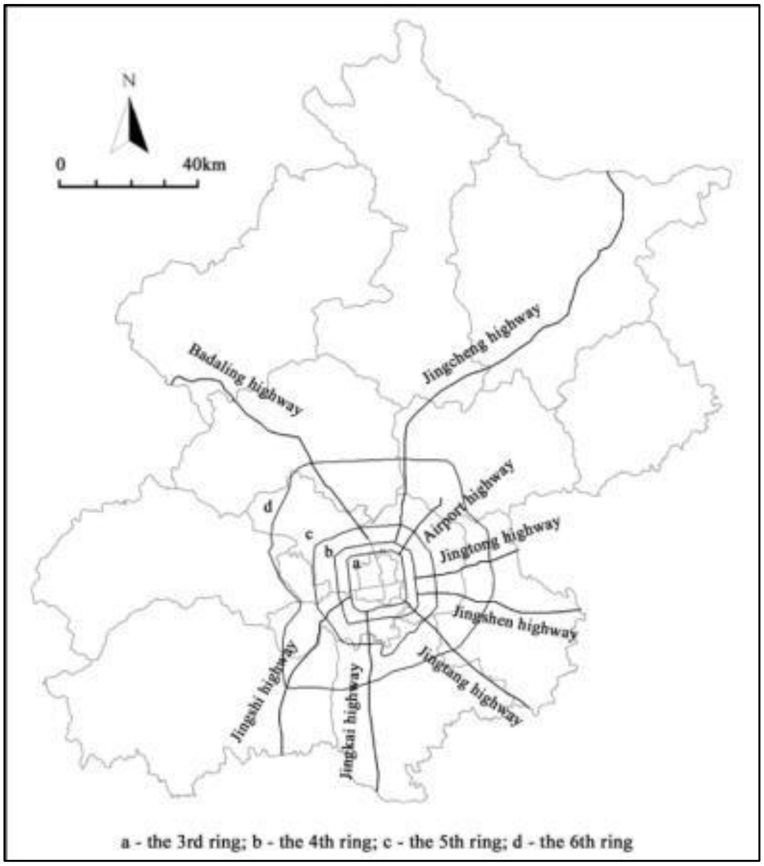
3.1 The Road Systems

Beijing's fast road system features a "Ring Roads + Expressways" model (see Map 3.1). The construction of the 2nd Ring Road started in 1950s and was completed in 1992. Since then, the development of the Ring Roads system has been accelerated. By 2010, 6 Ring Roads (RR) had been constructed around Beijing, enclosing an area of 2,260 km^2 (see Table 3.1). There are eight main expressways connecting Beijing with major cities to the South, East and North Two axes should be recognized when analyzing Beijing's spatial structure. Chang'an Avenue (Chinese: 长安街) runs in front of Tiananmen and forms the West-East axis. The North-South axis, instead, is a conceptual/architectural principle which dictates that important public buildings be aligned on either side of this axis to demonstrate a symmetrical arrangement. This principle is a heritage from the imperial era (Ming Dynasty), when rulers believed that a centralized configuration of buildings would serve as a reflection of the orderly heavens. The Tiananmen, the National Centre for Performing Arts, and the Bird's Nest stadium, which served as the main venue for the 2008 Olympic games, are all located right on or near this architectural axis.

Table 3.1 Ring Roads in Beijing

RR	Designed Speed (km/h)	Start Year	Complete Year	Length (km)	Area Enclosed (km2)
2nd	60-80	1950s	1992	32.7	62.5
3rd	80		1994	48	150
4th	100	1990	2001	65.3	300
5th	90-100		2003	98	667
6th	100		2009	188	2260

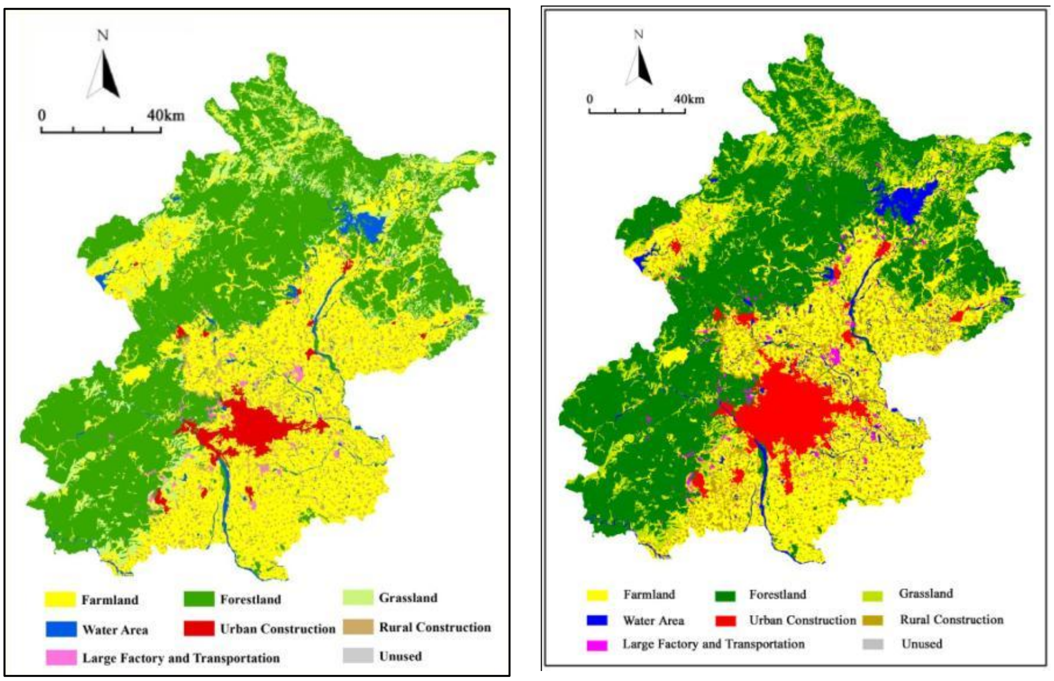
Source: the author, 2011



Map 3.1 The Road System of Beijing

Source: (Y. Xie*, et al.*, 2007)

This road system defines the skeleton of Beijing's spatial structure and plays a significant role in its urbanization and suburbanization processes. With more Ring Roads being constructed, more land became available for development due to better transportation accessibility. As shown in Map 3.2, the urban construction area keeps expanding outwards, with extensions along major expressways. Between1990-2008, the total built-up area of Beijing increased from 397km^2 to 1,311km^2. Meanwhile, the total permanent population grew from 10.86 million to 16.96 million. More importantly, evidence shows that the years when the Ring Roads were completed are coincident with the time when significant increases of built-up area happened (see Figure 3.1). To be more specific, the total built-up area increased slightly from 1990 to 1994 when the 2nd and 3rd Ring Roads were completed. After that, the total built-up area remained the same for seven years until a sharp increase happened in 2001 when the construction of the 4th RR was completed. In 2003, after the 5th Ring Road was constructed, there was another major increase in the total built-up area of Beijing. The completion of the 6th RR in 2009 potentially triggered more outward development.



(a) 1990 (b) 2000

Map 3.2 Land Use Maps of Beijing in 1990 and 2000

Source: (Y. Xie, et al., 2007)

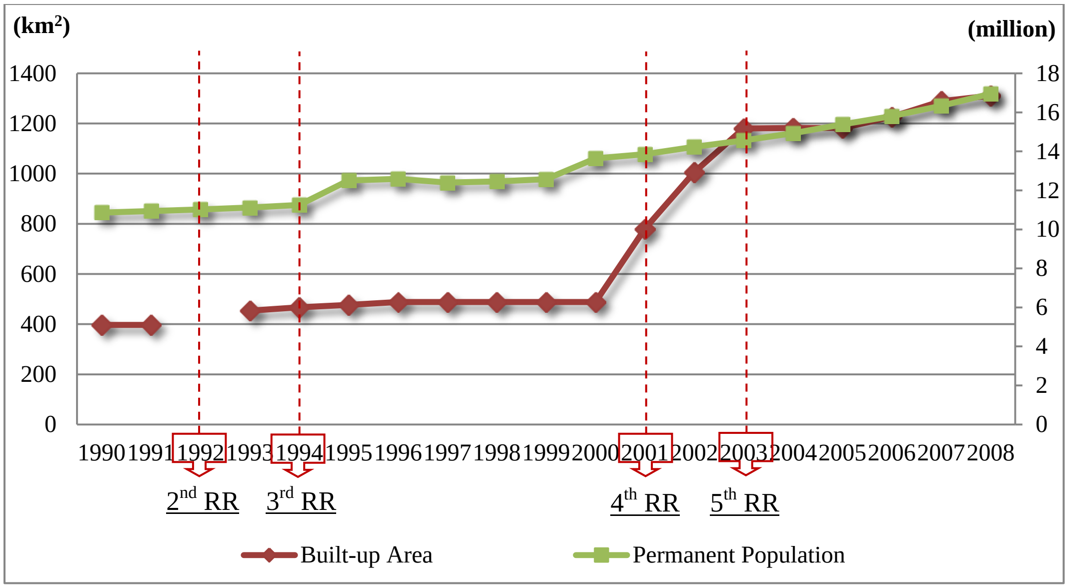


Figure 3.1 Changes of Built-up Area, Permanent Population and Urban Population in Beijing since 1990, as related to the Completion Years of Ring Roads

Source: China City Statistical Yearbook, various years.

3.2 Beijing's Spatial Evolution

The transitioning city building processes and key stakeholders since the "Open and Reform" movement of 1978 are the main forces shaping Beijing's spatial structure. The highly concentrated political power in the planned economy era slowly gave way to decentralization and more local autonomy. Land and housing markets have been established by changing land use rights from termless administrative allocation to termed paid uses, and by allowing land and property transactions (see Figure 3.2). These reforms broke the spatial dependency between employees and their work-units who allocated living spaces to them, accelerating land conversion, and changing the socialist work-unit based physical layout of the city significantly (L. Xie, 2007). It was during this reform period since the 1980s that individuals started to have the choice of deciding where they wanted to live, and private developers began to play a significant role in land acquisition and house building. These changes have been implemented gradually. Even now, some features from the planned economy era can still be found in today's urban spatial structure.

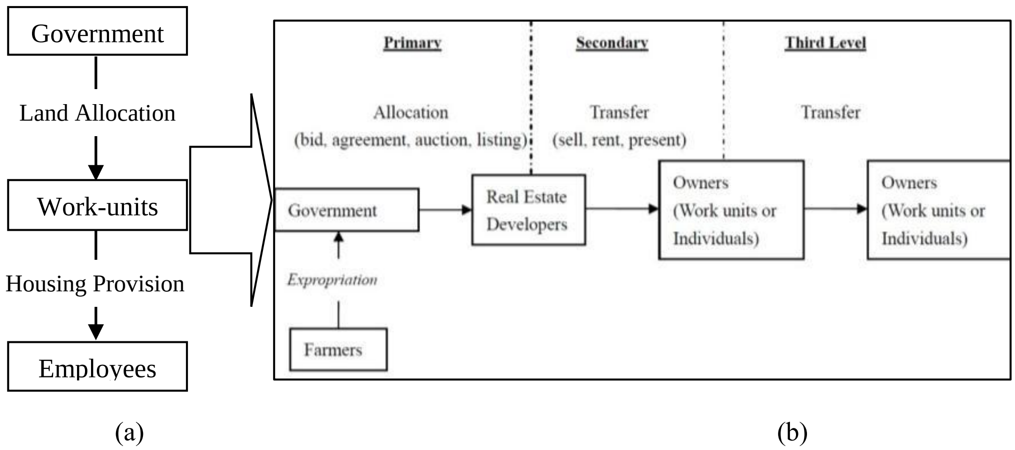
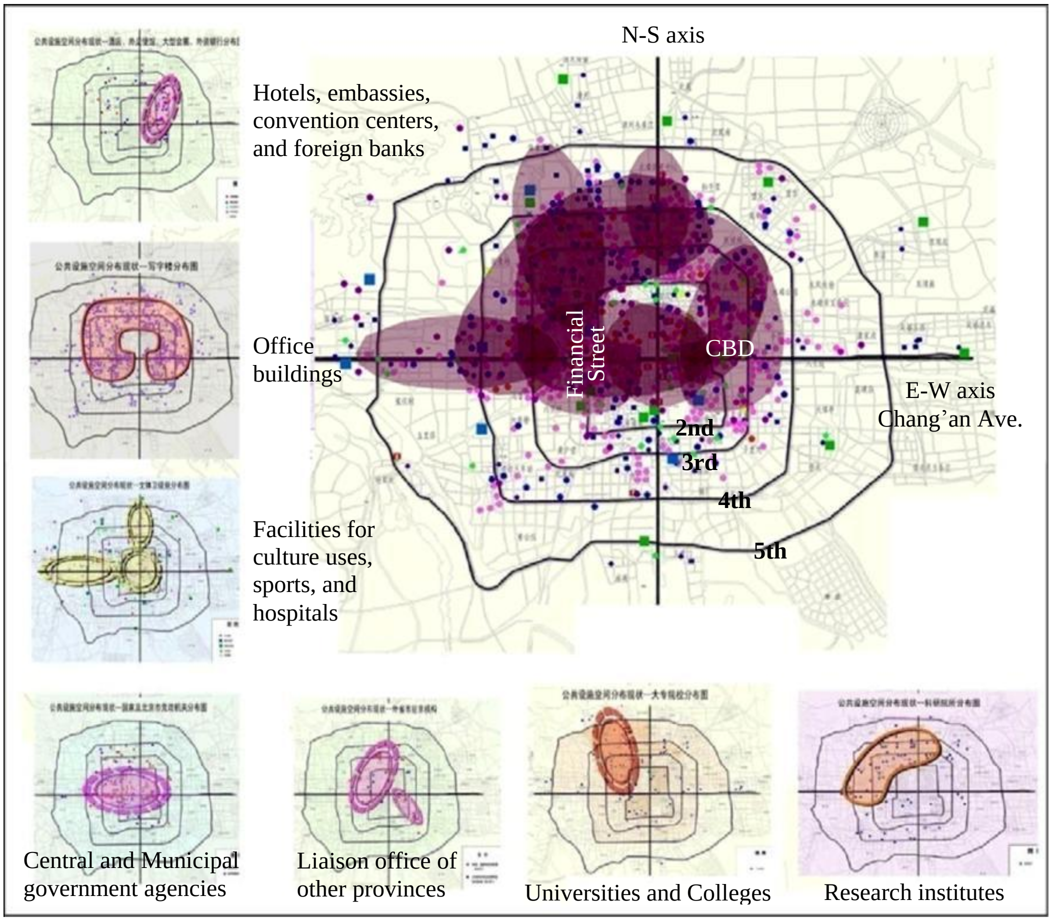


Figure 3.2 The Land Allocation System before 1978 (a) and The Triple-Level Land Market after 1978 (b)

Source: (L. Xie, 2007)

Major city functions are concentrated within the 4th RR, with a few clusters reaching out to the Northwest Quadrant of the 5th RR (see Map 3.3). The city proper (colloquially considered to be contained within the 2nd RR) is largely occupied by offices of the central and municipal governments. The hearts of Beijing's business and financial functions are found within the Central Business District (CBD) and the Financial Street, which are both expanding. The majority of embassies are located between the East/Northeast 2nd and 4th RRs, as are major hotels, convention centers and foreign banks. The Northwest Quadrant is the municipal and national hub of education / research institutes and IT industries. Office buildings are distributed largely within the 3rd RR and the North sections of the 4th and 5th RRs. All evidence shows that Beijing's spatial development patterns exhibit a multi-nodal model consisting of several nodes with high concentrations of differentiated or combined activities and employment clusters within the 4th RR.

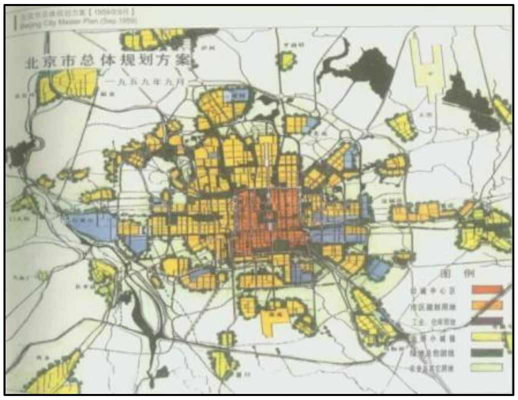


Map 3.3 Spatial Clustering of City Functions

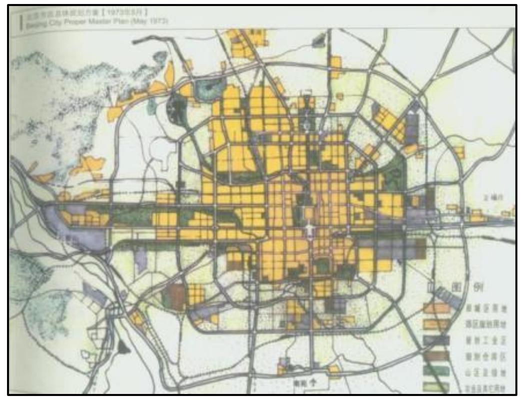
Source: China Academe of Urban Planning & Design, Beijing Urban Spatial Development Research. 2003.

From a spatial perspective, the development levels in Beijing are not evenly distributed. The northern half has historically been more developed than the southern half of the city. In more specific terms, more development and activities have taken place to the north of Chang'an Avenue than to the south, resulting in more intense land development in the north. This phenomenon can be attributed to several reasons. First, in the imperial time, the South was the "gateway" for people entering Beijing. The "Tianqiao" (Chinese: 天桥) area in the southern half of the city and was traditionally where members of lower social classes were concentrated lowering the image of this section of the city. Secondly, Beijing's international airport is located in the Northeast, attracting industries and services (such as logistics) to be located in the north part of the city. Thirdly, the education hub centered around Peking university and Tsinghua university is located in the northwestern part of the city, and has led to the creation of a business cluster specializing in technological enterprise. Additionally, several important events have been placed in the North, particularly the principal sites for the 1990 Asian Games and the 2008 Summer Olympics.

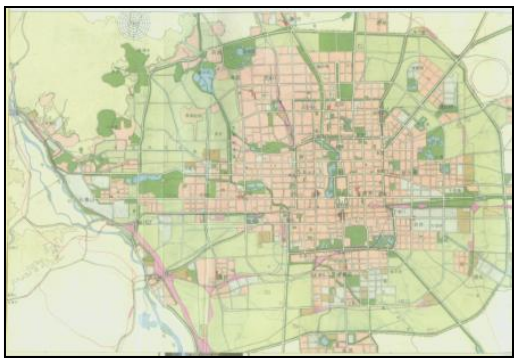
Master plans since 1950s have defined Beijing's spatial layout at the macro level. A "City Proper + Scattered Towns/Satellite Towns + Wedge-shaped Green Belts" system has been the key and consistent strategy of the City's Master Plans since the 1950s (see Map 3.4). According to the plans, the 4th RR should be the edge of city center, and the 5th RR was built to link the 10 scattered towns, while the 6th RR was designed as an intercity expressway connecting the satellite towns (Y. Huang, 2004). However, the regional connectivity provided by the Ring Roads encouraged land development between the scattered towns resulting in a "pancake style" development and loss of green belt. Complementary to the Ring Road system, radial expressways were constructed that promoted land conversion along them and created development corridors that extend to the outer suburbs of Beijing.



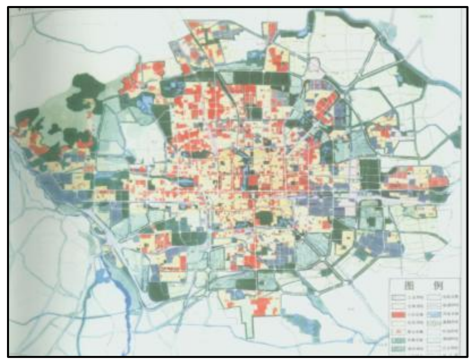
(a) 1953



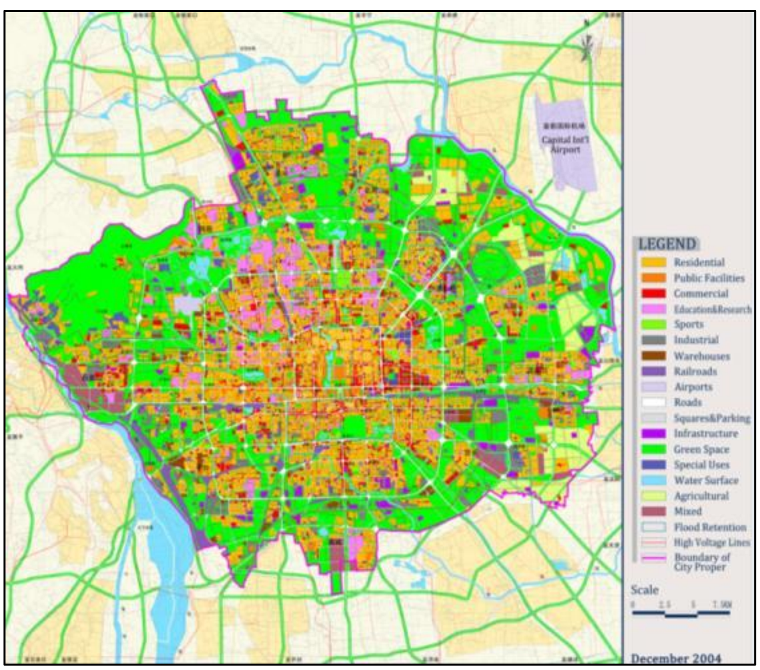
(b) 1973



(c) 1982



(d) 1992



(e) 2004-2020

Map 3.4 Master Plans of Beijing's City Center

Source: Beijing Municipal Institute of City Planning & Design

The master plans also defined the main use type of each land parcel in the city center (see Map 3.4e). However, in practice, this was often negotiated between the developers and the planning authority. Of all the features for development, “location” is often the most prized. Hence, sites with good road and/or mass transit access, as well as decent amenities, such as next to or in the green belts, are preferred. The result of these negotiations is directly shown in the spatial layout of the city as mismatches between the plan and the actual land uses.

From the perspective of economic clusters, Beijing’s spatial evolution since the 1980s may be divided into two periods: (1) from 1983 to 1997 when manufacturing was the main driving force; and (2) from 1997 to 2010 when the growth of service industries became a major shaping force (Z. Yang, 2010).

The urban center was largely concentrated within the 3rd RR during the first period when manufacturing industries were relocated from the urban area to the peri-urban areas beyond the 4th RR. This process of peri-urbanization was characterized by changing economic and employment structures, giving dominance to manufacturing, prevailing land conversion and increasing land costs (D. Webster & Muller, 2002). High-Tech Development Zones (HTDZ) and Economic and Technological Development Zones (ETDZ)[9] became popular practices in Chinese cities during this time. In Beijing, the first national level ETDZ, namely the Beijing Development Zone (BDZ), was planned and initiated in 1991 on land adjacent to the Southeast 5th RR with a total planned area of 46.8km^2.

[9] HTDZ and ETDZ are designated industrial development zones often located in the outskirts of cities. To attract industries, they often provide preferable land and tax policies and enjoy special administration.

The physical tie between work units and employees has slowly devolved since 1983 with emerging land and housing market. However, until 1997 working and living places for residents in Beijing were still closely related. Personal services and low-level services were provided in the vicinity of work-units, but sometimes insufficiently. On the other hand, people had to visit the urban center where higher-end services and goods were more available. A mono-centric spatial structure was formed in Beijing during this time period and was continuously consolidated by manufacturing growth (Z. Yang, 2010).

Since 1997, the urban center expanded rapidly with rapid population growth. Service industries exceeded manufacturing in becoming the largest share of the urban economic structure in terms of economic output. Spatially, traditional manufacturing industries were moved further outside of the urban domain - i.e., progressively outside the 5th RR - and differentiated service clusters started to be established in multiple locations in the city proper. For example, the Central Business District (CBD) was located between the intersections of Chang'an Ave and the East 2nd RR and 3rd RR and is recently planned to be extended further to the east. On the other side, at West 2nd RR, is the national level financial management center (Financial Street) which was initiated in mid-1990s. It enjoys a premium location at the west 2nd RR and excellent subway connections. It started with a few national financial policy-making institutions and headquarters of domestic banks, and soon formed into a significant cluster of financial industry. It is now the national center of financial policy-making and regulation, asset management, financial payments and settlement. The area hosts over 1,500 high-end financial institutions, including the People's Bank of China and China Securities Regulatory Commission, as well as headquarters of many national and international banks. Its total financial assets account for 78.4% of Beijing and 52% of the whole country. The rapid growth of the financial industry and increasing demand from current and prospective tenants have pushed the Financial Street to be expanded (H. Wang, Jan 25, 2011).

With traditional manufacturing industries moving further out of the city – some of them even moving to neighboring provinces – low-emitting high-tech industries have become major employers in Beijing. The organic evolution of industrial development toward high tech industries also has significant impacts on the outcome of the city's spatial structure. The most important example is the Zhongguancun Science and Technology Park (Z-Park), which is located in Haidian District and surrounded by the best universities and research institutes in China including Peking University and Tsinghua University. Small and medium computer and electronics companies emerged and clustered in this area taking advantage of the knowledge node of Beijing in the 1980s. The industry cluster soon grew by a significant margin and gained municipal and then national status in 1999. With the advancement of the IT industry, Zhongguancun has become the "Silicon Valley" of China and has now "moved up" the production chain by providing higher-end IT services and other high tech industries such as new energy, biotech enterprises, industrial materials developers and aviation technology companies. Z-Park now consists of ten sub-parks which are scattered in the North and South of Beijing. In 2009, the total income of companies in the Z-Park has exceeded 1200 billion RMB. All the sub-parks of Z-Park have become important employment nodes in Beijing while at the same time have promoted the residential development around them (see Map 3.5).

Map 3.5 Layout of Zhongguancun Science Park

Source: Z-Park website (http://www.zgc.gov.cn/english/)

Changes in consumer preferences, in terms of housing location and sense of place, is another shaping force of regional spatial structure. In the planned economy era, the building style of housing provided by the work-units was uniform: four to six stories walk-ups. Since the housing market reforms, people are given more choices, from walk-ups to mid-rises to high-rises and villas (detached houses or townhouses), by real estate developers. As with commercial development, the location of the development with respect to employment access and proximity to major transport links is one of the biggest factors driving the choice for housing products. However, with the rapid increase of housing prices in the past 10 years, people have had to make trade-off decisions between location and price. Suburbanization in Beijing, in this context, has been maintained at a certain level of development density. The housing styles provided in the suburbs are often similar to those found in the city center, and developers often provide spaces for retail and entertainment within the same residential development to provide residents with a "sense of community living" (according to my personal communication with developers). Despite the integration of retail and entertainment uses in residential projects, employment opportunities in suburban areas are often overlooked. This development style has been known as "New City". Green/public space design, shopping facilities, schools/hospitals and personal services within the real estate property become important factors for housing purchases. On the other hand, the luxury housing market, in the form of villas, has become increasingly popular in the suburbs of cities for the past 20 years with the rapid growth of the city's high-income population. Six clusters of villas have emerged in suburban Beijing, taking advantage of amenities (rivers or mountains) and privacies (see Map 3.6).

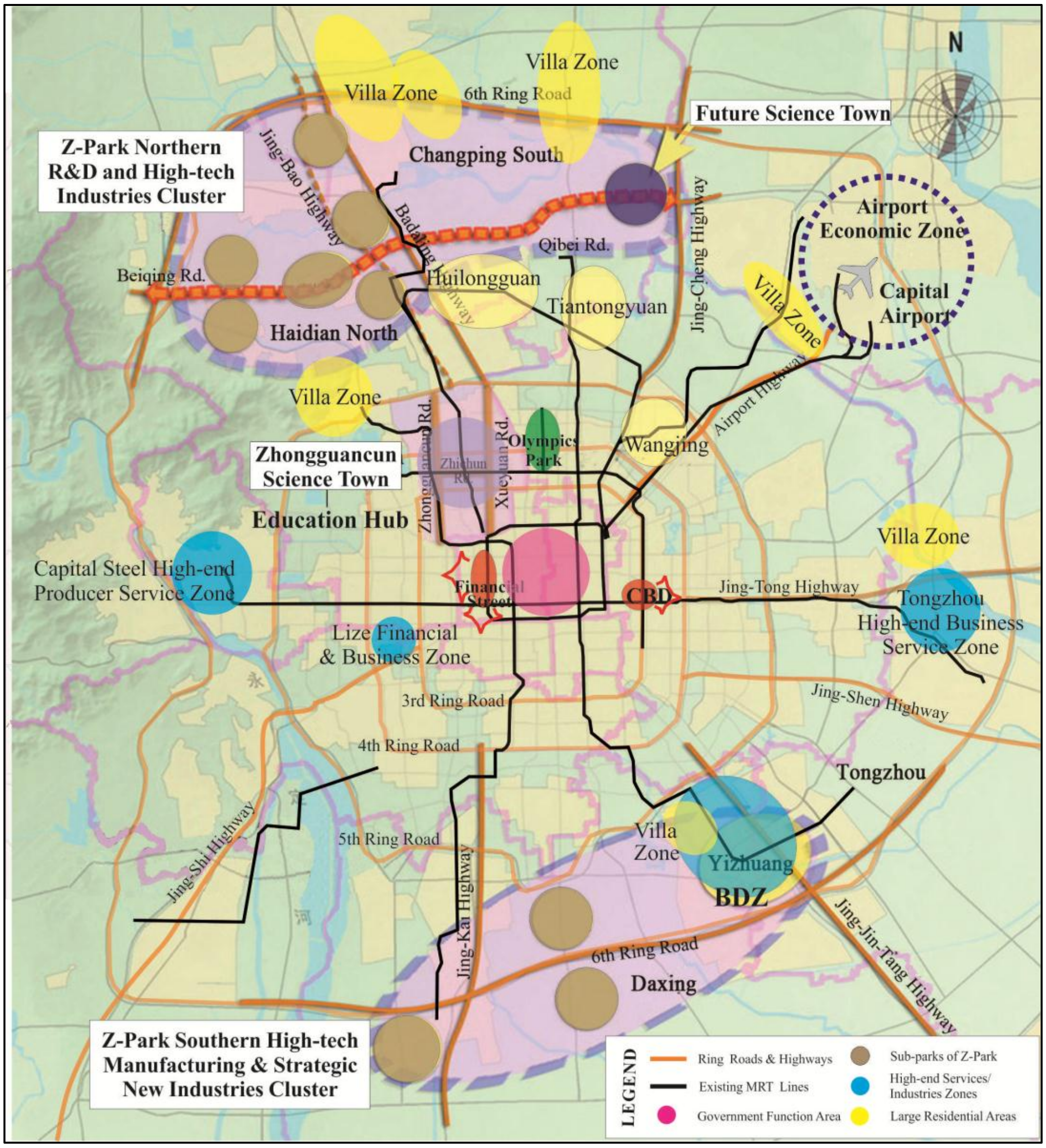
The future development of Beijing will continue strengthening its current multi-nodal spatial structure by reinforcing and expanding the existing nodes, promoting high-end services and industries and developing new nodes. According to the 12th Five-Year Plan of Beijing, six existing high-end functional zones as well as four new high-end services/industries zones will be the key development nodes of Beijing. At the same time, two towns (the Zhongguancun Science Town and the Future Science Town) and two belts (the Z-park Northern and Southern High-tech industrial clusters) are designated to be the principal sites for industrial growth (see Map 3.6).

The six existing high-end function zones are: 1) the CBD, for comprehensive business services, such as corporate headquarters, high-end producer services, cultural innovations, and international marketing, etc. The CBD is planned to expand to the east. 2) the Financial Street, to reinforce the financial policy-making and services cluster, will be expanded to the south and west; 3) the Olympics Area, to develop cultural industries utilizing existing sports and related structures, such as sports and convention industries, tourism and museums; 4) the Zhongguancun Innovation Area, to promote innovation and high-tech industries, will be expanded to include several sub-parks; 5) the Beijing Development Zone in Yizhuang, for high-end manufacturing and strategic new industries; and 6) the Airport Economic Zone, for high-end services related to the airport such as logistics, offshore finance services, and free trade services.

The four new high-end services/industries zones are distributed across the whole city to promote new development nodes for regional and local personal, business and producer services, such as conventions and training, medical services headquarters, R&D centers, cultural and leisure conventions/exhibitions. These four zones are the Tongzhou High-end Business Service Zone, the Lize Financial & Business Zone, the Capital Steel,[10] The High-end Producer Service Zone, and the Huairou High-end Service New Zone (this zone is further north in the outer suburban Huairou District and is not show on Map 3.6).

The two science towns will be focused on developing new and high-tech industries, including bio-pharmacies, new materials, aeronautic and astronautic technologies and new energies. The sub-parks of Z-Park are forming two high-tech industrial belts in the North and the South.

[10] This is where the Capital Steel company is located, but it will soon be relocated to Hebei province. This zone is named after Capital Steel only to refer to this location.



Map 3.6 Spatial Dynamics of Beijing in the Future

Source: the Author, 2011, with reference to the 12th Five-Year Plan of Beijing

3.3 The Story of MRT System

Besides road transportation, public transport is another important component of urban transportation system, especially the MRT system. Beijing started constructing its first subway line (Line #1) as early as 1965, and opened the service to operation in 1971. At that time, the total permanent population in Beijing was around 3 million and there was no urgent need for a rapid transit system. Interestingly, the initial intention of building a subway system was to address national security concerns; the underground spaces could also double as bomb shelters. Despite initial construction in the mid-1960s, the expansion of the MRT system was, at first, quite limited and insufficient for the needs of the growing population. By 2000, nearly 30 years since the opening of the first subway line, only two lines were in operation and the total length of MRT system in Beijing was 54km. In other words, only 1.3 km was constructed annually (see Map 3.7).

This slow growth of MRT development was inconsistent with the rapid increases of population and travel demand. It took the city 48 years (1949-1997) for the number of privately-owned vehicles to reach the one million mark, but only 6.5 years (02/1997-08/2003) to reach the two million mark. By 2012, there were 5 million private cars estimated in the city. The rapid growth of private car ownership was a result of both increasing income and increasing travel demand. Congestion also started to become a problem. On the other hand, Beijing won the bid for hosting the 2008 Olympic Games in the summer of 2001, which prioritized MRT expansion to deal with urban transportation.

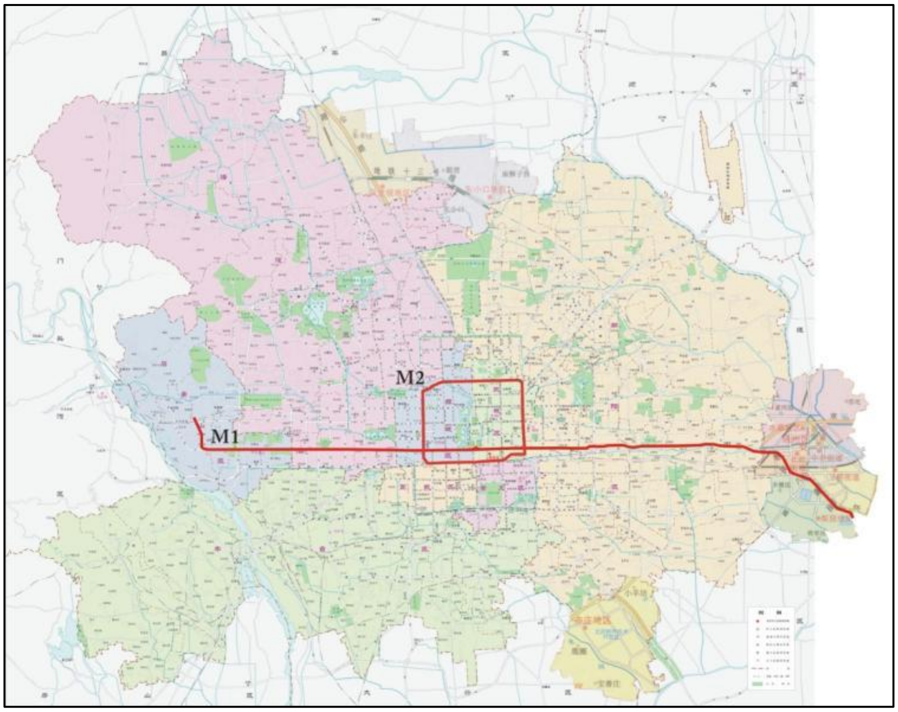
By 2008, just prior to the start of the Olympic Games, five new lines were added to Beijing's MRT system increasing the total system length to 200 km (see Map 3.8). During this period (2000-2008), total annual ridership increased from 434 million to 1.2 billion. During the first 9 hours after MRT line 5 was opened on May 7, 2007, the total ridership reached 340,000, indicating a strong travel demand (Xinhua News, May 8, 2007). The success of the MRT system in alleviating congestion and meeting travel demand during the Olympic Games, encouraged the city to explore further development to the system. In June 2009, "Beijing's implementation plan on humanistic, technological and green transport (2009-2015)" was approved by the Standing Committee of the CPC[11]

[11] CPC refers to the Communist Party of China.

Beijing Municipal Committee, announcing the target of developing "a public transport city" by 2015 (Beijing Daily, June 10, 2009). According to the plan, public transit (including all types of MRT, BRT, and traditional buses) is expected to capture 45% of the total mode split for all the journeys in the central city (refer to Map 3.4e). Major efforts include: 1) reducing the minimum headway of subway trains to 2 minutes at peak hours[12]; 2) ensuring that there is at least one public transport stop within 500 meters for all residents; 3) building 13 comprehensive passenger transport hubs; and 4) establishing more bicycle parking spaces in areas with heavy passenger flow.

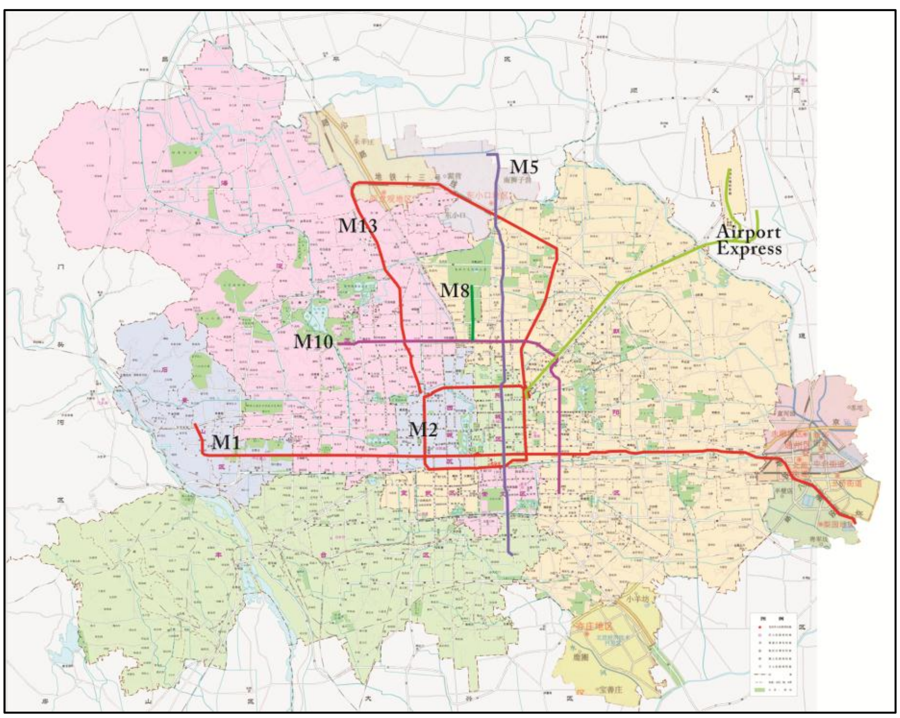
The "Beijing's Public Transport City 2015" Plan also includes a plan for the MRT system by 2015, determined to extend the total length to 561km. The pace of development anticipated by the Plan has been successfully attained: Line #4 was opened in July 2009; in December of 2010, 5 new lines (all suburban rail lines, with a total length of 108 km) were opened simultaneously. In 2011, the total length of operating MRT lines had already been increased to 336 km, with network intensification taking place both in the central city core and Inner Suburbs and extensification occurring in peripheral areas (see Map 3.9 and Map 3.10).

[12] In 2011, the headway of MRT Line 1 in Beijing at peak hours is 2 minutes and 5 seconds; 2 minutes for Line 2; 3 minutes for line 4.



Map 3.7 Beijing's MRT system in 2000

Source: the author, 2010

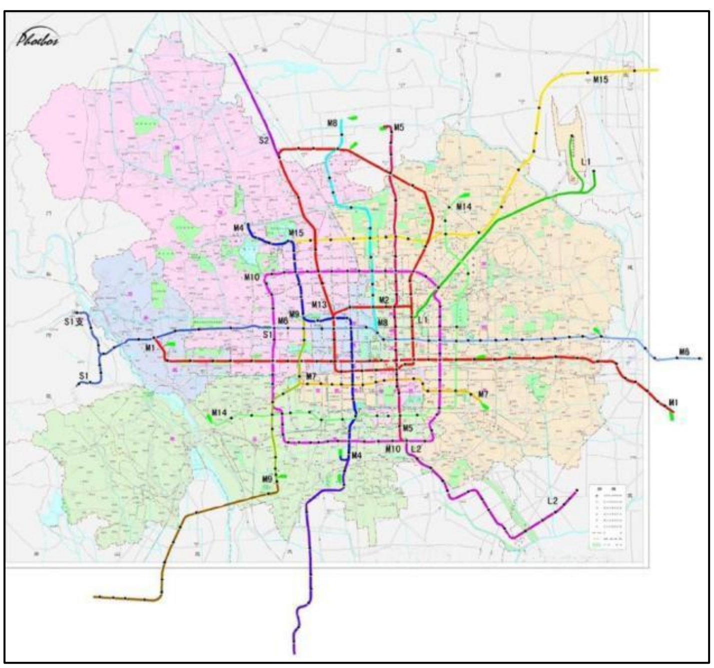


Map 3.8 Beijing's MRT system in 2008

Source: the author, 2010

Map 3.9 Beijing's MRT system in 2011

Source: Beijing Subway Authority



Map 3.10 Beijing's Public Transport City 2015 Plan

Source: http://www.jingcity.com/uploads/allimg/090409/bjgdjtsyt2015b.jpg

Figure 3.3 shows the changes of average daily ridership and total length of operating lines of Beijing's MRT system since 1971. Ridership increased steadily from 1984 to 2000 when no expansion of the network took place, indicating unsatisfied demand for public transit. Since 2000, whenever there was new line(s) opening, there was a significant increase of ridership. The MRT system has become an important part of people's daily travel.

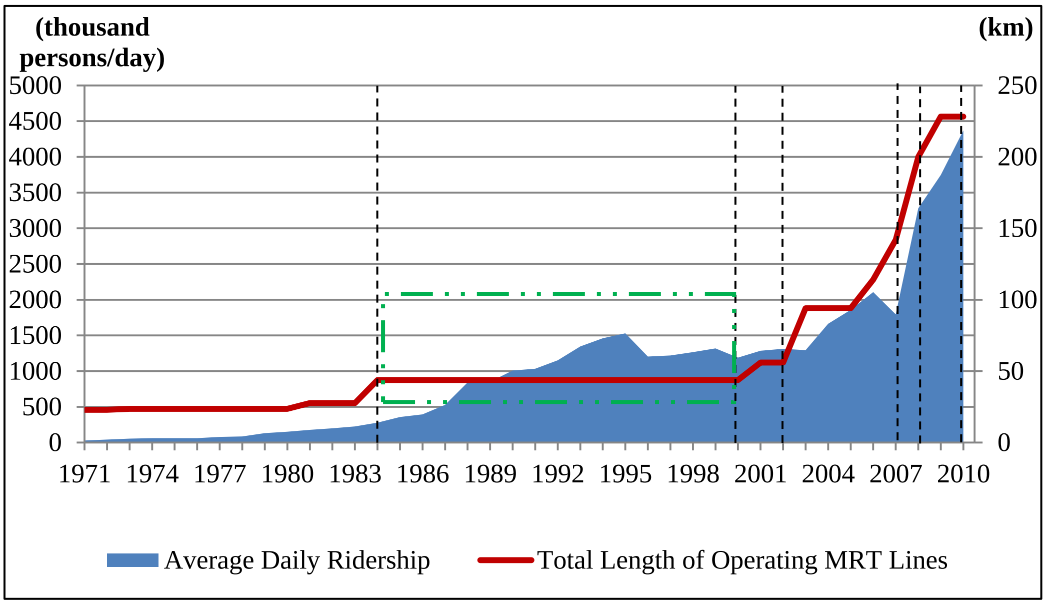


Figure 3.3 Average Daily Ridership of Beijing's MRT System since 1971, as compared to the Total Length of Operating MRT Lines

Source: the author, based on http://www.bjsubway.com

3.4 Demographics and Spatial Distribution

After reviewing the history of spatial evolution, road development and MRT expansion, I would like to focus on the period from 2000 to 2010 and examine the demographic changes, new trends in suburbanization processes and people's travel behavior in Beijing in more detail.

The permanent population[13] in Beijing increased rapidly in the last decade, rising from 13.64 million in 2000 to 16.95 million in 2009. The annual growth rate has ranged between 1.5% and 4.0% since 2001 (see Figure 3.4). Spatially, the population has been concentrated in the city proper in 2000, roughly within the 4th RR. By 2009, the Center and the Inner Suburbs were still the areas of the region with the highest population densities, accounting for 61.54% of total permanent population (see Map 3.11). The spatial distribution of employment shows a similar pattern. The Core area features the highest employment density which is 16,404persons/km^2 and the combination of Core and Inner Suburbs accounted for 75.28% of all jobs in Beijing in 2009.

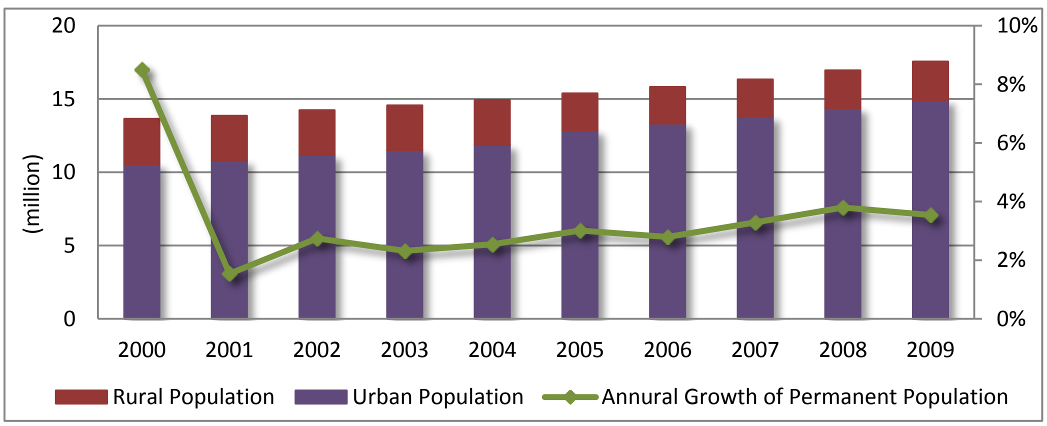
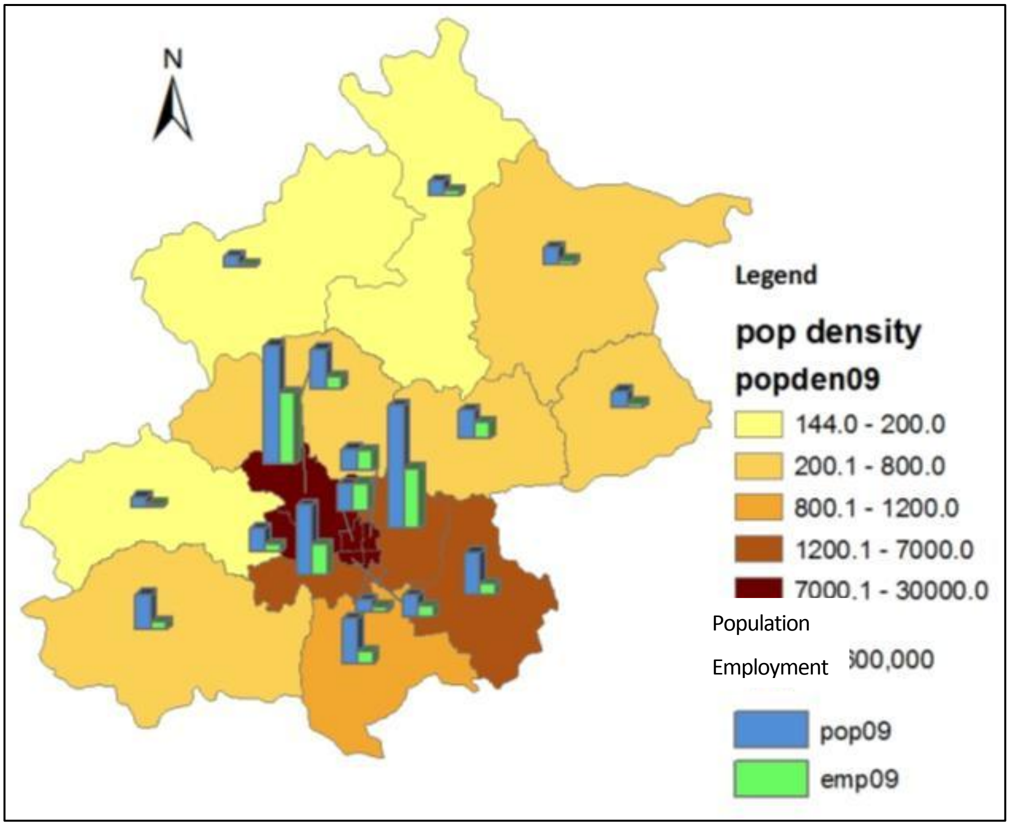


Figure 3.4 Permanent Population Growth in Beijing since 2000

Source: Beijing Statistical Yearbook 2010

[13] According to census definitions in China, permanent population includes residents with local household registration (hukou), and residents who have been living in the area for over 1 year but don't have local hukou. It excludes the residents who do have local hukou and have been living outside of their registered residence for over 1 year.



