Impacts of Transit-Oriented Development (TOD) on the Travel Behavior of its Residents in Shenzhen, China

by

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A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement of the degree of

Masters of Arts

in

Planning

Waterloo, Ontario, Canada, 2017

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Rapid urbanization in cities across the world has generated a number of issues including urban sprawl, segregation of land uses, traffic congestion and negative environmental impacts. Transit-oriented development (TOD) has been considered as the best urban development strategy and planning tool to approach these challenges. It is widely adopted as the urban development guide by planners and decision makers in North America and all over the world. TOD has been practiced by many different cities across the world since the early 1990s, however, its concept and practices in China are still at its experimental stage. The study identifies that implementation of TOD in existing high-density urban spaces is a major challenge in China.

A common goal of any successful TOD is to reduce automobile dependency, and encourage the use of public transit (e.g. subway, LRT, bus) and other sustainable travel modes (e.g. walking and cycling). This thesis aims to explore the effectiveness of TOD practices in Shenzhen by assessing the impact to the residents' travel behavior at the neighbourhood level. Two TOD practices have been selected to be further analyzed in this study – Grand Theatre Station and Houhai Station. Grand Theatre Station is located within the old urban centre, and Houhai station is considered to be a more conventional TOD design which is located in a reclamation area. To conduct the analysis, data is collected from Shenzhen subway authorities, field observations and survey. All the information is visualized using maps and descriptive statistics.

The result showed that both sites have experienced a significant growth in subway ridership since the implementation of TOD. Furthermore, TOD practice at Grand Theatre Station is significantly more effective comparing to Houhai Station. With further analysis of the differences between the two cases, three key qualities have been summarized to provide different insights for planners to

improve TOD practices in China, they include “rich mix of residential and commercial types”, “walkability/connectivity”, as well as “quality of subway services”. These qualities will be further explored in the study.

Keywords: Transit-oriented Development (TOD); Travel Behavior; Field Observation; Travel Survey; Descriptive Statistical Analysis; Shenzhen; China

Acknowledgements

First and foremost, I would like to express my sincere gratitude to my advisor Professor Joe Qian for bringing me into this dynamic program and for his continuous support of my study and research. He consistently allowed this paper to be my own work, but steered me in the right direction when needed.

Besides my advisor, I would like to thank my committee member Professor Alana Boland of the Department of Geography & Planning at the University of Toronto. She was always there to provide helpful suggestions whenever I ran into trouble spot or had a question about my research or writing. I am gratefully indebted to her for her very valuable comments on this thesis.

My sincere thank also goes to my friends in Shenzhen who helped me during data collection: Hao Liu, Jia Hui Zhang, Le Wu, Zhi Nan Chen, Shao Bin Guan, … It's impossible to list all the names.

I would like to acknowledge the support offered by the School of Planning at University of Waterloo during my study here. I am so grateful to have been part of this program and would love to keep contributing to the school in any possible opportunities given in the future. I would like to thank all my friends there for all the encouragements.

Last but not the least, I must express my very profound gratitude to my parents Wei Wei Qi and Hui Min Gong, to my brother Seven Qi and to my girlfriend Lily Huang for providing me with unfailing support and continuous encouragement throughout the years of my study. This accomplishment would not have been possible without them. Thank you.

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1 Introduction

China, the world's second largest economy, largest exporter and second largest importer, has demonstrated tremendous growth in the last few decades. Beginning with the initiation of economic reform in 1979, China has experienced a major transformation from a planned economy to a market-oriented economy. The result of this transformation has led to tremendous growth in the country's coastal region. Through the force of marketization, the populations in urban areas have increased exponentially, as millions of people are choosing to move to cities for better opportunities. Today, about a third of China's population live in cities along the east coast of China which shares 83% of China's population growth from 2000 to 2010 (Cox, 2011). As the urban population increases, large-scale urban expansion has occurred across the nation, and the necessity of finding new urban planning strategies to effectively control urban sprawl is inevitable.

In the late 1990s and early 2000s, several cities started to develop new Mass Rapid Transit (MRT) systems by implementing the concept of transit-oriented development (TOD) to accommodate the growth in urban areas. TOD is a well-known and frequently-used planning strategy in North American cities that was developed by Peter Calthorpe in the 1980s. The purpose of this strategy is to increase the density within urban areas to achieve a more compact urban form by maximizing the usage of public transit (Calthorpe, 1993). Many cities across North America have successfully adopted TOD, including Portland, Montreal, San Francisco and Vancouver. There are also many other cities across the world which are in the process of developing or implementing a TOD policy, such as Paris, Hong Kong, Singapore and Toronto.

Shenzhen, one of China's cities that has experienced significant growth since the beginning of the economic reform, is facing severe problems due to the rapid growth of the population and urban

expansion. The population increased from 314,100 in 1979 to 11,378,700 in 2015 (Shenzhen Statistics Yearbook 2015, 2016). Also, the developed land area has achieved 968 km^2 in 2014, leaving less than 8 km^2 to reach the maximum land area for development stated in 2020 comprehensive plan. Even though Shenzhen has about 62 km^2 developable land left in total, most of the land are located outside of the urban centres. (Qu, 2015). Thus, there is a lack of urban space to accommodate future population growth. Due to the major population increase, automobile ownership in the city has been increasing at a rate of 20% per year since 2001, and the percentage of the population that travels by personal automobile increased from 25% in 2001 to 43% in 2010 (Zhang et al., 2011). The substantial growth in automobile ownership has caused significant traffic circulation problems. To solve these major problems, the city has decided to develop a subway system while using TOD as a guideline for the municipal comprehensive plan (Shao et al., 2011). The public transit improvement of the city was initiated in the early 2000s, and for the past decade there have been many significant changes to the urban landscape of Shenzhen; however, the number of studies on the topic is minimal and the studies that do exist are outdated.