Map 3.11 Distribution of Population and Employment by District in Beijing, in 2009

Source: Beijing Statistical Yearbook 2010

3.5 Suburbanization in Beijing

Suburbanization in Beijing has gone beyond the government-initiated relocation of residents and polluting industries before the 1990s to a more market-oriented process in the 1990s and the 21st century. Physically, and unlike the US, suburbanization in Beijing is not characterized by low density sprawl. In the United States, this process has often been accompanied with a declining city center. But in Beijing, suburbanization since the 1990s has been driven by rising private vehicle ownership, construction of affordable housing and villas in the suburbs, and the development of large suburban shopping areas (Feng, et al., 2008), while at the same time the central city has retained its position as the strong, economic core of the region.

The built environment in the suburbs is also different from the West. Single family, detached homes, are referred to as “villas” in China and are often designed as luxury homes, and marketed for high income households. Average residential housing takes the form of multifamily apartment housing in six-story walk-ups or mid-to-high-rises. The suburbs are also where the affordable housing projects are often located. As little land is available for development in the center and housing prices have been increasing rapidly, developers started to move outwards to obtain land and households relocated to the suburbs for cheaper condos. Increasing private car ownership and the construction of the Ring Road and MRT system has accelerated the process of suburbanization by improving mobility options within the region.

The reasons why average households[14] move to the suburbs since 2000, have been closely related to the housing price and the availability of public transport. In 2009, average housing prices within the 4th RR were over 30,000 RMB/m^2. The price decreased to 20,000 RMB/m^2 between the 4th and 5th RR, 15,000 RMB/m^2 between the 5th and 6th RR, and 10,000 RMB/m^2 beyond the 6th RR. More specifically, homes located beyond the 5th RR have gained in price recently, as more people chose to live in area further out due to high prices in the city center. The American assumption of moving further out to gain living space for the same fixed cost should be contrasted with the Chinese context, where living spaces are roughly built to the same interior size regardless of location.

Location aside, suburban residents in Beijing enjoy similar living conditions to those residents dwelling in the urban core, since residential buildings are of a similar density and similar design, due to the low efficiency of the government-controlled land acquisition system in China and the profit-driven motives of both the government and the developers. Also, most of the neighborhoods in Beijing provide access to nearby services

[14] Here when making this statement, I exclude the high-income families moving to the suburbs seeking for luxury villas to enjoy better amenities.

that, to some extent, satisfy local residents' daily needs, such as grocery shopping, dining, entertainment, etc. However, there are still differences between living in the city center and in the suburbs from a social perspective. In Beijing, as in most Chinese cities, central city living confers numerous benefits over a suburban address, including greater access to major shopping centers, high-end services, employment, high quality schools and hospitals, and other activities(see Map 3.3).

The Inner Suburbs of Beijing are changing rapidly and some areas are already experiencing redevelopment. To sum up, the new trend of suburbanization in Beijing since the 1990s has been characterized by continuous outward urban development after land has been running out in the central city; yet high density development patterns have been maintained. With the size of the unit and design of the housing types largely remaining the same, the choice of household settlement in suburban areas has largely been driven by trade-offs between housing price and the monetary and time costs of travel.

3.6 Travel Behavior in Beijing

Human travel behavior is a dependent variable of travel demand, private vehicle ownership, availability and accessibility of different travel modes, prices (of petroleum and public transport fares), regulatory policies and personal preferences (Peter Næss, 2006). Before the mid-1990s, the bicycle was the primary mode of transport (65% in 1986) for people in Beijing, as well as in other Chinese cities. The latter half of 1990s and the first ten years of the 21st Century have witnessed an accelerating growth of private car ownership (see Figure3.5). This rapid growth of car ownership is encouraged in the context of nation-wide stimulus plan for promoting the auto industry, which made more cars available for people at a cheaper price. Most recently, Beijing's motor vehicle ownership grew from 3 million to 4 million in just 2 years and 7 months (from May 2007 to Dec. 2009). The growth of car ownership in Beijing has been much faster than China's average (see Figure 3.6). In 2010, there were 29.6 cars for every 100 households in Beijing - more than twice the national average of 13.1 cars per 100 households. Ironically, the "quota and lucky draw" system implemented in early 2011 to limit the number of new car licenses resulted, unexpectedly, in a sharp increase in car purchases in December 2010 - the month before the rule came into effect (Yin, January 10, 2011). By the end of April in 2012, the total number of cars in Beijing has exceeded 5 million.

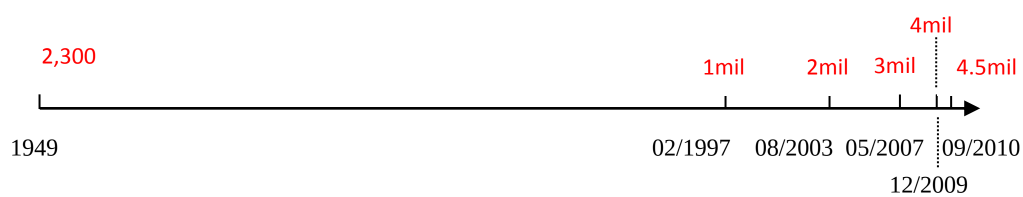


Figure 3.5 Landmarks of Private Vehicle Ownership Growth in Beijing

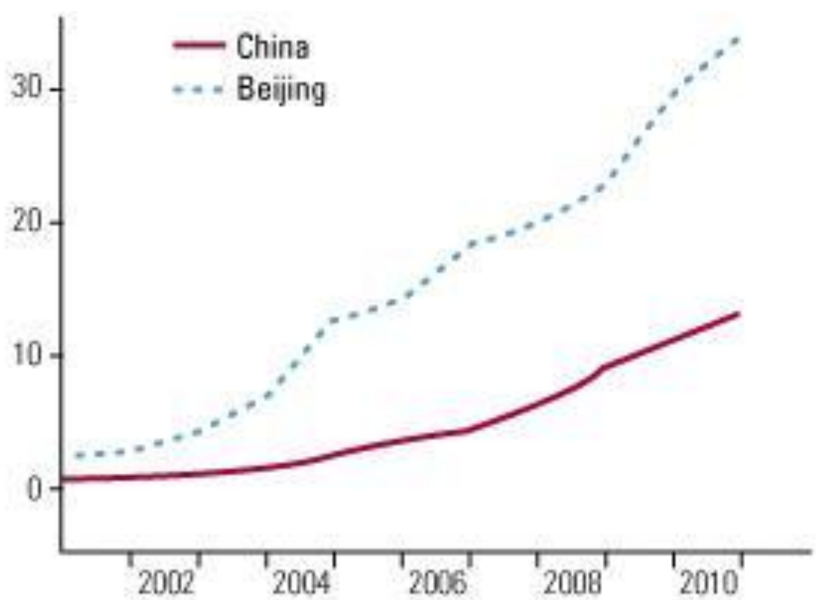
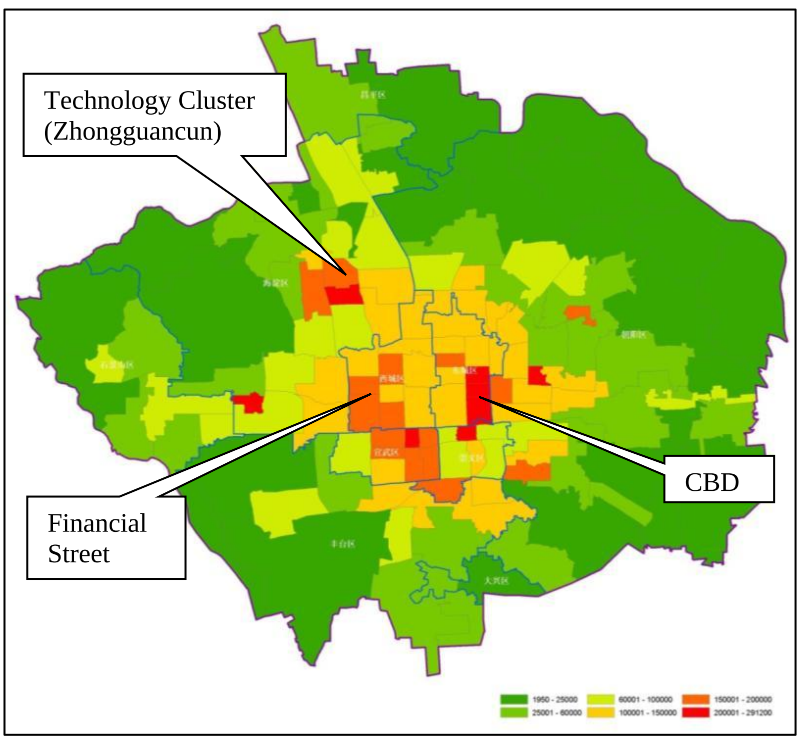


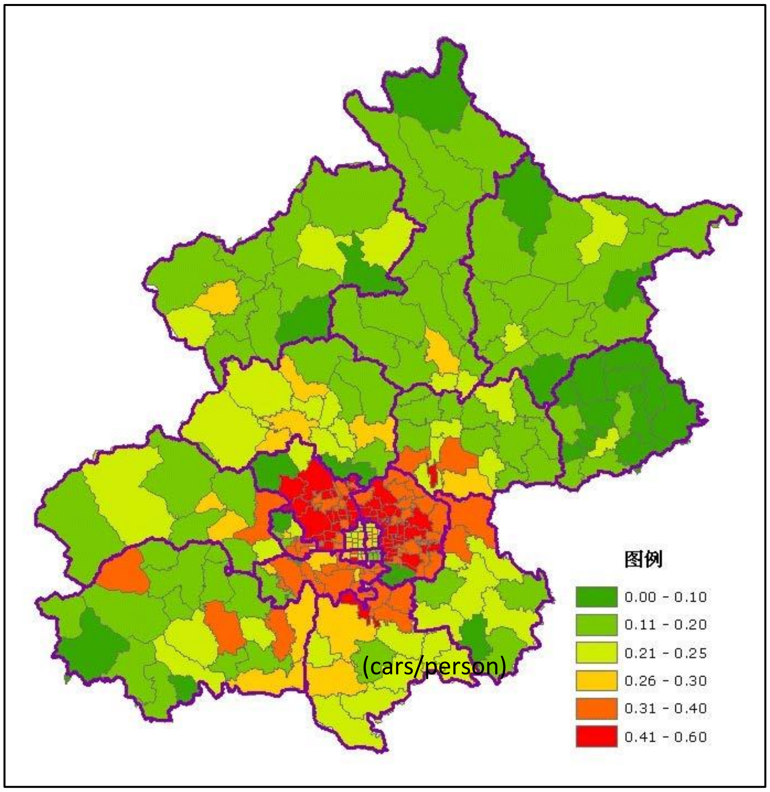
Figure 3.6 Number of Cars Owned Per 100 Urban Households in Beijing and China Average, 2000-2010

In Beijing, the main destinations are mostly concentrated in the city center, i.e. within the 4th RR (with the exception of the technology cluster located in the Northwest between the 4th and 5th RR). The CBD area, Financial Street and several major shopping and entertainment areas are the most attractive destinations for trips (see Map 3.12). Meanwhile, the highest densities of car ownership are also spatially concentrated in the Core and Inner Suburbs (see Map 3.13), indicating a high possibility/potential of short trips by cars in the city. Statistics show that 40% of car trips in Beijing are less than 5 km, with an average speed below 15kmph (China Daily, Dec. 12, 2010). Additionally, cars are intensively used in Beijing, as well as in China. The average annual mileage of cars in Beijing is 1.5 million km (40% is less than 5 km short trip), which is 1.5 times that of London and twice that of Tokyo. This intensive use of cars indicates significant impacts on the environment.



Map 3.12 Intensities of Trip Destinations in Beijing

Source: The 3rd Urban Traffic Comprehensive Survey in Beijing, 2005



Map 3.13 Density Distribution of Car Ownership in Beijing, 2005

Source: The 3rd Urban Traffic Comprehensive Survey in Beijing, 2005

According to travel behavior studies, the number of trips and total trip length has been increasing over time (X. Cao et al., 2008; Dill, 2004; Peter Næss, 2006; Pan, et al., 2009), for both commuting and non-commuting trips. Four rounds of Urban Traffic Comprehensive Survey have been done for Beijing, in 1986, 2000, 2005 and 2010[15] which have archived the residents' travel behavior changes. The frequency of travel has been increasing over time. The total number of trips in 2005 was three times more than 1986. The share of commuting trips decreased from 57.8% in 2000 to 47.5% in 2005, indicating more trips are being made for non-commuting purposes. Also, trips are becoming longer and longer. The average length of trips in 2005 was 9.3 km (see Table 3.2).

[15] The 2010 survey data has not been released yet.

Table 3.2 Change of Travel Demand in Beijing

Year	Travel Frequency (times/person)	Trip Length[16] (km/time)	Total trips (million person-times)
1986	1.61	-	9.39
2000	2.77	8.0	23.01
2005	2.64	9.3	29.20

Note: the survey area in 1986 and 2000 was the eight urban districts (the Core and the Inner Suburbs) and a few selected street offices in the Outer Suburbs (Level 1); while the survey area in 2005 was for the whole Municipality (however the survey area for travel demand in 2005 was the area within the 6th RR).
Source: The Urban Traffic Comprehensive Survey in Beijing, 1986, 2000 and 2005

Travel mode share has been changing in Beijing with increasing car ownership and recent rapid development of MRT system. In 1986 when private car ownership was very low in Beijing, non-motorized travel (mostly by bicycle) and public transport accounted for the majority of total trips. Car travel, on the other hand, only contributed to 5.24% of total trips. In the next 14 years, until 2000, the share of bicycle trips decreased dramatically from 65.09% to 39.68%, which was accompanied by increasing car travel (car trips quadrupled to 24% of all trips made in Beijing by 2000). Taxi trips increased rapidly during the same period too, while the share of public transport decreased slightly. While car use has increased since 2000, growth rates have begun to taper off, which may be attributed to the intensive development of the MRT system. In 2009, the share of car travel increased to about 1/3 of all trips. The level of MRT expansion in Beijing significantly encouraged travel by public transport which accounted for about 37% of total trips. The importance of bicycle travel has been decreasing over time (see Table 3.3). The total annual Vehicle Kilometers Traveled (VKT) in Beijing has been increasing too.

[16] Doesn't include trips by walking.

Table 3.3 Change of residents' travel mode share in Beijing

Year	Bus	MRT	Taxi	Private car	Shuttles	Bicycle	Total
1986	29.31%		0.36%	5.24%	-	65.09%	100%
2000	27.33%		9.03%	23.96%	-	39.68%	100%
2005	24.10%	5.70%	7.60%	29.80%	2.50%	30.30%	100%
2008	36.8%		7.40%	33.60%	-	20.30%	
2011	27.70%	13.20%	6.90%	32.70%	-	16.30%	

Source: The Urban Traffic Comprehensive Survey in Beijing, 1986, 2000 and 2005; (B. Mao et al., 2008); (Beijing Transportation Research Center, 2011).

Recognizing the fast growth of travel demand and environmental problems brought by car travel, the Municipal government of Beijing has adopted a strategy of developing the MRT system while limiting car ownership and use. During the Olympic Games in 2008, Beijing issued the first regulation on limiting the vehicle use by not allowing certain amount of cars to drive on the street. This limitation was enforced by license plate numbers[17].

Another important policy is to control the number of new private vehicles by limiting the number of license plates issued. Shanghai is the first city in China that adopted this policy as early as in 1994. The successful experience of Shanghai encouraged Beijing to implement this policy. Although there was some setback before the implementation of this policy in the beginning of 2011 when car sales rose significantly in December 2010, Beijing has been benefiting from this policy. The total number of new license plates issued in 2011 has been determined to be 240,000. New vehicle purchasers are required to turn in applications before a "Lucky Draw" is held every month to decide which bidders receive license plates.

[17] On odd (even) days, only vehicles with odd (even) plate tail numbers are allowed to be used (special purpose vehicles, transit buses and taxis are not included). This regulation has been revised several times by changing the rules of when a car with certain license plate could or could not be used, and will be in effect through April 2012.

3.7 Conclusion

Suburbanization in Beijing is significantly different from the "sprawl" patterns typified in the United States. The city has been expanding from the Core to the Inner Suburbs and to the Outer Suburbs while maintaining a certain level of construction density. Key city functions are still concentrated within the 4th RR, creating nodes of employment, activities and trip destinations. Instead of being passively relocated before 1990s, people are currently choosing to live in the suburbs seeking for cheaper housing prices or better environment. Although the density and building style are not much different from the city center, people living in the suburbs enjoy access to fewer amenities. While most new development is of the high density, multifamily form, suburban neighborhoods of detached, single family homes – or `villas` - have emerged to meet the demands of the high income households.

Intensive development of the MRT system and rapid growth of car ownership have been the main characteristics of travel behavior in Beijing in the 2000s. While more trips and longer travel are demanded by the residents, the significance of motorized travel has increased in the travel behavior of area residents. Besides accelerating MRT development, the Municipal government has adopted policies to limit both vehicle ownership and use.

Chapter 4

METHODOLOGY

The previous chapters assessed studies that have already been undertaken in the fields of suburbanization, land use and public transportation, and sustainability evaluation, as well as the context of Beijing. Future research priorities are also identified. This chapter focuses on research questions, identifying hypotheses to be tested, and the design of research methods to address the research questions. Spatial, statistical, and spatial analysis methods to be deployed are identified as well as data needs. The methodology triangulates analysis of urban and transportation plans, secondary data, time series spatial imagery, household surveys, and neighborhood observation.

4.1 Research Questions

The key focus of this study is to understand how the built form, social landscape and environmental quality have been impacted by intensive MRT development at the neighborhood level in three suburban neighborhoods of Beijing. Based on the review of the literature explored in Chapter 2 limited work has been done in this area, and there is little understanding of how these impacts affect the sustainability performance of local residents and the Municipality. The research questions that will be addressed in this dissertation are as follows:

i) What role does MRT access play in the development of suburban neighborhoods? This question is explored through four sub-questions:

   a. How does the existence, and location, of MRT stations affect the development trajectory of urban built environment in suburban neighborhoods?

b. How does the timing of the opening of transit service affect the built form development trajectory of suburban neighborhoods?

c. What impacts does a lack of coordination between land use and transportation planning have on the built form development trajectory?

d. How do planners/property developers respond to the existing or planned presence of MRT stations?

ii) Do people view MRT access as an asset? Is it capitalized into housing price? If yes, to what extent (in terms of percentage premium in housing price)?

iii) To what extent does rapid transit access influence suburban households in terms of choice of travel mode and travel behavior, both for commuting and non-commuting trips?

iv) What is the magnitude of incremental sustainability benefits (or costs) generated by MRT access for transit served suburban neighborhoods, in terms of GHG emissions, traditional air pollution, and energy consumption?

4.2 Hypotheses

It is hypothesized that property development is significantly path dependent in the sampled Beijing suburban neighborhoods. The function of the neighborhood, which could be residential, commercial or mixed-use, has changed little even after the availability of MRT access. MRT access is hypothesized to elicit a more powerful impact on residential development than the development of other land uses. And there is marginally more mixed-use and higher density development in the walkable areas (800 meters) around the MRT stations for neighborhoods planned and developed with the expectation of MRT accessibility.

It is hypothesized that people living in the suburban neighborhoods do value MRT access, and are willing to pay premiums for MRT access. But the relative property premium generated by the MRT is lower than that in comparable Asian cities. This is reflected in housing price, which declines away from stations, controlling for other factors; but the price gradient is relatively small.

MRT access is hypothesized to have significantly shifted residents' travel behavior in these suburban neighborhoods, increasing the share of both work and non-work trips captured by the MRT. And transit availability and accessibility are hypothesized to contribute significantly to metropolitan sustainability performance, by driving mode share changes. All the above hypotheses will be tested in this proposed study.

4.3 Analytical Framework

In order to answer the research questions and test the hypotheses, I focus my analysis on the neighborhood level (as discussed in Chapter 2). Key drivers and stakeholders are identified in the planning and development of suburban neighborhoods in Chinese cities. The influence of planning agencies exists from the very beginning of design of a neighborhood to the end of actual construction. The Master Plan of a city, compiled by the *municipal planning bureau*, defines and regulates the designated land use of each land parcel. All development activities are supposed to comply with these regulations but, in some cases and especially when involving large developers, some negotiation may occur. When a real estate developer acquires a piece of land from the government, they are required to come up with a detailed plan and a development design scheme as to how to develop the land. This detailed plan can be produced by the planners, developers, or be outsourced to any *planning agencies*. Additionally, this detailed plan has to be approved by the *planning authority* before it can be implemented.

In China, transportation planning and construction are separate processes from land use planning. The introduction of *MRT lines* into a neighborhood could happen before, after, or even in the middle of the construction of the neighborhood. Normally the availability of an MRT station increases the average housing price of the neighborhood and attracts *housing buyers*' attention.

Human factors are another important driver of neighborhood development. *People's preferences* for housing locations and choices of travel mode are often shaped by the physical environment and the services (including types and locations) provided for residents within the neighborhood. Such consumer behavior also has an interactive impact (including feedback loops) on the design and construction of buildings and micro environments in the neighborhood and/or around the MRT stations. Therefore, *planning agencies*, *real estate developers*, *MRT developers* and *consumer preferences* have been identified as the key drivers of neighborhood development in Chinese cities (see Figure 4.1). More importantly, the different timing of interventions of these drivers/stakeholders in the process of neighborhood development results in different development modes. In this study, I focus on suburban residential neighborhoods with early or late MRT access as well as mixed-use neighborhoods subject to a strategic plan and expectation of MRT services. There are other types of neighborhood development in Beijing, such as Economic and Technology Development Zones (ETDZ), which are not explicitly addressed in this dissertation. Since buildings and land uses are difficult to change after construction has completed, the different timing of mass transit interventions (expectation, construction) will have impacts on the built environment and, in turn, affect human travel behavior. One of the significant contributions of this research is the recognition and comparison of different development modes. The following analysis will be applied to each neighborhood before and the after the MRT service became available and the results will be compared across neighborhoods.

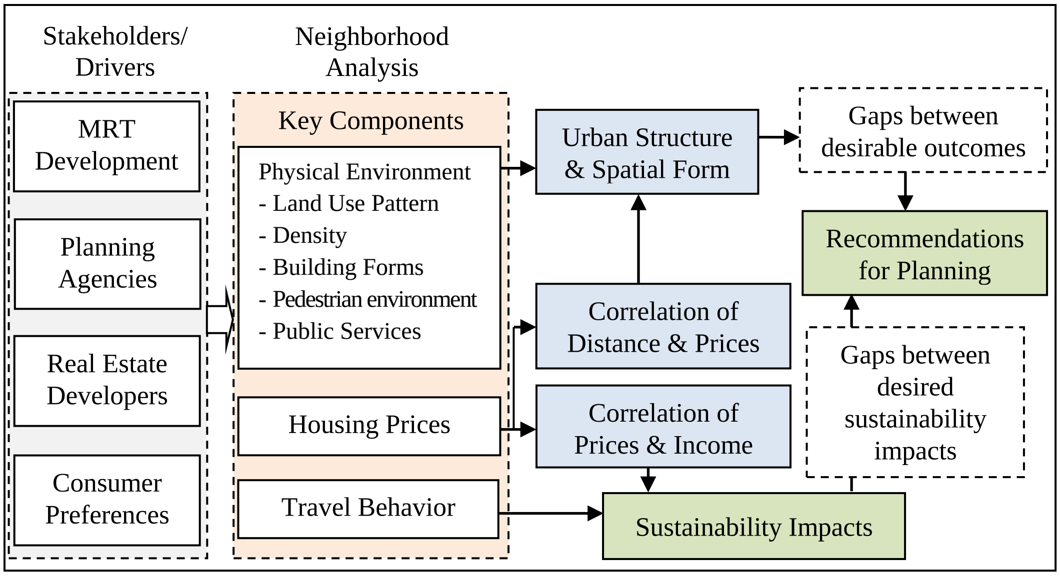


Figure 4.1 Analytical Framework

It is important to examine three key components of a neighborhood, i.e. the built environment, housing prices, and the residents' travel behavior, in order to address the research questions. The *physical environment* of the neighborhood affects the route and locations of MRT and MRT stations and, in turn, it is interactively shaped by the availability of MRT service. Of all the physical features, land use patterns, building forms, density, and the pedestrian environment are the most important factors to detect whether some kind of node of activities has been created around the MRT station in terms of business/shopping services and pedestrian experiences. The reasons for examining the *housing prices* in the neighborhood are related to the market forces that value the accessibility of MRT services, which is an important incentive for higher housing prices and densities at locations closer to the MRT stations. At the same time, housing prices play a key role in people's location decisions.

It is vital to compare people's *travel behavior* before and after the availability of MRT services, to understand the impacts of MRT accessibility on people's travel behavior changes especially in terms of increased use of public transit. On the other hand, by comparing the differences of travel mode shares between these neighborhoods and the Beijing's average level, I will be able to quantify the sustainability impacts of travel behavioral changes.

The significance of this dissertation is reflected in the quantification of sustainability impacts of MRT accessibility on the neighborhood level and the recommendations for land use transportation planning as derived from the interactive evolution of neighborhood development and MRT services. I intend to measure the evolution of urban structure and spatial form at the neighborhood level. By measuring spatial form, I can identify the gaps between the reality and most efficient spatial structure, sometimes referred to as Smart Growth (Song & Ding, 2009).

The correlation between housing price and distance from the MRT station assists in explaining spatial form. To be more specific, if there is a negative and statistically significant relationship between the price and distance, which means that residences closer to the MRT stations are significantly higher in price, market incentives will exist for developers to build at higher densities and offer a greater diversity of land uses (commercial, retail, etc.) around station precincts. However, if there is not a strong negative relationship, I will be able to argue that housing price is not a significant driver of the built environment of Beijing's suburban neighborhoods. At the same time, housing affordability will be measured based on the relationship between housing prices and household income.

The sustainability impacts of interest are those related to human travel, especially GHG emissions, traditional air pollutants, and energy consumption. These indicators can be quantified based on the differences of travel mode share, multiplied by travel distance, as derived from a comparison of neighborhood pattern and Beijing's average level. The quantification is not based on a comparison between the before- and after- situations for these neighborhoods because it does not capture the significant impact of demographic changes or rapid private car ownership increase over the years which largely offset the savings of increased MRT ridership. Therefore, by comparing to the Beijing mean level at the same point of time, I am able to assess the sustainability benefits of a MRT-served neighborhood as opposed to an average neighborhood in Beijing.

4.4 Study Areas

I have selected three neighborhoods in Beijing as the cases for my research. All three are located in the suburbs of Beijing[18], and a deliberate decision was made to choose suburban neighborhoods over more central areas because many employment nodes and higher-order services are still located within the eight urban districts, suggesting that suburban residents are disproportionately burdened with considerable travel distances and times compared with their central city counterparts. The arrival of an MRT station in these suburban neighborhoods can potentially make a significant contribution to the sustainability performance of the urban population in Beijing, as this research will seek to quantify. As discussed above, the neighborhoods selected should represent examples of different development modes with a variation in the timing of the opening of MRT service, in order to explore the effect of rapid transit on differences in sustainability performance in the chosen metrics. After extensive fieldwork in the summer of 2010, the following three neighborhoods were chosen as study sites (see Table 4.1); locations Map 4.1 shows the position of these three communities within the context of Greater Beijing, and its landmark ring road system. Detailed background information

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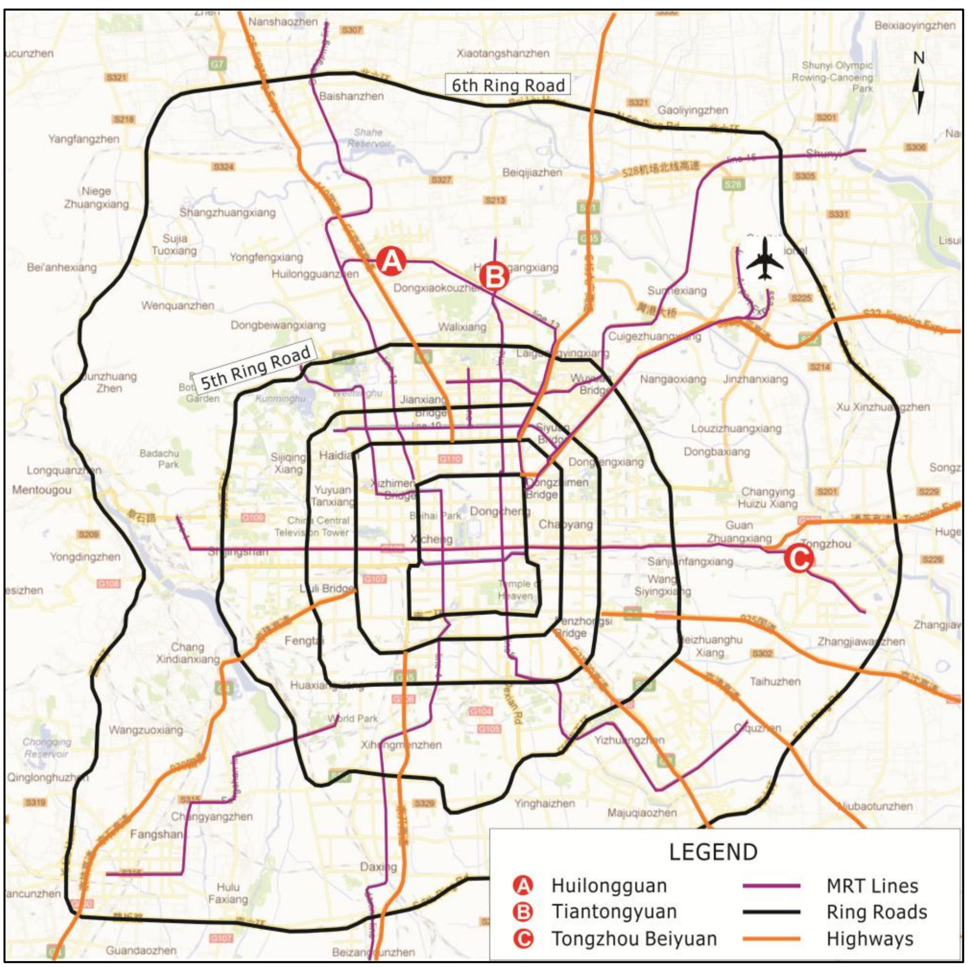
[18] The boundary of suburbs in Chinese cities is somewhat blurred, because the urban peripheral development process happens in a relatively higher density compared to suburbia in places such as the United States. In this dissertation, the suburbs of Beijing are roughly defined as the areas outside the North 5th RR (Ring Road), East 5th RR, South 4th RR, and West 4th RR.

and site context of these neighborhoods are introduced and analyzed in the next chapter (Chapter 5: The Neighborhoods). Land use change detection and investigation is performed for the area within 800 meters from the MRT station in each neighborhood, while household surveys were conducted (n = 468) for the residents living in the neighborhoods.

Table 4.1 Different Neighborhood Development Modes and Selected Neighborhoods

Neighborhood Development Modes	Selected Neighborhoods
Developer Driven Neighborhood / Early MRT Access	Huilongguan
Developer Driven Neighborhood / Late MRT Access	Tiantongyuan
Strategic Plan Driven / Expectation of Early MRT Access	Tongzhou Beiyuan



Map 4.1 Study Areas - The Selected Neighborhoods within Greater Beijing

4.5 Study Period

The period investigation spans the 10-years from 2001 to 2010, and this era was selected in order to explore changes in the physical environment of these neighborhoods during the period from their conceptual planning through their development, settlement, introduction and establishment of MRT service. In all three neighborhoods, the 2001-2010 time period affords a before- and after- comparison of resident travel behavior following the introduction of MRT rapid transit service.

Moreover, 2001 was used as a start date for the investigation since it coincided with the awarding of the 2008 Olympics to Beijing. This announcement spurred a massive investment in the MRT system in the region, and resulted in a period with the most extensive rapid transit expansion in the city's history. This study, therefore, affords a rare glimpse of how rapid transit expansion – on a network scale that affects not only local accessibility at neighborhood stations but aggregate accessibility throughout the region – can have impacts on individual travel behavior.

4.6 Data Sources and Data Collection

Based on the analytical framework, data requirements can be divided into categories: 1) Secondary data, including plans, remote sensing images, housing prices, etc.; and 2) Primary data, based on fieldwork, the resident travel survey and interviews with professionals. This section will list required data from primary and secondary sources, what these sources were, and how the data was acquired.

4.6.1 Secondary Data

Plans at the Municipal and District levels and for all the selected neighborhoods, including land use master plans and detailed plans, transportation plans, and urban design schemes, were obtained directly from the planning agencies involved in each neighborhood or from the developers.

Remote sensing images play a vital role in acquiring geographical information and documenting historical spatial changes. Google Earth was chosen for its remote sensing imagery due to its high resolution, which was necessary for understanding land use contexts at the neighborhood level.

Finding accurate housing price data at the neighborhood level proved challenging. There are three major official sources of real estate market data in China[19], but each is limited by its level of disaggregation – typically at the municipal level.

To ameliorate this, three alternatives were explored – all accessible online. Each dataset included important information regarding building form, apartment size (in m^2), FARs of properties, a list of the developers involved, and prices for each property development project. These sources include:

i) The Real Estate Agents' Database: Where large scale real estate agents build their own databases based on transactions they deal with. Individual transaction prices are averaged at the block/property projects level. One good example is the Anjuke Real Estate Agency, whose averaged data for the latest 6 months is available on their website.

ii) The "Soufun" (which means "searching for houses" in Chinese) Website: this is the largest public website providing house searchers with background information and price data for each property project in 106 first to third-tier cities in mainland China, plus 4 foreign cities: Hong Kong, Taiwan, Singapore, and Vancouver. The information on this website is also based on

[19] The 3 major official sources include: i) the National and Municipal Statistical Bureau, who is responsible for collecting and publishing aggregated statistical data such as Real Estate Price Index; ii) the Municipal Commission of Housing and Urban-Rural Development, who is responsible for publishing Real Estate Statistical Yearbooks for the city, emphasizing overall information such as newly constructed floor area, and average selling prices. The limitation of this source is that the data is not disaggregated to the neighborhood level; iii) the Real Estate Transaction Center of the city, which regulates property development projects, real estate agent licensing and real estate transactions, but do not provide information at the neighborhood scale.

actual online transaction data[20]. Monthly housing price data for the past year is published online.

iii) The "Fangjia" (which means "housing price" in Chinese) website: this is a specialized website which emphasizes housing price history. Massive online housing price information is harvested by a special proprietary search engine. Data cleansing is performed through human verification and through cooperation with real estate agents before being published. The website was established in December 2007. Weekly updated data for each property project is available since then.

The Soufun website was chosen as the secondary data source to support housing price estimation. This website provides consistent, detailed information for all three study neighborhoods, which distinguished itself from the Fangjia website which could only provide property price estimates for the Tiantongyuan neighborhood as a whole. Moreover, the information provided by real estate agents on The Real Estate Agents' Database was self-reported and based on averaged data for the transactions listed by each agent only, and was deemed to be too biased.

Newspaper reports were an important supplemental source of information when searching for historical events and changes in terms of MRT development, construction of major buildings in the selected neighborhoods, etc.

Information about public and private schools and hospitals in the selected neighborhoods can be found online. The quality level of each school and hospital is normally stated in their titles, such as "Key Schools", bi-lingual schools, Level Two and Three hospitals. Other information such as number of hospital beds is often included on specific hospital websites.

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[20] In China, when a transaction contract is signed, the buyer should register with real estate authority and publish the transaction online. A registration number is assigned to each case.

4.6.2 Primary Data

When data and information are not available from existing secondary sources, primary data collection methods have to be utilized. Fieldwork, interview and questionnaire surveys were the main techniques for obtaining the required primary data.

In order to explore the current land use patterns and spatial form features, *fieldwork* was conducted in the selected neighborhoods. This consisted of on-site investigation of the current land use pattern and spatial form, documentation of the actual use of individual buildings with map printouts, pictures and notes, and plotting this information on a specific layer over remote sensing images in ARCGIS; other layers will document land area, floor area (by multiplying the building footprint by number of floors), and distances to the nearest MRT station.

To develop an understanding of how key development stakeholders respond to the availability of MRT service in these neighborhoods, a series of *interviews* were conducted with key urban planners and real estate developers. The recruitment of interviewees proceeded via a "snowball" sampling technique, as follows: previous colleagues at the Beijing Municipal Commission of Urban Planning were initially contacted to identify the personnel who are engaged in master plan of Beijing. From there, personnel were able to refer the researcher to those planners/planning companies who were the most closely involved in the actual planning process for both local (neighborhood) and area transportation plans. The referral mechanism used was considered a good approach for interviewing people closely related to the targeted topic. Questions included in these interviews are listed in Appendix A.

To deeply understand the impacts brought by the MRT services at the residents' travel behavior and daily life, the *focus group* method was utilized. 10-15 local residents, for each neighborhood, were invited to talk about their personal experiences of living and traveling after they moved to the neighborhood. Main discussion questions were consistent with the research questions of this dissertation, and included: i) How was your travel mode share before the MRT was available? How is it now? What are the main differences? ii) What are the numbers, year of opening, scale and quality of public services in the neighborhood, especially schools, kinder gardens and hospitals? iii) When did commercial services (such as supermarkets and restaurants) the first open in your neighborhood and in what location? Do you think your daily needs are sufficiently met? iv) Are there any employment clusters in the neighborhood? If yes, where are they? and v) Are there any industries in the neighborhood? If yes, where are they?

The rough control factors for selecting the attendants were: 1) about 50% of them should have lived there before the opening of the MRT station; 2) there should be a stratified distance of residences to the MRT stations; 3) a diverse group of respondents based on car ownership (attendees were sampled to include both members of car-owning and non-car owning households) 4) a diverse age range, from young adults to senior citizens.

Ideally, a travel diary where respondents would be instructed to record each trip taken during a multi-day period would have resulted in the most accurate snapshot of travel behavior in each neighborhood. This method, however, was ruled out because it was deemed too cumbersome to coordinate a travel diary system online; local officials were also reluctant to manage and distribute a travel diary in their respective neighborhoods.

Finally, the *survey* was another important method used in this research to collect information on resident travel behavior and residential location choice. The household questionnaire survey was designed to include questions about the local residents' commuting and non-commuting travel patterns before and after the availability of MRT service, and their willingness to pay a location premium for better access, or shorter walking distance, to MRT stations (details in Appendix B). Based on the conventions in China, the in-house survey was distributed and collected by the local Residents committee in each neighborhood, and flexibility was built in to the recruitment and surveying procedure in each neighborhood. For example, both Huilongguan and Tiantongyuan neighborhoods had their own well organized online forums which were used by their residents on a daily basis. While the total population of these two neighborhoods is about 300,000 each, the total registered users of them are 260,000 and 100,000 respectively. After consulting with local social workers, these online forums represented the majority of residents and are qualified to be used to distribute and collect online questionnaire. However, Tongzhou Beiyuan does not have such a website. Hence in-house surveys were performed with the assistance of the local Youth League Committee at the street office level. The selection of survey respondents is randomized. In the end, 468 valid surveys were returned in total for all three neighborhoods.

The focus group discussion also serves as a triangulating data source that cross-checks with and validates information collected from questionnaire surveys. Qualitative information from discussion helps interpret the reasons and concerns of their choices which are not evident from survey results.

4.7 Analysis and Measurements

This section describes the research design and measurement mechanisms for analyzing the three key research components quantitatively and qualitatively at the neighborhood level, i.e., the physical environment, housing prices, and the residents' travel behavior. I have identified the following measurements for suburban neighborhoods in Beijing based on extensive fieldwork and careful assessment of data availability and accessibility.

More importantly, these measurements are not only applied to define the current conditions of each neighborhood, but are also used dynamically, e.g., to compare current conditions with status before the introduction of MRT services. Measurement is undertaken both within neighborhoods and across neighborhoods. The latter is undertaken to explore whether different neighborhood development modes make a difference.

4.7.1 Physical Environment

The purpose of measuring the physical environment of a neighborhood is to examine whether nodes of higher density or more mixed use development are formed around the MRT stations, and to enable comparison before and after the MRT access became available. Hence, the key dimensions of the physical environment are identified as land use patterns, density, building forms, pedestrian environments, and availability and locations of public services.

Review of the Plans

Master plans, detailed plans, and urban design schemes of all neighborhoods were consulted to understand the historical trajectory of development in the three communities. These plans serve as guidelines for neighborhood development. As buildings are hard to move or change, it is important to see whether the plans anticipate the introduction of MRT services, identify station locations, and recognize the convergence effect of MRT stations in terms of pedestrian flow and business opportunities (Rodier et al., 1998). However, in many cases, neighborhoods are not constructed exactly according to design. The differences between the plan and the reality demonstrate the impact of market forces and the preferences and desires of the developers.

In addition, interviews of key development stakeholders - typically urban planners and real estate developers, (elaborate on who I interviewed: urban land use planner, transportation planner, local real estate developers, higher scale developers; won't be too many people to interview because I am dealing with local scale.) – was conducted to explore professional opinions about MRT accessibility. Important questions asked in these interviews included: 1) Did you expect MRT access to the neighborhood when you were working on the development plans? 2) What kinds of impact do you think the MRT services brought to the neighborhood? 3) Do you consider the MRT lines and stations as assets for the neighborhood which will attract more potential buyers of the residential or commercial spaces; will these buyers be willing to pay more? 4) Do you think more commercial spaces should be zoned around the MRT stations; are you under the opinion that Floor Area Ratios (FAR) for commercial properties should be higher? 5) Do you take pedestrian-friendly considerations into account in your design? 6) Do you recognize the convergence effect of stations, generating large scale daily pedestrian flows? (see Appendix A: Interview Questions for Key Stakeholders of Neighborhood Development).

Patterns of Land Use

The land use pattern is a key dimension in defining urban spatial form. The most common measurements are land use mix and the spatial distribution of these uses, which are often plotted on maps. The emphasis of this research was to examine the relationship between the MRT stations and the land use patterns. The purpose, meanwhile, was to explore if there was increased intensity and mix of uses in close proximity to stations. Hence I focused my analysis on the area within an 800 meter radius (elaborate on it: 800m and 1000m) from the MRT stations as the willingness to walk to a transit station decreases sharply when the distance exceeds 800 meters. Besides tracking land use changes over time with the help of historical maps, the distribution of different land use types over time was calculated to demonstrate the trend of changes. Analysis for land use patterns in the past was facilitated by historical satellite images (for 2003, 2006 and 2010), available GIS shape file data for 2006, and interviews with local residents.

Overall, the land use typologies defined these neighborhoods included the following use categories: 1) Urban Residential; 2) Rural Residential; 3) Commercial; 4) Mixed use; 5) Industrial; 6) Administration; 7) Education; 8) Public Facilities; 9) Hospital; 10) Parks and Public Space; 11) Parking; 12) Railroads and Roads; 13) Special Uses, such as military; 14) Vacant Land.

Density

Because the neighborhoods are composed of blocks/property projects delimited by streets, the FAR of each block was calculated by dividing the total floor area by site area with assistance of GIS software. FAR of all the blocks was plotted on a map identifying the location of MRT stations, enabling the determination of relationships between FAR values and distances to transit station.

Public Services

The most important public services related to quality of life are schools (public or private, from kindergartens to high schools) and hospitals (public or private, from clinics to general hospitals). The number of schools and hospitals in each neighborhood was counted and a per capita figure calculated.

Also, according to China's standards, schools and hospitals are classified into levels based on their qualities. The best schools are entitled as District, Municipal or Provincial "Key Schools". And bilingual schools (English-Chinese) in China normally have access to better educational resources. Hospitals of higher levels[21] provide a wider range of services, better quality of equipment and doctors. As a result the number of "Key Schools", bilingual schools, Level Two and Level Three hospitals were counted in each neighborhood as an important proxy for defining the quality of area public services.

4.7.2 Housing Prices and Location Premiums

As discussed in the analytical framework, the property prices in each neighborhood are indicators of the attractiveness of the neighborhood, including the extent to which property buyers value MRT service access. Residential buildings will be the focus of this analysis since they are the most related to the residents' location decision making.

The relationship between housing price and the distance from an MRT station explains whether the availability of MRT service is reflected in property value. If the property located closer to a transit station has a higher selling or renting price, it may infer that purchasers value MRT access. Higher priced residential real estate may then generate knock-on effects that shape urban form and activities around the station. I will display the selling price of each block/property project[22] on a chart for each neighborhood, as related to its distance from a MRT station, to examine if there is a price gradient.

The hedonic pricing model is often used to investigate the relationship between housing price and its potential influencing factors including housing structure characteristics, neighborhood characteristics, and distances to major nodes (such as CBD)

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[21] There are three levels of hospitals in China: 1) Level Three Hospital: general or comprehensive hospital at national, provincial or city level; 2) Level Two Hospital: Hospital of Medium size city, county or district level; 3) Level One Hospital: township hospital.

[22] In this dissertation, block is defined as a land parcel enclosed by streets surrounding it. Property project refers to a single real estate project constructed by one developer, which occupies the land of a block or several blocks.

or major transport facilities (such as transit station) (Heikkila et al., 1989; Kain & Quigley, 1970; Ottensmanna et al., 2008). In this study, as an effort to find out the factors affecting housing prices in these suburban neighborhoods and whether MRT access is valued as an asset and capitalized into housing price, I applied the hedonic model to all available housing prices and potential influencing factors in these three neighborhoods. Residential houses are built into property projects bounded by streets into blocks. The average prices for each project are obtained from Soufun website, in the unit of RMB per m^2. Affecting variables are selected as distance from the closest MRT station, age of building and density (dummy variable). The regression results are illustrated and interpreted in Chapter 6.

People's willingness to pay a location premium for better access to MRT stations is likely to be reflected in their travel mode choice. In the questionnaire, a question about whether there should be a location premium is included. If a respondent expresses a willingness to pay a location premium, he/she will be asked about how much more he is willing to pay for MRT access.

4.7.3 Travel Behavior

Commonly used measurements for intra-urban travel behavior are quite straightforward, including travel length, travel frequency, travel mode share, etc. In this research, the residents' travel behavior in each sampled neighborhood was measured and compared *before and after* the MRT service was available, for both commuting and non-commuting trips. The results are presented and interpreted in tables in Chapter 7 that include the followings:

i) Travel length for commuting trips: distance from residential to employment locations.

ii) Average travel time for commuting trips.

iii) Travel mode share for commuting trips: percentages of trips done by automobile, car-pooling, taxi, public transit, bus, motorcycle, bike, and foot.

iv) Trip length, average travel time and average travel mode share for sending kids to school.

v) Estimated trip length, average travel time and average travel mode share for weekly non-commuting trips, as defined by grocery shopping, entertainment shopping, and leisure/entertainment activities (such as dining out, clubbing, and Karaoke).

Share analysis was applied to explore the characteristics of switchers among different travel modes after the MRT became available, especially who switched to MRT travels. It was performed in Excel by tracing the change of travel mode for each survey correspondent and compiling into an aggregated chart (refer Figure 7.10 in Chapter 7). The results are interpreted in terms of how strong the drawing force of MRT access is.

In addition, correlation analysis is performed for daily trips to work to understand the factors that affect people's commuting travels. Multinomial Logistic Regression (MLR) is applied because the outcome variable (travel modes) is categorical. Special emphasis is put on trips made by MRT, private cars and buses, as MRT accessibility has little impact on people who choose to bike or walk to work. Factors that have potential significant influence on the residents' commuting trips include: i) household income level; ii) age; iii) education level; iv) the distance from home to office (or total commuting distance); v) distance from office to the closest MRT station; vi) distance from home to the closest MRT station. The results of this MLR analysis are interpreted to find out which factors are of statistical significance for people's commuting trip decisions (refer to Table 7.11 in Chapter 7).

To further understand the factors and conditions shaping people's travel decisions, the residents surveyed are also asked to rate the importance of factors such as gas prices, MRT fares, location of destination, travel time, etc. The results are presented in tables in Chapter 7.

4.7.4 Sustainability Implications

In order to evaluate the sustainability impacts of human travel behavior changes, I have selected six key dimensions of sustainability: 1) GHG emissions, focusing on CO_2; 2) Conventional air pollution, focusing on CO, VOC, NOx, PM[23]; 3) Energy consumption, as translated to units of coal equivalent.

The travel mode share of each neighborhood is compared with Beijing's average level, which is obtained from Beijing Transportation Research Center, to enable the quantification of the savings of the above indicators if Beijing's moves from the current status (given the regional accessibility and density of the current MRT system) to a city in which the majority of residents reside within walking distance of a MRT station. This level of city-wide walking accessibility to transit stations happens to coincide with the goal outlined in the Beijing Public Transport City Plan 2015 (Please refer to Chapter 3 for details).

Of all the travel modes, buses, private cars, taxies and MRT are the major emitters and consumers of various types of energy. A linear model is utilized in the quantification with application of coefficients for each type of emission and energy consumption derived from the latest studies on Beijing's motor vehicle fleet. The detailed measurements are explained as follows:

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[23] PM includes PM_{10} and $PM_{2.5}$, refer to Chapter 8 for details.

GHG emissions (CO_2)

Buses, private cars and taxies are major local sources for CO_2 emission, while MRT trains are considered as off-site sources because they are powered by electricity generated in centralized plants. Equation (1) describes how CO_2 emissions were quantified at the neighborhood level; coefficients for CO_2 emission by different travel modes are illustrated in Table 4.2.

(1) CO_2 savings per capita of a MRT-served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/CO2} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/CO2} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/CO2} + (\%MRT_{BJ} - \%MRT_{NH}) \times TD_{MRT} \times EI_{MRT/CO2}$

Where, BJ = Beijing
NH = Neighborhood
TD = Travel Distance
$EI_{Bus/CO2}$ = Emission Intensity of CO_2 by Bus
$EI_{Car/CO2}$ = Emission Intensity of CO_2 by Car
$EI_{Taxi/CO2}$ = Emission Intensity of CO_2 by Taxi
$EI_{MRT/CO2}$ = Emission Intensity of CO_2 by MRT

Table 4.2 Coefficients for CO_2 Emission by Travel Modes (unit: kg/100km•person)

	Bus	Car	Taxi	MRT
Coefficients for CO_2 Emission	1.3	21	15.6	0.23

Source: (B. Yang et al., 2011), (iCET, 2011), (Zhu, 2010)

Traditional Air Pollution (CO, VOC, NOx, PM)

CO, VOC, NOx, PM are the traditional air pollutants of special interest in this study. Buses, private cars and taxies are all major local sources for air pollution; again the electrically-powered MRT is not considered to be a local source for air pollution – at least not in the study neighborhoods. Equation (2) outlines the quantification of traditional air pollutants in the study neighborhoods. The coefficients of traditional air pollutants by different travel modes are listed in Table 4.3.

(2) CO savings per capita of a MRT-served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/CO} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/CO} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/CO}$

Where, BJ = Beijing
NH = Neighborhood
TD = Travel Distance
$EI_{Bus/CO}$ = Emission Intensity of CO by Bus
$EI_{Car/CO}$ = Emission Intensity of CO by Car
$EI_{Taxi/CO}$ = Emission Intensity of CO by Taxi

Similarly, for all other air pollutants:
VOC savings per capita of a MRT served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/VOC} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/VOC} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/VOC}$
NOx savings per capita of a MRT served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/NOx} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/NOx} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/NOx}$
PM savings per capita of a MRT served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/PM} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/PM} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/PM}$

Table 4.3 Emission Factors for Traditional Air Pollution for Beijing Sub-fleets

	CO		VOC		NOx		PM	
	Tons/day	g/km	Tons/day	g/km	Tons/day	g/km	Tons/day	g/km
PCarA*	250.6	6.9	42.0	1.2	32.3	0.9	0.3	0.009
Bus	105	28.4	3.7	1	29.3	7.9	1.2	0.311

Source: (Oliver et al., 2009)
*PCarA means Personal Cars running on Arterial roads.

Energy Consumption

As different travel modes consume different types of energy, all energy consumption will be converted to units of coal equivalent to be comparable. In Beijing, most private cars and taxis run on gasoline; MRT trains consume electricity. According to the Beijing Public Transport Holdings, Ltd which runs and manages all public transit buses in Beijing, in 2010, 79.03% of the buses ran on gasoline, 6.36% on diesel, 12.13% on natural gas, and 2.48% on electricity. Energy intensities of each type of travel mode for Beijing were calculated accordingly (Equation (3), Table 4.4).

(3) Energy Consumption savings per capita of a MRT-served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EnI_{Bus} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EnI_{Car} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EnI_{Taxi} + (\%MRT_{BJ} - \%MRT_{NH}) \times TD_{MRT} \times EnI_{MRT}$

Where, BJ = Beijing
NH = Neighborhood
TD = Travel Distance
EnI_{Bus} = Energy Intensity of Buses
EnI_{Car} = Energy Intensity of Cars
EnI_{Taxi} = Energy Intensity of Taxis
EnI_{MRT} = Energy Intensity of MRT
1kg Coal Equivalent = 7000 Kcal

Table 4.4 Energy Intensities of Different Travel Modes for Beijing Sub-fleet (unit: Kcal/person•km)

	Bus	Car	Taxi	MRT
Coefficients for CO_2 Emission	43.41	21	15.6	0.23

Source: (Xian Zhao, 2007)

Chapter 5

THE NEIGHBORHOODS

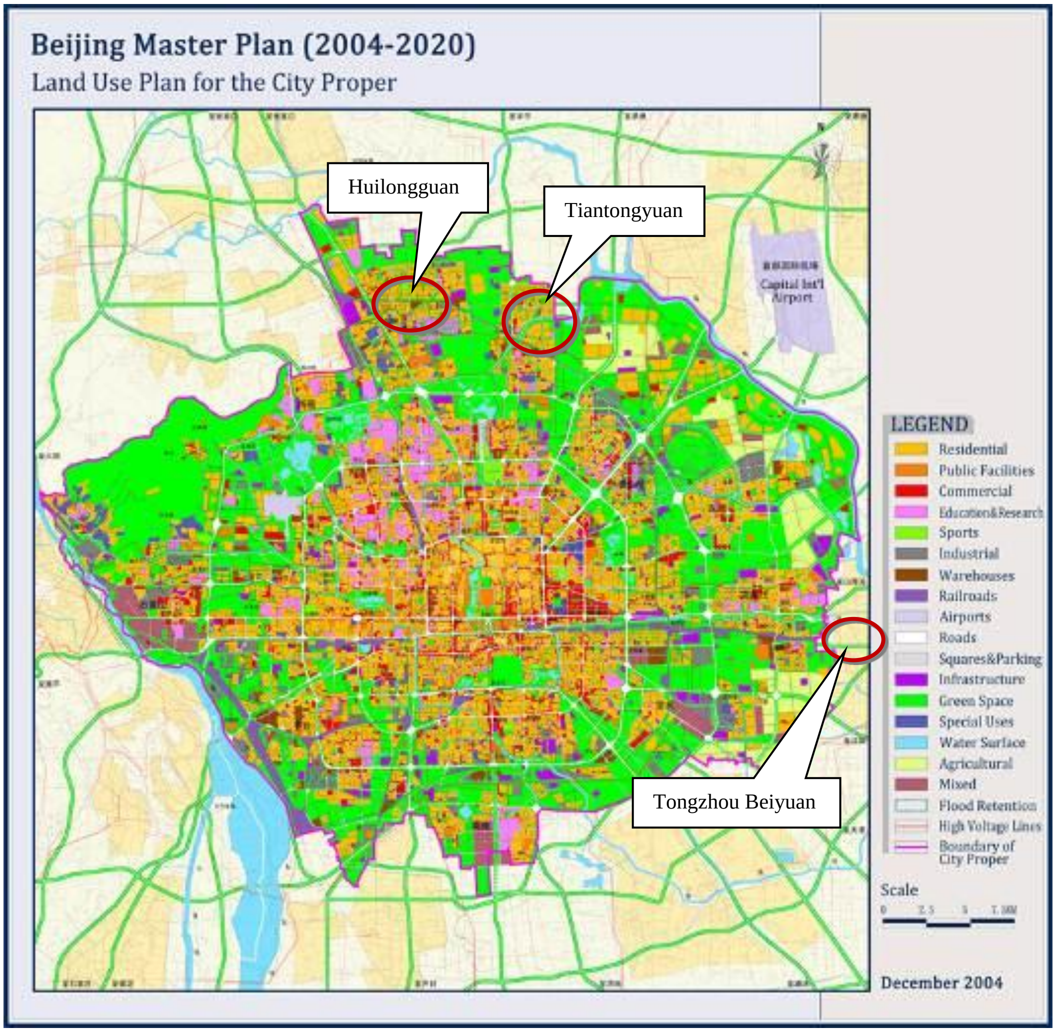
To examine the impacts of MRT development on land use changes and individual travel behavior, my analysis is focused at the neighborhood level in suburban Beijing. Three neighborhoods with varied development modes are selected as the study area, to enable trajectory analysis of each neighborhood and comparison among neighborhoods. This chapter introduces these three neighborhoods. I first introduce their location in the context of metropolitan Beijing. Then selection criteria for the neighborhoods and their defining characteristics, both historical and contemporary, are explained.

5.1 Site Context

As elaborated in Chapter 3, Beijing's built form is largely structured by ring roads and greenbelts. Spatially, the east-west Chang'an Avenue is considered the central avenue of Beijing. The northern half of the city and region has historically exhibited development of greater economic value than the area to the south of Chang'an Avenue, both in terms of household income and economic complexity (see Chapter 3). Moreover, the favorable economic conditions and employment attractors in the northern half of the region has, over time, resulted in a more extensive built up area to the north of the Chang'An Avenue than to the south, such that the built up area of greater Beijing now extends north beyond the 5th RR, while development in the south is largely confined within the 3rd RR. The first greenbelt was designated along the 4th ring road in 2003 to control urban sprawl, provide environmental services, and offer leisure destinations for residents (Ouyang et al., 2005). A second green "belt" – which more physically resembles a set of wedges emanating outwards - is being designated for the land area between the first green belt and land 1 km beyond the 6th RR. The total area of this second green belt is 1,650km^2, with 1,061km^2 of actual protected green space as well as the addition of selective green space-related development projects (Qianlong News, Apr. 5, 2004).

According to Beijing's Master Plan 2004-2020 (see Map 5.1), the development pattern of the second green "belt" was intended to be wedge-shaped beyond the 4th ring road consistent with contemporary best practice in green space planning, the wedges will protrude into the first greenbelt, continuing into the second greenbelt.

Of the three selected neighborhoods for this research, two of them (Huilongguan and Tiantongyuan) are located right on the edge of the city proper in the north. Another neighborhood (Tongzhou Beiyuan) is located just beyond the east edge of the city proper, which is planned to be an important mixed use center of the Tongzhou New Town (see Map 5.1). In the master plan of Beijing's city proper, both Huilongguan and Tiantongyuan are defined as residential neighborhoods with local commercial centers/strips. Tongzhou Beiyuan is designed to be part of the business/commercial center of Tongzhou New Town due to its convenient location just beyond the east extension of Beijing's CBD.



Map 5.1 Land Use Plan for the City Proper, Beijing Master Plan 2004-2020, and Location of Study Neighborhoods

Source: Beijing Municipal Commission of Urban Planning, translated by the author.

5.2 Selection Criteria and Importance of the Neighborhoods

As land use and transportation planning are often not coordinated in the process of city building in China, the sequencing of transportation and development/redevelopment in the city can be observed in a variety of permutations and combinations resulting in different outcomes. For Beijing, key factors that shape the urban form and human travel behavior include locational factors - such as access to expressways, distance to MRT stations and the spatial distribution of employment by types, and real estate/land markets - but the status and content of planning documents also have an effect. In particular, the official status (e.g., complete, official approved) of plans, the content of detailed land use plans, and the legal status and content of transportation plans shape urban form and, ultimately, urban travel. After examining the development history and current conditions of suburban neighborhoods in Beijing, the following three are identified as representative generic cases exhibiting different city building processes / sequences. Given the extensive ring road and radial expressway way network of Beijing, most neighborhoods have relatively easy access to expressways even though they may not be in the immediate vicinity of expressway ramps. Therefore, access to expressways was not used as a control variable in selecting sample neighborhoods. The neighborhoods selected for in-depth study are illustrated in Table 5.1.

Table 5.1 Different City Building Modes and Selected Neighborhoods

Neighborhoods	City Building Mode	MRT Opening Date
Huilongguan	Developer Driven/ Early MRT Access	Jan. 9, 2003
Tiantongyuan	Developer Driven/ Late MRT Access	Oct. 7, 2007
Tongzhou Beiyuan	Strategic Plan Driven/Expectation of Early MRT Access	Dec. 28, 2003

By focusing on these generic cases, based on the sequencing of development (which in turn are divided into developer- and more public sector- driven cases) and MRT access, and comparing them, I will be able to not only examine the impacts of the key development stakeholders (urban planners, transportation planner and real estate developers), but also explore whether the sequencing of intervention by these stakeholders made a substantial difference in outcomes, both in terms of the built environment constructed and travel behavior of the neighborhood residents.

5.3 Huilongguan: A Developer-driven Community with early MRT Access

The type of development represented by the Huilongguan study area is largely initiated and driven by real estate developers (see Figure 5.1). When development started in late 1990s, the Huilongguan neighborhood was considered to be relatively remote, because it was outside the northern arc of the 5^{th} Ring Road and was not well connected by roads to the city center (the Badaling expressway was under construction at that time, see Map 5.2 for location). The development was initiated as an affordable housing project[24] with a Gross Floor Area (GFA) of 8.5 million m^2, the majority of which was designated as residential. The initial average selling price for residential property was approximately 2,600 RMB/m^2 and developers planned for an eventual population of roughly 300,000 people when built out. The building style has been predominantly 6-storey walk-ups until some high-rise developments[25] began appearing in 2009.

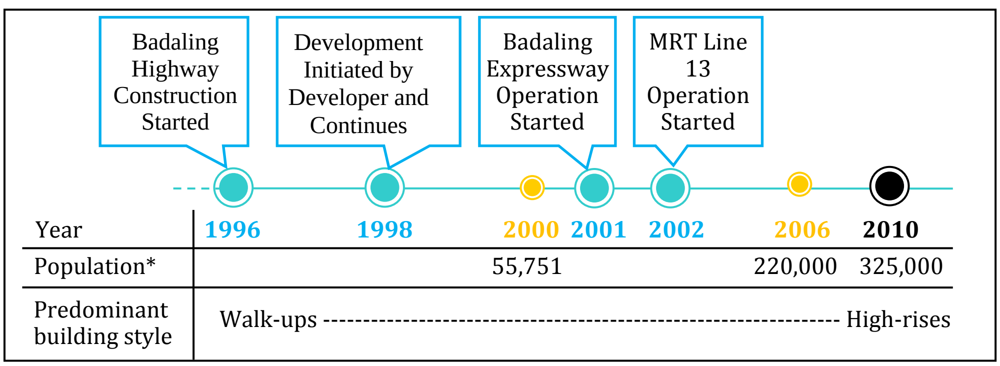


Figure 5.1 Timeline of Development Process of Huilongguan Neighborhood

Note: * refers to total population of Huilongguan street office, of which Huilongguan neighborhood constitutes a significant part.

The Huilongguan Cultural Residential Area refers to an extensive residential development cluster in Huilongguan Township of Changping District. For the purpose of

[24] Affordable housing is one type of subsidized residence provided by the government in corporation with real estate developers, to lower income families at a price much lower than the market price. The ownership is not allowed to be transferred until five years after the purchase.
[25] There are mainly three types of building styles in these neighborhoods: i) Walk-ups, which are 6-storey residential buildings; ii) mid-rises, which are between 7 and 12 stories; and iii) high-rises, which more than 12 stories tall.

this dissertation, I define the Huilongguan study area as a subset of the larger residential neighborhood by the same name, which is served by two MRT stations, Huilongguan and Longze. Map 5.2 describes the larger neighborhood. This neighborhood is 7.95 km^2 in size and has an estimated population of 325,000 (2010 data).

Map 5.2 Boundary of Huilongguan Neighborhood (Cultural Residential Area)

Source: The author, 2012

The construction of the Badaling expressway was completed in 2001, connecting the northern arcs of the 3rd, 4th, 5th and 6th ring roads, extending further northwest into neighboring Hebei Province. At the same time, construction started on MRT Line 13. Its operation started in January 2003 which was quite early in the development history of the Huilongguan neighborhood. Before MRT Line 13 was in operation, most commuting trips were made by buses and taxies. Due to the remoteness of the area, and limitations of buses (capacity, speed, and comfort), the travel demands of a rapidly growing population "could no longer be satisfied by traditional surface public transport" (according to focus group discussion). This increasing demand for a more efficient and affordable travel mode became a major driving force to provide the area with MRT service. Since the launch of MRT Line 13 in 2003, the MRT has become one of the main commuting modes for the local residents.

However, MRT Line 13 is built along a railroad track, creating an accessibility barrier for residents living in the area south of the MRT line. One of the main reasons for this ostensibly less than optimum routing was that the MRT authority pursued extension on the lowest-valued land and to minimize property expropriation and the relocation of existing residents. Because the cost for building underground MRT lines is high, most of the MRT lines in suburban Beijing run above ground[26]. To get to the Huilongguan transit station from the south requires passing through a tunnel where the north-south Yuzhi East Road intersects with the MRT line and the railroad track. As a result, the effective service area of the MRT station is more limited than would otherwise be the case.

A consequence of this barrier has been to steer development to the north. After more than a decade of development, residential development/redevelopment on the south side has been largely limited within a one or two blocks proximity to the station, while the development activities on the north side expand as far as 2 km from the station. At the same time, shopping and entertainment centers have also been developed to the north of the station, primarily at the major intersections along Huilongguan W Street (see Map 5.2), about 1km from the Huilongguan station.

By 2011, the neighborhood has been predominantly residential with shopping and entertainment areas mainly catering to local residents. Green and public spaces are

[26] In Beijing, MRT lines within the city proper mostly run underground, and the overall cost is about 600 – 900 million RMB/km, of which only a small percentage is relocation cost. In suburban Beijing, most MRT lines run above ground, and the overall cost is about 600 – 700 million RMB/km, of which about 30-40% is for relocating the original resident. MRT line 13 is a light rail system, completed in 2002. The overall cost was about 160 million RMB/km.

scattered among buildings. In 2007, the “affordable houses” in the neighborhood started transferring to “commodity houses”. The average residential housing price increased to 6,500 RMB/m^2 in a short period. Most of the residential buildings are 6-storey walkups; only the most recent development tends to be high rises, such as Xinlongcheng (see Image 5.1 and Map 5.2 for location).

There are bus lines connecting the neighborhood to the city center and other key areas of Beijing, as well as feeder buses that run through residential blocks within the Huilongguan neighborhood, collecting people and dropping them at the MRT stations. Many residents also choose to carpool or drive to the MRT stations and park on the street, and then take the MRT to work or other destinations (see Image 5.1). As is the case in most cities in China, there are no official Park-and-Ride facilities in the vicinity of MRT stations.

Image 5.1 Huilongguan Neighborhood

Walk-up Residential Development

Cars parked outside the light rail station

Xinlongcheng

Restaurants that cater to local residents

Source: The author, 2011

5.4 Tiantongyuan: A Developer-driven Community with late MRT Access

Like the Huilongguan neighborhood, the development of Tiantongyuan (Map 5.1) neighborhood was also developer-driven, and also started as an affordable housing project in the late 1990s. Map 5.3 shows the boundary of the Tiantongyuan neighborhood, which covers an area of 6.5 km^2, with an estimated population of 360,000 in 2010 (a similar size as Huilongguan). When development was initiated in the late 1990s, the project was branded as the "largest and least expensive" affordable housing community in Asia, with an initial price of 2,650 RMB/m^2. Housing began to be transferred to commodity status in 2007 with a starting price of 6,500 RMB/m^2, echoing changes to the ownership structure found in the Huilongguan neighborhood.

Despite similar sizes, densities, as well as development and tenure histories, Tiantongyuan and Huilongguan differ in that Tiantongyuan is not directly connected with the city center by an expressway and was not served by MRT until late 2007 (see Figure 5.2). The main arterial road connecting the area to the city center is Litang road, which experienced severe congestion until the opening of MRT line 5 in 2007 (see Image 5.2 for comparison and Map 5.3 for location).

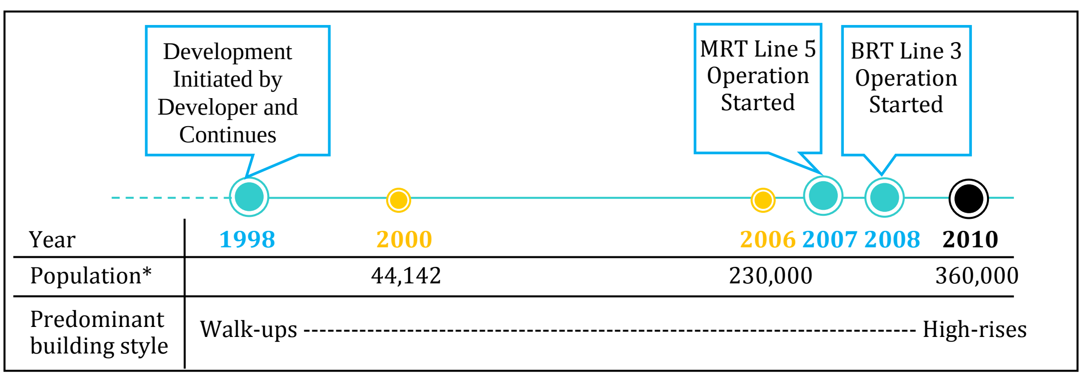
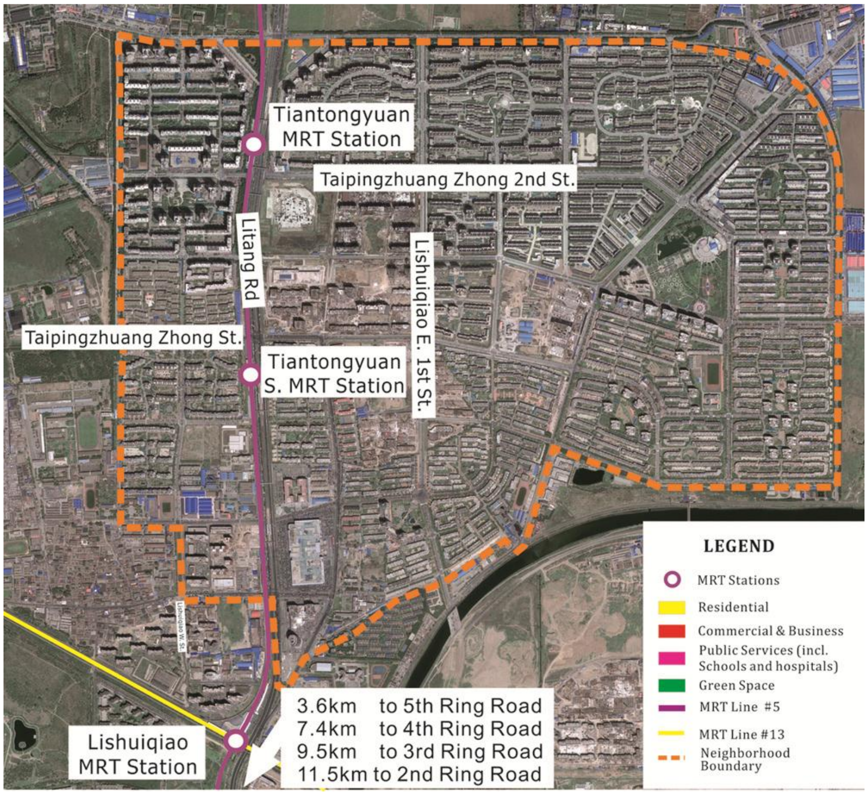


Figure 5.2 Timeline of Development Process of Tiantongyuan Neighborhood

Note: * refers to total population of Dongxiaokou street office, of which Huilongguan neighborhood constitutes a significant part.



Map 5.3 Boundary of Tiantongyuan Neighborhood

Source: The author, 2012

Image 5.2 Litang Road

Litang Rd in June 2004, severe congestion

Litang Rd in Oct 2007, flanked by MRT Line 5

The land use in Tiantongyuan neighborhood is also predominantly residential, with shopping and entertainment areas mainly catering to the local residents. The development pace of Tiantongyuan was slower than Huilongguan. Even at the time of writing in 2012, some land lots remained either vacant or under construction. The principal residential housing form also differs from Huilongguan in that there are more high rise residential buildings in Tiantongyuan, while Huilongguan predominantly consists of 6 storey walk-ups. Early development in Tiantongyuan also focused on walk-ups, as seen in the south central area of the neighborhood, but high-rise buildings began to appear as early as 2003 in the northwest corner of the neighborhood adjacent to the current Tiantongyuan MRT Station; coincidentally at about the same time that the construction of the MRT line that would eventually serve the neighborhood commenced. This appears to provide circumstantial evidence that developers preemptively responded to the arrival of rapid transit.

Anecdotal evidence gathered prior to conducting the field work, suggests that the Tiantongyuan neighborhood operates like a bedroom community; residents commute to work in the morning and return home in the evening. Shopping and entertainment services can be found within the community, Longde Square being the largest shopping center that caters to the local residents. Employment opportunities that match the skills and income requirements of local, middle class residents appear to be limited (according to focus group discussion). One major office building, named the Longde Zijin complex, exists but suffers from a high vacancy rate and is mainly occupied by lower end small firms such as printing services and small businesses catering to the decidedly niche industry of wedding planning (see Image 5.3). The commuter nature of Tiantongyuan can be observed by the massive passenger flows entering and leaving the two MRT stations during the morning and evening peak hours, respectively. The large commuter traffic has stimulated the concentration of street vendors in areas around the MRT stations, especially at the pedestrian overpasses (see Image 5.3) but, again, this suggests a jobs-housing mismatch between the residents who live in the area and the employment that caters to them.

Image 5.3 Tiantongyuan Neighborhood

High-rise residential

Longde Zijin Office Building

Longde Square

Street vendors at the foot of a pedestrian overpass

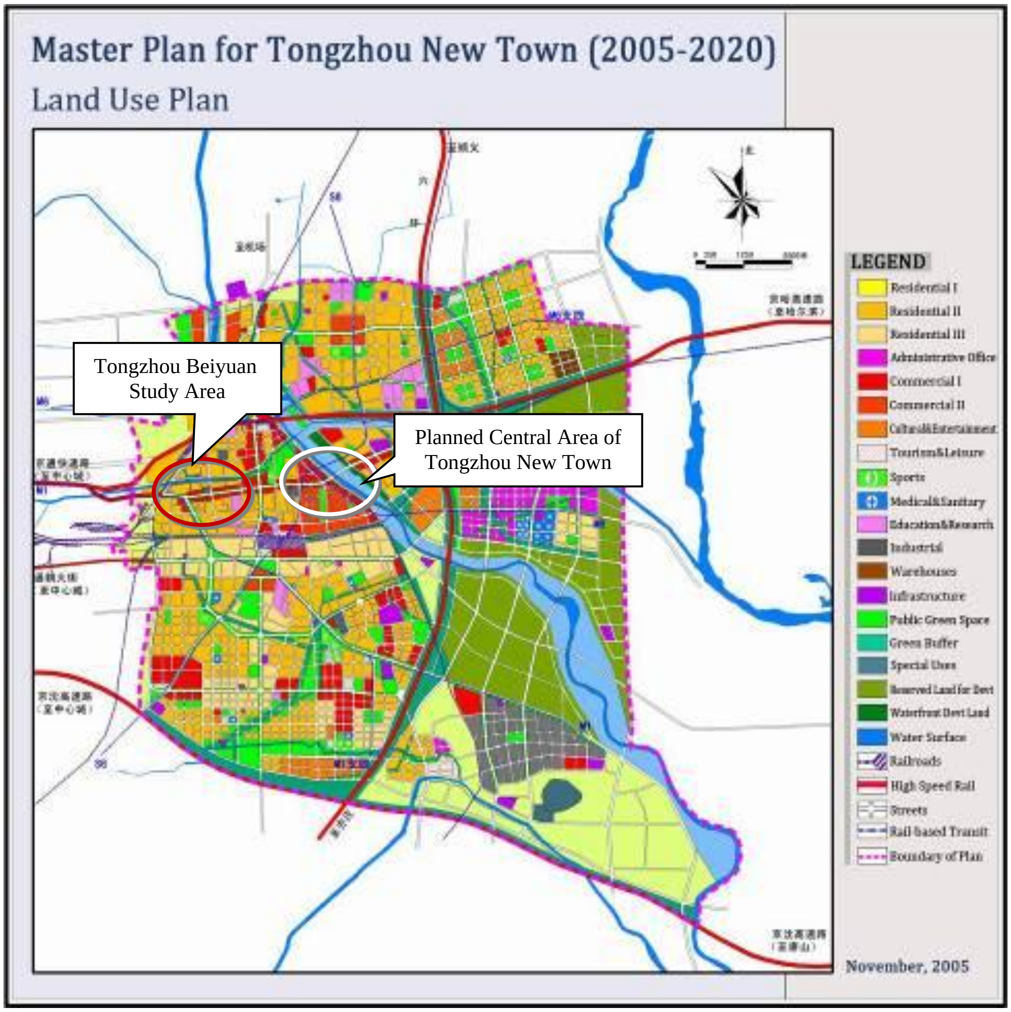
Source: The author, 2011

5.5 Tongzhou Beiyuan: A Strategic Plan-driven Community with an Expectation of Early MRT Access

Tongzhou Beiyuan presents a different development trajectory from the other two study neighborhoods. Tongzhou Beiyuan is a natural outgrowth of an existing old town of Tongzhou, in the Tongzhou District, and therefore has a much longer development history. Physical development to date has been more mixed-use in nature, including residential, commercial, industrial (including warehouses) and facilities catering to the national railroad, compared with the more residential nature of Huilongguan and Tiantongyuan. Tongzhou Beiyuan is conveniently connected with Beijing's city center via the Jingtong Expressway and is accessed by the eastern leg of MRT Line 1 (also known as the Batong Line),opened in 2003. The neighborhood is located about 13.5 km, or a 15-20 minute driving time away from the CBD of Beijing and 2.7 km from the designated central area of Tongzhou in the Tongzhou New Town Plan to the east (see Map 5.4). The Tongzhou Beiyuan neighborhood also constitutes the main part of Tongzhou New Town's western gateway to Beijing's CBD. In the District Master Plan, the main functions of Tongzhou Beiyuan Neighborhood are defined as serving a residential community and offering a regional retail center (according to Tongzhou Planning Bureau).

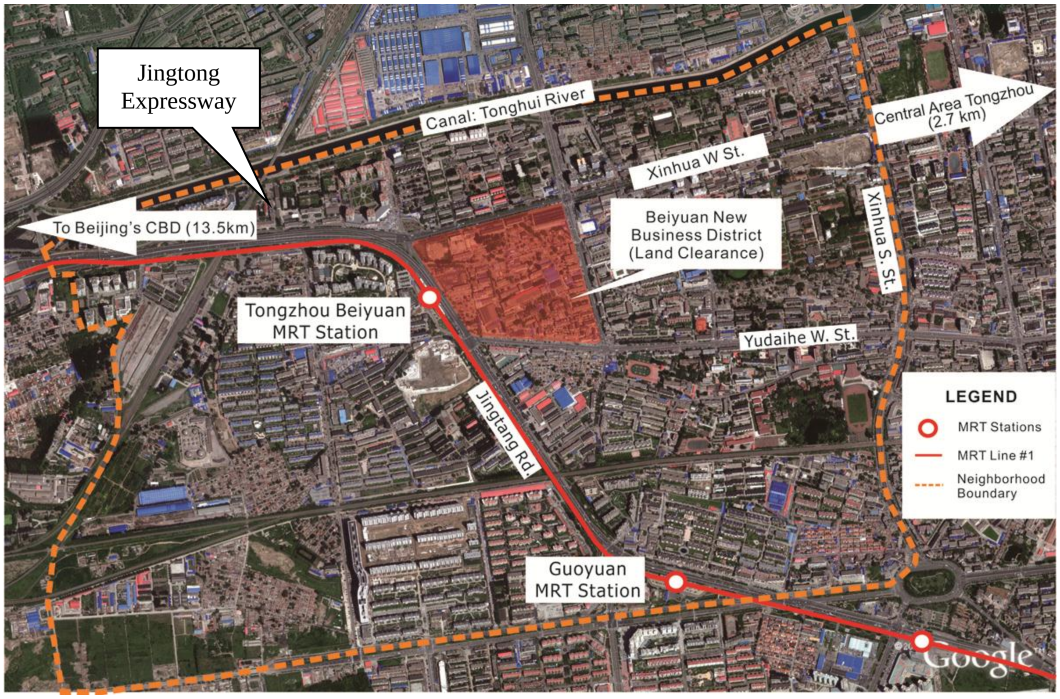
Map 5.5 shows the boundary of Tongzhou Beiyuan neighborhood studied in this research project. Encompassing an area of 5.9 km^2, with an estimated population of 53,300 in 2010, this study area coincides rather fortuitously with the official boundaries set by the Tongzhou Beiyuan Street Office.

Due to its strategic location in the region and the planned construction of the Batong MRT line, Tongzhou Beiyuan was anticipated to serve as the local CBD of Tongzhou District. A master plan for the "Tongzhou Beiyuan Business District" was approved in 2001 (see Map 5.5) located adjacent to the Tongzhou Beiyuan transit station, and covering an area of 0.24 km^2. At its inception, the Tongzhou Beiyuan Business District was designated as a business and commercial center for serving local residents and industries as well as transplanted commercial properties from Beijing's CBD in 2001. Despite these early ambitions, the area lacked a detailed plan until 2009. By 2010, nearly 10 years after the approval of its original conceptual plan, little action had taken place on the ground. The sluggish development was exacerbated by original residents seeking higher compensation for relocation, knowing full well of the proposed alignment of the future MRT line. This contributed to a slow land clearance process in the community.



Map 5.4 Land Use Master Plan for Tongzhou New Town, 2005-2020

Source: Tongzhou Urban Planning, translated by the author.



Map 5.5 Boundary and Site Context of Tongzhou Beiyuan Neighborhood

Source: The author, 2011

According to a new detailed plan completed in 2009, the new business district will consist of two main functional areas. One is a residential development along Yudaihe West Street in the southern part of the neighborhood, with a total construction area of 340,000 m^2. The other is a business and commercial cluster featuring luxury hotels (74,200 m^2), high-end office spaces (138,000 m^2) and shopping malls (92,400 m^2). At the time of writing (June 2012), the land was in the process of being cleared and will be ready for development in the end of 2012 (see Map 5.5, Image 5.3 and Figure 5.3).

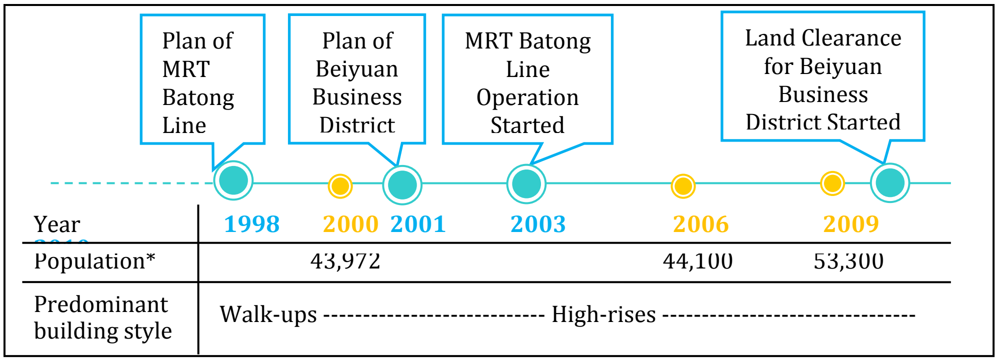
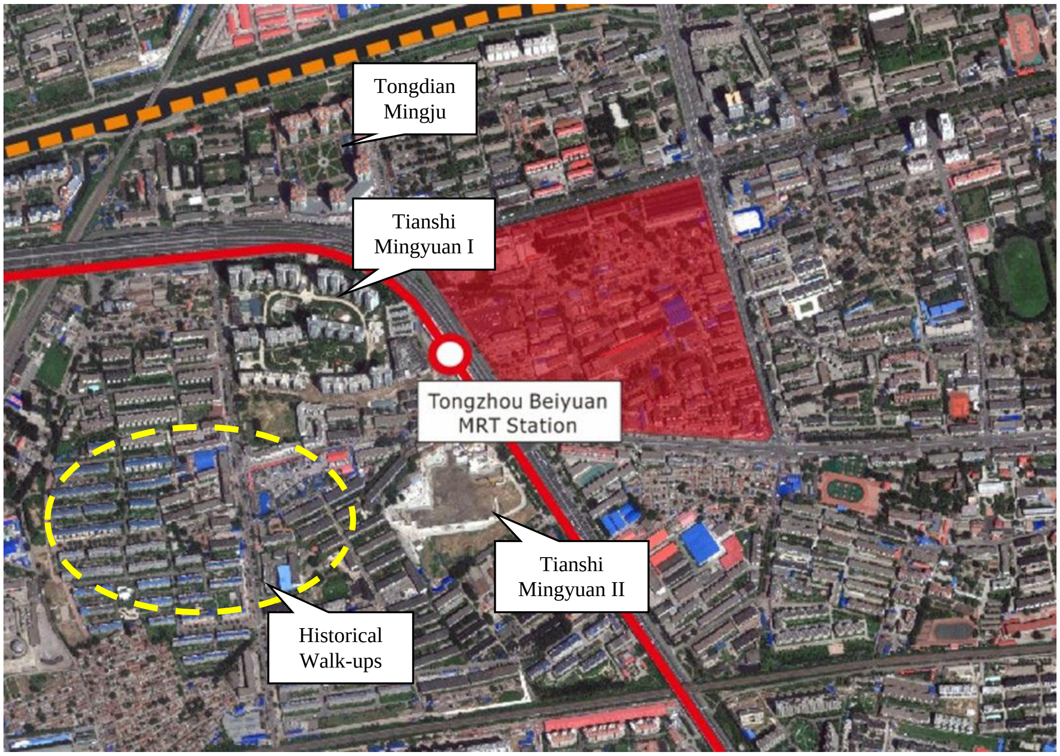


Figure 5.3 Timeline of Development Process of Tongzhou Beiyuan Neighborhood

Note: * refers to total population of Dongxiaokou street office, of which Huilongguan neighborhood constitutes a significant part.

Tongzhou Beiyuan Neighborhood also represents an example of a suburban area being redeveloped in Beijing with easy public transit access. There are many long established residential buildings in the Tongzhou Beiyuan neighborhood, with most being approximately 20 to 30 years old, and few land parcels were available for new development. As part of the peri-urbanization process of Beijing, most of the industries in the neighborhood have been moved outward and the land has been redeveloped mostly into residential properties. The area adjacent to the Tongzhou Beiyuan MRT station, for example (see Map 5.6), was the site of three major redevelopment projects: Tongdian Mingju was completed in 2003, acquiring land redeveloped on the grounds of the former Beijing No. 2 Plastic Factory. The other two projects are Phase I and II of Tianshi Mingyuan, which redeveloped land that previously accommodated both manufacturing plants and workers' dormitories of the Beijing Zhong Ke Printing Co., Ltd. All three projects are residential properties, with some shopping facilities (see Image 5.4).



Map 5.6 Redevelopment Projects around the Tongzhou Beiyuan MRT Station

Image 5.4 Tongzhou Beiyuan Neighborhood

Old residential neighborhoods

Land clearance underway

Shopping space of Tongdian Mingju

High-rise Residential Buildings, Tianshi Mingyuan

Source: The author, 2011

Chapter 6

IMPACTS ON LAND USE AND REAL ESTATE MARKET IN SUBURBAN BEIJING

This chapter focuses on investigating changes to land uses brought by MRT development in the three selected neighborhoods and evaluating the impacts of MRT availability on the built environment and local housing prices. The study areas are defined as part of the three selected study neighborhoods, centered on their own MRT station with a radius of approximately 800 meters. The boundaries of these study areas are defined by the existing streets to maintain contiguity (one patch of land) and integrity. The neighborhood land uses are explored in this chapter and the impact of the history of land use and built environment planning (or lack, thereof) on the residents is qualitatively presented in the form of quotes from the resident focus group discussions. I end this chapter by assessing the implications of land use and transportation changes and the real estate market on the social development of the neighborhoods and, more widely, in Beijing. I conclude with a discussion of policy implications from these findings.

6.1 Huilongguan Study Area (Huilongguan MRT Station)

The Huilongguan study area is one part of Huilongguan neighborhood as introduced in Chapter 5, centered on the Huilongguan MRT station on Line 13, with a radius of approximately 800 meters. It is about 3 km^2 in size. This study area is bounded by Huilongguan W St in the north, Wenhua Rd in the east, Yuzhi W Rd in the west and Huangping Rd in the south (see Map 6.1). This area is divided into north and south parts by an inter-city railway line and the above ground MRT line.

As shown in Map 6.1, the north side has primarily been developed for residential and some commercial uses since late 1990s. Comparatively, the (re)development of the southern part has proceeded much more slowly. Except for an area of residential walk-ups and villas in the southeast quadrant developed around 2000, the rest of the area remained unchanged until the land directly adjacent to the railroad in the southwest quadrant was developed into new residential property in 2007.

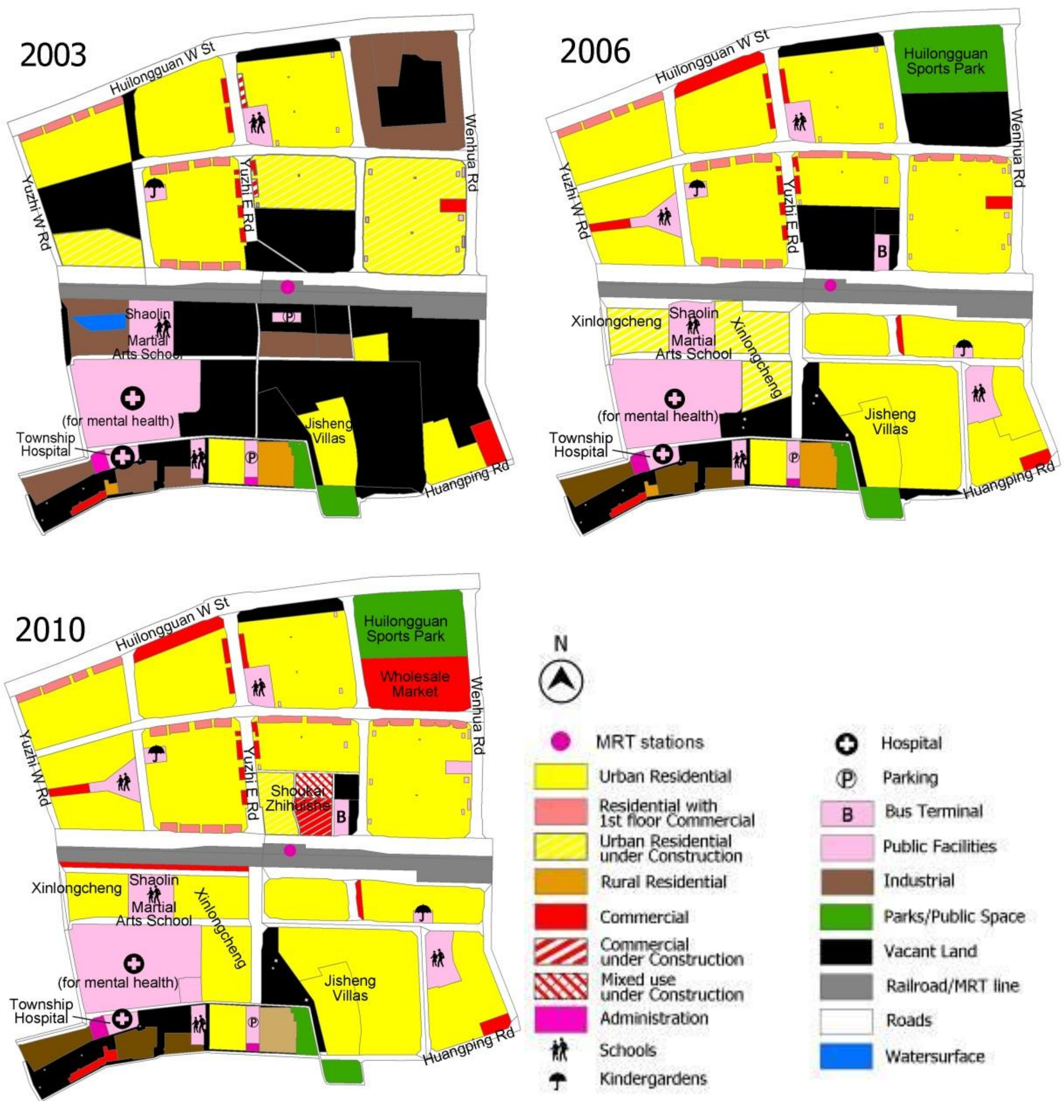
Map 6.1 Huilongguan Study Area Context

Source: The author, 2011, Google Earth.

6.1.1 Land Use Changes

Utilizing temporal land use data, historical remote sensing images, and information gathered in field investigation, changes in land use in the study area since 2003 are mapped in Map 6.2.