Encouraging public transit and active transportation (walking and cycling) has always been one of the main goals of TOD (Banister, 2011). By providing sustainable transportation options, mixed-use developments and higher density, TOD residents will be able to take public transit and have shorter travel distances and travel times to desired destinations as employment, commercial and entertainment destinations are brought into the TOD area. But in many cases, results may vary when implementing conceptual theories in practice, and this research will attempt to explore the impacts implementing TOD have on residents' travel behavior. In many Chinese cities, one of the biggest challenges in implementing TOD has been accommodating the existing neighbourhoods that were built prior to the introduction of TOD. When MRT (e.g. subways, LRT, and BRT) was

introduced to most Chinese cities, the urban core was often completely developed and it would have been extremely difficult to redevelop the entire area in a short period of time. Modifications to the scheme had to be made for these developed lands to practice TOD. One of the most common cases is that the transit station is not located at the center of the TOD area due to the original characteristics of the specific urban landscape, thus impacting the effectiveness of TOD. Even though the relationship between TOD and travel behavior has been widely studied across the world, further studies on Chinese practices are still needed due to the country's rapidly changing urban landscape, especially at the neighbourhood scale regarding existing neighbourhoods prior to the implementation of TOD.

TOD is normally designed and planned with MRT such as subways, LRT, BRT, etc. With different transit systems, TOD needs to be designed differently as well. For example, a subway station provides a much larger capacity compared to LRT and BRT, and it is often implemented in TODs with higher density and higher transit needs. Dittmar & Poticha (2004) identified several general types of TOD and illustrated what transit modes they should be paired with, which is discussed in the Literature Review section. This study of Shenzhen only examines the impacts of subway-led TOD, the results of which may be very different from TOD with other types of transit systems.

The purpose of the research is to identify the impacts of TOD on residents' travel behavior and identify key factors of TOD practices in China that could have significant influences on reducing the use of cars and encouraging travel by public transit and other sustainable travel modes. The study consists of two case studies of subway-led TOD practices in Shenzhen: Grand Theatre Station and Houhai Station. In particular, this research will explore TOD residents' travel methods before and after having access to the subway for both commute trips and non-work-related trips. The two TODs are very distinct from each other in terms of their development history and physical

environment. The Grand Theatre Station study case will be looking at a TOD practice in an old urban centre where TOD was implemented in a well-established urban area. The Houhai Station study case will be looking at a more conventional TOD implementation in a relatively newer urban area, where the residential and commercial developments were planned and developed shortly after the location of the subway station was determined by the city. It would be valuable to explore how have the two TODs attempted to achieve the goal of encouraging public transit and other sustainable travel methods.

This research will answer the following main question through field observations and a short travel behavior survey focusing on the travel methods used by residents in selected neighbourhoods: How has TOD influenced the residents' travel behavior at both study areas, and what could be some key factors in the changes of residents' travel behavior?

The following sub-questions will be further discussed:

1) How have the residents' travel behavior changed since having access to the subway within the two study areas?
2) Are there any differences between the results of the two study areas?
3) Based on the results and the different urban characteristics of the two study areas, what key elements of the two TOD cases can be identified that would improve subway ridership and encourage residents to choose other sustainable travel methods (e.g. bus, walking or cycling)?

As urban space continues to grow in China, many cities (e.g. Beijing, Shanghai and Guangzhou) have adopted the strategy of creating multi-centers to disperse stresses in the urban core (Jiang & Han, 2009; Wang, 2016; Xu, 2012). Within each urban center, intensified developments are

occurring in different nodes. To connect these urban centers, transit-oriented development has been found to be the popular solution. In most Chinese cities, TOD is practiced along Mass Rapid Transit (MRT) due to the significantly higher capacity that is more suitable in many high-density cities (Xu, 2012). In the case of Shenzhen, TOD is practiced in close relation to the subway, which is the most common type of MRT. In the past decade, the subway line has increased from 22 km to 177 km in length, connecting two urban cores and five suburban centers (Shenzhen Statistics Yearbook 2015, 2016). According to the Shenzhen Comprehensive Plan, there will be twenty subway lines by 2040 (Deng, 2012). This research will help identify some of the impacts of the current subway-led TOD on residents' travel behavior at the neighbourhood level, and past experiences will be drawn on to improve the implementation strategies of future TODs. Similar to Shenzhen, many other cities in China are also facing urban expansion issues such as rapid urban sprawl causing traffic congestion, and are also seeking a more sustainable urban solution through the implementation of TOD. Implementing TOD in existing neighbourhoods and new towns is a major challenge for many other cities in China, and this research can potentially be used as a precedent study for those cities. The method that is designed for this study could be further developed and modified for different contexts.

2 Context

Shenzhen has become one of the frontier cities that is leading the economic growth of China as the first of the nation's five Special Economic Zones SEZ (The Economist, 2010). After less than twenty years of development, Shenzhen has transformed from a small fishing village to one of the largest metropolises in China. In the 1990s, the economy in Shenzhen continued to grow exponentially, with a significant increase in secondary industry (Shenzhen Statistics Yearbook 2015, 2016). The socialist market-oriented strategies and policies allowed foreign investment, which has led to continuous growth in the manufacturing industry (Vidal, 2010). However, since marketization has begun to be widely adopted by cities across China, many mid-sized and large cities have become competitors of Shenzhen for foreign direct investments (FDI) (Zacharias & Tang, 2010). Since the early 2000s, Shenzhen's economy and population have started to incline more slowly than before, and the city has started to design and develop a new development strategy for the city called the "Shenzhen 2030 Urban Development Strategy", which has stated the importance of focusing on public transit as the city's major form of infrastructure development (Fan, Pu & Zhou, 2006).