Map 6.2 clearly indicates that the north section was developed much earlier and faster than the south section, mainly due to the spatial separation resulting from the railroad and MRT line. In 2003, after the opening of the Huilongguan MRT station, Yuzhi East Rd was not built yet, leaving the south section with even poorer pedestrian access to the station than is currently the case. The main land use function in the north section has been, and remains, residential. The proportion of land coverage by residential properties in the study neighborhood is also increasing, and grew from 31.4% in 2003 to 47.9% of all land in the Huilongguan study area in 2010. However, a few small land plots have been developed for similar commercial uses, such as a strip of restaurants along Yuzhi East Rd and Huilongguan West St in Map 6.2-2010.



Map 6.2**:** Land Use Changes in the Huilongguan Study Area, in 2003, 2006, and 2010

Source: The author, 2011, Beijing Municipal Bureau of Land and Resources, China State Bureau of Surveying and Mapping

At the same time, it is a common phenomenon that residential buildings facing a street turn their first floor apartments into small shops such as grocery stores, printing workshops, or offices for real estate agents (see Image 6.1). These properties show a trend of adaptive and spontaneous action towards maximizing commercial activities in the absence of planning controls when the main, officially-designated land use type – in this case residential – is settled and hard to change. This adaptation is the spontaneous market response to the local commercial demands presented by the existence of a large number of residents. It deepens the residential function by turning the buildings into *de facto* mixed-use properties. Such adaptation happens in an incremental manner, rather than via dramatic changes. Nevertheless, these restaurant strips and first floor commercial enterprises remain low-end and necessarily small due to the lack of space and lack of clustering effect.

As seen in Map 6.2, much of the land to the south of the MRT line was vacant in 2003. Between 2003 and 2006 the majority of this vacant land was developed for residential purposes. During this time, the fragmentation of these land lots was reduced as land was combined to make larger properties and streets were built. To the far south are rural collective properties, used for residential, parking, industries and green space – land use in this area has stayed unchanged over the study period.

Despite the lack of urban development in the southern section of the Huilongguan study area, some public facilities were already built and in operation by 2003. These facilities were, however, not facilities that catered exclusively to area residents. For example, a mental health facility has been existing in this area. To address the growing need for public facilities, from 2003 to 2010, two new primary schools and one new kindergarten were built in the south section. Additionally, a large park/public space, namely Huilongguan Sports Park, was constructed in the northern part of the study area for family and sports activities. A wholesale market was developed to the south of it, featuring one storey buildings geared for the sale of low value merchandise.

One special piece of land under development was the parcel immediately north of Huilongguan MRT station, which was not initiated until 2009. Instead of being a predominantly residential property, such as the parcels around it, the Shoukai Zhihuishe complex, as it was known, was officially designated as a mixed use development from the start and includes residential, mixed use (office and apartments), and a shopping components.

In terms of building styles, there are more high-rise buildings in newer developments that started after the MRT line was opened. Earlier residential properties, especially in the north section, were 6-storey walk-ups. New residential development are mostly found in high-rise buildings, such as the Xinlongcheng project in the southwest quadrant adjacent to a nearby railway line, and the Shoukai Zhihuishe development directly to the north of the MRT station which remained under construction at the time of writing in 2012 (see Image 6.1). The development of Shoukai Zhihuishe demonstrates the change in developer approaches in the area, from solely residential development to more mixed development adjacent to the MRT station. At the time of writing, no major commercial development is occurring in the south and there has never been any office development during the study period. Furthermore, while commercial uses appeared along main avenues in the north section (Huilongguan W St., Yuzhi E Rd.), commercial properties did not historically take advantage of access to the MRT station.

Overall, residential development has been the main type of land use in the study area, increasing from 31.4% in 2003 to 47.9% in 2010. Unfortunately, with the study area fully built up only the northern section of the larger Huilongguan neighborhood (beyond the study zone mapped in Map 6.2) has potential for office development to the fact that a railway right-of-way bisects the area to the south, restricting access to the rest of the community. Additionally, the land use mix of the neighborhood has been impacted by the phasing out of industrial uses over the study period. Industrial uses accounted for 8.35% of the study area's land use in 2003 to 1.59% in 2010. A summary of all land use changes in the study area from 2003 to 2010 is shown in Table 6.1.

The discrepancy between the original land use plan and the "on the ground" reality remains a subject of controversy in the case of many neighborhood development projects in Chinese cities. Land allocated in the plans for public services such as parks and public space, schools, hospitals are often "eaten up" by residential buildings due to the developer's activities of chasing higher profits. The majority of land (about 48%) in Huilongguan has been developed into residential buildings. The building style has been predominantly 6-storey walk-ups in the earlier stage, but there is a trend toward high-rises lately, especially after the MRT commenced operations. However, this shift is less real and obvious than would otherwise be the case because there was not much land left for development at the time of the opening of the MRT line.

The residential properties were designed with what was considered adequate parking space (one parking space for each residential unit), both above ground and underground, from the very beginning, although not many residents owned cars at that time. The parking fees were set at affordable rates for the residents (1,200 RMB/year for above ground and 1,600 RMB/year for underground). The ownership of cars has increased rapidly since 2008, particularly in 2010 right before the Beijing vehicle restriction policy[27] was released. Currently, about 70% of the households own a car.

[27] Starting from the first of 2011, a "quota and luck-draw" system was enforced in Beijing's automobile market, which sets quota for total number of purchases and assigns these quota to applicants by luck-draw.

Commercial and mixed use land which provide personal services for local residents only account for a very small percentage (i.e. 1.1%) of total land in the Huilongguan neighborhood in 2003. Based on focus group interviews, local residents recall a shortage of retail services for their needs in the earlier parts of the decade. In 2010, the share of commercial and mixed use land was still low but had increased to 6.1%. Beside six supermarkets, most of the services provided included restaurants, movie theaters, barber shops, real estate agents and small private clinics and massage parlors. By 2010, many residents agreed that their daily needs could largely be satisfied within the neighborhood. However, spatially, these services were unevenly concentrated along Huilongguan W St instead of around the transit station, forming a *de facto* neighborhood center some distance from the transit station that was their primary point of access to the rest of the city.

Table 6.1 Huilongguan Area Land Use Change by Type, 2003-2010

	2003		2006		2010	
Land Use Types	Area (m^2)	Share (%)	Area (m^2)	Share (%)	Area (m^2)	Share (%)
Urban Residential	935693	30.6	1400540	45.7	1454813	47.6
Rural Residential	26542	0.9	26542	0.9	26542	0.9
Commercial	32570	1.1	52584	1.7	170093	5.6
Mixed Use	0	0.0	0	0.0	13790	0.5
Industrial	255661	8.3	48832	1.6	48832	1.6
Administration	6362	0.2	6362	0.2	6362	0.2
Education	71559	2.3	112061	3.7	115115	3.8
Public Facilities	3491	0.1	4191	0.1	4039	0.1
Hospital	157840	5.2	156261	5.1	156508	5.1
Parks/Public Space	30171	1.0	136719	4.5	132276	4.3
Parking	11889	0.4	7564	0.2	7564	0.2
Bus Terminal	0	0.0	8102	0.3	8102	0.3
Railroads & Roads	613428	20.0	772389	25.2	778128	25.4
Vacant Land	906230	29.6	330105	10.8	135927	4.4
Water Surface	11374	0.4	0	0.0	0	0.0
Total	3062807	100.0	3062251	100.0	3058092	100.0

Source: The author, 2011.

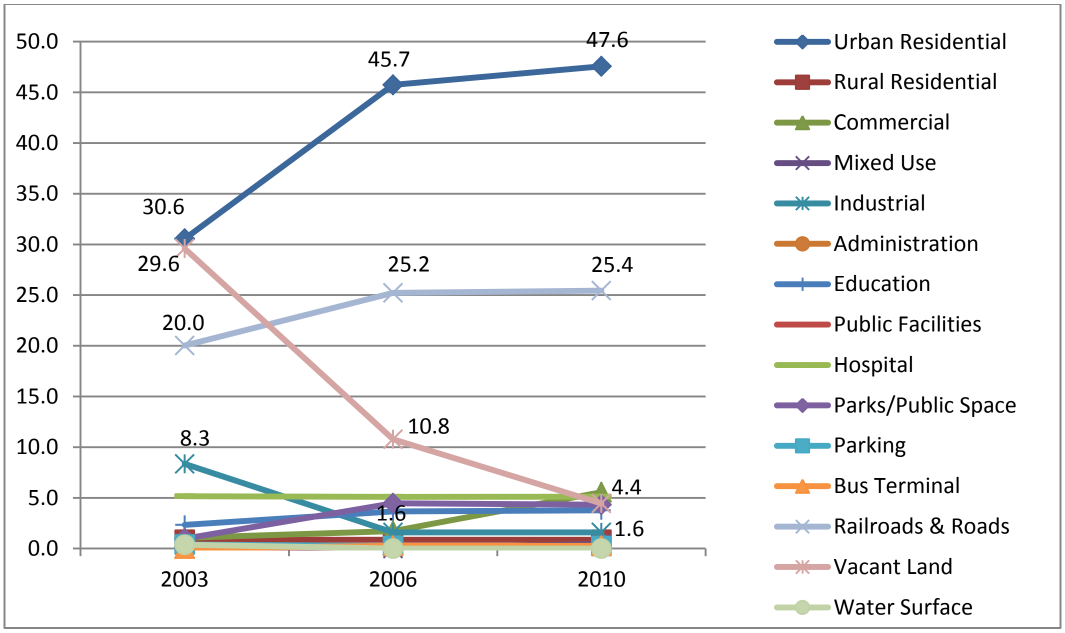


Figure 6.1 Huilongguan Area Land Use Change by Type, 2003-2010

Source: The author, 2011.

Image 6.1 Street Views of Huilongguan Study Area

Restaurants along Yuzhi E Rd, north to the MRT Station

Shaolin Martial Arts School

6-storey Walk-up Residential with 1st floor commercial

Xinlongcheng

Source: The author, 2011.

6.1.2 A Changing Sense of Living

The Huilongguan neighborhood is located outside the 5th Ring Road in Beijing. It was one of the earliest "affordable communities" (see Chapter 3) in Beijing, built in the late 1990s. At that time, it was basically a stand-alone community on the far northern edge of Beijing, lacking convenient and effective transport linkages with other parts of the city before the MRT line 13 opened in early 2003. The low prices of homes - 2,600 RMB/m^2 - attracted many buyers and demand was amplified by the fact that some employers offered housing subsidies. However, demand was curtailed by the poor accessibility of the area. Prior to 2003, the only transportation options were taxi and poor bus service. In addition, a resident-organized shuttle bus traveled to major employment centers or transportation nodes, such as Zhongguancun and Guomao (the CBD area of Beijing), but suffered from extremely long travel times (a 1.5-2 hour one-way travel time) and a poor schedule. Focus group interviewees responded that, at the time, residents did not feel they were living in Beijing. As one longtime resident recalled,

> *"Even the taxi drivers would try to attract business by leaning out of their cabs and asking, '[Are you] going to Beijing?' It was as if [we] were living in a new town far away from the city."*

Many of the interviewees remarked that when they did travel out of the neighborhood on day trips, they lacked the will to leave the neighborhood upon returning on the same day since everything was considered too far away. "Suburban isolation" was the prevailing sense of living in this neighborhood.

The lack of commercial development in the original planning resulted in scarce shopping facilities in the neighborhood in the earlier years. Some of the residents would do shopping around their work places and bring groceries back home; some others would just shop within the community, where there were limited choices. Gradually, a few restaurants opened along Yuzhi E Rd and Huilongguan W St; additionally, a few supermarkets were opened on the north side of Huilongguan W St; and the first floor of some residential buildings facing the streets was turned into low value commercial uses. The pressure on the lack of commercial facilities was relieved by such spontaneous and market driven adaptation. One advantage of development of commercial activities along streets is that it creates street life, e.g., restaurant streets. But the streets in Huilongguan area are normally too wide to "create an intensive street life ambience" (see Image 6.2).

The arrival of the MRT provided a sea change for the quality of living and residents' appreciation and use of their community, bringing the community closer to other parts of the city and reducing travel time markedly. As one interviewee recalls:

> *"The change of travel opportunity brought by the MRT line was phenomenal. We felt that here is Beijing! (sic) [i.e. 'We felt that we were actually living in the city of Beijing']"*

However, the MRT station also brought "chaos and messiness" according to the interviewees. The area adjacent to the MRT station was an open space filled with street vendors, tricycles, illegal taxis (private cars without taxi licenses looking for passengers) and unregulated car parking, and residents expressed that the area was unpleasant and unsafe to walk around (see Image 6.2).

The majority of interviewees indicate that they have no idea what is being developed in the south section of the study area (south of the MRT station and railroad). Their psycho-geographical sense of the “Huilongguan Community” only refers to the area that extends 2km north of the station, indicating the social segregation created by the physical barrier of railroads.

Image 6.2 Huilongguan MRT Station and the Wide Streets

Street vendors and unregulated parking outside the Huilongguan MRT station

Wide Streets

Source: The author, 2011.

6.1.3 Population and Labor

According to interviews with local residents and real estate agents, the majority of early residents in Huilongguan were young people working in the Shangdi or Zhongguancun IT employment clusters. Because the MRT improved accessibility to the neighborhood, more people with a wider range of employment destinations began to move in. As of 2012, according to interviews, most of the residents are between 30-40 years old.

Despite the affordability of the community in 2000, the occupancy rate of residential units was low at the time at just roughly 50%. There were several reasons for this: i) The community was too far from the other parts of the city and commuting was not convenient; ii) There were speculative buyers; iii) Some bought homes in the community because their employers offered subsidies (the community was affordable housing to begin with); iv) The affordability of the area prompted some households to occupy a home(s) in a more central location of Beijing and to utilize their Huilongguan properties only on weekends. But, as of 2011, the occupancy rate was very high – approaching 100%. A considerable percentage of current residents are renters.

Table 6.2 presents estimates of household occupancy patterns in the Huilongguan Study Area. These figures are presented in terms of the number of households, average household size, and occupancy rates in the respective dwelling types. Because there is a villa project in the south section, the residents of average dwellings and villas were estimated separately.

Table 6.2 Residents Estimates in Huilongguan Study Area

	Average Households			Villa Households			Estimated Total Residents (persons)
	Number	Size (p/hh*)	Occupancy Rate (%)	Number	Size (p/hh*)	Occupancy Rate (%)	
2003	13800	2.9	70%	300	2	60%	28,374
2006	17000	2.7	90%	743	2	60%	42,200
2010	19900	2.45	95%	743	2	60%	47,200

Data source: Census Data 2000 and 2010, Beijing Population 1% Survey 2005, interviews of local residents. (*p/hh: persons/household)

As mentioned above, most local residents work in other parts of Beijing and commute daily. There are very limited employment opportunities within the community. Most local employees work in service industries, such as restaurants, real estate agent offices, small stores, etc. The other employment opportunities are primary schools, kindergartens and hospitals. Employment in the study area is estimated in Table 6.3.

Local employees, especially those in the service industries such as restaurants, normally cannot afford to live in Huilongguan. Instead, they rent places in the rural collective villages nearby, such as Dingfuzhuang and commute themselves.

Table 6.3 Employment Estimates in Huilongguan Study Area

	2003	2006	2010
Huilongguan Hospital	1200	1200	1200
Changping No.2 Primary School (public)	0	75	75
Mingshi Primary School (private)	0	70	70
Huilongguan No.2 Primary School (public)	100	100	100
Xingfutongnian No.2 Kindergarten	50	50	50
Lvbeier Kindergarten	0	60	60
Service Industries	2000	2500	4000
Administration	100	100	100
Industries	200	100	50
Total	3,650	4,255	5,705

Source: Websites and Interviews.

6.1.4 Public Services

The main complaint residents express about the Huilongguan neighborhood concerns the lack of schools and hospitals, both in terms of their availability and the quality of those that exist. The residents have been complaining that the kindergartens and schools illustrated in the plan - which were motivating factors for their purchase of homes - often never materialized. It is common for the developers to reduce the number of the schools and/or postpone building them.

I conducted a survey of the wider Huilongguan Residential Area for availability of public services. Currently, there are 32 kindergartens serving around 300,000 people; about 90% of these kindergartens are private and beyond the financial means of many residents. There are 8 primary schools and 2 middle schools, and residents expressed that these were of a questionable quality. For example, the Mingshi School is private and branded as a branch school of Beijing's No.2 Experimental Primary School. But the teachers are mostly retired teachers from other schools whose teaching style has been questioned as outdated. As a result, the families who have other options choose not to let their children enroll in local schools. Some have *guanxi*[28] with schools with good

[28] "Guanxi" is a popular Chinese term that can be loosely translated as "connections". It refers to

reputations closer to the center of Beijing; others buy or rent an apartment in a good school district and rent out their apartment in Huilongguan to subsidize the living expenses in the city center.

There is only one level three hospital[29] in Huilongguan, but it is for mentally challenged patients. Other than that, there are 2 public hospitals and 3 major private hospitals. But they are not considered to be of high quality by local residents. The residents generally only go these hospitals for physical exams or to treat minor ailments. For anything more serious, they go to the large general hospitals in the city center. While access to hospitals at the neighborhood level may seem luxurious in a Western context, one must remember that the Huilongguan neighborhood has a population of 300,000 people and is practically the size of a mid-sized city in the US and Europe! The inadequacy of public services will be further constrained by the growing affluence and expected increases to living standards from the growing middle class that inhabit Chinese cities and the Huilongguan neighborhood.

6.1.5 Real Estate Market

The average price of residential apartments in the Huilongguan Neighborhood was around 17,000 RMB/m^2 in 2011, while properties adjacent to s the MRT station were about 5% higher in terms of price than those further away from the station. This figure, essentially a small accessibility premium, is corroborated by the local residents (based on interviews).

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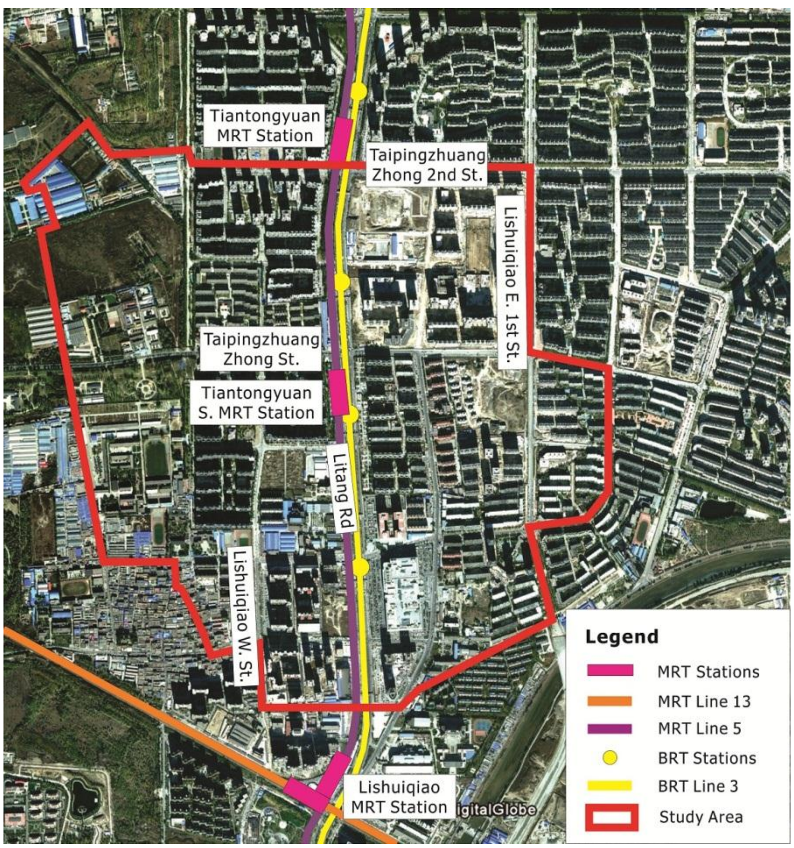
possessing fortuitous social capital or being closely acquainted with people in influential positions.

[29] There are three levels of hospitals in China: 1) Level Three Hospital: general or comprehensive hospital at national, provincial or city level; 2) Level Two Hospital: Hospital of Medium size city, county or district level; 3) Level One Hospital: township hospital.

6.2 Tiantongyuan Study Area (Tiantongyuan S MRT Station)

The Tiantongyuan Neighborhood was designed to be a large affordable housing community, mostly developed by one sole developer, Beijing Shuntiantong Real Estate Development Group. The Tiantongyuan study area is centered on the Tiantongyuan S MRT Station, and bounded by Taipingzhong 2nd St in the North, Lishuiqiao E 1st St in the East, and small unnamed streets in the South and the West (see Map 6.3). The area is about 3.5 km^2 and had a population of 300,000 in 2012. The north-south road in the middle of the study area, Litang Road, is the artery that connects Tiantongyuan with the central city. Both the MRT line 5 and the Bus Rapid Transit (BRT) line 3 run along Litang Road. In the southernmost tip of the study area is the interchange station of MRT lines 5 and 13, Lishuiqiao Station.



Map 6.3 Tiantongyuan Study Area Context

Source: The author, 2011

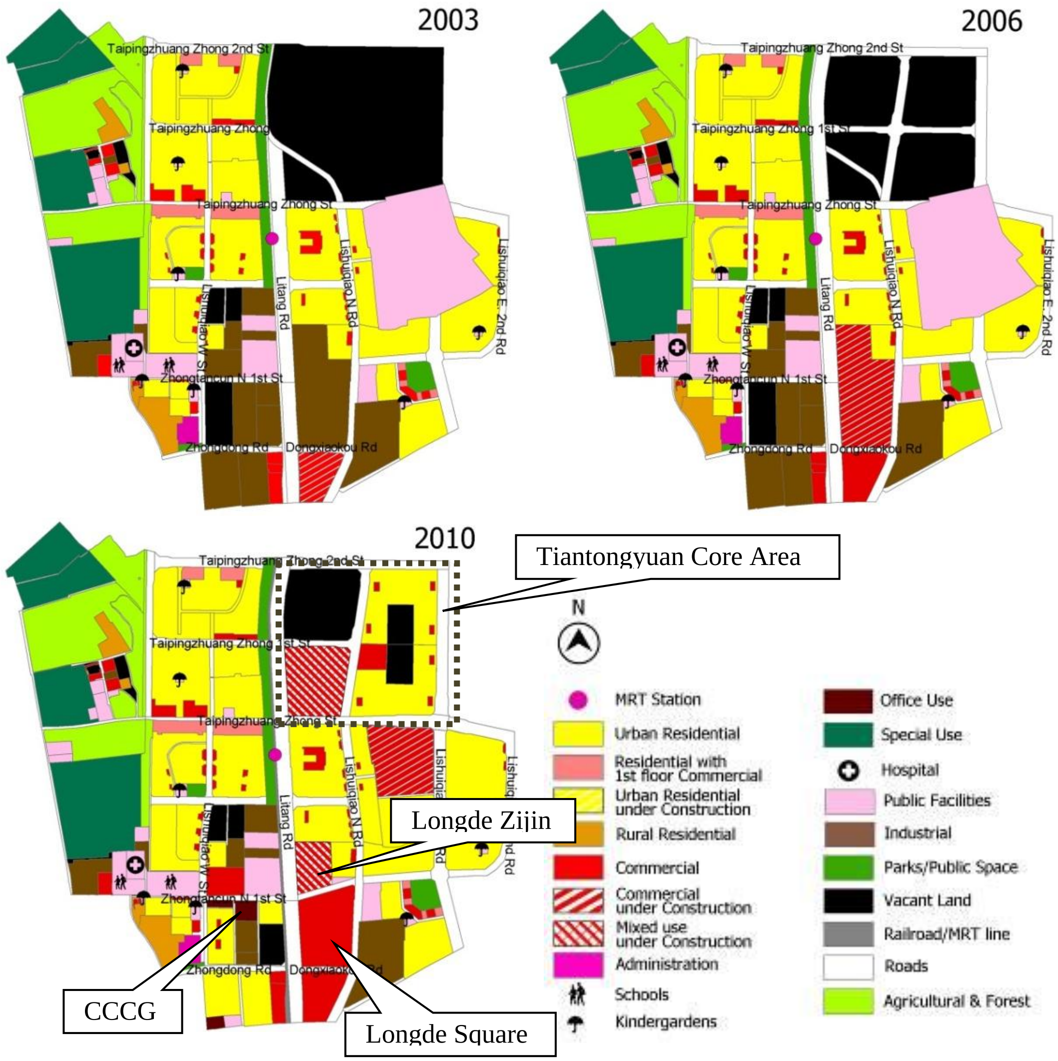
Connectivity between the Tiantongyuan Community and the city center has been greatly improved with the opening of MRT line 5 in 2007 and BRT line 3 in 2008. MRT line 5 runs from Tiantongyuan North (between the north 5th and 6th Ring Roads) all the way to Songjiazhuang (between the south 3rd and 4th Ring Roads). BRT line 3 runs from about 3km further north than Tiantongyuan to Andingmen (north 2nd Ring Road), but only enjoys exclusive right of way in the section north to the 5th Ring Road. Both of these systems provide fast and reliable alternatives for people's travel and contribute significantly to the reduction of traffic jams along Litang Road.

6.2.1 Land Use Changes

The changes of land use for the study area since 2003 are detected and obtained with the assistance of land use data, historical remote sensing images, and information gathered in field investigation and local resident interviews and illustrated in Map 6.4.

The Tiantongyuan study area is located on the urban periphery where land was previously used for agriculture/forestry, industry (small workshops or company in auto services or wholesales) and special uses (military uses). The development of an affordable neighborhood has turned the land to mostly urban residential use, in phases, with a clear boundary. The westernmost part of study area (about 16% of the total study area), although still located within an 800 meter radius of the MRT station, has remained in agricultural and military (indicated as 'special' uses) use. Special uses, such as military use, are under their own jurisdiction and usually remain unchanged as urban development occurs in surrounding areas. Furthermore, agricultural and forest land is subject to protection in China and its development is carefully limited and managed by the supervisory state department.

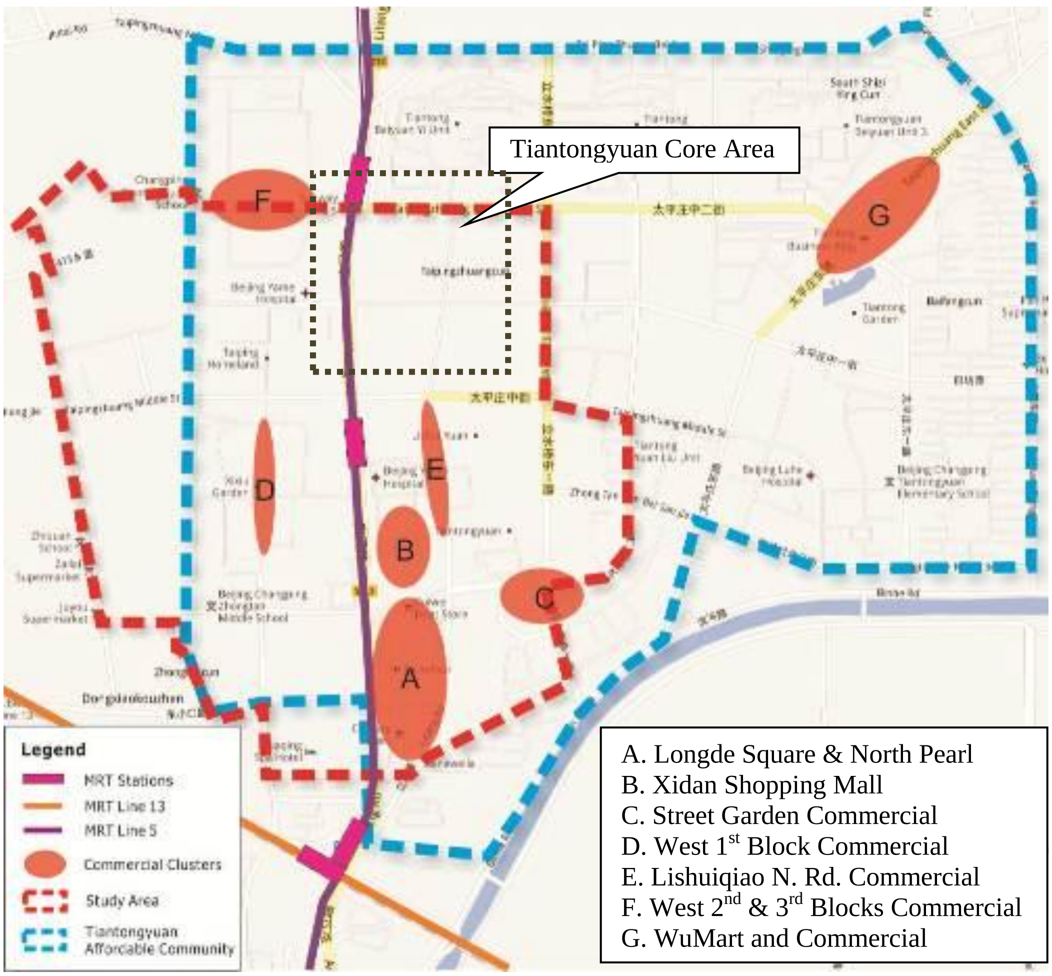
Industrial land has been decreasing over time in Tiantongyuan, from 11.36% of the total land area of the study area in 2003 to 4.19% in 2010. Areas that were previously industrial have been transformed into urban residential, commercial, and mixed uses. There is no heavy industry in the study area. Most remaining industrial firms are small scale light industries producing products such as paint and coating materials, and construction materials.



Map 6.4 Land Use Changes in the Tiantongyuan Study Area, in 2003, 2006, and 2010

Source: The author, 2011, Beijing Municipal Bureau of Land and Resources, China State Bureau of Surveying and Mapping

There are several commercial clusters serving the Tiantongyuan study area, and the whole Tiantongyuan Neighborhood (see Map 6.5). The largest and most diverse commercial center is Longde Square (shown in Map 6.4 and Image 6.3), with a total land area of 86,000 m^2 and a total construction area of 330,000 m^2. The first phase was opened in 2007. Its main tenants include supermarkets (Carrefour), department stores (Cuiwei), special stores (Paper Tiger Bookstore, B&Q Furniture Store, GoMe Electronics Store), Wanda International Cinema, Cafes (Starbucks), and various restaurants. Other commercial clusters are scattered within the Tiantongyuan Neighborhood, providing daily shopping and dining services for the residents. Most of them consist of restaurants, supermarkets and small commodity markets (see Image 6.3).



Map 6.5 Commercial Clusters in Tiantongyuan Neighborhood

Source: The author, 2011

Commercial clusters D and E in Map 6.5 are good examples of commercial strips in the Tiantongyuan study area. Three-story buildings are built along the streets, backed by residential development, which accommodate commercial services, mostly restaurants, massage parlors, real estate agents, etc. Such a spatial arrangement not only offers close and easy to access to services for the residents nearby, but also creates walkable streets within the neighborhood (see Image 6.3).

Of the six main commercial clusters shown in Map 6.5, five are located along MRT line 5, although not immediately adjacent to the MRT stations. Apparently, not many people travel from other parts of Beijing to this area for shopping and entertainment purposes. Thus these commercial clusters mainly serve residents in the Tiantongyuan Community. As is the case in Huilongguan, the walking environment around the stations in Tiantongyuan is not very appealing. MRT line 5 runs above ground in the study area, and Litang Road is 70 meters wide and contains exclusive lanes for BRT. There are nine overpasses along this 3km long section of Litang Road to help people cross the road. This poor pedestrian connectivity and accessibility resulted in formal commercial services being located some distance away from the MRT stations. However, informal commercial activities, such as the street vendors, tend to be found right outside of the stations and on the overpasses (see Image 6.4). Careless littering and loud noise brought by the street vendors have been a source of complaint by local residents, and are felt to contribute to a deteriorating living environment and unpleasant walking environment. Another main complaint of the residents is the presence of motorized tricycles which are used as informal "taxis" running within Tiantongyuan to more distant parts of the neighborhood further away from the stations. Motorized tricycles tend to cluster by the foot of the pedestrian overpasses that lead to the MRT stations in a large number, especially at the evening peak hours. Residents remarked that the riders usually did not obey traffic rules and often block the pathways of pedestrians and cars. Some residents remarked that tricycle drivers "get violent" on occasion when fighting for passengers heightening negative perceptions of safety in station area precincts.

Image 6.3 Commercial Clusters in Tiantongyuan Study Area and Tiantongyuan Neighborhood

Commercial Cluster A Longde Square: Wanda International Cinema & Cuiwei Department Store

Commercial Cluster A Longde Square: Starbucks & Restaurants

Commercial Cluster E: Roadside Commercial Strips along Streets

Commercial Cluster F: Small Commodity Market & Restaurants

Longde Zijin

Source: The author, 2011

There are two main mixed use land parcels in the study area. The one to the south is Longde Zijin, a residential/office building with podium shopping space completed in late 2008. The total construction area is 100,000 m^2. It enjoys a very good location, only

450m from the Tiantongyuan S. MRT station. The project consists of two 12-story towers. There are 940 residential/office units and sufficient parking space (above ground plus a three-story underground parking). From the perspective of New Urbanism, providing this much parking space for a residential complex within walking distance from a MRT station undermines the goal of encouraging transit use. Such inefficiency is mainly resulted from the separated planning processes between the infrastructure and urban development, which is a prevailing problem in many Chinese cities. On the other hand, until September 2011, the podium shopping space of Longde Zijin was still unoccupied, suggesting a lack of attractiveness in the market as compared to the Longde Square right next door. Most of its residential/office units are occupied by small companies such as printing shops, wedding planning services, and tutoring companies.

Image 6.4 The Pedestrian Environment on Litang Road

Exclusive Lanes for BRT Line 3

Looking from the Overpass to access the BRT Stop & MRT Station

Street Vendors at the foot of an Overpass by a MRT Station

Overpass to the MRT Station

Source: The author, 2011

Some land in the west part of the study area was industrial land in 2003, but has been turned into office buildings by companies by 2010, such as China Coal Construction Group (CCCG), as seen in Map 6.4. Altogether, commercial, office and mixed uses accounted for 12.68% of the total study area in 2010, increasing from 3.28% in 2003.

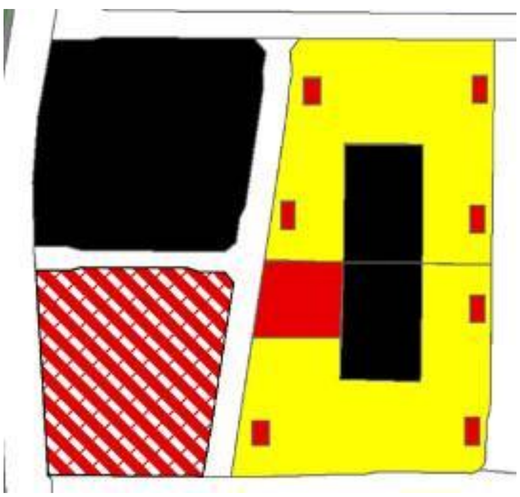
The area bounded by Litang Road, Taipingzhuang Zhong 2nd Street, Lishuiqiao E 1st Street and Taipingzhuang Zhong St was identified as the core area of the Tiantongyuan Neighborhood, defined by the planners. It is located right by Litang Road and between two MRT stations. The plan was released and revised in 2006, aimed at creating a local core of business, financial, and administrative activities and to provide medical service facilities for local residents. The original detailed plan included a round central green space in the center with a diameter of 280 meters. All the other buildings were to be arranged in a concentric pattern (see Map 6.6). Later, this plan was revised, dividing the land into four blocks. The Northwest block was designated to be a level 3 hospital. The Southwest block was designated to be mixed use, featuring office buildings and commercial space. The other two blocks were planned to be residential, with some commercial buildings and a central green space. The share of residential construction area was increased to 88.8%, as compared to the previous plan. The actual development has followed the revised plan.

Although the design and development of this core area looks like a transit oriented development (TOD), it is not the result of an intentional TOD process. The land was left to the last to be developed, after almost all the residential development in the Tiantongyuan Neighborhood was completed, suggesting that it is more of a response to the demands of local residents. The whole Tiantongyuan Neighborhood was developed in phases, starting in 1998. Residential development was first, followed by commercial development that serves the local residents. There has been a lack of office development.

With the surge in housing prices since 2007, real estate developers consider residential development as a highly profitable development product with rapid payback. The priority given to residential development and delayed development of public services echoes suburban development trajectories in general in Beijing.

Original Detailed Plan in 2006

Adjusted Detailed Plan in 2006



Actual Land Development in 2010

Satellite Image in 2010

Map 6.6 Tiantongyuan Core Area

Urban residential development has been the main land use in the study area. Its share of land use increased from 24.56% in 2003 to 34.73% in 2010. The earliest development appeared on the east side of Litang Road and is mostly 6-story walk-ups.

Later residential development is mostly high-rises, like those on the west side of Litang Road (see Table 6.4 and Figure 6.2).

Table 6.4 Tiantongyuan Study Area Land Use Change by Type, 2003-2010

Land Use Types	2003		2006		2010	
	Area (m^2)	Share (%)	Area (m^2)	Share (%)	Area (m^2)	Share (%)
Urban Residential	871201	24.6	871201	24.6	1231683	34.7
Rural Residential	52240	1.5	52240	1.5	52240	1.5
Commercial	116242	3.3	235245	6.6	319102	9.0
Mixed Use	0	0.0	0	0.0	113373	3.2
Office	0	0.0	0	0.0	16855	0.5
Industrial	402930	11.4	283928	8.0	148716	4.2
Administration	11218	0.3	11218	0.3	11218	0.3
Education	56149	1.6	56149	1.6	56149	1.6
Public Facilities	321327	9.1	321327	9.1	83334	2.3
Hospital	10209	0.3	10209	0.3	14024	0.4
Parks/Public Space	67350	1.9	67350	1.9	67350	1.9
Agricultural & Forrest	280006	7.9	280006	7.9	273724	7.7
Railroads & Roads	475394	13.4	604392	17.0	651756	18.4
Vacant Land	573141	16.2	444140	12.5	197070	5.6
Special Use	309567	8.7	309567	8.7	309567	8.7
Total	3546975	100.0	3546972	100.0	3546164	100.0

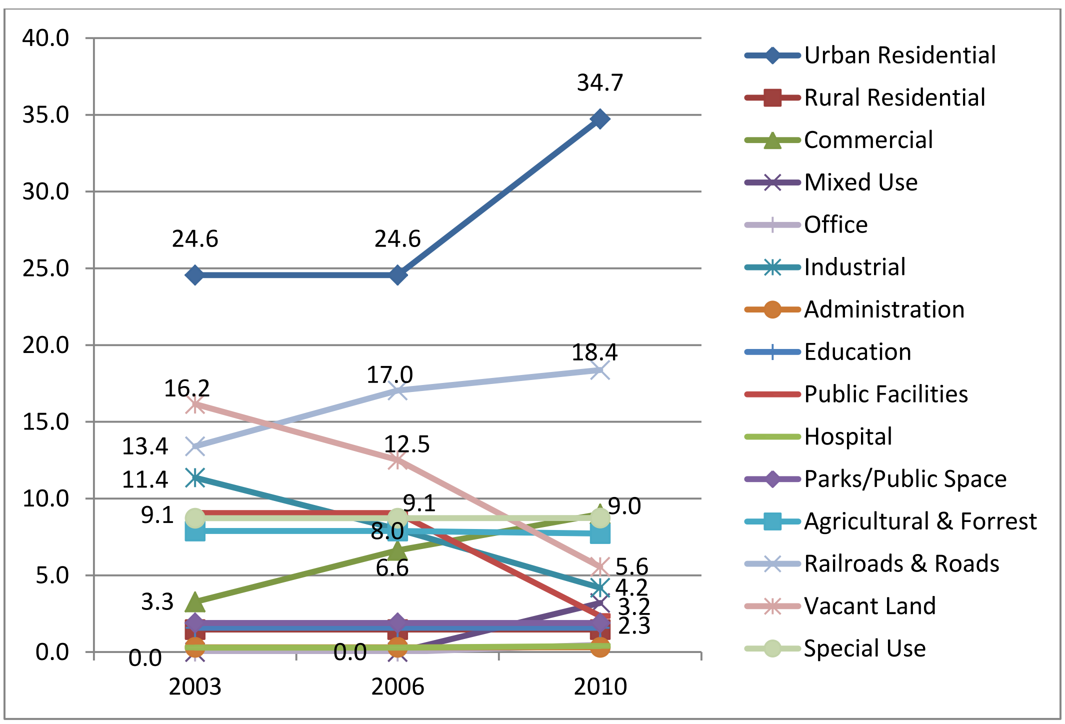


Figure 6.2 Tiantongyuan Study Area Land Use Change by Type, 2003-2010

6.2.2 Population and Labor

Both the total number of residents and occupancy rates have been increasing over the past ten years. According to interviews with local residents and real estate agents, the majority of early residents in Tiantongyuan were young people looking for affordable housing. The fact that the 8km^2 Tiantongyuan Neighborhood was constructed by one sole developer guaranteed a critical mass of residential space. Based on this massive development, there are a few other development projects in the adjacent areas, especially those next to the Lishuiqiao MRT interchange station. Although never published officially, the total number of residents in the Tiantongyuan area is estimated to have exceeded 300,000 in 2010. With commercial and mixed use properties being developed in recent years, the area is turning into a comprehensive neighborhood. However, office space is severely inadequate. Local employment opportunities are largely confined to retail and dining services.

Household occupancy patterns in the Tiantongyuan Study Area are shown in Table 6.5. The figures are presented in terms of the number of households, average household size and the occupancy rate of residential units.

Table 6.5 Residents Estimates in Tiantongyuan Study Area

	Average Households			Estimated Total Residents (persons)
	Number	Size (p/hh*)	Occupancy Rate (%)	
2003	20,000	2.9	55%	32,000
2006	20,000	2.7	70%	37,800
2010	26,000	2.45	95%	60,500

Data source: Census Data 2000 and 2010, Beijing Population 1% Survey 2005, interviews of local residents.
* p/hh: persons/household

According to focus group interviews with local residents, about 50% of Tiantongyuan’s residents work in major employment clusters of Beijing, (e.g. the CBD, Zhongguancun, Shangdi and Dongdan). Anecdotally, the morning rush hour is characterized by a massive exodus of passengers leaving from the Tiantongyuan area via MRT line 5, and a comparably limited number of passengers arriving into Tiantongyuan from other destinations. Although anecdotal, this observation suggests a residential-employment imbalance in the Tiantongyuan area.

There were limited employment opportunities within the study area before 2006. But with the opening of MRT line 5, Longde Square, Ya'ao Hailong Electronics Market, North Pearl Market, Longde Zijin were developed, creating thousands of jobs in retailing and service. The number of employment places in the study area is estimated in Table 6.6, based on the types and sizes of business.

Table 6.6 Employment Estimates in Tiantongyuan Study Area

	2003	2006	2010
Commercial Cluster A (Longde Square & Ya'ao Hailong Electronics Market)	0	0	5000
Commercial Cluster B (Longde Zijin)	0	0	1500
Commercial Cluster C	500	500	500
Commercial Cluster D	200	200	200
Commercial Cluster E	100	100	100
Commercial Cluster F	300	300	300
Other Streetside Restaurants and shops	200	200	300
Others (kindergartens, clinics, etc.)	200	300	600
Total	1500	1600	8500

Source: Websites and Interviews.

6.2.3 Public Services

It is obvious that a certain amount of public services are required to serve a large community of over 300,000 residents. However, the inadequacy of public services, especially hospitals, schools and kindergartens has been one of the main complaints of the residents in the Tiantongyuan Neighborhood. According to a survey undertaken by the community in 2010 (results are displayed on their website), when queried "why [are] residents leaving our neighborhood?" 83% of the respondents indicated that they had already moved or were planning to move. Of all the reasons for moving, children's education accounted for 60% of responses; traffic congestion 30%, and the inadequacy of hospital and health care facilities 9% (BJNews, June 5, 2010). The lack of adequate public services is significantly affecting resident's quality of life in Tiantongyuan Neighborhood.

Currently, there is no Level 3 hospital in the Neighborhood. Medical services available are mostly Level 1 hospitals and clinics, which do not meet demand. Fortunately, a Level 3 General Hospital started construction in April 2010 and will be opened by the end of 2013. Before then, the residents have to travel to other parts of Beijing for medical care.

There is also a limited choice of kindergartens and schools that live up to the standards expected by residents. For a community of 300,000 people there are nineteen kindergartens, insufficient to meet the population demands, according to focus group discussion. And all kindergartens are privately-owned. The situation is worse for schools. In the larger Tiantongyuan area (Tiantongyuan Neighborhood and the areas right adjacent to it), there are only two public primary schools and two public middle schools, yet they serve a catchment area of 10,000 school-age children (Beijing Evening News, July 26, 2010).

The profit-chasing motives of developers have resulted in a rapid expansion of residential development and an inappropriate, or even negligent, accommodation for public services. Among other social problems, this has led to increased travel outside of the neighborhood for school and medical services that, I argue, should be normatively accommodated within the boundaries of a community of 300,000 people.

6.2.4 Real Estate Market

Housing prices in the Tiantongyuan were initially low in 1998, at about 2,500 RMB/m^2. Due to a policy change in 2007 whereby housing were allowed to be changed from ‘affordable’ to ‘commodity’ designation (see Chapter 3), and an exogenous housing price surge that affected all of Beijing, the average resale price jumped to 8,000 RMB/m^2 in 2007 and has kept growing; as of 2012, the average sale price in Tiantongyuan reached 15,000 RMB/m^2 (see Figure 6.3).

Roughly, a 5% location premium exists for apartments closer to the MRT stations in Tiantongyuan neighborhood. According to the results of the resident survey, 68.5% of the correspondents agree that there should be a price premium for apartments located closer to the MRT stations. Of those residents, the majority think that a 5% premium is an acceptable price to pay.