To accommodate the future economic growth and physical growth of the city, the city planned to introduce an MRT system since the very beginning of the emergence of the city as a Special Economic Zone (Shenzhen Metro, 2007). In 1988, the city proposed a light rail transit system, which was approved by the State Development Planning Commission in 1992. Due to the limited capacity of light rail transit, the city reassessed the "Shenzhen Passenger Rail Transit System Comprehensive Plan" in 1994, and decided to introduce a subway system instead of at-grade light rail transit. (Zhang, 1999). The updated plan was later included in the "City of Shenzhen Comprehensive Plan 1996-2010". The plan introduced 9 passenger rail lines, which included 3

existing at grade railway and 6 future subway lines and light rail transit lines (Zhang, 1999). However, the General Office the State Council of the People's Republic of China suspended any subway approval process for cities other than Beijing, Shanghai and Guangzhou in 1995, which delayed the subway development in Shenzhen (Zhang, 1999). After Hong Kong's reunification in 1997, Shenzhen once again submitted an application for subway development to the state with the reasoning that it would improve the connection between the two cities. This application was approved in 1998 (Zhang, 1999).

The construction of the first phase development started in 1998, and was completed in 2004. The first phase consists of two subway lines that mainly connect the east and west of the city, and the total length of the subway lines is 64 km (Shenzhen Metro, 2007). In 2003, the city's Urban Planning, Land & Resources Commission developed the 'Shenzhen Urban Rail System Development Plan, 2005-2010' which includes the second phase of the subway development. This plan was approved in 2004. The second phase development included the extension of the two existing subway lines, and 3 new lines. However, due to a delay in clearing lands along some of the planned subway lines, the construction of the second phase did not start until the end of 2007 (Nanfang Daily, 2007). In 2010, all 5 subway lines of the second phase started operating one after another, and the total length of the subway line in Shenzhen has been expanded to 177 km. In 2010, the city created a development plan for the third phase of subway development starting from 2011 to 2016. And according to the rail transit development plan (2011-2016) approved by National Development and Reform Commission (NDRC), the city was expected to have 10 subway lines with a total length of 350 km by the end of 2016 (NDRC, 2011). Currently, the city is in the process of developing a detailed plan for the fourth phase of subway development in Shenzhen and is planned to finish by 2022. The fourth phase will develop 3 extension lines and 8 new lines, and

line 14 will connect Shenzhen and the city of Huizhou, 9.1 km of which will be within the boundary of city of Huizhou (UPLRC, 2008).

2.1 Subway-led TOD in Shenzhen

The "Shenzhen 2030 Urban Development Strategy" has identified the city's issues and proposed and repositioned Shenzhen for three major functions (Zacharias & Tang, 2010). First, Shenzhen should become the national center for the high technology industry, as it is currently the largest electronics manufacturing base in the world. Following this, Shenzhen should become China's center for regional logistics, as one of the busiest ports (Yantian Port) in Asia is located in the city. Lastly, it is important to promote and maintain the economic connection between Shenzhen and Hong Kong, so together they can become a global metropolitan region (Zacharias & Tang, 2010). Compared to the strategies adopted during the reform and post-reform periods, there is a greater focus on economic efficiency and sustainable development rather than the speed of growth (Fan, Pu & Zhou, 2006). One of the most effective methods for achieving this result is through an efficient transit system (Casello, 2010).

According to the "City of Shenzhen Comprehensive Plan 2010-2020", the city will focus on developing the urban core with multiple centers along three vertical axes and two horizontal belts "三轴两带" as the framework (Zhen, 2012). This will improve the connections within the city, and with Hong Kong and other surrounding cities in the Pearl Delta River Region. To achieve this goal, the city has developed planning strategies that will incorporate TOD at the regional development level, which means TOD will be implemented city-wide. Based on "Transit-Oriented Development Framework and Planning Strategies in Shenzhen", TOD will be implemented at three levels (Zhang et al., 2011). At the macro level, the city will set ultimate goals and strategies

for TOD for the entire city as an entity. At the intermediate level, the city will look at significant TOD areas, and the connections between multiple urban centers. At the micro level, the city will examine each TOD, and focus on land use planning, transit planning and urban design. For the purpose of this study, we will examine the impacts at the micro level, which focuses on the area surrounding transit stations. City planners have further categorized three types of TOD to be developed across the city: special TOD, urban TOD and neighbourhood TOD (Shao et al., 2011).

It has been more than 10 years since the first subway line in Shenzhen started operating and the impacts have been significant. According to studies, the land increment benefit created along subway line 1 has been 33.5 billion yuan, which is three times the total investment of the subway development (Zhen, 2012). Housing values in properties along the subway line have increased from 5% to 15% (Zhen, 2012). With the connections provided by the subway, residential developments are no longer restricted to within the urban core, which has successfully expanded the city's potential space for more developments (Zhen, 2012). With a large amount of daily passenger flows around subway stations, commercial land developments will also change significantly. The high rent for retail spaces around station areas will force developers to develop more commercial spaces outside of the urban core, which will create an organic transit integrated land development pattern to foster growth in the suburbs and sub-centers of the city (Lin, 2009).

3 Literature Review

This section will comprehensively review literature related to Transit-Oriented Development and the relationship between TOD and travel behavior to date both in English and Chinese. We will focus on the following aspects:

1) Definition, historical background and applications of Transit-Oriented Development;

2) TOD in Chinese cities;

3) TOD and travel behavior;

4) TOD and travel behavior in Chinese cities; and

5) Literature gaps.

3.1 Transit-Oriented Development

3.1.1 Background of transit-oriented development

Transit-Oriented Development/Design (TOD) was first developed by the American architect Peter Calthorpe. According to his original definition, TOD promotes mixed-use developments located within walking distance of a transit stop, which is also a core commercial area (Calthorpe, 1993). The result is the provision of convenient traveling for residents and employees within and outside of the community. With different contexts and more practices, various definitions of TOD have been developed by different government authorities and researchers (Nasri & Zhang, 2014). Some of the main objectives of TOD have also been identified, such as encouraging transit use, improving housing opportunities, promoting walking and cycling and facilitating neighbourhood revitalization (Lund, 2006). A more specific version was developed by Bernick and Cervero (1997), as they identified a half-mile buffer zone around the transit station, and a quarter-mile transit village extends from the transit station based on the original definition given by Calthorpe. They

also stated that these transit villages should be comprised of nodes that are connected by transit and form "beads on a string" on a regional scale. Furthermore, each transit village along the transit line should be self-sufficient by providing enough amenities and facilities for residents' daily needs (Bernick & Cervero, 1997). According to Calthorpe and Fulton (2001, p.218), a successful TOD should satisfy the following standards:

- Decrease traffic congestion at a local or regional scale;
- Make investments in transit more efficient in terms of costs and operations;
- Increase the pedestrian friendliness of neighbourhoods through urban design; and
- Increase mobility by increasing options for walking and transit, and offering viable housing alternatives to traditional suburban development.

3.1.2 Defining transit-oriented development and its current condition

Ever since the early 20th century, as urban sprawl and traffic congestion have become some of the most concerning urban issues across the world, scholars and practitioners have been striving to find sustainable solutions. In North America in particular, automobile-oriented development strategies have exposed and continued to intensify the problems created by the separation of workplace and residence. TOD is regarded as one of the most sustainable urban development forms and has become popular in the United States and around the world. Between 1992 and 2004, over 30 counties and municipalities in the United States have adopted TOD regulations (TRB, 2004). Many more similar development concepts have been adopted across the world, including South America, Western Europe, Asia, and Australia (Bernick & Cervero 1997; TCRP, 2002; Zhang, 2007). The following table illustrates a few successful TOD cases that has been practiced outside of North America (Hua et al., 2009; Song & Tang, 2016; Tang & Lo, 2008):

Table 1 TOD models in different cities (Hua et al., 2009; Song & Yang, 2016; Tang & Lo, 2008).

City	TOD models
Copenhagen	Hand-shaped land use transportation plan
Stockholm	Multi-centered built form
Singapore	Ring-shaped urban form with satellite towns surrounding the urban centre
Tokyo	High density rail transit network and land redevelopment
Hong Kong	Rail + property development

In practice, every city has its own unique characteristics, and different cities may face different problems when implementing TOD, which requires different approaches to solve them. Thus, Planners and decision makers across the world commonly use the TOD definition developed by Peter Carlthorpe as guidance in developing their own version of TOD models that would be the most applicable to their situations. Because there are so many variants of TOD across the world, even with more than two decades of practice, the evaluation of TOD has just begun. Expanding on the work of Calthorpe and many others, Dittimar and Poticha (2004) developed a performance-based definition of TOD that outlines five main goals that any TOD project should aim to achieve:

- Location efficiency;
- Rich mix of choices;
- Value capture;
- Place making; and
- Resolution of the tension between node and place.

Based on this performance-based definition and surveys, planners and researchers would be able to develop quantifiable indexes and benchmarks to evaluate the quality of TOD projects.

With further studies of existing TOD cases, scholars have further developed a series of key components of successful TODs, also known as the 5Ds (Cervero & Murakami, 2008). According to Cervero and Kockelman (1997), the first "3 Ds" are density, design and diversity. They state that "higher densities, diverse land uses and pedestrian friendly designs…must coexist to a certain degree if meaningful transportation benefits are to accrue" (page 19). Having higher density within a walkable distance will generate high transit ridership from residents, workers, and shoppers within the TOD (Cervero & Murakami, 2008). In 2002, John Holtzclaw led a team of researchers to study the relationship between residential density and driving in three metropolitan areas (the San Francisco Bay Area, the Chicago region, and Southern California), and they found that as residential density increases, there will be fewer people driving, and vice versa (John Holtzclaw et al, 2002). The fourth D is the distance to transit. Studies show that the distance between home and a station or the workplace and a station plays a significant role in generating high transit ridership, as ridership grows exponentially when people live or work in close proximity to the transit station (Holtzclaw et al, 2002; Lund et al, 2004). The fifth D is destination accessibility, in which the transit station should be well connected to popular destinations, such as retail shops, movie theatres, restaurants, and activity centres (Cervero & Murakami, 2008).

3.1.3 Other TOD Practices

3.1.3.1 TOD Practices in Europe

There are many successful TOD practices in Europe as well, and some of them are considered to be textbook examples of TOD practices that has been widely studied by scholars from across the world. Unlike the American TOD, TODs that have been practiced in Europe does not have a universal definition as the approaches to design and implementation of TOD vary from case to case due to the differences in urban characteristics and cultures between cities and countries. In

this section, we will closely look at the TOD practice in Stockholm, Sweden as it has been generally agreed by scholars as one of the most successful TOD practice in Europe (Cervero, 1995; Cervero, 1998; Wang, 2016; Jiang & Han, 2009).

Stockholm is the capital and the largest city of Sweden with over 930,000 (by the year of 2016) residents (Statistics Sweden, 2017). The TOD practice in Stockholm has successfully demonstrated the integration of rail transit and urban development on a regional scale. The success of TOD practice in Stockholm can be summarized into following key aspects (Jiang & Han, 2009):

1. Long-term urban planning

The urban development of Stockholm has been strongly influenced by Ebenezer Howard's Garden City concept. In the 1940s, architect Sven Markelius believed that suburbanization is inevitable, and having satellite towns and urban developments that are driven by the subway system is the