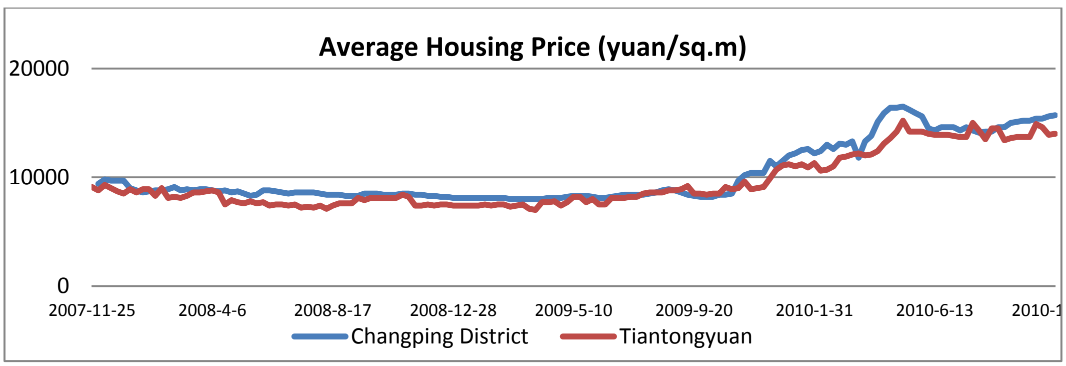
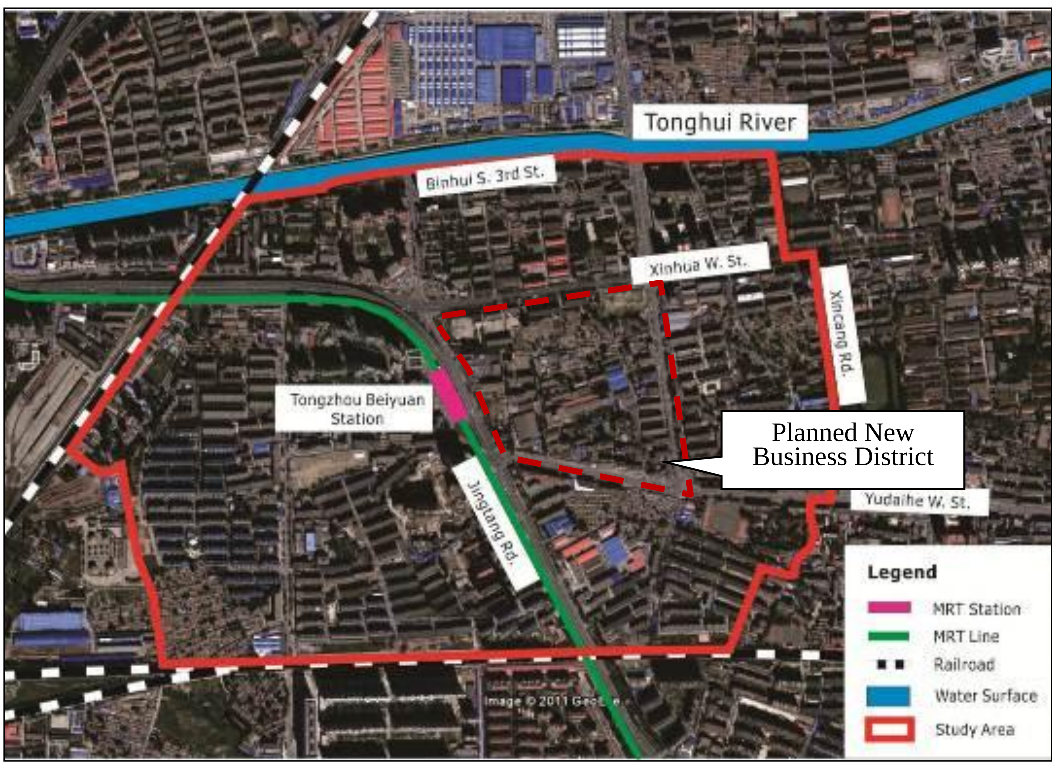


Figure 6.3 Change of Housing Price in Tiantongyuan, as Compared to Changping District Average, 2007-2010

Source: http://www.fangjia.com

6.3 Tongzhou Beiyuan Study Area (Tongzhou Beiyuan MRT Station)

The Tongzhou Beiyuan study area is located within the Beiyuan Street Office of the Tongzhou District. It is strictly bounded by the Tonghui River in the north, two railroads in the west and the south, and Xincang Road in the east (see Map 6.7). The total area is about 2.4 km^2, noticeably smaller than the other two study areas. The MRT station is called Tongzhou Beiyuan, on MRT line 1 (also known as the Batong line, as the extension of line 1). The study area has had a long history of settlement and the plans for MRT development were announced as far back as late 1990s. Since the beginning of the study period in 2001, there has always been some urban development in Tongzhou Beiyuan and the area was already planned to accommodate a business district.



Map 6.7 Tongzhou Beiyuan Study Area Context

Source: The author, 2011

Urban redevelopment is the key dynamic for growth in this study area. Due to the high cost of relocation, this process has been taking place slowly, especially the planned business district. Although the plan was proposed around 2000 by the Beijing municipality in consideration of the incoming MRT line, land clearance did not occur until around 2009. By 2011, only a small portion of the land had been cleared.

6.3.1 Land Use Changes

With the assistance of land use data, historical remote sensing images, information gathered in field investigation and local resident interviews, the historic land use changes for the study area since 2003 have been analyzed in ArcGIS and illustrated in Map 6.8.

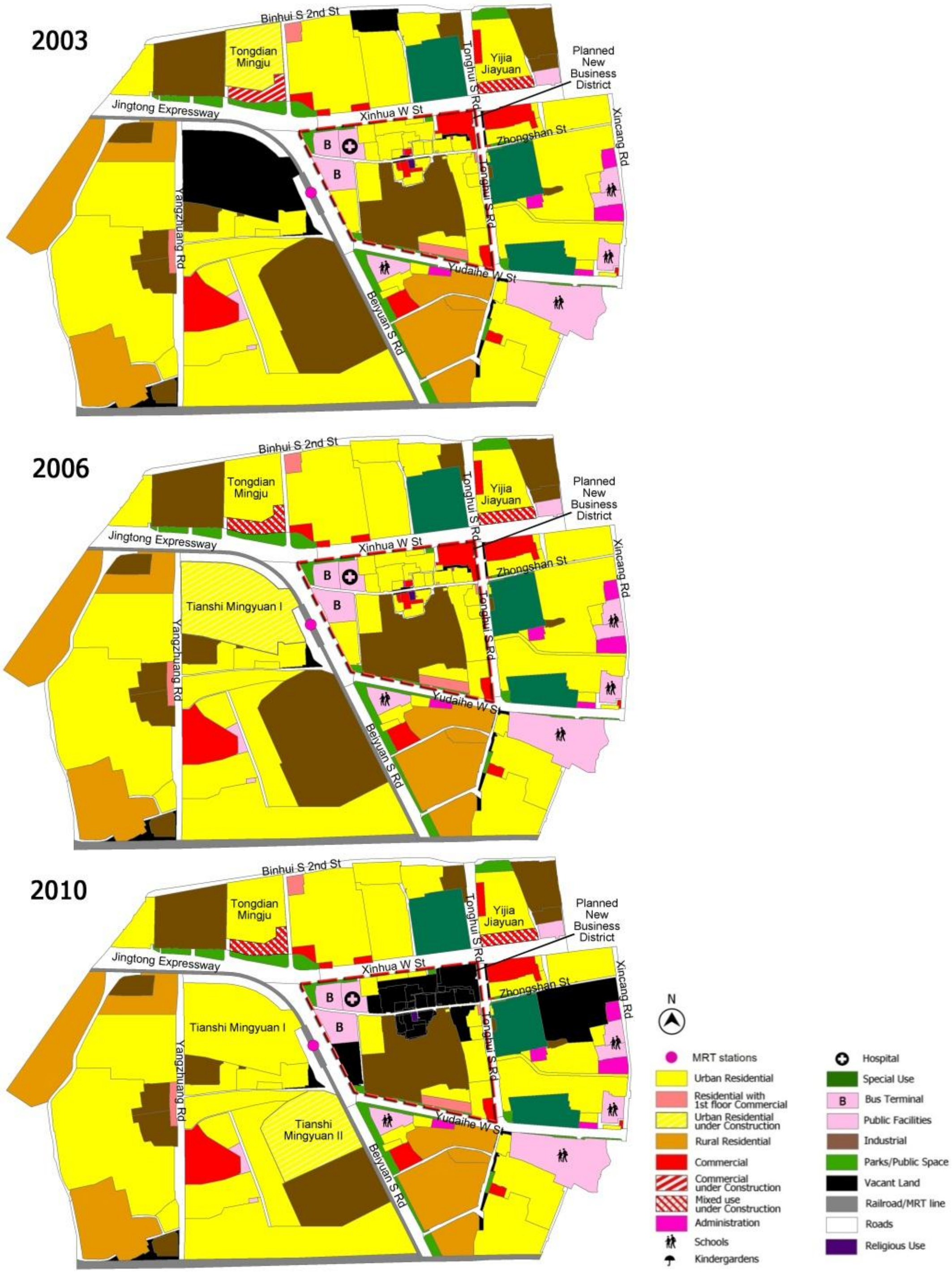
Unlike Huilongguan and Tiantongyuan, all the changes in land usage in Tongzhou Beiyuan happened in an area within 450 meters from the MRT station, primarily in the area to the immediate west of the station. Two major redevelopment projects were built since 2003, the majority of which is urban residential development. The result is that the share of urban residential land use increased slightly from 41.15% in 2003 to 44.62%. During this time, rural residential land remained the same. Several land parcels for special use also remained unchanged.

Xinhua West Street connects the area with Beijing's CBD area directly, and is the busiest street in the area. Its two intersections with Jintang Road and Tonghui South Road are the main clusters of commercial activities.

Land clearance of the planned business district has been remarkably slow. There had been much progress from 2000 to 2008. By 2010, of the total 240,000 m^2 land, only about 30% had been cleared. According to interviews with local administrators, there are several reasons for this slow redevelopment progress: i) the land was occupied by various small units and it has been difficult to negotiate the deals with them one by one; ii) with the plan and early availability of MRT service the land value has been increasing quickly, and existing residents have leveraged this knowledge to negotiate for high relocation fees; iii) due to severe traffic congestion on the road leading to the CBD, attracting commercial tenants to relocate to this area has been difficult; iv) two 'special units', a military hospital and a mosque, have not reached an agreement to relocate.

In 2010, when land clearance work finally began, news reports released information about the developmental details of this business district. It will be developed by two sole developers, Beijing Wangfujing Department Store Group and Canadian Ivanhoe Group. It will include financial sector office spaces, commerce, retail space, cultural amenities, and apartments. Major company headquarters, department stores, luxury stores, five star hotels, movie theatre and business apartments will be built with expectation of such tenants. This project has the best potential to become a TOD among all three study areas, if well planned and developed, as there is land available for it and proposed plan for such a mixed-use development.

The proportion of land taken up by industrial uses slightly decreased from 14.05% in 2003 to 11.21% in 2010. Major industries in the Tongzhou Beiyuan study area include optical-electronics, telecom technologies, publishing and printing. Like the old work unit style plants, these factories normally include residential dormitories for their employees (see Table 6.7). However, as part of the redevelopment process, some of these factories have been, or are in the process of being, redeveloped into exclusively residential projects such as the Tianshi Mingyuan Phase II site in Map 6.8-2010. The relatively high share of industrial land and the prevalence of some government offices offer employment opportunities for the local residents. There is also a significant share of residents who work in the CBD of Beijing or Chaoyang District that are conveniently connected by the Jingtong expressway and MRT lines.



Map 6.8 Land Use Changes in Tongzhou Beiyuan Study Area, in 2003, 2006 and 2010

Source: The author, 2011

Table 6.7 Tongzhou Beiyuan Study Area Land Use Change by Type, 2003-2010

	2003		2006		2010	
Land Use Types	Area (m^2)	Share (%)	Area (m^2)	Share (%)	Area (m^2)	Share (%)
Urban Residential	980265	41.2	1088012	45.7	1062723	44.6
Rural Residential	230227	9.7	230227	9.7	230227	9.7
Commercial	81143	3.4	70605	3.0	57595	2.4
Mixed Use	7677	0.3	18215	0.8	18215	0.8
Industrial	334615	14.0	334615	14.0	267108	11.2
Administration	14249	0.6	14249	0.6	14034	0.6
Education	68708	2.9	68708	2.9	68708	2.9
Public Facilities	7847	0.3	7847	0.3	7762	0.3
Hospital	7587	0.3	7587	0.3	7587	0.3
Parks/Public Space	45043	1.9	45043	1.9	45043	1.9
Railroads & Roads	374544	15.7	374544	15.7	372011	15.6
Vacant Land	119922	5.0	12176	0.5	120815	5.1
Special Use	89981	3.8	89981	3.8	89981	3.8
Bus Terminal	19481	0.8	19481	0.8	19481	0.8
Religious	607	0.0	607	0.0	607	0.0
Total	2381897	100.0	2381897	100.0	2381897	100.0

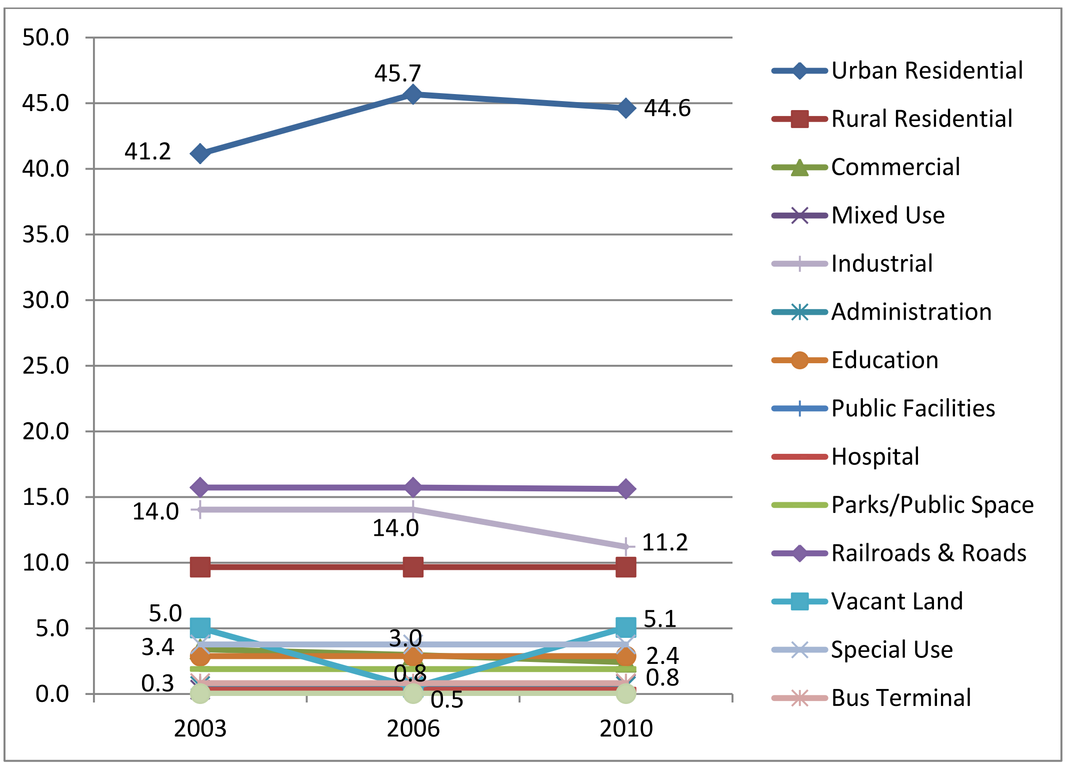


Figure 6.4 Tongzhou Beiyuan Study Area Land Use Change by Type, 2003-2010

Source: The author, 2011

6.3.2 Population and Labor

The Tongzhou Beiyuan Study Area is predominantly a residential neighborhood with an established history. According to a local official, some old blocks feature older residents and some new properties are mostly occupied by young white collar workers employed in the CBD or its surrounding area. Population data for 2010 is available on the street office's official website. For the whole district, there were 82,000 permanent residents and a floating population of 28,000 people in2010. For the study area, there were 53,300 residents in 2010. The numbers of total residents for 2003 and 2006 were estimated by deducting population from the new residential buildings built and adding the residents relocated after 2006 (Table 6.8).

Table 6.8 Residents Estimates in Tongzhou Beiyuan Study Area

	Estimated Total Residents (persons)
2003	48,000
2006	48,000
2010	53,300

Data source: http://by.bjtzh.gov.cn/.

6.3.3 Public Services

All public services in Tongzhou Beiyuan Street Office and the surrounding areas are accessible to the Tongzhou Beiyuan Study Area. Overall, there are adequate and quality medical and education resources available for the residents according to focus group discussion.

For a total number of 82,000 residents in the Tongzhou Beiyuan Street Office, there are four good general hospitals nearby. These are very good public hospitals and very accessible for the residents.

For the Tongzhou Beiyuan Study Area, there are over 10 primary schools, 80% of which are public schools. There are also over 10 middle/high schools, most of which are public too. One major international school is currently under construction and will be open soon. There is also a campus of Beijing Normal University.

6.3.4 Real Estate Markets

Overall, urban planning and redevelopment plans have played an important role in the fluctuating house price in the Tongzhou District since 2007. This steep fluctuation of real estate market is also reflected in the Tongzhou Beiyuan Study Area. The Tongdian Mingju residential project, for example, saw property prices fluctuate between 7,000 to10,000 RMB/m^2 from 2007 to 2009. However, prices surged in early 2010, peaking in mid-2010 at 20,000 RMB/m^2, when a series of talks was held by district government officials at the end of 2009 regarding the “Tongzhou New Town” plan. The talks conveyed the strong determination of the District government in terms of pushing the redevelopment of Tongzhou District into a “Regional Service Center, Cultural Industrial Base and Waterfront Amenity New Town”, with a planned central urban area of 115km^2 and total population of 900,000 by 2020. In January of 2010 this plan was ultimately approved by the Municipal Planning Commission and the Beijing Municipal government. Such a strong commitment of the District government was taken advantage of by a lot of developers and incited many private citizens to rush out and buy property causing a temporary housing bubble. Soon after mid-2010, prices dropped off dramatically and purchases. At the time of writing, the average prices in Tongdian Mingju were reported to be around 16,000 RMB/m^2 (see Figure 6.5), comparable to other residential developments located beyond the 5th Ring Road and near MRT access.

A small location premium of roughly 5% seems to exist between apartments of comparable quality located either near or away from MRT stations, based on interviews with local real estate agents. This figure is smaller than those of Huilongguan and Tiantongyuan neighborhoods and is consistent with the relatively small contribution of MRT service to the residents’ travels (see details of travel mode share data in Chapter 7). More mixed land uses in Tongzhou Beiyuan study area results in shorter commuting distances for residents who work close by their residence. The survey results echo this low location premium. 53.1% of the correspondents do not think that apartments right by the MRT stations should be more expensive than those farther away from the stations. Of the remaining respondents who would be willing to pay a location premium, 60% think the premium should be lower than 5% above current market prices while 30% think it should be in the range of 6-10%.

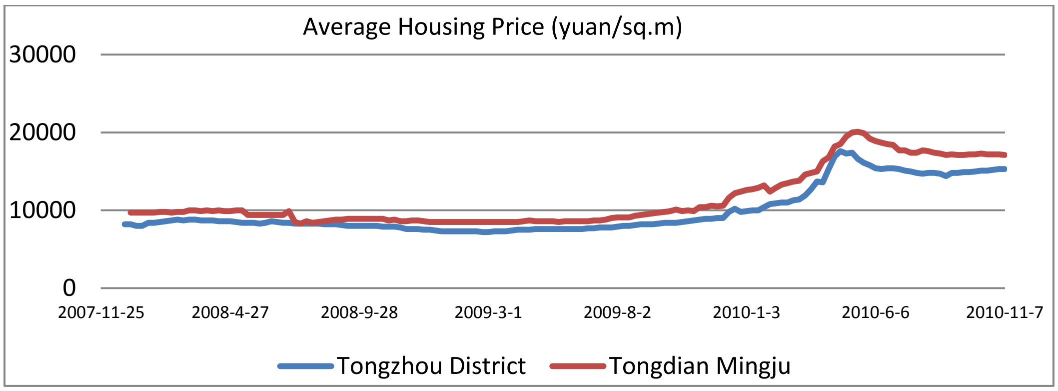


Figure 6.5 Change of Housing Price in Tongzhou Beiyuan, as Compared to Tongzhou District Average, 2007-2010
Source: http://www.fangjia.com

6.4 Comparison across Neighborhoods

6.4.1 Land Use Changes

Trajectories of land use changes of all three selected neighborhoods are illustrated and compared in Figure 6.6. In all cases, residential use has benefited more than any other land use types as it accounts for the biggest share. This is mainly due to: i) the fact that both Huilongguan and Tiantongyuan were designed to be affordable housing projects from the beginning; ii) land prices have gone up significantly since 2000 (see Figure 6.7 for example) and land available for development has become very limited; and iii) the developer's priority for profit chasing as the investment return time of residential sales is short. Mixed use development has been emerging lately, but only account for very small percentages in all neighborhoods.

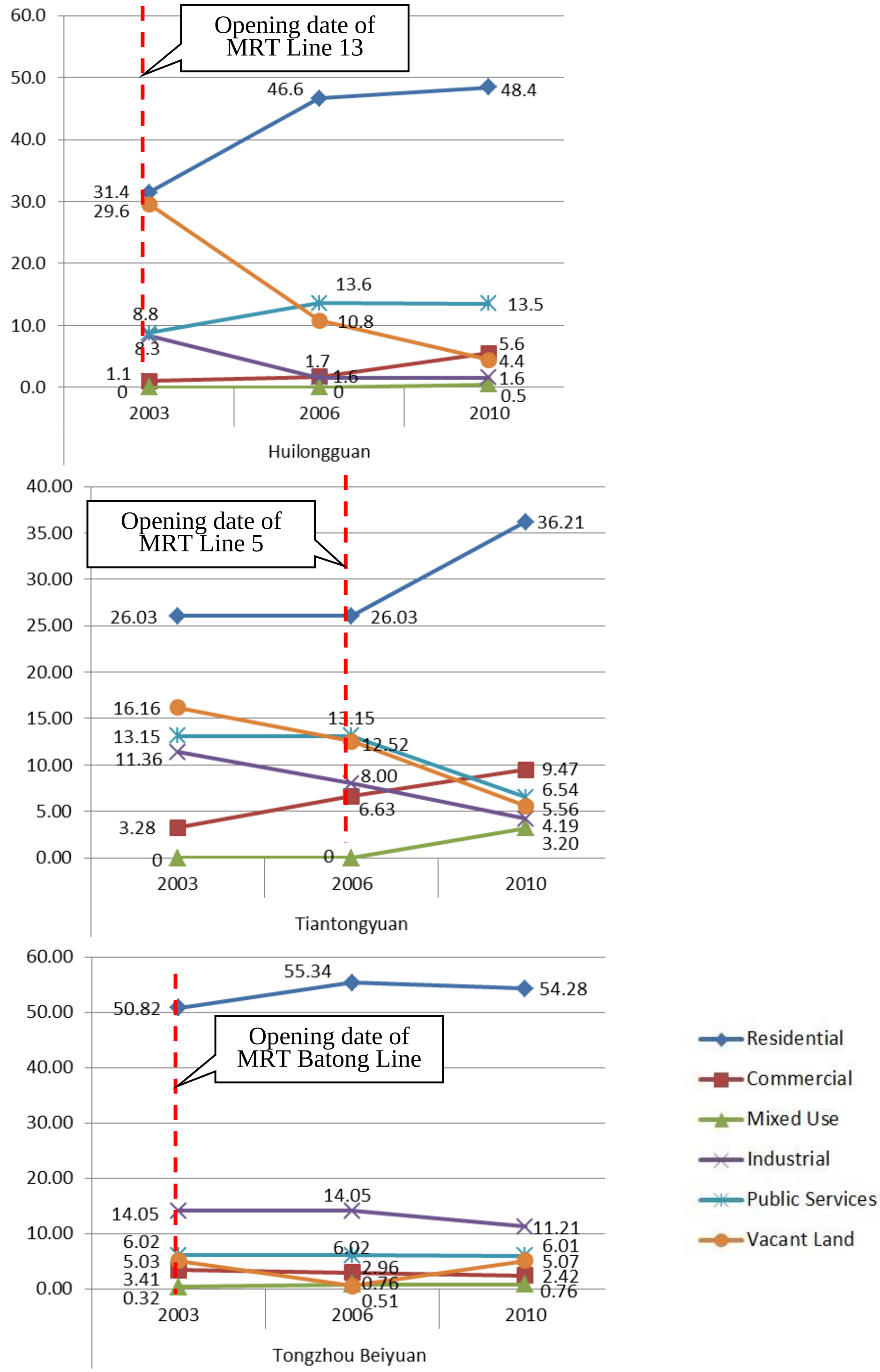


Figure 6.6 Comparison of Major Land Use Changes, with Reference to MRT Opening Date, 2003-2010

Source: The author, 2011

The timing of MRT availability affects the land use development in a notable way. Right after the MRT line became available in the selected neighborhoods (2003 for Huilongguan and Tongzhou Beiyuan, and 2007 for Tiantongyuan), the area for residential use increased significantly (see Figure 6.6). Furthermore, as Tongzhou Beiyuan is an established neighborhood with longer history, it has less flexibility than the other two in terms of land use changes, which is reflected in the smaller growth rate of residential use

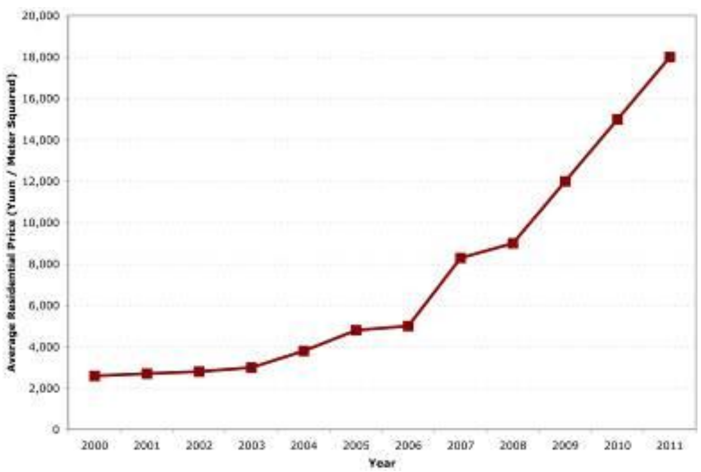


Figure 6.7 Land Prices in the Huilongguan Study Area, 2000-2011

Source: Webster et al, 2011.

6.4.2 Building Form and Densities

Increased population density and actual FAR are observed in all of the study areas (see Table 6.9), of which the main land use type developed has been residential. The building forms in all three neighborhoods are similar, in a way that earlier development takes the form of 6-storey walk-ups and newer development tends to be mid or high rises. The walk-ups have an average FAR of 1.5-2.2, while the FARs of mid and high rises range between 3 and 5, such as the Xinlongcheng project in Huilongguan whose FAR goes up to around 4.5[30]. Map 6.9 shows the FARs of actual development by blocks in all three study areas, calculated by hand. Higher FARs are also observed at the intersections of major roads, where commercial or mixed-use are the main land use types.

[30] This is actual FAR, based on calculation by the author.

Map 6.9 Actual FAR in all three Study Area, 2011

It is observed that the actual FAR on the ground is much higher than the officially released data which was reported by the real estate developers, especially for newer development projects. In China, the allowed range for residential FAR is preset at a relatively low level, with little flexibility for strategic locations such as the areas around a transit station. But the market incentives encourage the developers to build in higher densities as there is still a large demand for housing. As a result, the FAR guidelines are often compromised in newer development and the developers tend to twist the numbers on paper in order to comply with the regulations. Such market action is not necessarily a bad thing, because it encourages denser development where appropriate and improves land use efficiency by accommodating more people on a given amount of land.

The increases of FAR are more related to the construction date than the spatial location relative to the transit station. The main reasons are: i) the land parcels right by the station were already developed when MRT service became available; and ii) there is a lack of incentives for developing in higher densities by the transit station as the center of living for the neighborhood is effectively located to the north of the station and along the Huilongguan W St.

Table 6.9 Estimates for Population Densities in the Neighborhoods, 2010

	Population Density (person/km^2)		Residential FAR Range	
	2003	2010	2003	2010
Huilongguan	9,500	16,000	0.9-2.4	0.9-4.5
Tiantongyuan	9,200	17,500	1.5-3.8	1.5-5
Tongzhou Beiyuan	20,000	22,500	0.9-2.4	0.9-3.8

Overall, actual FARs in the Tiantongyuan study area is higher than those in Huilongguan study area. And high-rise development appeared earlier in Tiantongyuan than in Huilongguan which features an early MRT access. However, this does not necessarily indicate that the availability MRT services failed to encourage development with higher FAR. According to an interview with the developer of Tiantongyuan

Neighborhood, the choice of building style is purely their preference for maximizing their profits when there was no sign of MRT development in the Neighborhood.

6.4.3 Physical Barriers

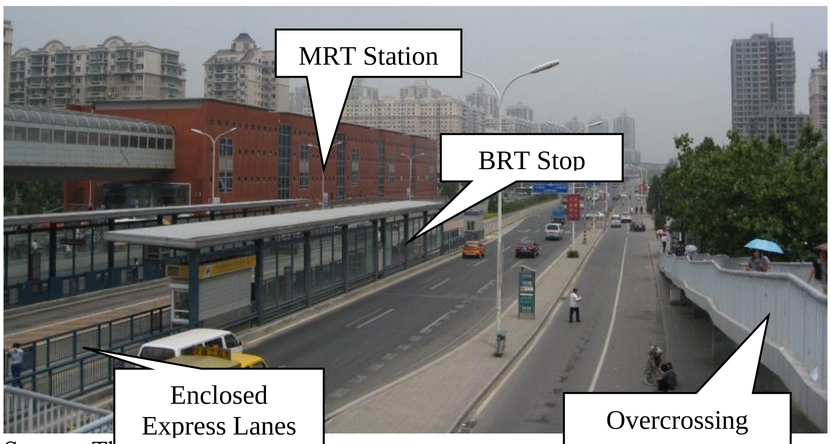
Due to the plan of MRT routes, above ground MRT tracks, wide streets with designated lanes, or lack of pedestrian friendly design of micro environment, physical barriers exist in all three neighborhoods which reduce the actual service area of transit stations and make it more difficult for the stations to be integrated with surrounding development.

In Huilongguan, the MRT line runs side by side with an existing railroad track, presenting a barrier for residents in the south section wishing to access the MRT station on foot, largely limiting the effective service area to the north side. Such a physical barrier contributed to the much slower and more fragmented development in the southern part of the community. Land parcels in the north were developed in a checkerboard style with newly constructed grid pattern roads. But in the south, partly due to previous existing land uses such as the martial arts school, and the Huilongguan hospital, land development has been taking place on less regularly-shaped parcels. Socially, the residents in the north section share a sense of neighborhood, but most have little idea about what is happening in the south and do not consider residents there to be part of the same community.

In Tiantongyuan, the MRT stations are separated from the east part of the neighborhood by the 70-meter wide Litang Rd., which contains designated lanes for BRT line #3. Eight pedestrian overcrossings were placed across the 2.8km section of Litang Rd as the solution for access facilitation, without being connected with any buildings around the stations. MRT riders have to detour and walk a long way to be able to use these overcrossings to get to the MRT station (see Image 6.5). According to focus group discussion, the residents find it unpleasant to walk to or around the station, especially in harsh weather such as hot summer or snowy winter.

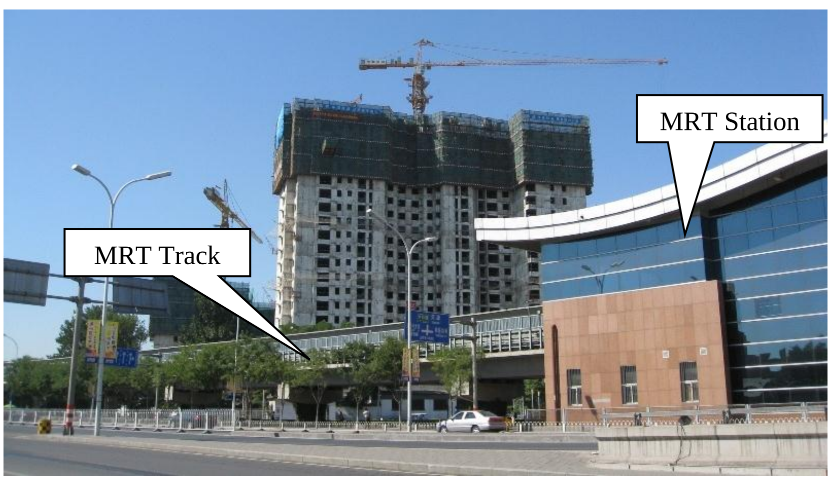
In Tongzhou Beiyuan, the physical barrier is mainly caused by the above ground MRT track and the parallel arterial road (Jingtong Expressway) (see Image 6.6).

Image 6.5 Lanes and Functions of Litang Road



Source: The author, 2011.

Image 6.6 Tongzhou Beiyuan MRT Station and Above Ground Track



Source: The author, 2011.

6.4.4 Housing Affordability and Location Premiums

A hedonic model was run to predict the proximity of residences to MRT stations on housing prices in RMB/m^2. Due to the similarity of apartment quality and floor plans for most of the residential buildings in these neighborhoods and, most importantly, by the fact that housing price in China is measure by RMB per square meter, the explanatory variables were limited to distance to the MRT station, age of the building, and density. Density was represented by a dummy variable depending on whether the residential building was mid- to high-rise or low-rise. Because none of the explanatory variables were expected to vary in a non-linear fashion (e.g. the marginal rate of return on an increasing number of bedrooms gets progressively smaller) I chose to run an ordinary least squares regression, rather than a logarithmic regression more typical of hedonic housing price models, in STATA. The result is shown in Figure 6.8. Distance and density show the expected signs (is negatively associated with housing price), but both are insignificant at the 95% confidence level. Age of the building is neither significantly associated with housing prices, nor does it show the expected sign (increasing age is associated with increasing housing prices). One of the main limitations for this regression analysis is the limited number of observations (50 blocks). But since this represents all the available data points in these neighborhoods, I opted to rely on the results of the survey of the residents and interviews with local real estate agencies to understand the dynamics of the housing price difference.

```
. reg price distance age density

      Source |       SS       df       MS              Number of obs =      50
-------------+------------------------------           F(  3,    46) =    1.12
       Model |  7235141.19     3  2411713.73           Prob > F      =  0.3500
    Residual |  98875514.8    46  2149467.71           R-squared     =  0.0682
-------------+------------------------------           Adj R-squared =  0.0074
       Total |   106110656    49  2165523.59           Root MSE      =  1466.1

------------------------------------------------------------------------------
       price |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    distance |  -.0121214   .4231934    -0.03   0.977    -.8639656    .8397227
         age |   8.506401    81.7788     0.10   0.918    -156.1058    173.1186
     density |  -975.2205   614.3075    -1.59   0.119    -2211.757    261.3163
       _cons |   15918.62   966.7834    16.47   0.000     13972.59    17864.66
------------------------------------------------------------------------------
```

Figure 6.8 Hedonic Analysis for the Neighborhoods

Based on my survey, which will be explained in more detail in the next chapter, the average monthly household income levels for Huilongguan, Tiantongyuan and

Tongzhou Beiyuan are 16,000, 17,000 and 6,000 RMB/year respectively, while the average housing prices in 2011[31] were about the same for all three neighborhoods: 15,000 – 17,000 RMB/m^2. Assuming an average apartment size of 80 m^2, the ratio of housing price to annual income for Huilongguan and Tiantongyuan are 6.7 and 6 and a remarkable 17.8 in Tongzhou Beiyuan. The World Bank considers the ratio of 5 to 1 as affordable for local residents, while the United Nations sets the standard at even lower, 3:1 (Xinhua News, December 22, 2006). Obviously, Tongzhou Beiyuan has a much lower housing affordability than the other two neighborhoods.

Based on the survey, the residents in all three neighborhoods regard a 5% higher price for apartments closer to the MRT station as acceptable, a price they would be willing to pay. For higher quality units, a 10% accessibility premium was indicated as acceptable by local residents.

6.5 Assessment & Implications of Land Use Changes and Real Estate Market

Analysis in both Chapter 5 and 6 reveal the timeline of development of all three study areas, and the impacts of MRT development on the changes of urban land use and the real estate market. Assessment of these changes is made in the following sections from the perspective of sustainability implications.

6.5.1 Suburbanization in Beijing

Government policies and planning are strong pushes of the suburbanization process in Beijing, as well as in many Chinese cities, from much earlier transitions in land and housing regimes and industrial relocation to more recent old town

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[31] Due to stringent state policies over the real estate market in China which limit the number of houses per household and require higher down payment, the housing price in Beijing has been declining slightly in 2012. But this is beyond the time frame of this study (2001-2011). So this latest change in housing market is not reflected in this dissertation.

redevelopment, policy oriented housing[32] movement and dynamic catalyst of important events (such as the 2008 Olympic Games). During this process, residential development (whether for relocated population or as subsidized residences) contributes largely to the incremental urban development on the edge of the built-up area. The high percentages of residential projects in the three selected neighborhoods showcase such residential biased suburban development.

Suburban neighborhoods in Beijing are developed at high densities with modern structures which do not look much different from their urban counterparts. But functions of the buildings in the suburban areas are much less diversified than those in urban areas. This trend has resulted from the "New City" development style that has been popular among real estate developers in China for over a decade. In a typical "New City" development, residential buildings account for the majority of the total floor area (often over 75%). Internal green public open spaces are nicely designed and laid out for the entertainment of its residents. A commercial center, including supermarkets, shops and restaurants, is provided to meet the daily demand. These "New Cities" usually take a large piece of land in near suburban areas and provide a complete living experience for the residents. However, a major weakness of this development style is that it does not provide any employment opportunities other than low-skilled service jobs (in restaurants and stores) that the decidedly middle income occupants would not consider. At the city level, these "New Cities" contribute significantly to the dramatic increase of length and time of commuting trips over the past decade, as well as the rapid growth of car ownership. Some may argue that residents could choose to live in the neighborhood close to their workplace. Assuming that some of them are able to afford such choice, the

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[32] Policy Oriented Housing refers to residential development that enjoys some form of public subsidy, either in terms of land supply or taxes. There are different types of such policy oriented housing in China, including affordable housing, low-rent public housing, limited price housing, etc.

chances of all family members working in the same location are very slim. Thus, in reality, only a subset of family members would benefit. The two neighborhoods of Huilongguan and Tiantongyuan, although do not bear the title of "New City", share similar employment and housing characteristics.

The availability of MRT services in these suburban neighborhoods encouraged the expansion of development that was initiated by policies or plans. But evidences in this study show that residential use benefits significantly more than any other types of land use, as a result of the developers' activities of maximizing profits and quick return.

6.5.2 Station Precincts Present Impediments to TOD, despite Increased FAR and Population Density

MRT stations in the suburbs are significantly underutilized. They are commonly left as open space (considering the massive passenger flows at peak hours) and sometimes separated from residential buildings or other services by physical barriers, as observed in all three selected neighborhoods. Such physical barriers often result in poor access at the micro level, exacerbated by a lack of pedestrian overpasses and controlled railroad crossings, wide (barrier) streets, etc. As noted, these conditions often skew growth to one side, such as in the case of Huilongguan neighborhood.

The lack of regulation in the station areas is resulting in chaos and unsafety, which is not pedestrian friendly. Local residents simply take the stations as the entrance to a travel mode. The large population of residents in these neighborhoods causes overwhelming passenger flows at peak hours, especially in the morning, that demands an open space as buffer zone and makes it difficult to plan any development around the stations (see Image 6.7).

All three study areas demonstrate a trend toward high-rise buildings in newer residential development and, related, higher FARs (see Table 6.9). Higher FARs increase the total population but also provide more spacing between buildings and more public space within the properties, albeit semi-private space. This cycle creates an environment potentially conducive to redevelopment near stations. All three study areas feature new redevelopment projects after the opening of MRT services near the MRT stations; in all cases in the form of high-rise development. As shown in Maps 6.2, 6.4 & 6.7, over half of the blocks near the stations have been (re)developed into high-rises. All of the blocks are anticipated to support high rise developments once the new Business District in Tongzhou Beiyuan is completed, indicating a positive impact of the strategic plan strengthened by early MRT construction.

Image 6.7 Morning Peak Hours at the MRT Stations

On the platform of Huilongguan Light Rail Station heading to Xizhimen, at 8:10 am, July 28, 2010.

Outside Huilongguan Light Rail Station, at 8:30am, July 28, 2010

Lining up to get into Tiantongyuan Station, morning peak hour, December 21, 2009

Lining up to get into Tongzhou Beiyuan Station, 7:30am, July 6, 2009

Source: The author, 2011

As a mixed-use development argued to yield optimal environmental and economic outcomes for MRT station areas, well planned and implemented TOD is rarely seen in Chinese cities. Many reasons contribute to this phenomenon:

i) Fast urban development results in unavailability of vacant or (re)developable land after MRT lines come in or even before the lines and stations are planned;

ii) For the developers, residential projects offer much shorter return period, higher profits and are in high demand; therefore residential development has appeared to be the main land use in all three study areas (see Figure 6.6);

iii) The developers observe the passenger flows induced by MRT and have begun to build some commercial and mixed-use properties adjacent to stations. This is seen in all three study areas. However, these developments appear to be a response to the demand of local residents and providing adequate public services have lagged far behind residential development;

iv) Although some commercial and mixed-use buildings are appearing around the stations, the scale of the blocks and building (e.g., in Tiantongyuan study area the blocks are about 300m*350m in size and the buildings are also large in scale), and above-ground/elevated MRT tracks largely reduce the walkability of these mixed-use areas, which should be a main feature of TOD; and,

v) The availability of MRT services becomes an impeder of TOD development, as it largely increases the land acquisition cost. The best example is the Tongzhou Beiyuan business district, which had been delayed for almost ten years. As soon as the difficulties of relocation are resolved and land cleared, this area has the potential to be a good example of TOD in Beijing.

In conclusion, land banking is important in the process of urban development, to provide opportunities of land development with higher efficiency.

6.5.3 Rural Collective to Urban Land Transition

In Beijing's recent development history, rural collective land has been disappearing and replaced with urban built area. Land transition processes from rural to urban have been a feature of the area around Beijing since the late 1990s when vacant land within the informal boundaries of the city center (within the 4^{th} Ring Road) was built out and urban development began to push outwards. In a recent study on land efficiency in Beijing, the demise of rural collective land at some locations in suburban Beijing has been dramatic and very rapid, e.g., from 54% in 2002 to 7% in 2010 Xiaohongmen, south of the 4^{th} Ring Road (Douglas Webster et al., 2011).

In the meantime, some villages were left behind and appear to be "trapped" by surrounding urban development, due to either lagging effect in the redevelopment process or high land acquisition costs brought about by nearby development. These villages are the main sources of low income housing for migrant workers and provide decent access to transportation links within the region.

The availability of MRT service acts as both accelerator and impeder of rural to urban land transition, the latter mainly due to the increased redevelopment cost. In the three study areas examined above, all had essentially completed the transition process to urban use by 2003. The percentage of rural collective land remained low and unchanged in all study neighborhoods in 2010. As seen in Table 6.10, the Huilongguan and Tiantongyuan study areas, feature every little remaining rural collective land. This is mainly because both of them exhibited "leap frog" development plans in which new affordable housing developments were constructed before any other (re)development happened in the surrounding area. Most of the land had been acquired before construction started and they acted as the catalyst for further redevelopment around them. The opening and operation of MRT lines did not affect the land transition process much. But adaptation activities have taken place to expand the functions of buildings, turning them into some form of mixed-use. Informal services are also arising spontaneously in response to market demand, most notably in the growth of informal as street vendors and tricycle “taxi” services. In the case of Tongzhou Beiyuan, the share of rural collective land is a little higher than the other two. The early availability of MRT service increased the land value and therefore the relocation cost of rural households for authorities. Relocation costs of existing residents were also one of reasons for impeded redevelopment of the planned business district area.

Table 6.10 Percentage of Rural Collective Land: 2003-2010

Study Area	2003	2010
Huilongguan (Huilongguan MRT)	0.87%	0.87%
Tiantongyuan (Tiantongyuan S. MRT)	1.47%	1.47%
Tongzhou Beiyuan (Tongzhou Beiyuan MRT)	9.67%	9.67%

Source: The author, 2011

6.5.4 Inadequate and Delayed Provision of Public Services

In China, public services, such as hospitals and schools in new development neighborhoods are required to be built by the developers and transferred to the local government for operation. However, in reality, developers hardly follow this rule due to their profit-maximizing nature. Both Huilongguan and Tiantongyuan study areas suffer from severely inadequate and delayed provision of community services (Tongzhou Beiyuan study area is an exception because it is a mature neighborhood).

The Profit-maximizing nature of the developers and the lack of supervision and enforcement of plans and other regulatory guidelines related to land development are the main reasons for inadequate public services. In new development neighborhoods, like Huilongguan and Tiantongyuan, residential uses become the main land use type. Land originally planned for medical facilities or schools most often is left to be built much later or changed to residential development completely or partially. Delays to build adequate public facilities may take up to ten years to be resolved, and often are not resolved at all. In some cases, e.g., the Zhongshan School in Tiantongyuan, public facilities were built by the developers at a certain point, but were leased to private service providers – a private, for-profit school in Tiantongyuan's case – instead of ceding them over to the local government.

The emergence of private for-profit schools, hospital and clinics creates a gap / shortcomings in public service provision. Private services in these neighborhoods are a market response to the inadequacy of public service provision. Despite the higher fees of private services, residents often do not consider them as good as the public ones, with established reputations.

As a result, adaptive actions are observed in both the Huilongguan and Tiantongyuan study areas. Many residents leave the neighborhoods and choose to rent in the city center for access to education for their children. At the same time, they rent out their suburban property to partially compensate their higher, central city living expenses.

6.5.5 Low Actual and Perceived Location Premium

The 5% property accessibility premium found in all three selected neighborhoods appears to be relatively low, considering the specific characteristics of Chinese suburbia especially in terms of high development densities and less car orientation. As noted in the work of Webster, et al (2011), the failure to capture and maximize the social and economic values from improved accessibility near MRT stations is one of the largest land use efficiency shortcomings in Beijing and in most other large cities in China. This situation is illustrated in the lack of housing price gradient with increasing distance from the stations. The housing price data of these three study areas corroborates this finding.

There is little price premium for housing closer to the stations. According to data in 2010, the location premium in all three study areas appear to be at the same low level, i.e., around or lower 10%. Most interestingly, on the west side of Tiantongyuan study area, agricultural land and forest still exist within 800 meters from the MRT station.

The perceived location premium shows surprisingly consistence in all study areas. About 68% of the correspondents of my questionnaire survey agree that there should be a location premium for housing within walking distance (800 meters) to the MRT station. But the majority of these people think the reasonable level should be around 10%, similar to what is actually observed in the housing market.

As compared to other East Asian cities, such as Seoul, Tokyo, Bangkok, Singapore and Hong Kong, the housing location premium in these study areas is very modest. This may be just a lag effect, which means the benefits of high accessibility take some time to be realized and captured in the price. It may be that as human time in Beijing becomes more economically value, there will be more of an accessibility premium. An increase in the premium could be reflected in the price of existing properties or it might induce redevelopment, or a mixture of the two.

This undervaluation of highly accessible land in Beijing is poorly understood. Factors contributing to this situation may include:

i) The planning and administration guidelines fail to assign differentially higher FARs in area of high accessibility. FAR in New York City could be as high as 18. But FAR in all areas in Beijing remains absolutely low. The highest FAR observed in these three study areas is only 4.5.

ii) The previous low value of labor (and hence the cost of time) in China is reflected on the low value of land that is highly accessible.

iii) Housing price in Beijing is adding to the low time cost factor. To afford a place to live, people are relocate to the peripheries of Beijing due to extremely high price in the city center where most of the jobs are located. Longer commuting time has been documented over time. A noticeable share of population spends 1.5 hours one way to work (see more details in Chapter 7).

iv) The developers lack of awareness or incentives for the types of TOD development that feature much longer return period.

Therefore, the impact of MRT station proximity on urban built environment and the spatial distribution of economic functions in Beijing appear to be weak, with little evident influence on property price and land use mixes. However, due to the limitation of data points in these neighborhoods, this analysis on property accessibility premium is exploratory and the finding of an approximate about 5% accessibility premium is preliminary. To better understand the dynamic impacts of MRT system on property values in Beijing, further and more in-depth studies are required, with support of city-wide data points to explore the correlation between property prices and their distances from MRT stations.

6.5.6 Occupancy Levels

Property speculation activities have contributed to inequity in housing ownership across socio-economic groups and high vacancy levels. Some people own more than one housing unit[33] while others in need could not afford one, especially since 2007 when the housing price surged in Beijing, and many other Chinese urban areas. Rents have also been increasing since 2007.

[33] Best estimate is that approximately 30% of Beijing households own more than one housing unit.

In all three study areas, MRT services have an important effect in increasing the occupancy levels significantly (see Table 6.11). Improved occupancy levels are evidence of land use efficiency enhancement.

Table 6.11 Case Study Area Average Occupancy Levels, 2002-2010

Study Area	2003	2010
Huilongguan (Huilongguan MRT)	70%	95%
Tiantongyuan (Tiantongyuan S. MRT)	55%	95%
Tongzhou Beiyuan (Tongzhou Beiyuan MRT)	80%	95%

Source: The author, 2011

6.5.7 Not Necessarily All Beneficial

Not all impacts of MRT access are beneficial to everyone. The lack of good planning and / or enforcement in MRT station areas has resulted in street vendors, tricycles and illegal taxis (private cars looking for passengers) proliferating. Noise, chaos, and careless littering are common outside the stations. This situation of deteriorating station environments contributes to the low location premium.