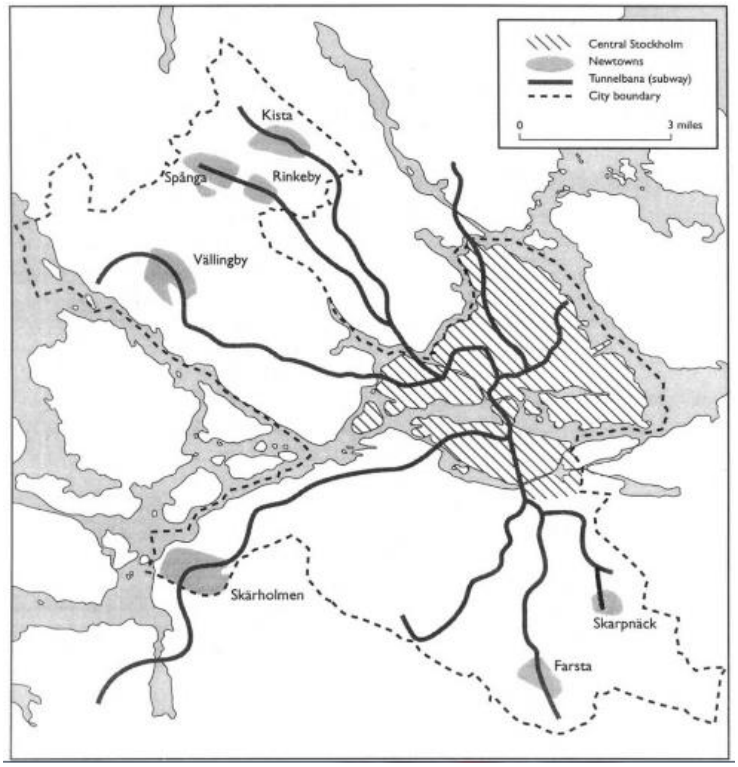

Figure 1 Stockholm's rail transit system and major satellite towns (Cervero, 1998).

solution. With this concept in mind, he has developed the *General Plan of 1945-1952*. In the past 60 years, Stockholm has transformed from a single-centred city to a multi-centred city. The city core of Stockholm is surrounded by many satellite towns, and they are all connected by the subway system. Land ownership has been one of the most common challenges in TOD practices. But the City Council of Stockholm had foreseen problems of land supply for public goods and started to purchase land since 1904. After World War II, the city council was able to build mid-rise and apartment buildings on the government owned lands to accommodate the needs during the housing shortage, and 90% of the Residential developments after 1946 were built on government owned lands (Jiang & Han, 2009). This forward thinking planning of the city council has lay down the foundations for the future integration of transit and urban developments in Stockholm.

2. Public transit guided development of satellite towns

The urban developments of Stockholm has always been following the General Plan developed by Sven Markelius. The subway system and the satellite towns were developed simultaneously. At the beginning of the development, the subway system was losing money for a long period of time due to limited number of people living in the new satellite towns. But Markelius and the city council believed that the subway system would show its advantage when the development of the satellite towns is truly completed. In order to become self-sustaining, architects and planners designated commercial and industrial lands based on the expected population growth of the first-generation satellite towns to create job-housing balance (Cervero, 1998). The outcome however was not as planned in terms of job-housing balance and the self-sufficiency of the design, with most people still working in the core centre of Stockholm or even other satellite towns (Hall, 2002). This experience shows that job-housing balance is not essential in reducing automobile dependence. Instead, the integration of residential development and public transit service found to

be far more important in encouraging residents of Stockholm to take public transit. Over time, Stockholm developed into a city with high density residential developments located around the subway or railway stations along with a rich choice of services and amenities provided to the residents. Currently about two thirds of Stockholm's residents along the subway or other public transit lines, and more than half of the residents living in satellite cities would choose to use public transit as their main commuting method (Jiang & Han, 2009).

3. Complete public transit system

A complete public transit system and high efficient transit service has played a significant role in supporting high transit ridership in Stockholm. As mentioned earlier, the city core and its satellite towns are mostly connected by the regional subway system, also known as Tunnelbana. With 110km total length and 100 stations, Tunnelbana has become the main structure and the mostly used travel mode of the entire transit system (SL, 2007). Other than the subway system, the city also has three regional rail way system, three LRT lines, and a well-developed bus system (SL, 2007). The complete and integrated public transit system have made it a lot easier for people to travel by public transit even when comparing to cars. And since 1967, all the public transit services within Stockholm have been managed by a single transportation agency (Storstockholm Lokaltrafik) to improve the efficiency and services of the public transit system (Jiang & Han, 2009). And to further encourage people taking transit, the transit fare has been set very low ranging from US$1.0 to US$1.5 per trip based on the travel distance, and extra fares are not required when transferring.

4. Policies to support transit riding

Despite the importance of the physical integration of public transit and urban development, without policy supports it would still be difficult to promote public transit in Stockholm. In order to reduce automobile usage and promote public transit, the city has adopted a series of public policies. As mentioned earlier, fare for public transit is maintained very low. In contrast, parking and taxi fare are extremely expensive, especially in the centre of Stockholm. In 2007, Stockholm has become the second city in Europe that has adopted "congestion charges" (Jiang & Han, 2009). The charges are applied to the roads that are often congested. Aside from the public policies carried out by the city, there are also supportive policies are implemented by the Swedish government. Sweden has extremely high tax charges and registration fees applied on car purchasing comparing to other countries. Furthermore, high tax charge is also applied on gas purchasing in order to reduce automobile dependency (Jiang & Han, 2009).

In conclusion, Stockholm's multi-centred built form and the integration of public transit and urban development has successfully achieved the TOD goals in reducing automobile dependency. The concept of focusing on public transit development has always been a priority for urban development in Stockholm since the beginning of urban expansion after WWII. Very different from Stockholm, many cities in US and Europe has focused on developing highways and low density urban expansion. TOD was only introduced in early 1990s to be implemented in this car-oriented urban landscape aiming to achieve what has been practiced in Stockholm for over 60 years. Many key aspects are worth taking away from the Stockholm case for TOD practices in China. However, Chinese cities arguable share more in common with cities in the US, which are pursuing TOD strategies that can be successfully implemented in already built-up urban landscapes where people have already established transportation patterns.

3.1.3.2 TOD Practices in Asia

Successful TOD practices can also be identified in Asia. Tokyo has been often studied by researchers for its advanced rail transit network and successful real estate developments along the transit lines. Tokyo is one of the largest megacity and most populous metropolitan area in the world (Bagan & Yamagata, 2012) with a population of 36.13 million by 2015 (Statistics Bureau of Japan, 2016). Tokyo has the world's largest rail transit system, with a total of 119 lines including both subway and at grade railways. The total length of rail transit network has reached over 2,000 km. The development of rail transit service started since early 20th century (Han & Jiang, 2009). Like many western countries, Japan underwent rapid industrialization from 1915 to 1935. Very much like cities in North America, most of the employment was located within major cities and rail transit was the only method for people to travel in and out the cities (Han & Jiang, 2009).

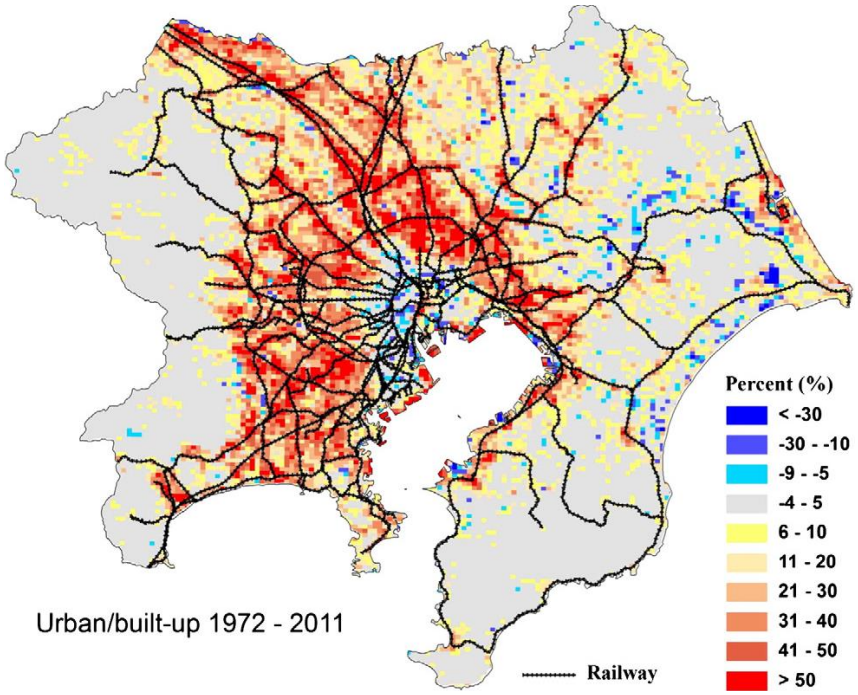

Figure 2 Change in population density of Tokyo between 1970 and 2005 (Bagan & Yamagata, 2012).

Therefore, the suburbanization of Tokyo would follow the development of the railway. After WWII, unlike many North American and European cities, Tokyo continued to focus on rail transit

development instead of highway development, and housing developments continued to be located along the transit network. In Figure 2 we can clearly see that the population of Tokyo is mostly located along transit lines and outside of the Tokyo city core (Bagan & Yamagata, 2012). And in Figure 3, we can see that most of the changes of urban/built-up area are also located along the transit network. With the complete rail transit system and real estate developments along the transit lines, Tokyo rail transit has successfully achieved a mode share of over 90% for both commute and non-work related activities. There are many good qualities of TOD practice in Tokyo that Chinese cities can learn from since both cities have very high density. But similar to Stockholm, Tokyo has adopted this integrated transit and land use development strategy since the beginning

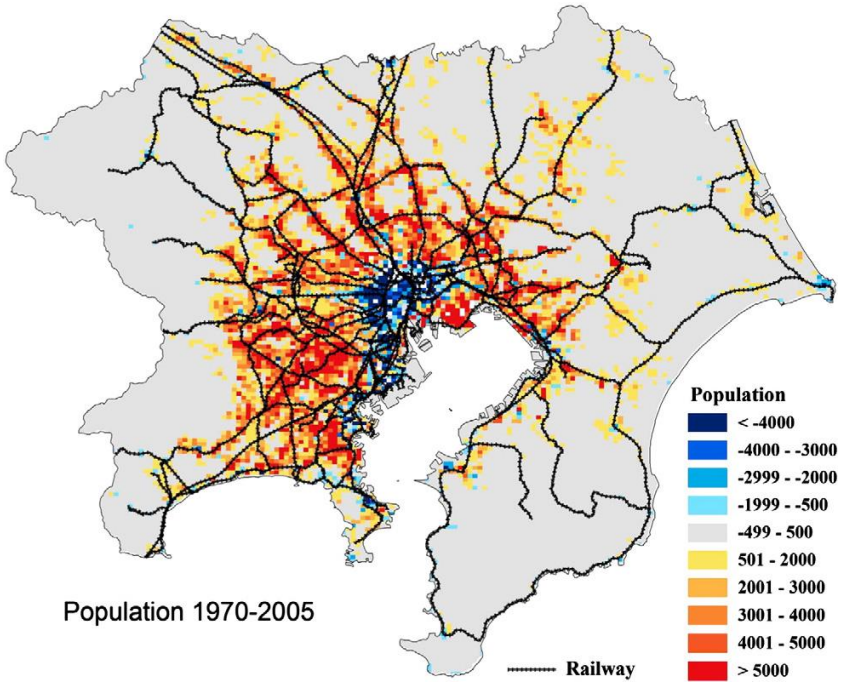

Figure 3 Percentage change of urban/built-up area in 1-km^2 grid cells from 1972 to 2011 (Bagan & Yamagata, 2012)

of its urban development history which does not solve the problem of how to implement an effective TOD in an existing car-oriented urban environment.