On the one hand, MRT accessibility has offered the residents a convenient and affordable alternative for travel, attracting more home buyers or renters to these neighborhoods. This is of special benefits for Huilongguan and Tiantongyuan which are newer neighborhoods. On the other hand, for a more mature neighborhood, such as Tongzhou Beiyuan, it has a higher share of older residents who do not commute far on a daily basis. The arrival of the MRT did not change much of their travel pattern. At the same time, local administrations cleared land where farmers had habitually sold fresh vegetables. As a result, residents have to go to supermarkets to purchase food at a higher price.

The existence of a accessibility premium for housing close to the MRT station is a result of the wealthier willing to pay more for the privilege of having shorter commutes. However, such premium does not always exist especially when multiple choices of travel modes are available, as argued by Glaeser in his latest book *Triumph of The City* (Glaeser, 2011). When making travel decisions, people are actually balancing the trade-offs between money and time. In areas with high density, such as Manhattan, public transit offers the fastest and most convenient travel experience than driving. As a result, there are more rich people living in the center of Manhattan than more distant areas, which in turn induces higher housing price. But this is not the case for most American cities, where the poor live closer to the center than the rich, while jobs have increasingly migrated to automobile-dependent suburban areas. While automobile commutes in the US are typically one half as long (in time) as public transit commutes of a similar distance, in Beijing driving is not perceived quite as favorably (or public transit as negatively) due to severe congestion on area roadways. The average road surface per capita in 2008 was only 6.2 m^2, as a result of rapid population growth and high density. On the other hand, MRT trains are often packed with passengers especially during peak hours; and the design of transfer stations forces people to walk long distances to their next train. The factors involved in travel decision are more complicated than the American cases. Interestingly, in the interviews, the term “dignity” was brought up somehow frequently when people are making travel decisions, because of the over-crowdedness of MRT trains. Residents acknowledged that they would choose to drive or take the taxi if they needed to show up in more formal attire or to exude a stress-free appearance.

Nevertheless, shorter commuting times were seen as a major benefit of MRT lines, if the origin and the destinations were close to stations, none or few transfers between lines were not needed. But for people who do not need to commute long distance on a daily basis, MRT accessibility delivers few benefits to them. Instead, it brings noise at the cost of local economic activities.

6.5.8 Differences between China and U.S. – Do suburbs exist in China?

There are some trends in Chinese suburban development that mirrors practice in the US, including high car ownership rates, segregated land uses, specialized neighborhood development etc. (Sadownik & Jaccard, 2002). However Chinese cities have developed under completely different institutional and resource conditions than cities in the US and a direct comparison is fraught with problems, if not impossible. This dissertation has traced the trajectory of development patterns in three neighborhoods on Beijing's periphery, and it should be evident that our understanding of the process of suburbanization from decades of study in the United States cannot be applied to understanding the Chinese context.

In the U.S., the process of suburbanization has been strongly related to social trends such as the increase of private car use, demand for larger and separated living space. Therefore, it is characterized by low density, car-oriented development, detached single family houses with yards and travel behavior that is almost exclusively tied to the automobile. Moreover, US cities have strict statutory zoning laws that separate residential areas from commercial and industrial properties. Culturally, "suburbanization" in the US is synonymous with an entirely different lifestyle, culture and political affiliation of individuals compared to their central city counterparts; in other words, there is a sharp delineation, both culturally and spatially, between inner city areas and "the suburbs".

I argue that, on the contrary, development happening in the suburban areas in Chinese cities is more of a peripheral development being added to the existing built area, instead of a distinctive process of suburbanization. It features high development density, mixed travel modes (including MRT, buses, private cars, shuttles, etc.), and condos as its building style which is similar to those in the urban core (there are also some detached houses, called villas in China, that target high-end markets). Plans usually include mixed-use development. Efforts are made to provide daily needs within walking distance. There are few parking lots. Roads are designed in the same way as the city center, sometimes just a little bit wider. Cosmopolitan is only a little less than the city center. And there is not much difference in terms of culture and demographics from the urban core.

6.6 Policy Implications for Improving Urban Sustainability

Smarter plans and regulations should be enforced to relieve the heavy passenger flows during peak hours that have exceeded the carrying capacity of most MRT lines. Current practice of "staggered office hours" in government offices intends to relieve traffic congestion in the city center and crowdedness of MRT trains, and to induce change of office hours for companies and institutions. However, due to the large number of commuters, the result turned out to be that both morning and evening peak hours have been extended. The real effective way of reducing passenger flows is to reduce the number of commuters.

Most importantly, the "New City" style of development should be discouraged in the future, to avoid the emergence of more isolated suburban bedroom communities. For existing suburban neighborhoods, opportunities for incremental changes should be identified and utilized to increase local employment opportunities, such as redevelopment opportunities for older blocks and buildings. Also, adaptation actions at the building level when land use is already settled and difficult to change should be encouraged and facilitated through policies such as quick registration processes and tax incentives.

In the future, when planning new neighborhoods, more mixed-use buildings should be included in the detailed plan for development, to avoid the predominance of residential buildings and inadequacy of public and personal services. Strong regulation should be enforced to ensure that public services, especially schools and hospitals, in suburban neighborhoods gets built as planned and at an earlier development stage, and that the services are adequate and of good quality. As many high quality hospital and education resources are currently concentrated in the city center of Beijing, effective schemes should be developed to extend these resources to the suburbs, such as establishing branch hospitals and schools that are worthy of the name. Public funds should be ensured and allocated to build the infrastructure and purchase good facilities such as medical equipment and computers. It is understandable that human capital is the most important factor of these services, i.e. good doctors and good teacher, who would be difficult to relocate. But training can be provided by the good schools for the teachers who work in these suburban schools. Adequate hospitals and schools of good quality not only attract home buyers, but create local employment.

Regulations for FAR should be adjusted to provide more flexibility. It is observed that actual FAR on the ground is commonly higher than the plan guideline, which is also the level reported by the developer. This represents a market adjustment to the present FAR guidelines, which encourages development of higher density that serves a demanding housing market. Therefore, it should be allowed to have high FAR at strategic locations such as the areas around MRT stations while low FAR at other locations so that the overall FAR remains at a reasonable level. Such flexibility will provide essential incentives for developers to build more densely where appropriate and encourage vertical development.

More pedestrian friendly design of the walking environment in the area immediately adjacent to the MRT stations is highly needed. The current solution, such as placing multiple pedestrian overcrossings in the Tiantongyuan neighborhood, is short-sighted and ineffective, and incorporating pedestrian-sensitive design should be part of a systematic and integrated mobility plan. Due to the existing physical barriers caused by above ground MRT tracks, railroad track, and wide streets with designated lanes, a well-connected pedestrian overpass system that links the second floor of the residential, commercial or mixed use buildings right by the stations would provide a practical solution, and could be modeled on a similar project in Central Hong Kong. Such a system not only avoids interaction between pedestrian flow and surface car traffic, but also brings more passenger flows to the businesses around the station. It also provides shades for the pedestrians at times of harsh weather. However, such a connected overcrossing system can only be feasible and effective when the above suggested mixed-use development and higher density of buildings are achieved.

Clear plans, early action and land banking are important in the process of urban development, to provide opportunities of land development with higher efficiency. The case of Tongzhou Beiyuan New Business District is an important example showing how ambiguous plans, delayed action and speculative market activities can harm the implementation of a well-intended project. On the other hand, the dramatic change of the plan for Tiantongyuan Core Area demonstrates adaptive strategies for a large piece of land which was left behind because it was originally planned as public facilities but now enjoys a premium location near the MRT station. Such good luck does not happen all the time, but provides a good opportunity for mixed-use development.

Better planning and design should be made for MRT stations that are currently highly underutilized. Collaborative thinking should be encouraged between both planners and developers, and the objective should be to turn the stations into mixed-use and pedestrian friendly trip destinations instead of just utilitarian entranceways for commuters. Such change also requires stronger regulations of the informal activities that currently occupy the open space right outside the stations. Interviews with planners and developers show that planners' work ends with the route design for the MRT lines and location selection for the stations has been established, with no oversight over station precinct planning. Some high-end developers understand the importance of MRT stations if their project is near one and seek corporation with the government for better utilizing it. But most developers only focus their work within their land parcel and consider the station a jurisdiction of the government with which they do not get involved.

Policy makers should realize how MRT services can contribute to improvement of land use efficiency and make good use of this positive impact. In all three selected study areas, MRT services play a significant role in increasing the occupancy levels dramatically, which is an important evidence of land use efficiency enhancement. This positive relation should be recognized by policy makers to be used to solve many social tensions and to create more development catalysts in suburban neighborhoods. Vacancy rates in the first-tier cities in China are worryingly high, due to a high level of speculative home purchasing activities, while many lower income families are not able to afford a place to live. Policies should be implemented to lower housing prices in general on the one hand (Beijing is doing this in 2012 with price controlling policies) and to improve MRT connectivity of policy oriented housing projects on the other hand instead of just locating them in distant suburban areas with poor transport accessibility chasing low land cost.

At the same time, high occupancy rates imply the presence of large populations of residents. Again, plans for neighborhood development should include mixed-use projects and buildings as well as projects that generate employment opportunities such as office buildings, schools and hospitals.

Current practice of how public services are provided needs to be revised. Instead of leaving the construction of actual buildings to the developers, the city building and social welfare offices should take over the responsibility with the assistance of mandatory input from the developers so that the provision of public service takes place at the beginning of neighborhood development and grows with the demand of increasing population both in terms of quantity and quality.

It is not self-evident to argue that an accessibility premium has to exist for housing near transit stations. The relationship between housing price and accessibility to MRT services is much more complicated than a linear relationship in large cities like Beijing. It helps to understand this complexity by looking at international cases. For cities like New York, Boston, and Philadelphia, four transit and income zones exist which are: i) inner zone where the rich walk or use the public transit, such as Manhattan; ii) a second zone where the poor commute by transit; iii) a third zone where the rich drive; and iv) an outer zone where the less wealthy live and drive. For cities like Paris, however, there are only two zones: i) an inner zone where the wealthier people use the metro or walk; and ii) an outer zone where the poor live in distant areas that are still connected to the city by train. New cities such as Los Angeles tells a different story, where everyone drives. (Glaeser, 2011) In Beijing, the zone right by a MRT station and within walking distance from the station can consists of both rich people in higher end housing and poorer people who need the easy access to public transit. For zones that are farther from the stations, there can be people who choose to drive to commute or enjoy the quieter living environment away from the station area. As a result, significant location premium is not observed in any of the study areas.

Attention should be paid to the phenomenon of resident organized shuttle services that are appearing in two of the selected neighborhoods, which reflects a market demand within the neighborhoods and the inefficiency or inadequacy of MRT service to these neighborhoods. These shuttles are an effective alternative for those run by companies. The destination selection and route plan of these shuttle services are based on surveys conducted among the residents. When demand reaches a level that justifies the cost of running a shuttle line, organizers will go ahead and arrange appropriate vehicles. These organizers are usually the representative bodies of the neighborhood residents which run as non-profit organizations. Policies should be proposed and implemented to support such shuttle services and facilitate the operation of these organizations Nevertheless, it is perhaps wisest to leave such work to these organizations rather than taking them over to government operations, as these grass root institutions understand the market thoroughly and respond to changes quickly and effectively.

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Chapter 7

IMPACTS ON PEOPLE'S TRAVEL BEHAVIOR IN SUBURBAN BEIJING

Questionnaire surveys were conducted in the three study areas to collect information about people's travel behavior and housing location preferences, during the period July – September 2011. The survey questions were distributed and collected through an online survey website and in-house visits, with the help of local residents committees and Youth League Committees. The questionnaire is designed to collect information on: i) Demographic and economic characteristics of the residents; ii) Decision-making factors in housing location; iii) Commuting and non-commuting travel behavior, including travel distances, travel frequencies, travel modes and travel time; iv) Changes in travel behavior before and after the MRT service was available; v) Factors influencing travel mode decisions; vi) Perception of location premium; and vii) Living Satisfaction in the neighborhood.

7.1 Basic Information

The questionnaire surveys were targeted at whole neighborhoods. More specifically, the Huilongguan survey covers the whole Huilongguan Cultural Living Community which extends to over 2000 meters to the north of the Huilongguan MRT station; the Tiantongyuan survey covers the whole Tiantongyuan Affordable Community which extends over 2000 meters to the east of the Tiantongyuan S. Station; the Tongzhou Beiyuan covers the Beiyuan Street Office territory which extends over 1600 meters to the east of the Tongzhou Beiyuan Station.

Different modes of distributing and collecting questionnaires were utilized across neighborhoods based on the demographics of the residents in the three communities. Both Huilongguan and Tiantongyuan are new affordable communities built in late 1990s.

The residents are mostly 20-40 years old, and are active on the well-organized community websites (hlgnet and ttyva respectively). Therefore, I chose to upload my questionnaire to an online survey service provider and exhibited the link on the community websites. Prompt responses were received. 192 responses were received from the Huilongguan community. 146 responses were received from the Tiantongyuan community. On the other hand, Tongzhou Beiyuan is an established community with a wider range of ages and professions. Most importantly, it has a well-organized resident committee system, which includes staff of the Youth League Committees. 160 questionnaires were distributed and collected by the Youth League Committees staff through in-house visits. 146 answers were returned, of which 130 answers are valid. The overall return rate is 81.25% (see Figure 7.1).

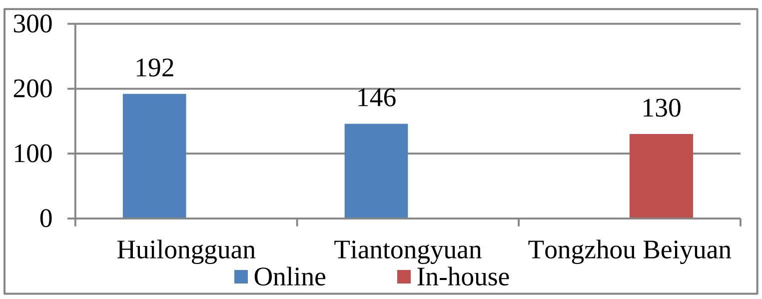

Figure 7.1 Questionnaire Survey Methods and Numbers of Valid Returns

Compared with the total population of these three neighborhoods, the sample size of this survey is not large enough to be statistically significant due to time and financial constraints facing the researcher. But the samples were selected based on the principle of randomness among representative pools. Focus group discussions were conducted for each neighborhood to investigate the representativeness of the samples. 10-15 people were selected randomly from each neighborhood, about 50% of who have been living there since before the MRT served the neighborhood in question. Similar questions to those in the questionnaire prompted discussion in these focus groups. Focus group discussions yielded results consistent with questionnaire responses.

7.2 Demographic and Economic Characteristics of the Survey Correspondents

The age distribution, education levels and household monthly income levels of all the survey correspondents in the three communities are illustrated in Figures 7.2, 7.3 and 7.4. The age profiles of Huilongguan and Tiantongyuan are similar[34]. People from 26 to 50 years old account for the majority of all correspondents, of which, the bracket of 31-40 years old constitutes the biggest share (69.79% in Huilongguan; 72.6% in Tiantongyuan). This is in line with the fact that these are affordable communities built in late 1990s when most of their buyers were young professionals in their 20s. For the case of Tongzhou Beiyuan, the age distribution is flatter, indicating a more diverse age cohort structure. Although the majority of its population also falls in the brackets between 25 and 50 years old, the numbers are more evenly distributed in three brackets, i.e. 34.6% in the 26-30 bracket, 25.4% in the 31-40 bracket and 24.6% in the 41-50 bracket. Tongzhou Beiyuan also contains larger shares of residents in the younger and older brackets of 18-25, 51-60 and over 61 years old, indicating a fair share of young employees who are starting to form daily commuting routines and retirees who do not commute.

While the share of college graduates is similar level for all three communities, the share of residents holding graduate degrees in Huilongguan (24.4%) and Tiantongyuan (26.7%) are much higher than Tongzhou Beiyuan (5.4%). On the other hand, the combined share of high school graduates and less than high school education is as high as 36.9% in Tongzhou Beiyuan, suggesting a higher level of under educated population in that community than in the other two communities.

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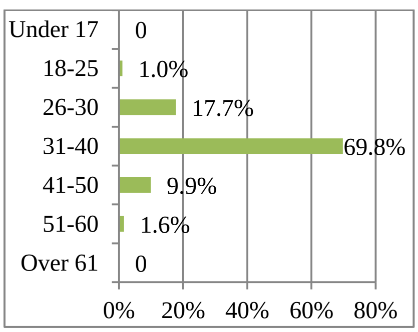
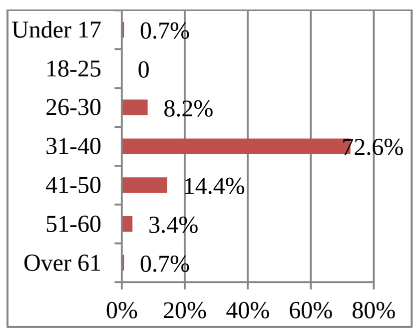
[34] The smallest tracts of both Census and Statistical Yearbooks in China are the street office boundaries, which are larger than the confine of these neighborhoods. Studies targeting the demographics of these neighborhoods are not found. Therefor, secondary data for the demographic profiles of these neighborhoods are not available for comparison and cross-check for my survey.

The average monthly household income levels for Huilongguan and Tiantongyuan are about the same, which are 16,000 and 17,600 RMB respectively, while the average household in Tongzhou Beiyuan earns 6,000 RMB a month. In Huilongguan and Tiantongyuan, households with monthly income between 5,000 RMB and 20,000 RMB constitute the majority (70.4% and 63.1% respectively). Tiantongyuan seems to have more residents in the higher income brackets, i.e. 25.4% of the correspondent families earn more than 20,000 RMB per month. Comparatively, the majority of households in Tongzhou Beiyuan fall in the lower income brackets between 2,000 and 10,000 RMB.

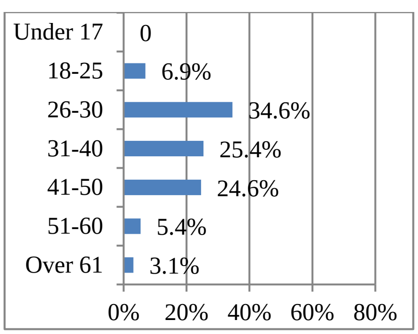
In sum, Huilongguan and Tiantongyuan feature more middle aged residents with higher education levels and higher household incomes than Tongzhou Beiyuan, while the latter is characterized by more evenly distributed age groups, more residents lacking post-secondary education, and lower household income.



a. Huilongguan



b. Tiantongyuan



c. Tongzhou Beiyuan

Figure 7.2 Age Distribution of the Survey Correspondents, 2011

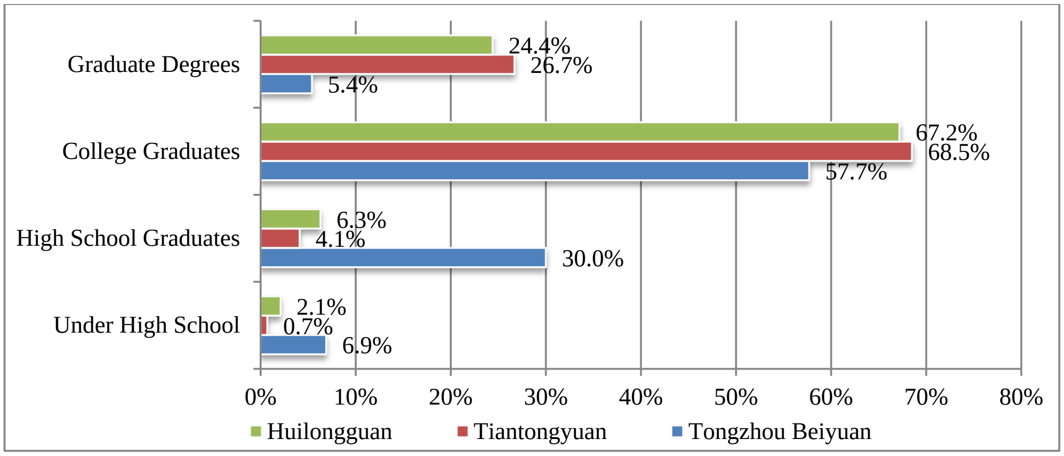
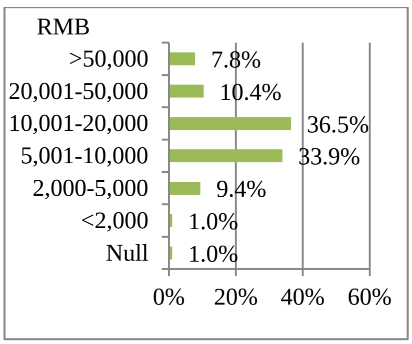
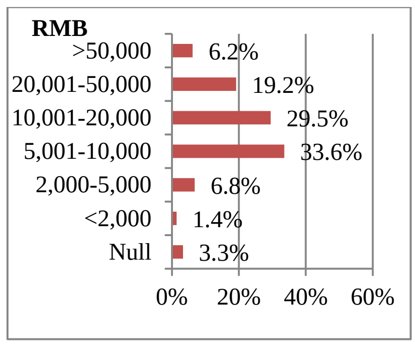


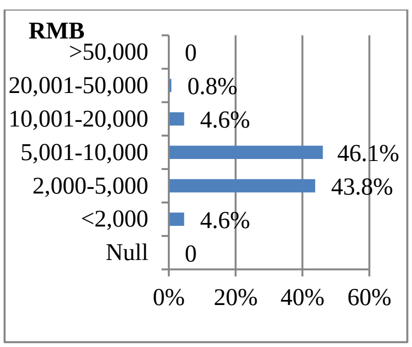
Figure 7.3 Education Levels of the Survey Correspondents, 2011



a. Huilongguan



b. Tiantongyuan



c. Tongzhou Beiyuan

Figure 7.4 Monthly Household Income Levels of the Survey Correspondents, 2011

Of all the correspondents, residents in Huilongguan and Tiantongyuan demonstrate high purchase rates. 82.8% of the survey correspondents in Huilongguan own the unit they live in. This number is even higher in Tiantongyuan (95.2%). Home ownership in Tongzhou Beiyuan, on the other hand, is lower (68.5%), see Figure 7.5. This can be explained by similar housing prices, but differentials in household income. As indicated in Chapter 6, housing prices all roughly fall in the 13,000 – 20,000 RMB/m^2 range, with a few more expansive properties in Tiantongyuan and slightly lower average price in Tongzhou Beiyuan (see Figure 6.2, 6.5 and 6.8). But the household income in Tongzhou Beiyuan is lower than Huilongguan and Tiantongyuan (see Figure 7.4), indicating lower capability to own in the latter neighborhood.

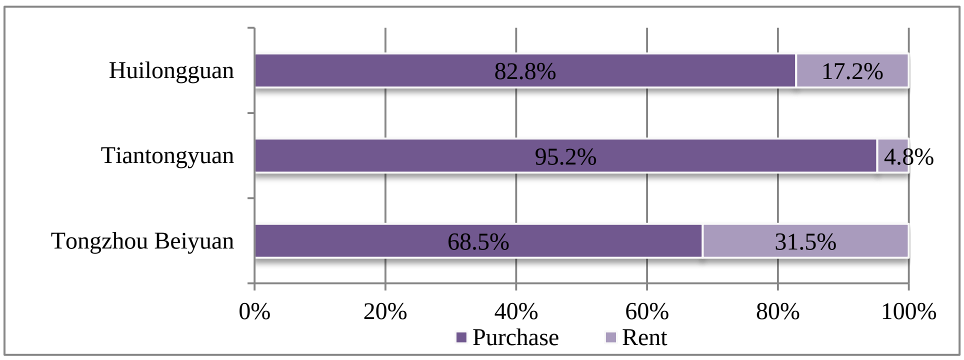
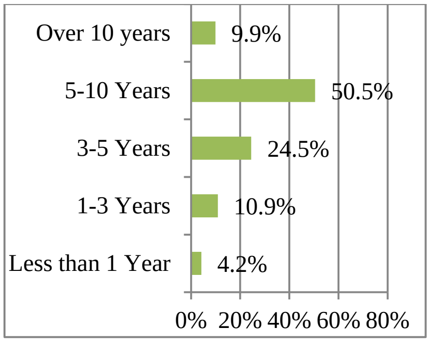


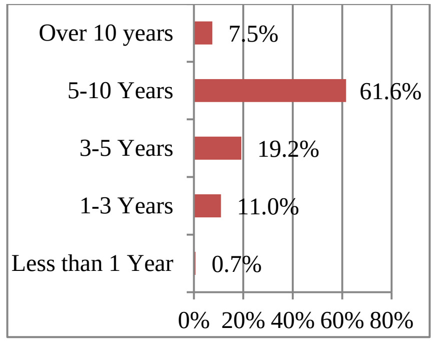
Figure 7.5 Home Ownership of the Survey Correspondents, 2011

As seen in Figure 7.6, the majority of all survey correspondents in Huilongguan and Tiantongyuan have been living in their current house for over 5 years (60.4% and 69.1% respectively), indicating that the majority of the sample from these communities provides data on comparative travel behavior before and after the MRT service was available. It also shows that the residents in these two communities are rather locationally stable. On the contrary, only 42.3% of the correspondents have been living in Tongzhou Beiyuan for over 5 years. But there is a higher share of population (19.2%) who has been living there for over 10 years, as compared to the other two communities.

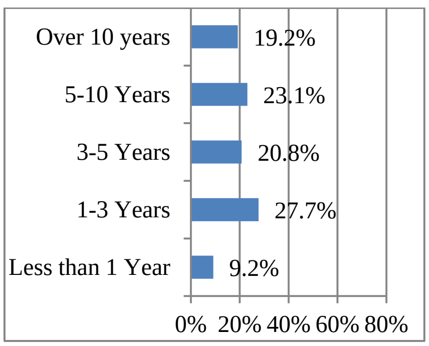
Car ownership is the highest in Tiantongyuan (77.4%) and the lowest in Tongzhou Beiyuan (40%), which is closely related to the lower household income and shorter commuting distances (see Figure 7.4 and Figure 7.8). All three communities have high bike ownership, i.e. over 60%. The ownership of electric bikes (a fast emerging trend in Beijing) is still low in all three (see Figure 7.7).



a. Huilongguan
(MRT opened in 2003)



b. Tiantongyuan
(MRT opened in 2007)



c. Tongzhou Beiyuan
(MRT opened in 2004)

Figure 7.6 Length of Residence: Survey Correspondents, 2011

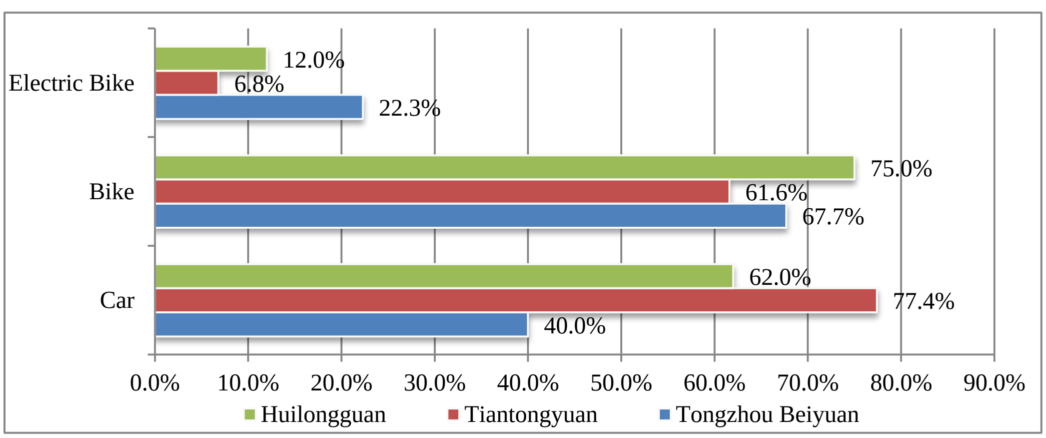
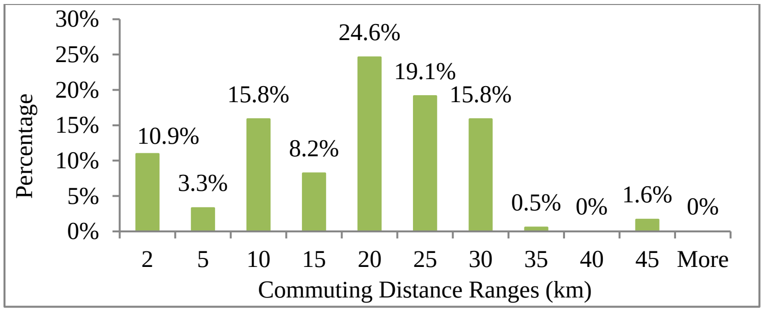


Figure 7.7 Ownership of Car, Bike and E-Bike: Survey Correspondents, 2011

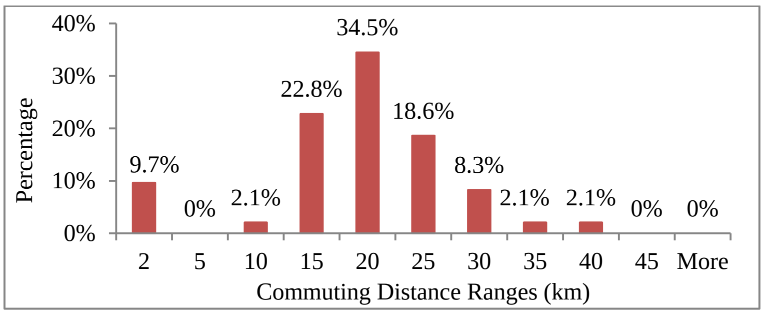
7.3 Travel Behavior after the MRT was Available

7.3.1 Commuting Travels

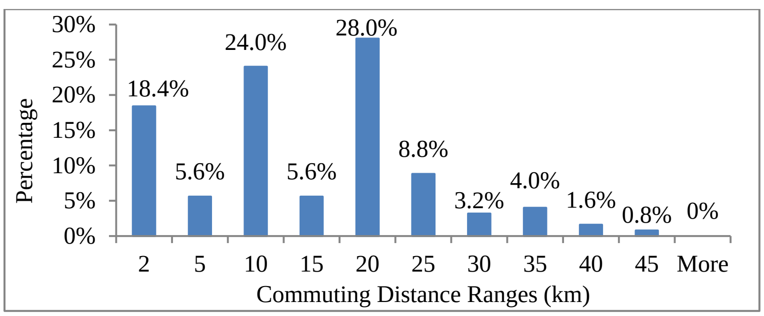
Travel distances for commuting trips are estimated through map measurement based on reported destinations by the survey correspondents. The numbers of valid answers to this question are 183 for Huilongguan, 145 for Tiantongyuan and 125 for Tongzhou Beiyuan. The distribution of population by commuting distance ranges is illustrated in Figure 7.8. The percentage of residents who travel for less than 5km to work is the highest in Tongzhou Beiyuan (24%), as compared to 14.2% in Huilongguan and 9.7% in Tiantongyuan. The figures for commuting distance less than 10km are 48%, 30% and 11.8% respectively. Results suggest that the workplaces of residents in Tongzhou Beiyuan are closer to their homes than the other two neighborhoods. The median commuting distances for these three neighborhoods are 19km (Huilongguan), 18km (Tiantongyuan) and 14km (Tongzhou Beiyuan). One of the main reasons for shorter commuting trips and more local employment in Tongzhou Beiyuan is that the higher proportion of residents with lower education (refer to Figure 7.3) have greater access to a wider range of local jobs than the residents in the other two neighborhoods. In Huilongguan and Tiantongyuan, respondents were more likely to be more educated, have special skills, and relied on traveling for employment outside of the immediate neighborhood, particularly in the central city or other major employment nodes.



a. Huilongguan



b. Tiantongyuan



c. Tongzhou Beiyuan

Figure 7.8 Distribution of Commuting Distance Ranges: By Neighborhood, 2011

The travel mode shares by the three neighborhoods are illustrated in Table 7.1. Because one person may choose different travel mode on different days, main commuting mode is determined as the most often used mode in an average week. Overall, the combination of driving and MRT explains the majority of commuting trips in Huilongguan and Tiantongyuan (over 80%), while the trips in Tongzhou Beiyuan are more evenly distributed among four major modes, i.e. bus, driving, MRT, and bike. The more balanced mode split in Tongzhou Beiyuan is the result of a more mixed land use pattern and older development history (more and diverse local employment opportunities), a lower proportion of the population with higher levels of education (who may be able to be locally employed) and hence shorter commuting distances.

The share of commuting trips by MRT is higher in Huilongguan and Tiantongyuan (52.9% and 39% respectively), suggesting that a large share of the residents work in a location relatively well-served by the MRT system. But the MRT share is very modest in Tongzhou Beiyuan (21.8%), which is largely due to local employment and short commutes. At the same time, Tiantongyuan has the highest share of trips by driving (43.3%), while it is lower in the other two survey areas (29.6% for Huilongguan, and 21.8% for Tongzhou Beiyuan). The higher shares of commuting trips by bike (21%) and walking (4%) in Tongzhou Beiyuan suggest that a number of its residents live close to where they work.

Residents in all three neighborhoods suffer from long commuting times (see Figure 7.9), as compared to the Beijing average level and other large cities in the world. As noted in Chapter 1, in 2011, the average commuting time in Beijing was 45 minutes (China News, October 23, 2011); while people living in the New York metropolitan area spent 33.54 minutes on their way to work according to the New York Times (Roberts, September 23, 2011). The majority of people in this survey spend more than 45 minutes commuting to work, 68.23% for Huilongguan, 77.4% for Tiantongyuan and 52.31% for Tongzhou Beiyuan, probably best explained by suburban location (relative to work places) rather than access to transportation services per se. This finding is consistent with the focus group discussion. A higher share of residents in Tiantongyuan revealed that they worked in major employment nodes (such as Zhongguancun, Shangdi, CBD, etc.) that involved taking longer commuting trips and having a higher chance of encountering congestion. Huilongguan's lower proportion of time-intensive commute trips likely owes to location closer to some of the employment nodes (especially Shangdi and Zhongguancun) than Tiantongyuan.

About 30% of the correspondents in Tongzhou Beiyuan spend less than 30 minutes one way commuting to work, while the equivalent figure for Tiantongyuan and Huilongguan is much lower, only 12% and 17% respectively. There is also a certain share of residents in all survey areas who spend over 90 minutes traveling to work, indicating a significant loss of human time.

Table 7.1 Travel Mode Share for Commuting Trips by Neighborhood, 2011

	Huilongguan	Tiantongyuan	Tongzhou Beiyuan
Driving	29.6%	43.4%	21.8%
Car-Pooling	2.1%	1.4%	0.0%
MRT	52.9%	39.0%	21.8%
Taxi	0.5%	0.7%	0.0%
Bus	6.9%	9.9%	31.5%
Bike	4.2%	2.1%	21.0%
Walking	1.1%	0.7%	4.0%
Shuttle[35]	2.6%	2.8%	0.0%
Total	100%	100%	100%

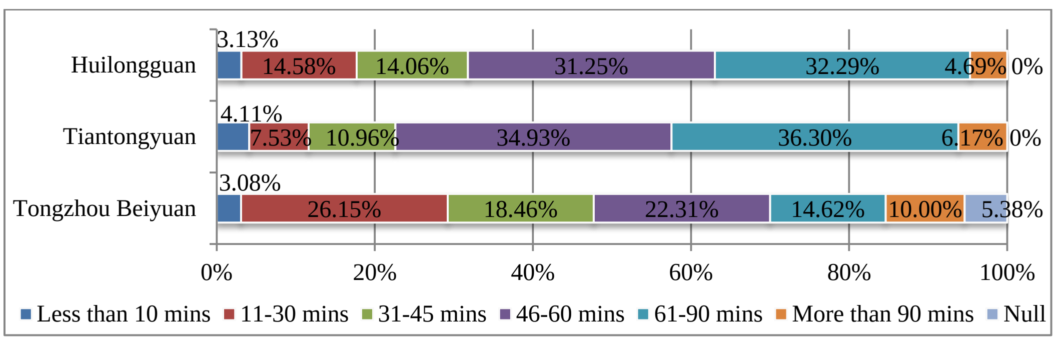


Figure 7.9 Travel Time for Commuting Trips, 2011

Note: Null refers to respondents who did not provide an answer to this question, or those who do not have commuting trips, such as retirees.

[35] Shuttles are gaining popularity in some neighborhoods (both urban and suburban) in Chinese cities. There are mainly two types of shuttles. One is organized by the employers (most often the State-owned Enterprises or larger scale companies who offer such service as part of their employees' benefits), and operates on several routes to the locations where most of their employees live. The other is organized by neighborhood residents themselves, mostly because a sizable population (which is very flexible; the more people, the larger the vehicle to rent, such as vans) work in the same locations or their workplaces could form a reasonable route.

7.3.2 Non-Commuting Travels

The main non-commuting trips considered in this survey are: i) Sending children to school; ii) Grocery shopping, and (iii) Dining or other entertainment.

Sending Children to School

Of all the survey correspondents, 68.2% in Huilongguan, 71.2% in Tiantongyuan and 60.8% in Tongzhou Beiyuan have one or more children living with them. Based on focus group discussions, although there are different opinions about when to allow children to travel to school on their own, most residents do not take their children to school after they commence high school. Results show that 94 correspondents (49% of all) in Huilongguan, 70 correspondents (47.9%) in Tiantongyuan, and 37 correspondents (28.5%) in Tongzhou Beiyuan take their children to school on a daily basis.

The results show that although most people choose to send their children to kindergartens and primary schools near to where they live, there are some noteworthy outlier travel patterns in all three survey areas. As seen in Table 7.2, about 90% of the parents' school trips in Tongzhou Beiyuan and Huilongguan occupy less than 30 minutes, while this figure is only 78% in Tiantongyuan which also has a higher share of trips that takes over an hour (5.7%). Based on focus group discussions, some residents in Huilongguan and Tiantongyuan expressed the concern that there were not adequate and quality schools in the neighborhood, thus some of them chose to send their children to better schools, either nearby or on the way to where they work. This unsatisfactory situation is worse in Tiantongyuan than Huilongguan. Harking back to a recurring theme, the transportation behavior in the case of taking children to school reflects strong underlying spatial characteristics in Beijing; in this case, better schools are not well-distributed and there is a strong bias toward them being located in the core city. In terms of travel modes, while more than half of the correspondents undertake school visits by bike or walking in all survey areas, more people drive their children to school in Huilongguan (30.9%) and Tiantongyuan (32.9%) compared to Tongzhou Beiyuan (18.9%). (See Table 7.3)

Table 7.2 Travel Time for Parents' School Trips, 2011

	Huilongguan		Tiantongyuan		Tongzhou Beiyuan	
	Count	Percentage	Count	Percentage	Count	Percentage
Null	1	1.1%	0	0.0%	0	0.0%
Less than 10 mins	48	51.1%	31	44.3%	11	29.7%
11-30 mins	34	36.2%	24	34.3%	22	59.5%
31-45 mins	5	5.3%	5	7.1%	1	2.7%
46-60 mins	3	3.2%	6	8.6%	3	8.1%
61-90 mins	1	1.1%	3	4.3%	0	0.0%
more than 90 mins	2	2.1%	1	1.4%	0	0.0%
Total	94	100%	70	100%	37	100%

Table 7.3 Travel Mode Share for Parents' School Trips, 2011

	Huilongguan		Tiantongyuan		Tongzhou Beiyuan	
	Count	Share	Count	Share	Count	Share
Driving	29	30.9%	23	32.9%	7	18.9%
Car Pooling	0	0.0%	2	2.9%	0	0.0%
MRT	4	4.3%	6	8.6%	0	0.0%
Bus	6	6.4%	3	4.3%	7	18.9%
Bike	5	5.3%	2	2.9%	12	32.4%
Walking	47	50.0%	32	45.7%	11	29.7%
Shuttle	3	3.2%	2	2.9%	0	0.0%
Total	94	100%	70	100%	37	100%

Trips for Groceries and Entertainment

Personal preferences in regard to non-commuting trips for grocery shopping or entertainment purposes differ among survey areas. Residents in Huilongguan and Tiantongyuan suggest that as the neighborhoods are far from the city center and major employment clusters, they tend to limit such trips (perhaps grouping them) or simply do grocery shopping and enjoy entertainment nearby where they work, i.e. there is a tendency of combining commuting and non-commuting trips. Therefore, a large percent of survey correspondents in these two neighborhoods make only 1-2 trips per week for groceries and entertainment (see Table 7.4). However, most residents in Tongzhou Beiyuan do not have this sense of “remoteness”. Places for grocery shopping are mostly within walking distance in that neighborhood and thus residents go out somewhat more. About 45% of the correspondents in Tongzhou Beiyuan go out 3-6 times every week. The share of people who go out more than 6 times per week is also higher than in the other two survey areas.

Travel mode shares for grocery and entertainment trips are divided into trips within and outside the larger neighborhood areas; the latter is obviously farther in terms of travel distance. For grocery shopping trips within neighborhoods, residents in Huilongguan and Tiantongyuan point out that as shopping facilities (such as supermarkets) are mostly concentrated at a couple locations and the streets are wide; therefore, they have to drive to these facilities to save the inconvenience of carrying shopping bags in hand through difficult pedestrian environments. On the other hand, there are more small shops and stores in addition to larger scale shopping centers in Tongzhou Beiyuan, which may account for the fact that residents of this neighborhood use bikes and buses more than the other two survey areas for shopping and entertainment purposes. As shown in Table 7.5, over 40% of the residents in Huilongguan and Tiantongyuan choose to drive, as compared to a much lower share of driving in Tongzhou Beiyuan (13.5%) for shopping and entertainment purposes. And the share of biking in Tongzhou Beiyuan is as high as 36.2%.

Table 7.4 Number of Trips for Groceries and Entertainment by Neighborhood, 2011

	Huilongguan	Tiantongyuan	Tongzhou Beiyuan
1-2	65.6%	63.0%	43.8%
3-4	21.4%	24.0%	28.5%
5-6	7.3%	6.8%	16.9%
7-8	2.6%	3.4%	7.7%
9-10	0.5%	1.4%	1.5%
>10	2.6%	1.4%	1.5%

Table 7.5 Travel Mode Share for Trips for Groceries and Entertainment within and outside of the Vicinity of Each Survey Area, 2011

	Huilongguan		Tiantongyuan		Tongzhou Beiyuan	
	Within	Outside	Within	Outside	Within	Outside
Driving	43.8%	40.1%	42.1%	55.5%	13.5%	26.9%
Car-Pooling	0	0.5%	0	0.0%	0	0.0%
MRT	5.7%	44.0%	2.1%	30.8%	1.2%	20.4%
Taxi	2.1%	4.2%	3.4%	2%	0.0%	1.5%
Bus	22.9%	10.7%	17.5%	11.0%	31.9%	43.5%
Bike	15.6%	0.5%	10.6%	0.7%	36.2%	6.2%
Walking	9.9%	0.0%	24.3%	0.0%	17.3%	1.5%
Total	100%	100%	100%	100%	100%	100%

For shopping and entertainment trips outside the vicinity of their neighborhoods, the shares of public transport uses (MRT and bus) increases significantly for all survey areas. For Huilongguan, the share of driving decreases as compared to the trips within the neighborhood, and the largest share of correspondents choose to travel using the MRT. In Tiantongyuan, residents suggest that driving is the preferred travel mode as long as they could afford a car, as it frees them from the hassle of traveling to the MRT stations which are beyond walking distance and involve crossing overpasses and large road intersections for a larger percentage of residents. MRT is the second preferred travel mode. On the contrary, bus is the most preferred travel mode for residents in Tongzhou Beiyuan to go out to places beyond the vicinity of their neighborhood for shopping and entertainment purposes. Correspondents from Tongzhou Beiyuan indicate that places nearby for groceries and entertainment are well connected by bus routes, such as Guanzhuang, Baliqiao Market, Carrefour, Liyuan, etc. If they decide to go farther for entertainment, they tend to drive (26.8%) or take the MRT (20.4%).

7.4 Comparison of Travel Mode Before and After the MRT was Available

All survey correspondents were asked to recall their travel behavior before the MRT line operated in their neighborhoods, if they were resident in the neighborhood before the service began. The response rates for this question are obviously dependent on the percentages of correspondents who were living in the neighborhoods before MRT service was available, and were making regular daily commuting trips. Their responses are compiled and shown in Table 7.6 and 7.7, with comparison to their current travel patterns in terms of commuting and non-commuting trips indicated.

For commuting trips, about half of the residents previously chose to take the bus to go to work before MRT was available. But the share of bus trips decreased dramatically in Huilongguan (from 63.2% to 6.9%) and Tiantongyuan (from 50% to 9.9%), while such decrease is more moderate in Tongzhou Beiyuan (from 50% to 31.5%) which is largely due to its lower car ownership rates, shorter commuting distance and higher share of local employment. The fact, the dominant shift in mode change was from buses to MRT, echoes similar research worldwide (Litman, 2012) – the Beijing pattern follows the global norm. Interviews and focus group discussions reveal that as Huilongguan and Tiantongyuan are both outside North 5th Ring Road. And bus was the only public transport mode available to those who could not afford a car, although it took them a long time to go to work by bus, residents previously had no choice. In some cases, when they were running late for work, residents would have to take a taxi, a more expensive alternative. After the MRT was opened, it became the major travel mode for residents in these two neighborhoods while the shares of both bus and taxi trips dropped significantly. On the other hand, a number of residents in Tongzhou Beiyuan work not too far from where they live, enabling bike to remain one of the main travel modes, which is not much affected by the availability of MRT.

However, contrary to what was expected, the share of driving to work increased for all three survey areas after the MRT services became available. According to interviews, I attribute this increase to the rapid increase of car ownership in China during the same period (from 1.3 million in 2000 to 4.95 million by September 2011), associated with increased household affluence and pro-motorization policies in China. In Huilongguan, for example, the residents estimated that only about 10% of households owned a car before 2003. But now about 70-80% of the households own a car. Car ownership has increased more than 6 times in Huilongguan, as compared to the before scenario. But the share of car trips to work only increased about 50% (from 20% to 29.6%) when MRT became the major travel mode (52.9%) during the same time period. Therefore, the availability of MRT services in these neighborhoods largely reduced the intensity of car use for commuting trips.

Table 7.6 Comparison of Commuting Trips Before and After MRT was Available

	Huilongguan		Tiantongyuan		Tongzhou Beiyuan	
	Before	After	Before	After	Before	After
Driving	20.0%	29.6%	39.4%	43.4%	17.4%	21.8%
Car-Pooling	2.1%	2.1%	2.1%	1.4%	0.0%	0.0%
MRT	0	52.9%	0	39.0%	0	21.8%
Taxi	2.1%	0.5%	0.7%	0.7%	0.0%	0.0%
Bus	63.2%	6.9%	50.0%	9.9%	50.0%	31.5%
Bike	8.9%	4.2%	5.6%	2.1%	29.1%	21.0%
Walking	3.7%	1.1%	2.1%	0.7%	3.5%	4.0%
Others	0.0%	2.6%	0.0%	2.8%	0.0%	0.0%
Total	100%	100%	100%	100%	100%	100%

Share analysis is applied to explore the characteristics of switchers among different travel modes after the MRT became available, especially those who switched to MRT, in terms of commuting trips. The most dynamic shifts are found among driving, MRT, buses and bikes (see Figure 7.10). The largest gain of MRT ridership is from bus (39.1% in Huilongguan, 25.3% in Tiantongyuan and 16.2% in Tongzhou Beiyuan), indicating the persistence of using public transport for a large number of people. Only a small number of people switched from driving to MRT, i.e. 4.7%, 6.8% and 0.8% respectively. A large share of people continues driving despite the availability of MRT, suggesting strong preference for the automobile. In other words, the drawing force of MRT accessibility is much higher for the people who took buses to work than those who drove to work. As noted above, this is consistent with virtually all international evidence.