3.1.4 Typology for TOD

As mentioned earlier, every city across the world has its own unique characteristics, and the TOD needs to be designed around and tailored to each case based on specific requirements and conditions. Even within a city, there are different sites that have completely different physical environments and functionalities. For example, a downtown urban centre is very different from a suburban town centre in terms of land use, density and even transit services. However, the original definition of TOD tends to suggest a one size fits all set of solutions for all different types of sites (Dittmar & Poticha, 2004). When planning TODs, planners should carefully consider the current conditions and future development potentials of the site, as it would be hard to justify putting a subway line in a low density suburban area. Peter Carlthorpe (1993) has identified two types of TOD: "urban TOD" and "neighbourhood TOD". "Urban TOD" is normally located along subway, LRT or BRT lines, which provide intensified commercial land uses, high density employment opportunities and medium density residential land uses (see Figure 1). Several "urban TODs" should be connected together to create "beads on the string" which will become the main development axis of the city. The "neighbourhood TOD" should be supported by bus stops at the centre, and it should take less than 10 minutes to reach one of the closest rail transit stations or BRT stations. The size and density will be smaller than the "urban TOD", and give more

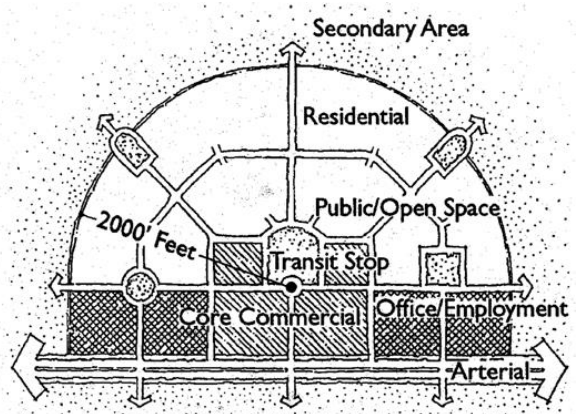

Figure 4 Ideal TOD Structure by Calthorpe (Calthorpe, 1993, p. 56)

consideration to residential density (Wang, 2016). Even though the two types of TOD are not the solutions for all different types of sites across North America this provides us a different perspective for examining the typology of TOD. Based on Calthorpe's work, Dittmar & Poticha further studied six common typologies of places, and how TOD can be applied in these places. The following table illustrates the standards of each type of TOD, and it only serves as a guide for designing a new TOD or evaluating an already implemented TOD (Dittmar & Poticha, 2004):

Table 2 General typology for TOD (Dittmar & Poticha, 2004).

TOD Type	**Land-Use Mix**	**Minimum Housing Density**	**Housing Type**	**Scale**	**Transit Modes**	**Frequencies**
Urban Downtown	-Primary office center -Urban environment -Multifamily housing -Retail	>60 units/acre	Multifamily Loft	High	All modes	<10 min
Urban Neighbourhood	-Residential -Retail -ClassB commercial	>20 units/acre	Multifamily Loft Townhome Single family	Medium	Light-rail Streetcar Rapid bus Local bus	10 min peak 20 min offpeak
Suburban Centre	-Primary office centre -Urban environment -Multifamily housing -Retail	>50 units/acre	Multifamily Loft Townhome	High	Rail Streetcar Rapid bus Local bus Paratransit	10 min peak 10-15 min offpeak
Suburban Neighbourhood	-Residential -Neighbourhood retail	>12 units/acre	Multifamily Townhome Single family	Moderate	Light-rail Rapid bus Local bus	20 min peak 30 min offpeak

	-Local office				Paratransit	
Neighbourhood Transit Zone	-Residential -Neighbourhood retail	>7 units/acre	Townhome Single family	Low access to a center	Local bus Paratransit	25-30 min Demand responsive
Commuter Town Centre	-Retail centre -Residential	>12 units/acre	Multifamily Townhome Single family	Low	Commuter rail Rapid bus	Peak service Demand responsive

In conclusion, according to either Peter Calthorpe's original definition or the new definitions developed by Cervero, Dittmar and many others, the most direct impact of TOD on residents is to change their travel behavior to achieve overall sustainability. TOD provides transit options such as subways, LRT, or BRT for residents to use to travel outside of the TOD. Within the TOD, the compact urban form, mixed land uses, and pedestrian-friendly environment encourages residents to walk or bike to different destinations.

3.2 TOD in Chinese Cities

3.2.1 Background of TOD in China

China's urbanization has been growing exponentially since a market-oriented economy was widely adopted throughout the nation in the 1990s. In the late 1990s and early 2000s, China started to notice some of the urban issues that came along with its rapid pace of urbanization. The urban issues are similar to the problems that American cities experienced in the 1970s and 80s, and one of them is the difficulty of integrating transit with land developments to improve land use efficiency and reduce traffic congestion. In recent years, these problems have become more severe, and major cities in China such as Beijing, Shanghai, Guangzhou and Shenzhen have reported an increased travel time needed to go to work. Studies show that the average commuting duration in

these cities has almost doubled since 2010 (Song & Tang, 2016). As illustrated in Figure 1, the average commuting duration in Beijing has increased from 52 minutes to 97 minutes, and similarly in Shenzhen, the commuting duration has increased from 46 minutes to 89 minutes.