Comparison across neighborhoods sheds some light on the varied outcomes in travel behavior changes due to different development models. Huilongguan and Tiantongyuan share similar characteristics re travel mode shifts, as observed above. But residents in Tongzhou Beiyuan, who travel shorter distances to work on average, have more diverse travel mode splits, in which bus takes the highest share (31.5%) while driving, MRT and biking are approximately the same level (around 21%). Those who used to take buses to work split evenly between MRT and bus rides.

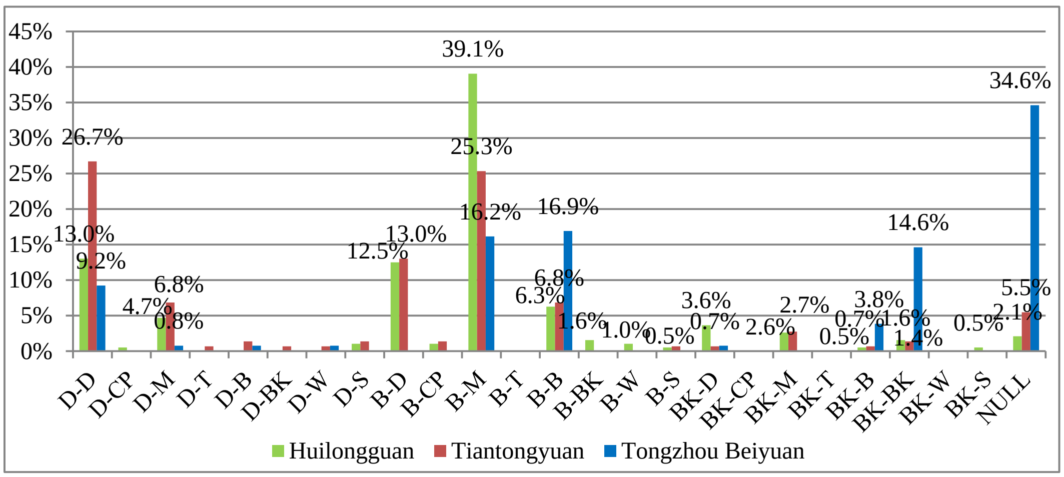


Figure 7.10 Commuting Mode Share Shifts: Before & After MRT Became Available

Note: D-driving, CP-car pooling, M-MRT, T-taxi, B-bus, BK-bike; W-walking, S-shuttle.

Similar travel patterns for Huilongguan and Tiantongyuan are also observed for non-commuting trips, where travels by bus, bike and walking all decreased considerably. But in Tongzhou Beiyuan, non-commuting trips by walking remained the same. Trips by bus only decreased a little. Only trips by walking decreased significantly. Local residents indicate that since the MRT line came in, authorities also started to clean up the area, eliminating some small scale street-side farmers' markets. As a result, they lost the option of walking down the corner of the block to buy fresh vegetables. Instead, they must go to supermarkets, which are also close, but not amenable to walking because of all the shopping bags that have to be carried.

A sharp increase in driving is observed in Huilongguan (from 14.1% to 42%) and Tiantongyuan (from 19.7% to 48.8%) for non-commuting trips, which is much higher than for commuting trips. However, the observed increase in these two neighborhoods is more moderate in Tongzhou Beiyuan (from 13.6% to 20.2%). MRT accounts for a smaller share of non-commuting trips (lower than 25%) than commuting trips for all neighborhoods. According to focus group discussions, such travel patterns for Huilongguan and Tiantongyuan are attributed to: i) The limited local availability of good schools and hospitals, resulting in outward movement of the residents searching for better public services, which are not necessarily along public transit lines; ii) High car ownership and the fact that grocery shopping generates heavy loads that encourage driving even though the travel distance might not be long; iii) The general lack of parking restrictions in Beijing encourages the use of car; iv) Trips for entertainment are normally less time sensitive, which mitigates the best advantage of MRT travels (travel time predictability), resulting in car travel being less affected by traffic congestion under such circumstances. On the other hand, the mild increase of the share of driving in Tongzhou Beiyuan is partly due to the considerably lower car ownership than the other two (see Figure 7.7).

Table 7.7 Comparison of Non-Commuting Trips before & after MRT became available

	Huilongguan		Tiantongyuan		Tongzhou Beiyuan	
	Before	After	Before	After	Before	After
Driving	14.1%	42.0%	19.7%	48.8%	13.6%	20.2%
Car-Pooling	1.8%	0.3%	2.0%	0.0%	58.0%	0.0%
MRT	-	24.9%	-	16.5%	-	10.8%
Taxi	13.6%	3.2%	12.3%	2.7%	2.3%	0.7%
Bus	28.4%	16.8%	26.7%	14.3%	40.3%	37.7%
Bike	17.7%	8.1%	13.5%	5.7%	21.2%	21.2%
Walking	24.5%	5.0%	25.9%	12.2%	22.0%	9.4%
Total	100%	100%	100%	100%	100%	100%

7.5 Travel Preferences

Human travel preferences are obviously very important influences on travel decisions. Several survey questions address this issue.

7.5.1 Important Factors for Travel Mode Decisions

The majority of all correspondents indicate that the location of the destination matters the most (see Figure 7.11) in making mode choice decisions, in terms of whether the trip destination is connected to, or within acceptable walking distance of a MRT station; whether the destination is better connected by expressways or arterials. At the same time, whether the total travel time is reasonable has a significant impact on travel decision making. The third most important factor is the gas price, which has more than tripled over the past 12 years (See Figure 7.12). The price of #92 gasoline in Beijing has been increasing rapidly since 1998, with only a few limited downturns. . The average annual growth in the price of gasoline from 1998 to 2011 is 9.6%. The extremely low MRT fares in Beijing, facilitated by large government subsidies, have been a significant promoter of its usage. Since the opening of the Olympics in 2008, the MRT fare in Beijing has been reduced to a flat rate of 2 RMB per trip, no matter how far one travels. At the same time, fares for buses have been reduced to as low as 0.4 RMB. In 2010, Beijing Municipal government subsidies for public transportation, including buses and MRT, totaled 13.53 billion RMB. On the other hand, the quality of MRT service plays a small role in travel mode decisions, as the survey correspondents did not rate it as an important factor. The implication is that despite the crowdedness in MRT stations and trains at peak hours and inefficient design of transfers, people choose to tolerate to some extent.

Survey correspondents also indicated other important factors in their travel mode decision, including: i) parking cost at the destination; ii) comfortness of the travel mode;

iii) travel time matters the most for commuting trips, while convenience is more important for non-commuting trips; iv) time versus cost.

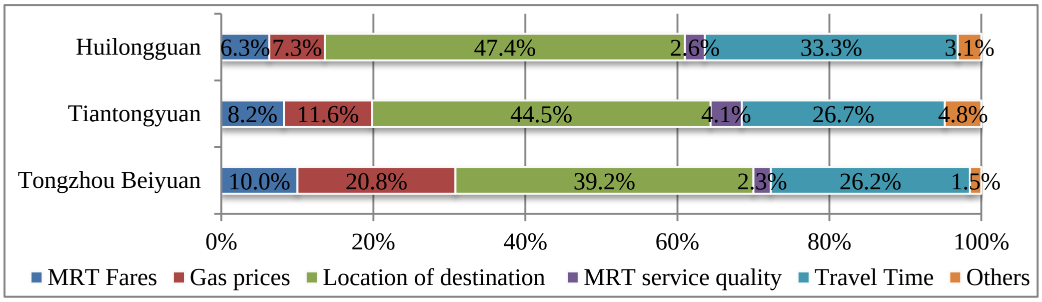


Figure 7.11 Important Factors that Affect Travel Mode Decisions

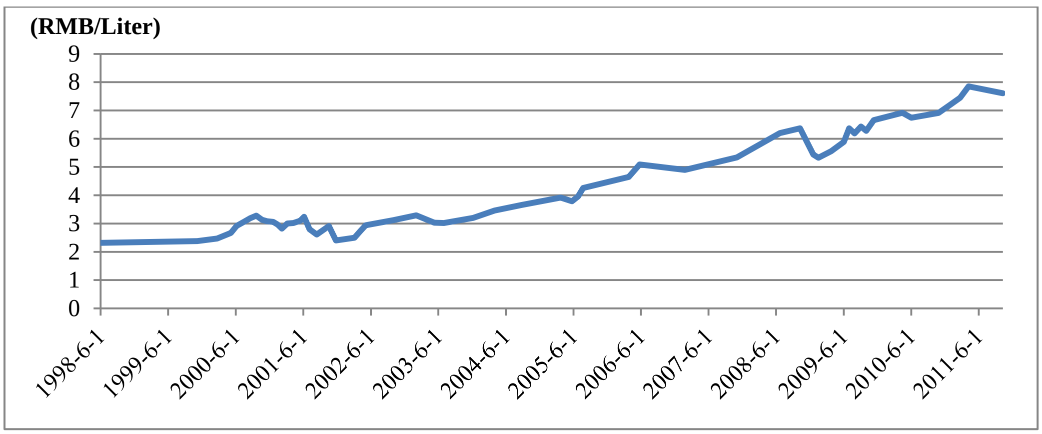


Figure 7.12 Historical Price Changes of #93 Gasoline in Beijing, 1998-2011

7.5.2 MRT Services

The commonly acceptable maximum walking time to the MRT stations determines the effective coverage of the MRT system. Survey results show that the majority of the correspondents in the three case study communities indicate that 10 minutes is the maximum acceptable walking time to a MRT station (see Figure 7.13). Studies show that the average human walking speed is about 5.0 km per hour (km/h), or about 3.1 miles per hour (mph). Therefore, the maximum acceptable walking distance is 1,250 meters.

The satisfactory level of MRT service in Beijing is also considered in the questionnaire. The results, as illustrated in Figure 7.14, show that only a very small percentage of residents are satisfied with MRT services and have no complaints, i.e. 6.2%. This high level of dissatisfaction suggests that the MRT services in Beijing need significant improvement. The correspondents indicate that leading causes of lack of dissatisfaction with Beijing's MRT system are:

i) Over-crowdedness, especially during peak hours: The development of the MRT system in Beijing has been rapid for the past decade, so has the population growth. Passenger flows have been increasing sharply over the same time. Low fares drive increased ridership. It has been observed that passengers have to wait in long queues and for two to three trains to pass to be able to board during peak hours (see Image 7.1).

ii) Low Density of MRT Lines: Currently there are 14 MRT lines in operation in Beijing, with a total length of 336km. The highest MRT density appears within the 2nd Ring Road, at the level of 0.77km per km^2. The overall density of Beijing's MRT system is 16.8 km per million persons in 2010, which is much lower than that of Tokyo, Seoul, New York and London (see Tables 7.8 and 7.9).

iii) Inconvenient Interchange Passages: Passengers are required to walk long distance at most of the transfer stations in Beijing, which in some cases includes a significant number of stairs. Long transfer times significantly increases passengers' travel time and decreases the effectiveness and comfort of MRT travel (see Table 7.10).

iv) Poor Walking Environment around MRT Stations: Areas outside the surveyed MRT stations are occupied by street vendors and "black" taxies most of the day (see Image 7.1). The stations are also often separated from high activity areas (residences, commercial complexes, etc.) by rail road lines, above-ground MRT tracks, wide streets, or exclusive BRT lanes in the three case study neighborhoods. Pedestrian connections with surrounding buildings are lacking, unlike the case of most large East Asian metropolitan areas.

v) Safety Issues: Some of the correspondents are concerned with the exposure to X-ray scanning every day. Some others think the transfer tunnels are long and narrow, which could be very dangerous in an emergency.

vi) Poor Connections between MRT and Buses: Some correspondents note that the connection between MRT stations and bus routes is inadequate and inconvenient.

vii) Lack of Parking Facilities at the MRT Stations: Most of the MRT stations in Beijing have parking places for bikes, but not for cars. This significantly reduces the service coverage of the MRT system. (Best planning practice indicates that park and ride stations should be built at the needs of MRT lines [almost invariably in suburbia], although not at core city stations.)

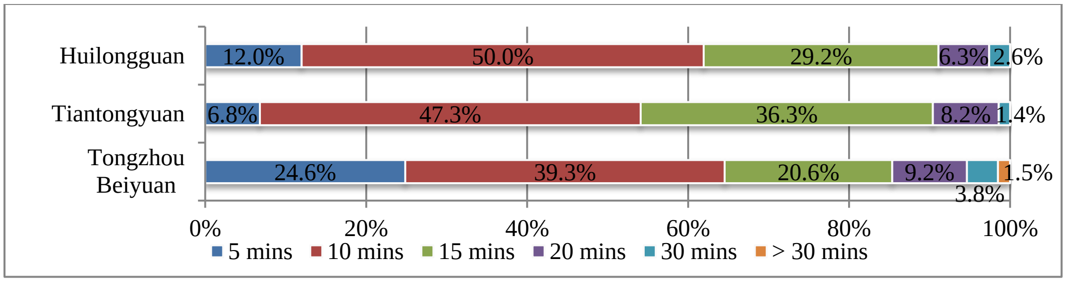


Figure 7.13 Acceptable Walking Time to MRT Stations

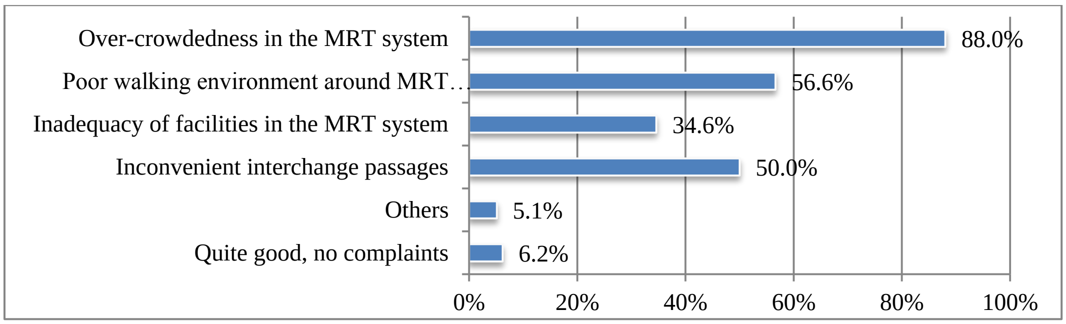


Figure 7.14 Shortcomings of the MRT System in Beijing

Image 7.1 Images outside Selected MRT Stations

Outside of Tiantongyuan S. Station, Dec. 21, 2009

Outside of Huilongguan Station

Source: The author, 2011

Table 7.8 MRT Density in Beijing, within the Territory of Ring Roads

	Length of MRT (km)	Area (sq.km)	Density of MRT (km/sq.km)
Within 2nd Ring Road	48.21	62.5	0.77
Within 3rd Ring Road	82.41	150	0.55
Within 4th Ring Road	123.55	300	0.42
Within 5th Ring Road	177.75	667	0.27
Within 6th Ring Road	321.41	2260	0.15

Source: I performed calculation with the assistance of Google Earth.

Table 7.9 Subway and Commuter Rail Densities of World Cities in 2010

	Rail Length (km)	Total Population (million)	Density (km/million persons)
Tokyo	2300	30.2	76.16
Seoul	344.7 (urban rail) / 821.2 (wide-area rail)	10.47	32.92 (urban rail) / 78.43 (wide-area rail)
Hong Kong	168.1	7.1	23.68
New York	368	7.17	51.32
London	408	7.83	52.11
Beijing	336	20	16.8
Shanghai	424	23	18.43

Source: I compiled the information from the different sources online for each city in the summer of 2011.

Table 7.10 Transfer Distance and Time at Selected MRT Stations in Beijing

MRT Station	Transfer of Lines	Walking Distance (m)	Walking Time (mins)
Xizhimen	Line 13 to Line 2	444	10
	Line 13 to Line 4	348	7
	Line 4 to Line 2	114	3
Dongzhimen	Line 13 to Line 2	237	8.5
Xidan	Line 4 to Line 1	193	5
Dongdan	Line 5 to Line 1	170	4
Fuxingmen	Line 1 to Line 2	163	4

Source: I walked in these stations to measure the distance and count walking time for transfers in the summer of 2011.

7.6 Living Experiences in the Neighborhoods

The correspondents are also asked to rate improvements associated with MRT services to their neighborhoods, in terms of their lives and living satisfaction in the neighborhoods in question. About half of the correspondents in Huilongguan and Tiantongyuan think MRT access improved their life somewhat or moderately, while 76.5% of the residents in Tongzhou Beiyuan consider their life improved. Less than 30% think their life is significantly improved with the availability of MRT. About 15% of the correspondents think their life is not improved or even worsened because of the MRT (see Figure 7.15). The main concerns for unsatisfactory perceptions of MRT service in Huilongguan and Tiantongyuan are: i) MRT access results in more home renters poured in; sometimes several households share one apartment to reduce living costs, which respondents associate with security/safety issues; ii) street vendors and black taxies/tricycles associated with MRT stations downgrade the environment; and iii) the availability of MRT rapidly drives up the housing price, which puts more pressures on the home renters and those who wish to buy a home. The situation is better in Tongzhou Beiyuan due to the smaller total population and less crowdedness of MRT trains, which in turn explains higher satisfaction levels despite the lower share of MRT trips.

In terms of satisfactory, only a very small number of the correspondents rate the impact of MRT on their living experience number 5, the highest level. The majority of residents consider the impact on their living experience moderately satisfying, i.e. level 3-4 (See Figure 7.16).

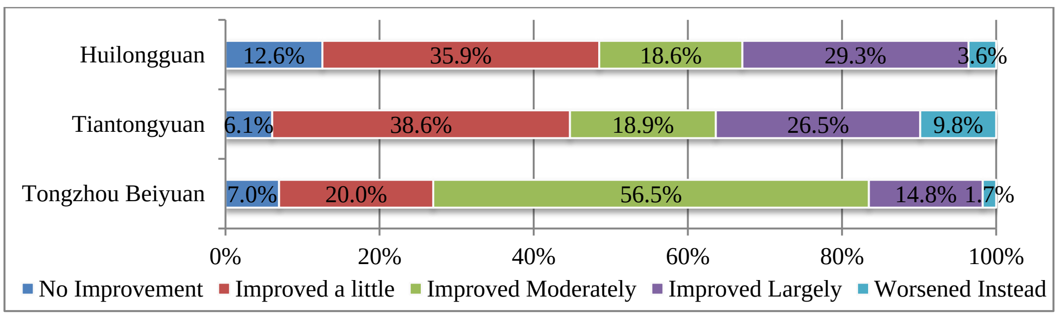


Figure 7.15 Answers to Question "Did the Availability of MRT Improve Your Life?"

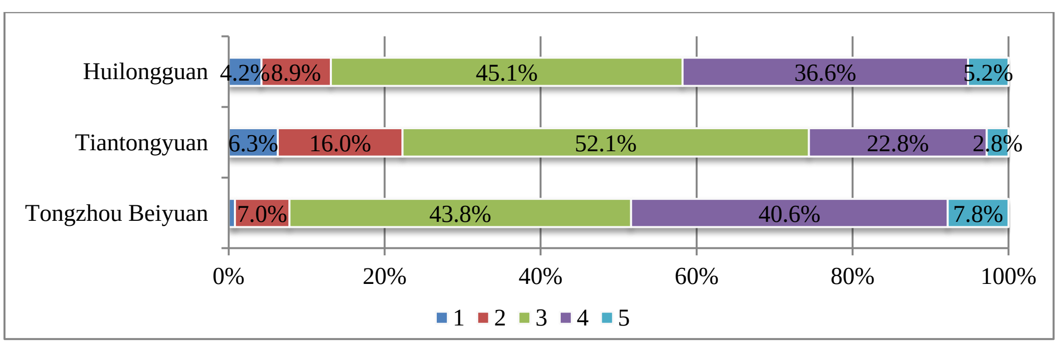


Figure 7.16 Levels of Satisfactory for Living in the Neighborhoods

Note: The correspondents are asked to rate their living experiences in the neighborhoods. Number 5 stands for the highest satisfactory level; while 1 stands for the lowest.

7.7 Synthesis and Implications

7.7.1 Correlation Analysis of Travel Behavior

In order to understand the factors that affect people's travel behavior, regression (correlation) analysis is performed for commuting trips. As the outcome variable (travel modes for commuting trips) is categorical, Multinomial Logistic Regression (MLR) is applied. For most residents who choose and are able to walk or bike to work, their travel decisions are not affected by the availability of MRT service. Therefore, this regression analysis is performed for the residents who commute to work by MRT, driving, or bus. Factors that have potential influence on people's commuting travels are selected from questionnaire survey, namely:

i) Distance from home to office (cmtdist), measured using a digital map service based on home and office location information from the household questionnaire and Beijing's road structure. The unit is kilometer.

ii) Household monthly income groups (income), which is re-categorized from questionnaire survey:
   - income1: Lower than RMB 5,000
   - income2: RMB 5,000 – RMB 9,999
   - income3: RMB 10,000 – RMB 19,999
   - income4: RMB 20,000 and over

iii) Age groups (agegrp), which is re-categorized from questionnaire survey:
   - agegrp1: Younger than 30 years old
   - agegrp2: 30 – 40 years old
   - agegrp3: 41 – 50 years old
   - agegrp4: 51 years old and above

iv) Education Levels (education), which is re-categorized from survey:

- education1: High School and Lower
- education2: College Degree
- education3: Master's and above

v) Distance from office to the closest MRT station (ofstdistnew), which is a categorical variable based on walking time from the office to the closest MRT station:

- ofstdistnew1: 5 minutes and less
- ofstdistnew2: 6 – 10 minutes
- ofstdistnew3: 11 – 20 minutes
- ofstdistnew4: 21 minutes and more

vi) Distance from home to the closest MRT station (homeloc), measured using a digital map service and based on home and station location information from the household questionnaire and Beijing's road structure. The unit is meter.

The total sample size for all three neighborhoods is 468. The number of survey correspondents who choose to commute by MRT, car, or bus is 356. In MLR, MRT travels are selected as the base outcome. The regression results are shown in Table 7.11.

Multinomial logistic regression						
				Number of obs	=	356
				LR chi2(24)	=	84.66
				Prob > chi2	=	0.0000
Log likelihood = -317.71878				Pseudo R2	=	0.1176

cmtmm2	RRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
car						
cmtdist	.9780057	.0153519	-1.42	0.157	.9483746	1.008563
income2	.731013	.3119858	-0.73	0.463	.3166974	1.687352
income3	1.406366	.6069299	0.79	0.429	.6036076	3.27674
income4	2.19525	1.009693	1.71	0.087	.8912069	5.407413
agegrp2	1.093453	.3624233	0.27	0.788	.5710455	2.093773
agegrp3	1.269972	.5581824	0.54	0.587	.5366255	3.005503
education2	1.050386	.4793375	0.11	0.914	.4294453	2.569152
education3	.9423823	.4751261	-0.12	0.906	.3508101	2.531524
ofstdistnew2	2.020937	1.091963	1.30	0.193	.7008536	5.827445
ofstdistnew3	2.500356	1.355119	1.69	0.091	.8643226	7.233156
ofstdistnew4	5.818105	3.337927	3.07	0.002	1.889886	17.91132
homeloc	1.000023	.0001788	0.13	0.899	.9996724	1.000373
_cons	.3655749	.3184118	-1.16	0.248	.0663115	2.015412
MRT	(base outcome)					
bus						
cmtdist	.910179	.0194275	-4.41	0.000	.8728872	.949064
income2	.4079559	.193155	-1.89	0.058	.1612852	1.031886
income3	.3796558	.1999181	-1.84	0.066	.1352592	1.065647
income4	.1011586	.086511	-2.68	0.007	.0189258	.5406944
agegrp2	.4429874	.1856794	-1.94	0.052	.1948085	1.007337
agegrp3	.9642143	.5039942	-0.07	0.944	.3461394	2.685938
education2	1.019863	.5931684	0.03	0.973	.3261893	3.188703
education3	.7405751	.5159105	-0.43	0.666	.1890568	2.900987
ofstdistnew2	.9640563	.8424069	-0.04	0.967	.1739041	5.344352
ofstdistnew3	1.035234	.9094112	0.04	0.969	.1850514	5.791415
ofstdistnew4	3.802859	3.400863	1.49	0.135	.6590047	21.94482
homeloc	.9998679	.0002434	-0.54	0.587	.9993911	1.000345
_cons	5.6416	6.766593	1.44	0.149	.5376038	59.20279

Table 7.11 Correlation Analysis of Commuting Travel Behavior using Multinomial Logistic Regression

The results show that household income level and the distance from office to MRT station play a significant role in people's decisions whether to drive to work or to take MRT. The effect of household monthly income is not significant when under RMB 20,000. But when it jumps from category 3 (RMB 10,000 – RMB 19,999) to category 4 (RMB 20,000 and more), the probability ratio of choosing to drive compared to traveling by MRT increases dramatically by 119%. Similarly, when the distance from the workplace (office) to the closest MRT station increases to 10 – 20 minutes of walking time, the probability ratio of choosing to drive increases by 150%; when it increases to 20 minutes of walking time or more, the probability ratio of choosing to drive increases even more significantly by 482%. On the other hand, age and education are not significant factors for choosing driving over traveling by MRT.

In terms of the travel decision for bus commuting trips, the distance between home and office, household monthly income level and age are significant factors. For every unit of change in distance between home and office (km), the probability ratio of taking a bus to work, as compared to MRT, decreases by 9%. Income level has a larger impact on bus trips, as does age. When household monthly income level moves up the ladder from category 1 to 2, to 3 and to 4, the probability ratios of choosing to take the bus to work decrease by 59%, 62% and 90%. When the age group increases from category 1 to category 2, the odds ratio of choosing bus decreases by 56%.

In conclusion, neither education nor the distance from home to MRT station is significant in people's commuting travel decision. Residents whose household monthly income is higher than RMB 20,000 or whose office is more than 10 minutes of walk from a MRT station are highly inclined to drive to work instead of taking the MRT. And MRT shows advantages over bus trips to work in cases of longer commuting distance, higher household income and younger age groups.

7.7.2 Qualitative Factors for Travel Behavior

The timing of MRT availability can have a significant impact on people's travel behavior, as illustrated by the cases of Huilongguan and Tiantongyuan. Overall, the earlier the availability of MRT, the easier to encourage MRT usage, because:

i) When MRT is already available, it is an important factor in the decision for of households whether to buy a car or not;

ii) There is usually inertia in behavior; so the earlier the MRT is available, the higher the chance that MRT travel will become a habit, or vice versa; and,

iii) The preferred choice of travel is often a factor when residents choose which neighborhood to live in; hence early MRT availability could attract more residents who prefer MRT travels over driving.

The routing of MRT lines and the walking environment around MRT stations also has important impacts on travel behavior decisions. Currently in Beijing, the design of MRT routes and stations is undertaken by transportation planners and is dominantly based on principles of easy acquisition and low cost of land, while often sacrificing walkability and service range. Policy makers need to recognize the importance of maximizing the service range of MRT facilities, and accordingly coordinate MRT routes and the neighborhood layouts, particularly their circulation systems, to increase the number of residents who are able to reach MRT stations within acceptable walking time, which is 10 minutes according to the researcher's survey based data. Currently, a considerable number of residents drive to the MRT station to take rail transit to work. But unregulated parking along street outside the MRT stations results in unpleasant walking environment (refer to Image 6.2 in Chapter 6).

7.7.3 Implications for Sustainability Benefit Assessment

The comparison of major travel mode shares with Beijing's average level for commuting trips is shown in Table 7.12. Huilongguan and Tiantongyuan are similar in many aspects, especially in terms of population profile and travel behavior. This is consistent with the fact that they started as affordable communities. Although the commencement of MRT service in these two neighborhoods varies (relative to their development trajectories), little difference is observed in the residents' travel patterns. On the other hand, Tongzhou Beiyuan presents another type of community, which is more mature and diverse in demographics. Although the MRT line was opened around the same time as the one for Huilongguan, the travel behavior of its residents is different from Huilongguan.

Table 7.12 Comparison of Major Travel Mode Shares with Beijing Average Level, for Commuting Trips

	Bus	MRT	Taxi	Car	Bike
Huilongguan	6.9%	52.9%	0.5%	29.6%	4.2%
Tiantongyuan	9.9%	39%	0.7%	43.4%	2.1%
Tongzhou Beiyuan	31.5%	21.8%	0	21.8%	4%
Beijing Average in 2009	27.7%	13.2%	6.9%	32.7%	16.3%

Source: (Beijing Transportation Research Center, 2011)

The share of car trips for both commuting and non-commuting purposes has been increasing compared with the years prior to the opening of MRT stations. However, considering increased car ownership levels, the intensity of car usage has actually been decreasing due to MRT accessibility.

Currently, public transportation, including MRT and buses, accounts for over 50% of the residents' commuting trips in all three neighborhoods, much higher than Beijing's average level which is 40.9%. But MRT accounts for the most significant share of all trips in Huilongguan (52.9%) and Tiantongyuan (39%). On the other hand, in Tongzhou Beiyuan, Bus plays a more important role (31.5%), even higher than the Beijing average. Its mode share for MRT is also slightly higher than the Beijing mean.

In the next chapter, which assesses the sustainability impacts of mode share differences, analysis is based on the travel mode share of the neighborhoods (obtained from my survey in 2011) and the latest available data for Beijing's average level (2011). The 2011 data, at both the neighborhood and overall city level, takes into consideration compound effects over the past years in terms of car ownership, demographic change, rising household incomes, housing price changes, etc. The researcher was unable to base the analysis in Chapter 8 on "before and after MRT became available" data at the neighborhood scale because sample size is too small; a relatively smaller population have been living in the same neighborhood and working at the same place for over 10 years.

Chapter 8

SUSTAINABILITY ASSESSMENT

This chapter assesses the sustainability benefits attributable to MRT-service to suburban neighborhoods in Beijing. It is hypothesized that after MRT service becomes available to a neighborhood inducing changes in people's travel behavior, there will be environmental benefits relative to non-MRT served neighborhoods. Such a hypothesis is based on reduction in the carbon footprint when more people use public transit. But little work has been done at the neighborhood level in Chinese cities to investigate the extent to which travel behavior has changed. In particular, to measure the extent to which car and bus trips were replaced with electric powered rapid transit. And, to what extent potential benefits are offset by CO_2 emissions from thermal power plants, given that the majority of electrical generation in China comes from coal-fired power plants. In this study, sustainability benefits are quantified according to the reductions or additions of GHG emissions, traditional air pollution (especially CO, VOC, NOx, PM), and energy consumption given the introduction of MRT service in the three study neighborhoods.

The latest information on Beijing's vehicle fleet and MRT trains are examined to determine the intensities of CO_2 and traditional air pollutant emissions, as well as energy consumption for each travel mode. Details of the emission intensities are explained in this chapter. Average travel distances by residents in each neighborhood for different travel modes are obtained from the household survey (see Chapter 7) – mean values associated with each neighborhood are used in this analysis.

Initial quantification uses a per capita metric. This unit of analysis is then up-scaled by multiplying by the total commuting population of each neighborhood and of Beijing. A linear model is applied in the quantification of these selected environment benefits. It is assumed that an average commuting resident in Beijing travels to work once a day (round trip) and five days a week.

8.1 Rationale for Comparing Neighborhood Travel Mode Share with Beijing's Average Levels

There are several approaches to relate current travel behavior to sustainability performance. The first approach is to compare differences in travel behavior for the same neighborhood before and after the opening of MRT stations. But since 2000, car ownership has increased significantly. Such a comparison will therefore result in biased results because the impacts of high car ownership will, to some extent, offset the attraction of other modes, including MRT. A more insurmountable problem is that residents have changed considerably in these neighborhoods between 2001 and 2011. Only a small percentage of current residents have been living in the same apartment and working for the same company as they were 10 years ago.

The second approach is to compare the case study MRT served neighborhoods with a non-MRT served suburban neighborhood. However, it was impossible to identify a comparable control neighborhood; that is, a suburban neighborhood in Beijing in 2011 with a similar size, comparable demographic and socioeconomic makeup, and the absence of an MRT station.

The third approach is to compare the three case study neighborhoods with Beijing's average travel mode share breakdown. By doing this, the researcher controls for both the increase in car ownership and the changes of economic growth since 2000. Because all three neighborhoods examined in this study are highly MRT accessible, such a quantitative exploration, which compares the travel mode performance of these neighborhoods to Beijing's average mode share levels simulates the potential sustainability benefits if the whole city were a MRT saturated public transport city with all residents enjoying easy MRT access. Due to the variance in, and unpredictability of non-commuting trips, only commuting trips are compared in this study, capturing the most frequent and regular trips for local residents. This level of city-wide walking accessibility to transit stations happens to coincide with the goal outlined in the Beijing Public Transport City Plan 2015 (Please refer to Chapter 3 for details). Saturation access to MRT services has been achieved in other East Asian cities, particularly Tokyo, and Seoul, with Shanghai moving toward saturation status.

As the three selected neighborhoods demonstrate different results in terms of the residents' travel pattern due to different demographics and other socio-economic characteristics, the comparison is conducted according to three saving profiles[36], with an effort to find out what kind of mode share would be most beneficial in terms of providing the optimum sustainability performance specified by the selected metrics.

8.2 Comparison of Commuting Travel Behavior

The quantification of sustainability benefits is based on commuting travel mode differences between the case study neighborhoods and Beijing's average, the difference being multiplied by emission and energy intensities. Mode share information is from the previous chapters.

Of the travel modes identified in this study, the following ones show significant differences when compared to Beijing's average (mean) level (see Table 8.1). Most cars and taxis in Chinese cities run on gasoline. MRT trains run on electricity. The fleet of buses in Beijing consists of gasoline (79.03%), diesel (6.36%), natural gas (12.13%) and electricity (2.48%) in 2010 (Beijing Public Transport Holdings, 2012). Buses, cars and taxis in Beijing produce GHG emissions, local air pollution, and consume energy. MRT is considered to be "clean" as it runs on electricity and does not emit local air pollution

[36] By "saving profile", I am referring to the equivalent per capita savings on GHG emission, traditional air pollution and energy consumption of three study neighborhoods, extrapolated to the whole Beijing commuting population.

when operating. However, electrical generation produces GHG, albeit not point source emissions. This is especially of concern in China where coal fired plants account for 82% of electricity generation (Z. Wang, June 2011), and the consumption of electricity by MRT trains may contribute significantly, per rider, to overall GHG emissions, given the predominant use of coal in electrical generation. Based on the need for standardized, comparable units, the energy consumption of each travel mode will be translated into the same unit, i.e., kg Coal Equivalent, or kg CE.

Table 8.1 Comparison of Major Travel Mode Shares in the Study Neighborhoods compared to the Beijing Mean, by Number of Commuting Trips

	Bus	MRT	Taxi	Car	Bike
Huilongguan	6.9%	52.9%	0.5%	29.6%	4.2%
Tiantongyuan	9.9%	39%	0.7%	43.4%	2.1%
Tongzhou Beiyuan	31.5%	21.8%	0	21.8%	4%
Beijing Average in 2011	27.7%	13.2%	6.9%	32.7%	16.3%

Source: The author, 2011; and (Beijing Transportation Research Center, 2011).

From the household survey, the mean commuting distance for each travel mode for Huilongguan, Tiantongyuan and Tongzhou Beiyuan residents was determined and presented in Table 8.2. Commuter trips taken by the MRT and automobile feature the longest distances, followed by buses. Taxis appear to be predominantly used for short commutes.

Table 8.2 Mean Travel Distance for Major Travel Modes by Neighborhood Residents (unit: km)

	Bus	MRT	Taxi	Car
Huilongguan	9.42	20.49	2	15.36
Tiantongyuan	12.29	18.67	2	19.3
Tongzhou Beiyuan	11.95	21.73	-	21.28

Quantification of each category of sustainability benefits related to changes in human commuting travel behavior is measured on a per capita base in the following three sections. In section 8.6, the researcher extrapolates the results to Beijing's total employed population.

8.3 CO_2 Emission

CO_2 emissions are generated by buses, cars and taxis (local sources), as well as MRT trains (regional sources). Yang *et al* (2011) assessed commuting patterns in Beijing to explore strategies for low-carbon development, using surveys that were conducted in September 2009 and September 2010. Based on capacity, occupancy rate, and energy efficiency of MRT trains and buses, it was estimated that every MRT commuter was responsible for 0.23 kg of CO_2 emission per 100 km of passenger travel; by comparison, the emissions intensities for bus passengers was 1.3 kg/100 km of travel. Based on current fleet and energy efficiencies, solo automobile drivers were estimated to produce between 18kg to 22kg of CO_2 emissions per 100km. These emission intensity figures correspond closely with the work of Zhu (2010), who compared energy consumption and GHG emissions between transportation options in Beijing and Shanghai. Zhu found that the CO_2 emission intensity per 100 km when driving alone in Beijing was 21 kg per person. CO_2 emission intensity from taxis in Beijing were determined in a study by the Innovation Center for Energy and Transportation (iCET), to be 15.6 kg per person per 100 km (iCET, 2011). Overall, based on the various studies, the intensity of CO_2 emissions from private (sole occupant) cars and taxis (not including driver) is 12-16 times that of buses (not including driver) or 70-90 times that of MRT per passenger per 100 km (see Table 8.3).

Table 8.3 CO_2 Emission Intensities of Major Commuting Travel Modes in Beijing (unit: kg/person•100km)

	CO_2
Bus	1.3
Car	21
Taxi	15.6
MRT	0.23

The quantification of CO_2 emissions for each selected neighborhood is performed according to the following equation:

(1) CO_2 savings per capita of a MRT-served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/CO2} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/CO2} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/CO2} + (\%MRT_{BJ} - \%MRT_{NH}) \times TD_{MRT} \times EI_{MRT/CO2}$

Where, BJ = Beijing
NH = Neighborhood
TD = Travel Distance
$EI_{Bus/CO2}$ = Emission Intensity of CO_2 by Bus
$EI_{Car/CO2}$ = Emission Intensity of CO_2 by Car
$EI_{Taxi/CO2}$ = Emission Intensity of CO_2 by Taxi
$EI_{MRT/CO2}$ = Emission Intensity of CO_2 by MRT

The results are presented in Table 8.4. Both Huilongguan and Tongzhou Beiyuan demonstrate lower CO_2 emissions per capita compared to the Beijing mean. Moreover, the level of savings in Tongzhou Beiyuan is much higher, about triple, than that of Huilongguan, which linked to the lower per capita incidence of trips made by car. On the other hand, Tiantongyuan emits more CO_2 per capita than the Beijing average for commuting trips, attributable to the higher proportion of trips made by car in that neighborhood. Although the share of public transport in Tiantongyuan is higher than Beijing's average, the share of trips made by car is also much higher (43.4% versus 32.7%, see Chapter 7). As private cars have the highest CO_2 emission intensities, the savings of public transport trips are largely offset by higher levels of driving.

The total CO2 emission savings are calculated by multiplying the total commuting population in the neighborhoods by the number of daily round-trip commutes made each day, the total savings in CO_2 emissions of the selected neighborhoods compared to Beijing mean are quantified and shown in Table 8.4.

Table 8.4 Savings of CO_2 Emissions per Day for Daily Commuting Trips in the Study Neighborhoods (Unit: kg per person per day)

	Amount	Percentage
Huilongguan	0.2554	11.44%
Tiantongyuan	- 0.7948	- 27.74%
Tongzhou Beiyuan	1.02	33.28%

8.4 Traditional Air Pollution

The emission sources of Beijing's air pollution remain a complicated issue, but are generally recognized to be attributable to both local sources (such as in-use vehicles, construction sites, coal-fired heating facilities) and regional sources (such as coal fired power plants or heavy industries in the surrounding areas). Layshock et al. (2010) monitor air pollutants at various urban and rural sites surrounding Beijing. Their findings suggest that regional sources contribute more than local sources to the concentrations of O_3 and CO (62% and 77% respectively). However, another study by An et al. (2007) finds that local sources are the main contributors for the following pollutants with the order of SO_2 > PM_{10} > $PM_{2.5}$, by 82%, 70% and 61% respectively.

Among local emission sources, mobile sources are identified by researchers as one of the most important contributors to Beijing's air pollution, estimated to account for over 50% of Beijing's local gaseous air pollutants. (Hao et al., 2000; S. Wang et al., 2010; Westerdahl et al., 2009). The contribution of urban transportation has been increasing with economic development, population growth and increased travel distances and frequencies (D. Wang & Chai, 2009b). It is also important to recognize that weather changes have an apparent relationship with local air quality; persistent rainfall, lower temperatures and easterly air flow positively impact air quality in Beijing (J. F. Liu et al., 2009).

Traditional air pollution generated by local road transportation is mainly the product of combustion of liquid fossil fuels. When combustion is incomplete, a small fraction of the fuel is oxidized to generate carbon monoxide (CO). At high combustion temperatures, atmospheric nitrogen is oxidized in different forms (NO, NO_2 and N_2O, or simply referred to as NOx). Exhaust from cars is another source for N_2O. Hydrocarbons (HC) are produced by incomplete combustion of gasoline during refueling as well as evaporation from storage. Transportation accounts for 40 to 50% of total emissions of HC and Volatile Organic Compounds (VOC) – hydrocarbons in a gaseous form. Particulate Matter (PM[37]) refers to particles and liquid droplets suspended in the air, which often result from the incomplete combustion of fossil fuels and from combustion in diesel engines, as well as other sources such as tire wear. Transportation accounts for around 25% of total emissions of particulates. .

The noted air pollutants from local traffic affect people's health and the environment in different ways. Both NOx and PM aggravate lung diseases leading to respiratory symptoms. Both CO and PM could cause or aggravate heart disease. Some VOCs may be carcinogenic. All air pollutants may contribute to an increase in premature mortality[38]. In terms of environmental and climate effects, both CO and VOCs contribute to the formation of CO_2 and ozone. NOx increases the level of acidification and nutrient enrichment of soil and surface water leading to biodiversity loss and also impacts levels of ozone and methane formation. PM affects the environment in a more direct way by decreasing visibility and air temperature. It may also impact rainfall patterns (United States Environmental Protection Agency, 2011).

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[37] PM_{10} has been traditionally monitored as one of the main air pollutants in China. But recent research has shown that $PM_{2.5}$ is more harmful for the human respiratory system and is significantly correlated with an increase in cardiovascular medical conditions (Colvile et al., 2001; Rodrigue et al., 2009a). $PM_{2.5}$ is mainly produced by anthropogenic activities with the most significant contributions coming from vehicle exhaust, coal combustion, factories, and construction sites. According to the last revised *Ambient Air Quality Standards* published by the Ministry of Environmental Protection of China in March 2012, $PM_{2.5}$ has been added to the list of regularly monitored air pollutants along with CO and O_3. Before that, only NO_2, SO_2 and PM_{10} had been regularly monitored.

[38] It is estimated by the World Health Organization (WHO) that outdoor air pollution causes 299,400 premature mortality in China every year (World Health Organization, 2009).

Table 8.5 Sources, Health Effects and Environmental/Climate Effects of Four Selected Major Air Pollutants Related to Urban Transportation

	Sources	Health Effects	Environmental / Climate Effects
Carbon Monoxide (CO)	Combustion of fuels (especially vehicles)	Reduces the amount of oxygen reaching organs and tissues; aggravates heart disease.	Contributes to the formation of CO_2 and ozone.
Volatile Organic Compounds (VOCs)	Incomplete combustion of gasoline; during refueling; evaporation	Some are toxic air pollutants that cause cancer and other serious health problems.	Contributes to the formation of CO_2 and ozone.
Oxides of Nitrogen (NO_x)	Combustion of fuels; exhausts of vehicles	Aggravate lung diseases leading to respiratory symptoms; increase susceptibility to respiratory infection.	Contributes to the acidification and nutrient enrichment (eutrophication, nitrogen saturation) of soil and surface water. Leads to biodiversity losses. Impacts levels of ozone, particles, and methane.
Particulate Matter ($PM_{2.5}$ and PM_{10}, with $PM_{2.5}$ having more severe impacts on public health)	Emitted or formed through chemical reactions; Combustion of fuels; unpaved roads.	Short-term exposures can aggravate heart or lung diseases and premature mortality; long-term exposures can lead to the development of heart or lung disease and premature mortality.	Impairs visibility, adversely affects ecosystem processes, and damages and/or soils structures and property. Variable climate impacts depending on particle type. Most particles are reflective and lead to net cooling, while some (especially black carbon) absorb energy and lead to warming. Other impacts include changing the timing and location of traditional rainfall patterns.

Source: (United States Environmental Protection Agency, 2011).

The impacts of regional sources of pollution on Beijing's air quality are also influenced by atmospheric conditions. However, the drastic actions taken by the Chinese government in preparation for the 2008 Olympic Games demonstrated that regional sources of pollution could also be effectively controlled through stringent policies. For example, the government closed heavy polluting industries in the neighboring regions, such as the coal mines in the Shanxi province. (T. Wang et al., 2010). Meanwhile, for local sources, policies such as the alternative day-driving scheme based on license plate numbers are able to take some vehicles from the streets and provide positive impact on improving the air quality. However, the demand for travel has continued to increase and must be accommodated with more sustainable travel modes, such as MRT. Therefore, it is important to understand how changes in travel behavior, especially in terms of the increasing share of MRT rides vis-à-vis driving, can contribute to the reduction of local air pollution

In a recent study on vehicle emissions in Beijing, data for vehicle sub-fleets (bus, private car on arterials, taxis), vehicle activity, and on-road emissions were collected and analyzed to quantify the emission intensities of different travel modes in Beijing (Oliver, et al., 2009). (see Table 8.6)

Table 8.6 Emission Intensities for Beijing sub-fleets

	CO		VOC		NOx		PM	
	Tons/day	g/km	Tons/day	g/km	Tons/day	g/km	Tons/day	g/km
Bus	105	28.4	3.7	1	29.3	7.9	1.2	0.311
PCarArterial	250.6	6.9	42.0	1.2	32.3	0.9	0.3	0.009
Taxi	61.4	2.6	19.5	0.8	24.8	1.0	0.1	0.005

Source: (Oliver, et al., 2009).

Emissions for each of the traditional air pollutants are calculated according to the following equations and the emission intensities for traditional air pollution by different travel modes are illustrated in Table 8.6.

(2) CO savings per capita of a MRT-served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/CO} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/CO} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/CO}$

Where, BJ = Beijing
NH = Neighborhood
TD = Travel Distance
$EI_{Bus/CO}$ = Emission Intensity of CO by Bus
$EI_{Car/CO}$ = Emission Intensity of CO by Car
$EI_{Taxi/CO}$ = Emission Intensity of CO by Taxi

Similarly, for all other air pollutants:

VOC savings per capita of a MRT served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/VOC} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/VOC} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/VOC}$

NOx savings per capita of a MRT served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/NOx} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/NOx} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/NOx}$

PM savings per capita of a MRT served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EI_{Bus/PM} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EI_{Car/PM} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EI_{Taxi/PM}$

The results are shown in Table 8.7 (negative values mean the neighborhood value is lower than the Beijing mean value, and hence savings). All neighborhoods demonstrate expected savings on all traditional air pollutants compared to the Beijing mean, except for VOC emissions for Tiantongyuan and PM generation for Tongzhou Beiyuan. The reasons are closely related to travel patterns associated with these neighborhoods. In Tiantongyuan, the high share of car trips leads to high VOC generation, which offsets the savings from lower shares of bus and taxi trips. The higher PM emission in Tongzhou Beiyuan is more related to the higher share of bus trips. In Beijing, the PM emission factor of buses is 30 times higher than that of cars and 60 times higher than that of taxis (Oliver, et al., 2009). The relatively higher share of bus commuting trips negates the savings from other modes.

By study neighborhood, Huilongguan shows the lowest intensity of emissions with respect to all four air pollutants followed by Tiantongyuan, and then Tongzhou Beiyuan. Traditional air pollution is closely related to the combined share of vehicle travel (cars and buses). Due to the high share of commuting trips by MRT, the combined share of motor vehicle travel in Huilongguan is the lowest in all three selected neighborhoods, at 36.5% of trips; the combined shares for the other two neighborhoods are both higher than 50%.

Table 8.7 Traditional Air Pollution Savings per Day, for Daily Commuting Trips based in the Study Neighborhoods (unit: kg per person per day)

	CO		VOC		NOx		PM	
	Amount	Percent-age	Amount	Percent-age	Amount	Percent-age	Amount	Percent-age
Huilongguan	128.54 $\times 10^{-3}$	54.32%	5.28 $\times 10^{-3}$	30.18%	34.48 $\times 10^{-3}$	65.11%	1.38 $\times 10^{-3}$	79.9%
Tiantongyuan	96.4 $\times 10^{-3}$	34.28%	- 0.38$\times 10^{-3}$	- 1.71%	31.08 $\times 10^{-3}$	47.51%	1.32 $\times 10^{-3}$	58.92%
Tongzhou Beiyuan	16.6 $\times 10^{-3}$	5.69%	5.82 $\times 10^{-3}$	23.77%	0.38 $\times 10^{-3}$	0.56%	- 0.13 $\times 10^{-3}$	- 5.67%

8.5 Energy Consumption

Energy consumption is another important aspect of the sustainability performance of urban transportation. In Chinese cities, there are different types of fuels for different vehicles, which feature different energy intensities (see Table 8.8). As mentioned, MRT trains run on electricity, which is predominantly generated by coal in China. The majority of cars in China run on gasoline. While taxis in China may either run on gasoline or Liquefied Petroleum Gas (LPG), the majority of taxis are gasoline powered in Beijing. Buses in Beijing run on a combination of different energy sources, including gasoline (79.03%), diesel (6.36%), natural gas (12.13%) and electricity (2.48%) (Beijing Public Transport Holdings, 2012; Zhu, 2010).

A case study conducted by Zhao (2007) used data on fleet usage, passenger capacity, and vehicle kilometers traveled to determine the energy intensities of different travel modes in Beijing. Zhao (2007) concluded that taxis have the highest energy intensity, followed by private cars (see Table 8.9). Both these modes used 8-12 times more energy than buses, and 30-50 times more energy than MRT trains, on a per capita basis for each unit of travel distance.

Coal Equivalent (CE) is a common unit for energy values internationally to enable comparison among different energy sources. There is no consensus yet for the amount of heat contained in 1kg CE. The United Nations indicates 6,880Kcal as standard, while China, Russia and Japan take 7,000Kcal as their standards.

Table 8.8 Vehicle Types and Fuel Types in Chinese Cities

Types of Vehicle	Types of Fuel
Bus	Gasoline; Diesel; CNG; LPG; Electricity
Car	Gasoline;
Taxi	Gasoline; LPG
MRT	Electricity

Note: CNG refers to Condensed Natural Gas; LPG refers to Liquefied Petroleum Gas
Source: (Zhu, 2010)

Table 8.9 Energy Intensity for Different Travel Modes in Beijing

	Types of Fuel	Energy Intensity (Kcal/person•km)
Bus	Gasoline (79.03%)	43.41
	Diesel (6.36%)	
	Natural Gas (12.13%)	
	Electricity (2.48%)	
Car	Gasoline	331.39
Taxi	Gasoline	544.43
MRT	Electricity	11.4

Source: (Xian Zhao, 2007)

Energy consumption is determined as follows:

(3) Energy Consumption savings per capita of a MRT-served neighborhood = $(\%Bus_{BJ} - \%Bus_{NH}) \times TD_{Bus} \times EnI_{Bus} + (\%Car_{BJ} - \%Car_{NH}) \times TD_{Car} \times EnI_{Car} + (\%Taxi_{BJ} - \%Taxi_{NH}) \times TD_{Taxi} \times EnI_{Taxi} + (\%MRT_{BJ} - \%MRT_{NH}) \times TD_{MRT} \times EnI_{MRT}$

Where, BJ = Beijing
NH = Neighborhood
TD = Travel Distance
EnI_{Bus} = Energy Intensity of Buses
EnI_{Car} = Energy Intensity of Cars
EnI_{Taxi} = Energy Intensity of Taxis
EnI_{MRT} = Energy Intensity of MRT
1kg Coal Equivalent = 7000 Kcal

The results of the analysis are shown in Table 8.10. Tiantongyuan is the only neighborhood that consumes more energy than the Beijing mean for commuting trips, which is related to its high share of driving trips. Tongzhou Beiyuan features the largest energy savings (31.39%) relative to Beijing, which may be attributed to having the lowest share of single occupancy vehicle trips as a proportion of total commutes; accordingly Tongzhou Beiyuan features a high public transit mode split (see Table 8.1). Although Huilongguan has the highest share of MRT commuting trips and its combined share of public transport trips is the highest of the three study neighborhoods, its energy savings are offset by a higher share of driving trips. At an energy savings rate of 11.67% compared to the Beijing average, this figure is considerably lower than that of Tongzhou Beiyuan.

Table 8.10 Savings of Energy for Different Travel Modes, compared to the Beijing Mean, for Commuting Trips (unit: Kcal per person per day)

	Amount	Percentage
Huilongguan	439.6	11.67%
Tiantongyuan	- 1153.6	- 24.24%
Tongzhou Beiyuan	1605.56	31.39%

8.6 Summary and Implications

8.6.1 Summary

Overall, the selected MRT-served suburban neighborhoods show significant savings in CO_2 emissions, traditional air pollution, and energy consumed by transportation as compared to Beijing's mean level. However, performance differs by neighborhood (see Table 8.11). Huilongguan has a net savings on all aspects examined. Of the three study neighborhoods, Huilongguan also features the highest reduction in traditional air pollutants relative to the Beijing's mean. The two areas in which Huilongguan performs poorer than Tongzhou Beiyuan were in CO_2 emissions and energy consumption. The main reason is the higher proportion of work trips made by private cars in Huilongguan, because CO_2 emissions intensity by private cars or taxis is 12-16 times that of buses or 70-90 times that of MRT trains on a per capita basis, and energy consumption of cars and taxis are 8-12 times more intense than buses and 30-50 times more intense than MRT trains. Tiantongyuan demonstrates this mode effect more strongly than Tongzhou Beiyuan, as the neighborhood with the highest share of commute trips made by car (43.4%). It produces more CO_2 emissions and a higher level of energy consumption than the Beijing mean. Therefore, while encouraging higher shares of commuting trips by MRT, policy makers also need to provide incentives for people to drive less to avoid the savings on CO_2 emission and energy consumption by increased MRT trips being offset by high level of driving to work.

Tiantongyuan fails to save on CO_2 emissions, VOC emissions, and energy consumption, as compared to the Beijing average. All these three environmental externalities are significantly related to driving. Tiantongyuan did not have access to MRT service until 2007, more than four years after the other two neighborhoods. Many residents were already driving before they had the option to take MRT. As discussed in Chapter 7, most of the gains in MRT ridership were from former bus riders, while the number of commuters who switched from driving private vehicles to MRT was small. At the same time, the route of MRT Line 5, skewed toward the western half of the neighborhood, limited walking access to the MRT station (refer to Map 5.3). For example, the residences furthest to the east side of Tiantongyuan are more than 2km from the MRT stations, discouraging the residents from using MRT even though there are shuttles within the neighborhood (as described in Chapter 6). The inconvenience of accessing the MRT system on foot (even when straight line distances are relatively short) may explain why the share of commute trips made by car is so much higher in Tiantongyuan than in the other two neighborhoods. In other words, micro access appears to MRT stations appears to make a significant difference.

Tongzhou Beiyuan excels in savings on CO_2 emissions and energy consumption, while failing to outperform Beijing in terms of PM pollution. This is related to its higher share of bus trips to work, as PM pollution by bus is about 34 times higher than cars and 60 times higher than taxis per passenger kilometer. In addition, Tongzhou Beiyuan has an uncharacteristically low share of commuter trips taken by private car (refer to Table 8.1)

Table 8.11 Percentage of Savings on CO_2, Traditional Air Pollution & Energy Consumption per capita, as compared to Beijing Mean

	CO_2	CO	VOC	NOx	PM	Energy
Huilongguan	11.44%	54.32%	30.18%	65.11%	79.9%	11.67%
Tiantongyuan	- 27.74%	34.28%	- 1.71%	47.51%	58.92%	- 24.24%
Tongzhou Beiyuan	33.28%	5.69%	23.77%	0.56%	- 5.67%	31.39%

The savings on CO_2 emissions, traditional air pollution, and energy consumption for the three selected MRT served suburban neighborhoods are summarized in Table 8.12 on a per capita basis cumulative for 365 days. According to the Beijing Statistical Yearbook (2011), the total employed population in Beijing was 6.47 million in 2010. The researcher extrapolated total possible savings, utilizing selected sustainability indicators, for the whole city; the results are presented in Table 8.13 Three saving profiles are put forward based on the neighborhoods examined in this study. The implication is that the commuting travel patterns of residents in Tongzhou Beiyuan present the best savings profile, out of the three study neighborhoods studied, for Beijing to save on CO_2 emission and energy consumption by urban transport. However, its high share of commuting trips by bus undermines its performance in reducing traditional air pollution, due to the higher emission intensities of Beijing's bus fleet, relative to other modes, and many other cities. This is validated in the model by the much higher emission reductions of traditional air pollution in the Huilongguan savings profile where the share of bus commuting trips is low (6.9%). However, the results of the model are not meant to advocate reduced bus use, but rather to phase out those bus models with high pollution intensity, and to replace them with products that run on energy sources that have a cleaner emission profile, as has occurred in many other cities, including in East Asia. The conclusion is that to improve sustainability performance, the ideal travel pattern should involve a low share of private vehicle driving (around 20% or lower shows very important environmental benefits) and high shares of MRT and buses running on clean energy (over 60% combined).

Table 8.12 Reduction of CO_2 Emissions, Traditional Air Pollutant Emissions, & Energy Consumption, per capita, per year, by Study Neighborhood Relative to Beijing Mean

	CO_2 (kg)	CO(kg)	VOC (kg)	NOx (kg)	PM (kg)	Energy (kg CE)
Huilongguan	93.221	43.27	1.93	12.59	0.5	22.92
Tiantongyuan	- 290.10	35.19	- 0.14	11.34	0.49	- 59.86
Tongzhou Beiyuan	372.30	3.87	2.12	0.14	- 0.047	83.95

Table 8.13: Total Reductions of CO_2 Emissions, Traditional Air Pollutant Emissions, & Energy Consumption per year for Beijing, based on three Saving Profiles

	CO_2 (mil. kg)	CO (mil. kg)	VOC (mil. kg)	NOx (mil. kg)	PM (mil. kg)	Energy (mil. kg CE)
Huilongguan Saving profile	602.80	279.80	12.48	81.41	3.23	148.22
Tiantongyuan Saving profile	- 1875.90	227.55	- 0.91	73.33	3.17	- 387.08
Tongzhou Beiyuan Saving profile	2407.42	25.02	13.71	0.91	- 0.30	542.85

Note: The total employed urban population was 6,466,348 (Beijing Statistical Yearbook, 2011).

8.6.2 Policy Implications and Discussion

Increasing the share of public transit trips in overall commutes should not be the sole objective when working towards more sustainable urban transport. Policy makers also need to consider incentives for reducing the use of cars. This is particularly pressing given the rise in automobile ownership and use in China since 2000 (refer to Chapter 3). Beijing currently has implemented policies for encouraging MRT ridership while officially discouraging the total number of vehicle purchases. For example, the MRT system in Beijing operates with heavy subsidies from the government to ensure low fares. Since 2008, the Municipal government provided subsidies so that passengers can make bus trips as inexpensively as 0.4 RMB one way and MRT trips for 2 RMB per ride.

Cars are the biggest consumers of energy and emitters of CO_2; this one of the factors (along with increasing traffic congestion) that drove the Beijing municipal government to initiate policies to limit car ownership by enforcing the “quota and lucky draw” systems that limit the number of vehicle licenses distributed in a given year. However, car ownership in itself, does not lead to unsustainable outcomes from an emissions perspective; the level of use of those cars is far more important. To achieve the desired energy and emission outcomes advocated in this dissertation, it is suggested that policy makers prioritize strategies that limit the number of trips made by cars, rather than solely the total number of cars purchased. To a degree, the municipal government of

Beijing has made efforts in this direction, e.g., by limiting the days during which a car with certain license plate digits can be driven, but the outcome has been less than satisfactory, since some car owners circumvented the law by purchasing second cars registered with different license plate. Ironically, this increased car ownership associated with vehicle registration related limitations on vehicle use echoes a similar paradox experienced in Mexico City that was chronicled by Davis (2008). Another challenge Beijing faces is the large number of government cars, which are hard to control or monitor and, in many cases, do not comply with the above mentioned policies. Information about the total size of the fleet of government cars is not released, so the impacts are impossible to evaluate.

People will choose not to use their cars less only when there is an efficient and convenient alternative, which is exactly the role the MRT is playing. The Beijing Public Transport City Plan 2015 outlines a progressive and correct strategy for working towards this objective by intensifying (in the core area) and extensifying (in the suburban area) the length of the system to 561 km by 2015.

Considering the emission factors of buses with gasoline and diesel engines, the public bus fleet of Beijing is not performing well in CO_2 emission reductions, air pollution and energy consumption. Apart from offsetting bus travel by increasing MRT trips, it is essential to phase out the dirtiest buses to more clean emitting technologies and fuels such as LNG. Attention also needs to be paid to the trade-offs among reduction policies for different pollutants. For example, reducing carbon dioxide emissions by increasing the proportion of diesel-powered cars may lead to increased PM emissions.

Providing MRT access to large scale suburban neighborhoods with a large number of residents is beneficial as the multiplier effects are significant. Both Huilongguan and Tiantongyuan have populations in excess of 300,000. The savings indicated utilizing selected sustainability indicators suggest that MRT accessibility improves local sustainability performance significantly – a dynamic which can be multiplied many times over throughout the existing and future Beijing built up areas. Appropriate complementary policies can leverage the effect even further as indicated in Chapter 9.

Chapter 9

CHAPTER 9 CONCLUSION AND IMPLICATIONS

This chapter summarizes the key empirical findings of the research, followed by discussion of the research's theoretical contributions to the literature on sustainable urban form, travel behavior studies and sustainability assessment in the Chinese metropolitan context. It puts forward insights in regard to our understanding of the interface between built form and human transport in major Chinese metropolitan areas, especially in recently developed suburban settings. Implications in terms of urban and transport planning and policies are also presented.

9.1 Key Empirical Findings

Below, key empirical findings are summarized in four areas: i) suburbanization in Beijing; ii) the impacts of MRT service on neighborhood development; iii) changes in suburban travel behavior before / after availability of MRT service; and iv) quantification of existing and potential sustainability benefits related to improved (quantity, quality) MRT access for Beijing.

9.1.1 Suburbanization in Beijing

The driving forces of suburbanization in Chinese cities have shifted over time, from creation of land and property markets in the post-1978 reform period, to industrial relocation in the 1980s and 1990s, to more recent residential development focused market-driven developer strategies since the late 1990s. The availability of MRT services, stimulated by important events (especially the 2008 Olympic Games), encouraged the expansion of suburban development; evidence from my study indicates that residential growth outpaced all other land use growth in Beijing's suburban areas.

A "New City" style of development, characterized by a predominantly residential landscape of mid-rises and towers has gained popularity among real estate developers since late 1990s. Although daily personal needs (such as grocery shopping and dining) are often considered in the design, employment opportunities (beyond local, personal services) catering to local residents are often neglected, resulting in high demand for transportation in general, and long, time-consuming commuting trips in particular.

The 'density gradient' - or drop-off in net residential densities from the central city to the suburbs is much less pronounced in Beijing than in US metropolitan areas. More uniquely, the residential building stock in suburban Beijing – at least for working and middle class households - is of a very similar design and density to those found in the central city (i.e., 6-story walkups, mid- to high-rises). This relative homogeneity (compared with Western metropolitan areas) in urban structure as the city expands needs to be taken into account in comparative studies on suburbanization. Suburban housing in Beijing's suburbs (or that of other Chinese metropolitan areas, for that matter) is completely different from the detached houses that prevail in the suburbs of US metropolitan areas versus denser, walkable neighborhood forms[39] found in many older US metropolitan areas. [40] The main reasons for this more uniform building / urban form style and uniformly higher density include: i) the land acquisition system in China, which is completely government-led instead of market driven. The easiest land available for development is located near the edge of the built up area - it requires virtually no relocation costs, generating more profit for developers. ii) profit-chasing activities of the government: land sales generate high profits and are an important source of financial income for municipal governments (in the order of 15-25% of total municipal revenues).

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[39] Albeit not as dense as most Chinese suburbs!

[40] Newer western metropolitan areas in the US do not fit this stereotype, often lacking significant walkable residential areas in the city core. Phoenix, for example, is characteristically suburban in its housing stock and built form throughout the metropolitan area.

And with effective marketing, a rural location can be positioned as a future local business center, which helps sell the land at a higher price. iii) profit-chasing activities of residential developers and a general lack of regulatory oversight from planning authorities; high land prices drive developers to build with high FAR for higher profits, while reporting lower FARs on paper to meet the planning requirements (refer to section 6.4.2 in Chapter 6).

Therefore, as compared to the “cost-space” trade-offs made by housing consumers the US, my research indicates that the trade-offs made by suburban housing consumers in China focus on the trade-off between “cost” and “access”. Because similar living spaces exist throughout the region, whether in the central city or the outermost suburbs – Chinese homebuyers choose residences based on cost, with lower prices than in the central city - and sacrifice easy access to major nodes such as employment centers and entertainment districts. In the US, in contrast, a similar housing expenditure buys a much different product in the suburbs than in the central city, US consumers make housing decision on that basis. Larger homes in the US are generally considerably more affordable the further they are from the city core. In sum, the Alonso space-access tradeoff is a much less relevant framework / model in assessing Chinese metropolitan spatial structure.

Suburbs in Beijing are, to a large extent, subordinate to the central city administratively and functionally, as jobs do not relocate with the middle class population to suburban areas, and public services of superior quality (especially schools and hospitals) are still overwhelmingly located in the urban core. (Although suburban “branch” middle schools, etc., attempt to assuage the Chinese housing consumer in this regard.) As a result, suburbanites in Beijing suffer from long commuting distances, with associated high time costs. At the same time, other than enclaves of luxury villas for the wealthy, suburbs are not considered the most desirable places for middle class households to work and live. In addition to the lack of quality services and long commutes, the periphery of Chinese cities is often regarded as less safe (again, opposite to the US case). Based on focus group discussions for this study, it became apparent that some residents trade their home in the suburbs for smaller living spaces in the central city to be closer to good schools.

In the US, there is a "suburban culture" which defines a distinct different lifestyle from inner city living. For example, cultural and political affiliations of suburbanites compared to their central city counterparts are often very different than core city residents. (For example, suburban residents may prefer barbeques while inner city residents might prefer more urbane activities. Also, US metropolitan regions are composed of many different small cities, which are often in competition with one another (such as Tempe, Mesa, Scottsdale and Chandler in the Phoenix metropolitan area). But in Chinese cities, such as Beijing, district level government has only limited autonomy, still being significantly under the authority of a single municipality. Thus the ability of local governments (districts) in China to shape local urban regimes, development themes, etc., is different than in the US where local governments may invest significantly to attract a certain type of resident, e.g., funding good schools to attract young affluent families or neglecting schools to entice retirees with lower property taxes.

This dissertation traces the development trajectory of three suburban neighborhoods in Beijing. The evidence indicates that the models and empirical evidence derived from suburbanization processes in US metropolitan areas cannot be directly applied to the Chinese context. Spatial and cultural distinctions between suburbanites and their urban core counterparts in Beijing are not as sharp and delineated as in the US. Suburban growth in Chinese cities can more accurately be termed peripheral development, the urban fabric essentially being reproduced and added to the existing built area. An analogy might be rolling out a rug with the same pattern. Chinese suburbs are characterized by relatively high densities (which are only slightly lower than the central cities of China and much higher than densities in core cities in the United States). The result of this suburban density in China is the availability of mixed travel modes, and similar building styles to the core city. The big difference between Chinese suburbia and the core city is that suburbanites in major Chinese cities incur far more travel obligations.

9.1.2 MRT Impacts on the Neighborhood Development

Evidence from the case study neighborhoods suggests that MRT routes and station locations are limited drivers of local land use development in suburbs Beijing. Suburban MRT lines in Beijing are often above ground (elevated), on inexpensive state-owned land (such as the railroad right-of-way in Huilongguan neighborhood) or along major arterial roads, which means relocation. The positive side is that dislocation of existing residents for MRT construction is minimal; however this benefit is outweighed by the fact that physical barriers (major arteries, railway, right-of-ways, and mega gated developments) to station access are common, limiting the service hinterland of MRT stations, lowering positive impacts on the surrounding neighborhood.

The availability of MRT is more associated with residential development than other land uses, such as commercial. The timing of MRT availability seems important. The proportion of land use devoted to residential uses increased significantly immediately after the MRT service became available in all three study neighborhoods. Meanwhile, Tongzhou Beiyuan, a community with a longer, established history, had less flexibility in changing its existing land use patterns; this was reflected in more limited physical impacts, and a smaller jump in the share of residential land within the hinterland of the station.

Mixed use development is found at locations that are not necessarily spatially related MRT stations. Even in the case of Tongzhou Beiyuan where a business district was planned immediately adjacent to the MRT station with the expectation of hassle-free MRT accessibility, there have been obstacles that have prevented the planned project from being developed. High relocation fees and an indeterminate approach to long term planning of this area are the main reasons for the failure of the planned TOD style development to be realized.

Office spaces are observed to be undersupplied both in terms of number of units and commercial quality in Huilongguan and Tiantongyuan, probably a factor in limited local employment creation, especially given the fact that Beijing increasingly is characterized by a white collar economy. Most households surveyed in these two neighborhoods suffer from long commuting distances. People who did work in these neighborhoods, such as at the restaurants and supermarkets, generally are lower income households who could not afford live locally, but needed to commute in to Huilongguan and Tiantongyuan. An exception to the jobs-housing imbalance was found, however, in the Tongzhou Beiyuan study neighborhood. The study area was adjacent to an established community with a long development history and a wide range of housing options for different socioeconomic groups, resulting in, a more diverse population. A higher percentage of residents were employed locally, travel distances were lower, and mode splits more evenly distributed between different transportation options.

It is noteworthy that in all three neighborhoods, establishment of MRT services has been associated with significantly increasing residential occupancy levels evidence of enhanced land use efficiency.

Focus group discussions provided very personal encounters with residents in regard to pedestrian access, and how this affected daily travel patterns. For example, residents in Tiantongyuan explained that shopping facilities (such as supermarkets) were mostly concentrated at a two locations along wide arterial roads that were too wide to cross safely on foot. Hence some residents chose to drive to these facilities to forego navigating a hostile pedestrian environment, despite the fact that the actual distance between residence and supermarket was not far.

There is limited, or impeded, integration of MRT stations with their environs, especially, with suboptimal surrounding development largely due to the lack of coordination between land use and transportation planning authorities. The stations are designed and operated as simple entrances/exits for MRT services. There is usually a small open public space right outside the station that is taken over by street vendors, motorized tricycles, illegal taxis, and other impediments to pedestrian movement. In focus groups it was revealed that the immediate station environment was often perceived negatively by local residents. The low efficiency of station area utilization also contributes to the limited property premiums as discussed below.

Limited property premiums are the norm near the suburban MRT stations compared to cities in East Asia and the US considering that Chinese suburbia is denser and less automobile oriented. The Hedonic model fails to explain the relationship among distance, density, building age and housing price, but merely suggests negative associations as expected. Preliminary analysis of property premium is performed based on interviews with local real estate agencies and my household survey results suggest, and found out that there is an approximately 5%of accessibility premium for houses closer to the station. The possible reasons for this limited accessibility premium include: i) the perception of larger zones of accessibility in suburban neighborhoods which extend the acceptable walking distance to 800 – 1500 meters (or 10-20 minutes); ii) the high car ownership and unregulated parking outside the MRT stations encourages people to drive to the station, effectively extending the acceptable residence distance much farther from the station; iii) as the station areas are taken over by street vendors, illegal taxis or tricycles, the chaos reduces the attractiveness of houses immediately in the vicinity of stations; iv) it is observed that houses farther away from the stations sometimes feature lower densities and more green spaces, targeted to buyers who expect to drive – probably a more affluent demographic group who keep the price of property from the stations at relatively high levels; and v) in the past, time was less economically valuable in urban China, leading to a lower willingness to pay a significant location premium. However, to better understand the dynamic impacts of MRT system on property values in Beijing, further and more in-depth studies are required, with support of city-wide data points to explore the correlation between property prices and their distances from MRT stations.

9.1.3 Travel Behavior Changes of Suburbanites in Beijing

Overall, MRT service has been welcomed by the residents in all three case study neighborhoods and changed their travel behavior significantly. Bus trips used to be the major travel mode for commuting trips, more than 50%, in all three neighborhoods before the MRT became available, but declined significantly in the two newer neighborhoods (from 63.2% to 6.9% in Huilongguan; from 50% to 9.9% in Tiantongyuan), but more moderately in the older neighborhood of Tongzhou Beiyuan (from 50% to 31.5%). A large share of bus riders switched to MRT, which increased its mode share to 52.9% in Huilongguan, 39% in Tiantongyuan, and 21.8% in Tongzhou Beiyuan. Clearly the increase in MRT ridership was mainly the result of bus riders switching to MRT. The attractiveness of MRT commuting is much higher for the people who took buses to work than those who drove to work.

While before the arrival of MRT service, buses captured the dominant mode share in all 3 study neighborhoods, after the introduction of the MRT, the dominant mode of travel for commuting in the 3 neighborhoods was differentiated. For example, in 2011, 52.9% of residents in Huilongguan choose to go to work by MRT; meanwhile, in Tiantongyuan, the most popular mode for commuting was the car, with 43.4% of residents in Tiantongyuan driving to work; in Tongzhou Beiyuan, however, while bus ridership declined, the bus still remained the dominant mode of commuter transport in that neighborhood capturing 31.5% of all commuting trips (Tongzhou Beiyuan had the most "balanced" mode split, with respectable bus, MRT, and biking shares). The differences in mode share among the three neighborhoods are attributable to variation in commuting distances, demographic profiles (especially education levels and household income), and the timing of MRT service. Due to the late arrival of MRT service in Tiantongyuan, some residents chose to purchase their houses there under the assumption that they would drive. Even after the MRT initiated service in Tiantongyuan, residents still disclosed that they preferred to drive. Therefore, MRT has a stronger impact on shaping people's travel mode behavior if it is introduced at an early stage of neighborhood development. Driving was up in all neighborhoods, but this reflected a significant increase in car ownership levels during the study period (2001-2010). Nevertheless, while car ownership rates increased dramatically, the associated rise in car use was much less. For example, car ownership rates grew 600% in Huilongguan between 2000 and 2011, but the share of car trips to work only increased by 50% during the same time period, suggesting that the availability of MRT services in these suburban neighborhoods largely reduced the intensity of car use for commuting trips. It appears that suburban Beijing suburbanites are using their cars more like Europeans or Japanese, e.g., for weekend outings and big box shopping than North Americans or Australians where a majority of car owners use their vehicles for commuting in most cities.

The more balanced mode split in Tongzhou Beiyuan was the result of a more mixed land use pattern and older development history (more and diverse local employment opportunities), higher share of population with lower levels of education (who have greater access to a wider range of local service jobs than the residents in the other two neighborhoods, who tend to have more specialized and higher education which usually necessitates working in the core city) and hence shorter commuting distances. It is also likely that a smaller percentage of residents in Tongzhou Beiyuan can afford cars, compared to the other two neighborhoods.

Not surprisingly, residents in all three neighborhoods suffered from long commuting times (see Figure 7.9), both compared to the Beijing average and compared to average commuting times in major world cities, such as New York.

For non-commuting trips within neighborhoods, unpleasant pedestrian environments, such as wide streets and a lack of pedestrian overpasses, encouraged residents to drive to shop, which also saved them from the inconvenience of carrying shopping bags. When the retail landscape in a neighborhood was more characterized by small shops and independent stores (in addition to larger scale shopping centers) and a walkable street environment, such as in Tongzhou Beiyuan, the residents were more likely to use buses and bikes to access local shopping.

For non-commuting trips *outside* the neighborhood, the share of trips taken on public transport (MRT and bus) increased significantly in all three case study areas. The travel mode with the highest share by neighborhood paralleled the data for commuting trips, i.e. MRT for Huilongguan, driving for Tiantongyuan and bus for Tongzhou Beiyuan.

In people's travel mode decisions, household income level and the distance from the destination MRT station to the workplace played a significant role in households' decisions on whether to drive or take the MRT to work. The higher the household income level, the more likely for people to drive; while the closer the workplace was to an MRT station, the more likely it was for people to use the MRT. In other words, potential MRT commuters seem more sensitive to the distance from the MRT from their workplace than the distance from their residence to the MRT. Evidence indicates that residents whose household monthly income is higher than RMB 20,000 or whose office is more than 10 minutes of walk from a MRT station are highly inclined to drive to work instead of taking the MRT. But age groups and education are found to be insignificant factors in predicting driving versus MRT travel. Also, MRT shows advantage, in terms of trip decision making, over bus trips to work in cases of longer commuting distances, higher household income, and younger age groups.

In terms of the travel decision for bus commuting trips, the distance between home and office, household monthly income level and age groups were significant factors. Neither education nor the distance from home to the MRT station was significant in people's travel decisions.

9.1.4 Sustainability Benefits of MRT Accessibility

When compared to the average (mean) modal split in Beijing, the MRT-served case study neighborhoods showed significant savings in CO_2 emissions, traditional air pollution, and energy consumption related to transportation. However, these net benefits differed by neighborhood. Huilongguan had net savings on all factors examined. Of all three study neighborhoods, Huilongguan also featured the highest reduction in traditional air pollution levels relative to the Beijing's mean level. Tiantongyuan failed to reduce its average CO_2 emissions, VOC emissions, and energy consumption below Beijing Municipal mean levels, largely because a high percentage of its residents choose to drive to work on a daily basis. Late MRT access, significant distance from major employment clusters in Beijing, and limited population with convenient access to the MRT due to the skewed route of MRT line 5 all contribute to the high use of private cars in Tiantongyuan. Tongzhou Beiyuan excelled in CO_2 emissions reductions and energy savings, while failing to reduce particulate matter (PM) pollution below the Beijing Municipal mean level. This is explained by its higher share of bus trips to work, as PM pollution by buses is about 34 times higher than for cars and 60 times higher than for taxis per passenger kilometer.

Although there are sustainability benefits from the increased MRT mode share, the benefits are easily offset if the share of driving is also high because CO_2 emissions intensity by private cars or taxis is 12-16 times that of buses or 70-90 times that of MRT trains on a per capita basis, and energy consumption of cars and taxis are 8-12 times more intense than buses and 30-50 times more intense than MRT trains. Higher shares of bus trips contributed to higher levels of traditional air pollution due to the fuels used by current bus fleet in Beijing, as suggested in the Tongzhou Beiyuan profile.

9.2 Policy Implications

The development history of the three case study neighborhoods suggests that land use planning needs to be flexible and evolving to accommodate adaptation related to MRT access.

A key policy implication, related to Beijing's macro spatial structure, is that more local employment generation and quality public service provision (e.g., middle schools) would contribute significantly to a cleaner more land efficient Beijing. In effect, large-scale expansion of MRT lines to the suburbs represents a "band aid" incremental approach to the urban sustainability issue. Large scale MRT development to the suburbs to a significant extent addresses the symptoms of a metropolitan scale jobs-housing imbalance, rather than fundamentally addressing the underlying problem.

FAR guidelines in local plans need to be adjusted, to be more detailed and differentiated. Instead of simply defining the FAR ranges for different land use types, strategic spatial locations needs to be identified, especially around MRT stations, and assigned higher FARs. Higher FARs within walking distance of MRT stations should be assigned, to provide incentives for developers for denser, mixed-use transit oriented development.

Although politically very difficult, there should be better integration between urban and transportation planning bureaus (departments) to improve network routing and design of station access. The objective of lowering land and relocation costs for MRT construction should be balanced by the significant benefits of enlarged service catchment areas around stations. Physical barriers, such as railroad right of ways and wide streets, should be addressed, e.g., through provision of pedestrian bridges or tunnels (attractively designed to be inviting). The design of MRT station precincts should not be limited to the station itself, but be part of larger mixed-use TOD development plans for the area surrounding the station, as is the norm in many North American and European cities. The goal of MRT authorities and local planner should be to maximize MRT passenger flows. Coverage areas within the same neighborhood can be increased, without encouraging short distance car use, if feeder bus circulator services using smaller buses or shuttle vans service the MRT stations on a regular basis. In some cities, such as Bangkok, all rise building within approximately 1.5 kilometers of rapid transit stations operate para-transit on demand (LNG powered “tuk tuks” in the Bangkok case).

Micro access to MRT stations appears to make a significant difference in terms of the willingness of residents to walk to, and use, the MRT service. The space around the station and within the suburban neighborhoods needs to be more sensitively designed to accommodate better pedestrian access. The MRT stations investigated in this dissertation were poorly integrated from a pedestrian standpoint. Evidence from the focus groups demonstrated that residents were discouraged from accessing the stations on foot because of micro design issues. A potential solution for ameliorating this problem is to appropriately develop the space around MRT stations, instead of leaving it as open space. For example, mixed-use commercial spaces, such as small shops, could be designed to substitute for street vendors. Another benefit of such arrangement would be that the spaces created could be used by the passengers to orderly line up for station access at peak hours. Ideally, shopping facilities, especially large supermarkets, in neighborhoods should be more spatially dispersed than concentrated, so that the residents have access to them within walking distance. Neighborhood streets should be narrower, thus easier to cross. More pedestrian friendly and traffic calming design should be implemented, such as zebra crossings, speed bumps, lower speed limits. These improvements will contribute to the reduced driving within the neighborhood for shopping and entertainment trips.

Low density exclusive neighborhoods should be banned within the coverage zones of MRT stations. Housing at different levels should be provided to cater to households from different socioeconomic backgrounds. As noted above, a diverse range of employment opportunities should be promoted to facilitate shorter commutes and drive more balanced peak time commuter flows. For example, office spaces should be developed to create local jobs for the middle class earners in suburban neighborhoods, while lower income housing should be available to meet the needs of local, generally poorly paid, service sector workers (in retailing, restaurants, etc.), again likely to result in shorter commutes.

The public sector, at the Municipal and District levels should invest in high quality public services in suburban areas, especially schools and hospital, instead of just relying on private real estate developers to (eventually) construct public facilities. If high quality public services were available in suburban neighborhoods, the length (and time) of non-commuting trips would be reduced substantially. At the same time, strong regulations should be enforced to make sure that public facilities, such as schools, promised by developers to meet legal subdivision requirement be built in a timely fashion, so that they are operational at an earlier stage in the neighborhood's life. As with mode choice, habits are established early, e.g., parents are unlikely to want shift their children's schools mid-way through their educational cycles. The fact that schools (particularly middle schools) with high reputations are opening branches of the famous flagship schools in the central city is a positive sign. However, effort should be made to ensure not only the name of school but also the quality, so that the suburban school is now perceived as vastly inferior to its namesake in the core city. Construction of high quality hospitals in suburban locations requires significantly more investment from the public sector. More diverse, including affordable, local housing choices could act as attraction for staff to work in the suburban schools or hospitals.

The increasingly significant contribution of urban transportation to Beijing's air pollution suggests that more sustainable travel modes (such as MRT) should be encouraged, in order to accommodate the increasing travel demand. Meanwhile, the fact that MRT riders are also victims of $PM_{2.5}$ reinforces the importance of reducing car driving. Therefore, while implementing policies to increase the use of MRT, efforts should also be made to reduce the frequency and distance traveled by private cars, as the sustainability benefits realized by the increase in MRT ridership are easily offset by increases in VKT from driving. Beijing is currently making progress in this regard by providing subsidies for MRT and bus ridership to encourage the use of public transport, while officially discouraging the total number of vehicle purchases by implementing the "quota and lucky draw" systems for car registration.

However, car ownership in itself, does not necessarily lead to unsustainable outcomes from an emissions perspective; the level of use of cars is far more important. Besides the current policy of limiting the days during which a car with certain license plate digits can be driven, policy makers should also consider other policies, such as HOV (High-Occupancy Vehicle) lanes and road pricing, that have been successfully implemented in other countries. HOV lanes stand for restricted traffic lanes that are reserved at peak travel times or longer for exclusive use of vehicles with a driver and one or more passengers. The main objectives of HOV lanes are to increase higher average vehicle occupancy and person throughput with the goal of reducing traffic congestion and air pollution. HOV lanes have become very common in North America, Europe and other countries and can be easily implemented by designating a subset of current lanes, without requiring additional construction work. Road pricing is another method for reducing car usage by charging the users for the marginal social costs, including environmental externalities, associated with driving. For example, in Singapore, drivers are required to pay for access to the core area of the city; the fee varies according to the time of a day. Tiered parking fees from the city center to the peripheral areas are another example.

When a convenient MRT system is available which allows the majority of residents to access the system within acceptable walking distance and the route network connects major destinations in the city, people are more likely to choose the MRT over driving. Therefore The Beijing Public Transport City Plan 2015 outlines a progressive and correct strategy for working towards this objective by intensifying the MRT system in the core area and further extending lines into less well-served suburban areas. Each additional kilometer of track creates higher marginal benefits to potential riders and is not a linear relationship.

The oldest models in Beijing's public bus fleet should be phased out and replaced by models that run on cleaner fuels, such as LNG, to reduce local air pollution,. This is consistent with the efforts underway by Beijing Public Transport Holdings, Ltd. (2012).

Targeting MRT access to large - scale suburban neighborhoods with a large populations is beneficial as the multiplier effects in terms of environmental benefits, time savings, etc., are significant. Furthermore, the earlier MRT service is provided, the better the outcome in discouraging car usage.

9.3 Theoretical and Methodological Contributions

The contributions of this study are both theoretical and methodological in nature. Theoretically, this research contributes to understanding the relationship between urban form and public transit, not only in terms of outcomes, but also the process (the role of timing of MRT expansion in neighborhood development) with detailed land use analysis. It also contributes to exploring and identifying the important factors in travel behavior decisions in the Chinese context. Housing premiums are investigated to understand the impacts of MRT stations on land use development, an important theme in the literature – the Chinese case appears to be an outlier in this regard.

Characteristics of the latest trends in suburbanization in China, an under researched area in current literature, are explored in this study. As articulated above, the "Access-Space" trade-offs that American suburbanites make to seek larger living space is juxtaposed against the "Access-Cost" tradeoff made by Chinese suburban residents seeking lower cost, but structurally similar, housing compared with what is available in the central city. This is the most important theoretical contribution of this dissertation –it posits a completely different framework from the Alonso model in understanding core – suburbia gradients.

Although Chinese suburbs are arguably less cosmopolitan than their urban cores, there is no distinct “suburban culture” in Chinese metropolitan regions compared to the US. I argue that, on the contrary, development happening in the so-called suburban areas in Chinese cities is better termed peripheral development (a process of adding similar urban fabric to the edge of the built up area)., Suburbanization is less a distinctive type of city building in the metropolitan Chinese case than in Western metropolitan regions. This framework represents another important theoretical contribution of the dissertation.

This research identifies the important aspects and dynamics of sustainability assessment related to urban transport in China, with special emphasis on the impacts of extensive public transit developments. These aspects are GHG emissions, traditional air pollution (especially CO, VOC, NOx, PM), and energy consumption. Quantification of the sustainability benefits is performed to measure the magnitude of the savings.

Methodologically, this research focuses on the micro level (neighborhoods), which offers the ability to closely examine changes in the built environment and better understand the factors that immediately impact people’s travel behavior directly and personally. Existing Chinese research at this spatial scale is not sufficient for understanding the micro-dynamics of suburbanization in Chinese cities. Also, sustainability benefits are much more the result of micro (neighborhood, district) level change than in the macro spatial reordering of cities. However, as indicated in this dissertation, learning from the cases, particularly in terms of the lack of jobs-housing balance, has led me to value the need for macro level spatial change in Beijing, and most large Chinese metropolitan areas. To a considerable extent the large scale suburbanization of the MRT system, and the significant changes in mode change that follow, along with modest changes in the physical environment in station environs, represents a response to a symptom, the root cause of which is inadequate job creation in Beijing's suburbs beyond low-level service sector work..

By comparing travel behavior and the environmental performance of transit-served suburban neighborhoods with Beijing's mean level, the sustainability benefits of Beijing's MRT network have been demonstrated.

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APPENDIX A

INTERVIEW QUESTIONS FOR

KEY STAKEHOLDERS OF NEIGHBORHOOD DEVELOPMENT

DATA COLLECTED MAY – OCTOBER 2011

1) Did you expect MRT access to the neighborhood when you were working on the development plans?

2) What kinds of impact do you think the MRT services bring to the neighborhood?

3) Do you consider the MRT lines and stations as assets for the neighborhood which will attract more potential buyers of the residential or commercial spaces, will these buyers be willing to pay more?

4) Do you think more commercial spaces should be zoned around the MRT stations, and FARs should be higher?

5) Do you take pedestrian friendly considerations into account in your design?

6) Do you recognize the convergence effect of stations, generating large scale daily pedestrian flows?

APPENDIX B

QUESTIONNAIRE DESIGNED FOR SURVEYING HUMAN TRAVEL BEHAVIOR

DATA COLLECTED JUNE – SEPTEMBER 2011

Apartment Building: ______________________
Surveyor: ______________________
Date:______________________
Survey Number:______________________

Introduction: We are surveyors of a research project of Beijing Normal University, the Institute of Geographic Sciences and Natural Resources Research at Chinese Academy of Science, and Arizona State University. The goal of this survey is to collect the information about transportation behavior of this community complex. The survey is anonymous, and does not deal with any personal information. Date collected in this survey is only for research purpose. Thank you for your participation.

1. How long have you been living in this neighborhood?
☐<1year ☐1-3 years ☐3-5 years ☐5-10 years ☐>10 years
2. Do you ☐Rent, or ☐ Own this home?
3. How many people live here? __________(adults)__________(children)
4. Where did you live before? (a rough area if in the city; or another city)_____________

5. How important were the following factors in influencing you move to the current location?

	Unimportant	Somewhat Important	Important	Very Important
Affordable housing price	☐	☐	☐	☐
Convenience of the MRT	☐	☐	☐	☐
Convenience of the expressway	☐	☐	☐	☐
Close to where I work	☐	☐	☐	☐
My parents/family live close by	☐	☐	☐	☐
Schools/Kindergartens	☐	☐	☐	☐
Community quality	☐	☐	☐	☐
Apartment design/floor plan	☐	☐	☐	☐
Medical Service (Hospitals)	☐	☐	☐	☐
Shopping/Entertainment	☐	☐	☐	☐
Others:___________	☐	☐	☐	☐

6. Do you own a car? ☐Yes ☐No, If yes, how many cars do you own? ____
7. Do you own a bike? ☐Yes ☐No
8. Do you have an e-bike? ☐Yes ☐No

9. Where do you work? (a general area, such as Zhongguancun) _________________
10. How do you normally get to work?
☐Automobile ☐Car-pooling ☐MRT ☐Taxi ☐Bus ☐Bike ☐Walk ☐Others: _______
11. How long does it take to get there?
☐<10mins ☐11-30mins ☐31-45mins ☐46-60mins ☐61-90mins ☐>90mins

12. Whether or not you go to work by MRT, how long does it take to walk from the nearest MRT station to your office?
☐<5mins ☐6-10mins ☐11-20mins ☐21-30mins ☐>30mins

About kids going to school (If you have more than 2 kids, please fill out for the older one)
☐No, I don’t have kid (Go to Q17)
13. Your kid is now going to?
☐Kindergarten ☐Middle School ☐High School ☐University or above (Please go to Q17) ☐Primary School ☐Too little to go to any kind
14. Where does your kid go to school? ☐within the neighborhood ☐ some other place__
15. How do you send him/her to school?
☐Automobile ☐Car-pooling ☐MRT ☐Taxi ☐Bus ☐Bike ☐Walk ☐Others: _______
16. How long does it take to get there?
☐<10mins ☐11-30mins ☐31-45mins ☐46-60mins ☐61-90mins ☐>90mins

About Non-Commuting trips (Trips other than going to work, such as shopping, grocery shopping, dining out, watching a movie, clubbing, etc.)
17. How many times do you go out every week? ☐1-2 ☐3-4 ☐5-6 ☐7-8 ☐9-10 ☐>10
18. How many times do you go to destinations within your neighborhood? ___________
19. Please estimate the total distance for non-commuting trip every week: ________KM
20. How do you go to destinations within the neighborhood?
☐Automobile ☐Car-pooling ☐MRT ☐Taxi ☐Bus ☐Bike ☐Walk ☐Others: _______
21. How do you go to destinations outside the neighborhood?
☐Automobile ☐Car-pooling ☐MRT ☐Taxi ☐Bus ☐Bike ☐Walk ☐Others: _______

22. Please roughly estimate your travel mode **before the MRT** (by week):

Commuting Trips	Non-Commuting Trips
_______ times by Driving	_______ times by Driving
(Total driving distance every week: ___ km)	(Total driving distance every week: __ km)
_______ times by Car-pooling	_______ times by Car-pooling
_______ times by Bus	_______ times by Bus
_______ times by Taxi	_______ times by Taxi
_______ times by Biking	_______ times by Biking
_______ times by Walking	_______ times by Walking

23. If you do take the MRT, what is the main way to get to the station?
☐Automobile ☐Car-pooling ☐Taxi ☐Bus ☐Bike ☐Walk ☐Others: ________

24. How long/how far, to the most, are you willing to walk to get to the transit station?
☐0-5mins ☐6-10mins ☐11-15mins ☐16-20mins ☐>20mins

25. What do you thinking about Beijing’s MRT Services? (Can choose more than one)
☐ Too crowded
☐ Bad walking environment around MRT stations
☐ Facilities in MRT are not enough/convenient
☐ Inconvenient Transfers, because: ______________
☐ Pretty good; No complaints
☐ Others: _________________

26. What factors influence your travel decisions?
____ MRT Fares
____ Gas prices
____ Location of destination (whether it's connected with MRT lines or expressways)
____ MRT service quality
____ Travel Time
____ Other: ________

27. For homes of similar quality, do you think it is reasonable that those closer to MRT stations are more expensive than those farther away from the station?
☐ Yes ☐ No
28. If yes, how much more do you think is acceptable (%)?
☐ 0-5% ☐ 5-10% ☐ 10-15% ☐ 15-20% ☐ 20-30% ☐ more than 30%

29. On a scale of 1-5 (5 being the most satisfied), please rank your overall satisfaction of living in the neighborhood: ________________

30. If you lived here before MRT, to what extent the MRT has improved your quality of life:
☐A little ☐Moderately ☐Significantly
Or, ☐No, it made my quality of life worse, because: ____________________________

31. What is your age range:
☐17 or younger ☐18-25 ☐26-30 ☐31-40 ☐41-50 ☐51-60 ☐ 61 or older
32. Education level of household head:
☐ Postgraduate degrees (Master/PhD)
☐ College graduate
☐ High school graduate
☐ Lower than high school
33. **Household monthly** income/wage level?
☐Lower than 2k ☐2k-5k ☐5k-8k ☐8k-10k ☐10k-20k ☐20k-50k ☐More than 50k

APPENDIX C

APPROVAL DOCUMENT FROM UNIVERSITY SUBJECTS

NSTITUTE REVIEW BOARD (IRB)

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Douglas Webster Professor
From:	Mark Roosa, Chair SM Soc Beh IRB
Date:	10/19/2010
Committee Action:	**Exemption Granted**
IRB Action Date:	10/19/2010
IRB Protocol #:	1010005573
Study Title:	Mass Rapid Transit Access and Suburban Neighborhoods: the Impacts on Built Environment and H and the Sustainability Implication- the Case Study of Beiing

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.