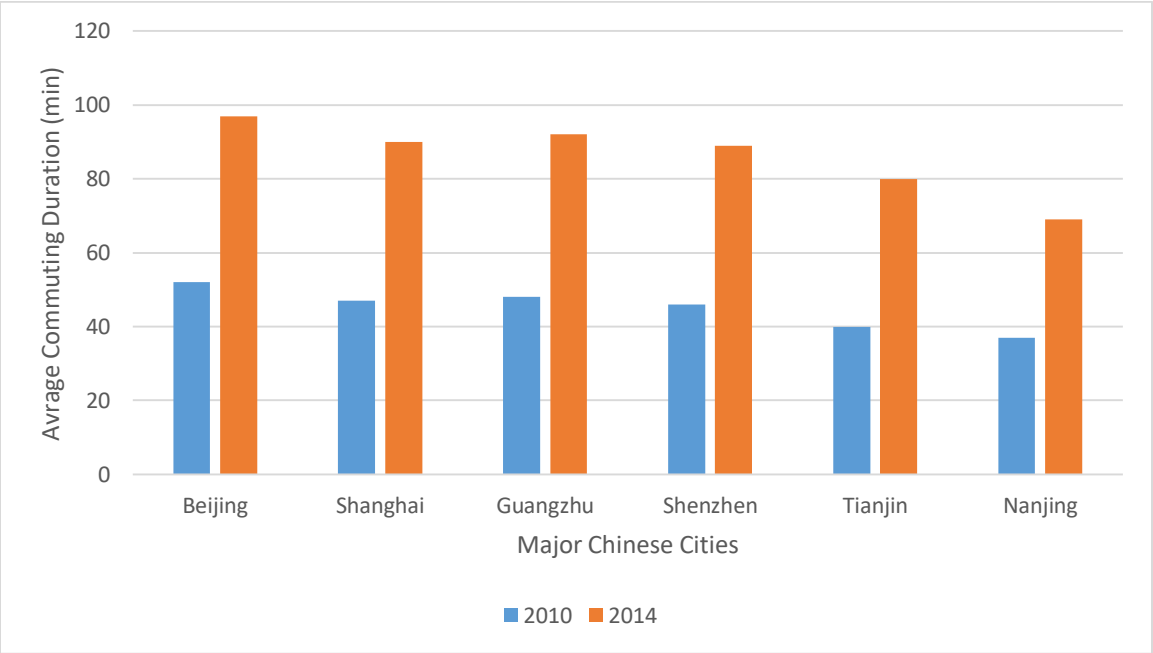

Figure 5 Average commuting duration statistics for 2010 and 2014. (Song & Tang, 2016)

The concept of TOD was introduced to Chinese policymakers and planners in the late 1990s, and it was considered a good development strategy to use to accommodate subways and other types of rapid transit developments in several major cities across China. But due to the huge differences in the characteristics of Chinese and American cities, the planning and design for American TOD is not completely applicable in China, and the original TOD concept has to be modified to work in the Chinese context (Zhang, 2007; Hua et al, 2009; Song & Tang, 2016; Wang, 2016). The following is a list of differences between Chinese and American cities that explains why TOD should be modified for Chinese cities (Wang, 2016):

1. Different urban development stages

The urbanization of American cities has been ongoing since the mid-19th century, and the urbanization ratio has achieved over 70% since the 1960s. By the 1970s, automobile ownership reached more than 400 vehicles per 1000 people. Due to the increasing ownership rate of automobiles, American cities have developed a large number of highways, car-oriented shopping malls and low density residential communities with parking garages. The TOD concept was raised and implemented after the car-oriented urban structure has been mostly completed. In comparison, the urbanization rate of Chinese cities had not yet reached 60% by 2015, and automobile ownership is much lower as well, since public transit, walking and cycling are the major means of travelling. Even today, most Chinese cities are still in the development stage, although they are expanding at an extraordinary speed and urban structures and infrastructures are still being planned. Based on the experience of American cities, this would be the best time to implement TOD in Chinese cities to achieve overall sustainable growth.

2. Density differences

There is about 7,600,000 km^2 of habitable land in the U.S., which is about twice the size of the livable land in China. However, China's population is about 5 times larger than that of America. There are about 10 cities in the U.S. that have a population over a million, but in China, there are over 140 cities that have a population over a million, and 12 mega cities that have a population over 10 million. According to Calthorpe, one of the main objectives of TOD is to address low density urban sprawl. He further stated that the lowest residential density requirement of TOD is 25 units per acre, and the most appropriate density is 45 units per acre (Calthorpe, 1993). But in China, this level of residential density is easily reached, and in fact, most urban spaces have a much higher density. It is unnecessary for Chinese cities to consider the problem of low density

sprawl, as high density sprawl is the current major urban issue in most Chinese cities (Zhang, 2007).

3. Land ownership differences

In North America, lands are privately owned and the states assure that all lands have equal development rights. All local governments have planning acts to control new developments and to ensure that these new developments do not have significant impacts on surrounding lands. In China, urban lands are owned by the state and rural land is owned by the collective (e.g., village or township). Individuals can only rent as opposed to having ownership with right to develop state-owned lands. All state-owned lands have a rental period based on different land use types, and residential land has a rental period of 70 years, commercial land 30 years and industrial land 50 years (Zhang & Liu, 2010). Lands that are collectively owned are strictly designated as rural lands on which large-scale developments are not permitted (Zhang & Liu, 2010). Some may argue that land ownership in North America is much better, but the strictly controlled land ownership in China has allowed Chinese cities to control urban growth and avoid low density sprawl. It also provides advantages for the implementation of TOD in terms of providing the integrated land developments needed to support the transit.

4. Differences in investments in public transit

As mentioned earlier, American cities are very car-oriented, and people usually do not pay much attention to public transit investments. New subway projects are rarely supported by city councils due to a lack of funding. Also, even though transit lines often increase the surrounding land values, because the lands along transit lines are mostly privately owned, the investors of the transit lines can hardly receive any benefits from increasing land values. Therefore, most cities in the U.S. do not have the support or funding to build or operate rapid transit systems to support TOD (Wang,

2016). Unlike American cities, public transit has been considered one of the most important elements that will support the rapidly growing cities in China. Because of the high density in Chinese cities, citizens desire and strongly support public transit developments. As of February 2016, 40 Chinese cities have been granted permissions by the central government to develop subway systems, and 10 more cities will also be granted permission in the next three years. With a government that strongly supports public transit developments, this has provided a great foundation for TOD implementations (Wang, 2016). And due to the land ownership policy in China, transit systems can also profit from state-owned land development around the transit station or along the transit lines to achieve financial self-support. The Rail + Property development strategy allows transit systems to operate on their own profits through property developments along transit lines without any government subsidies. This TOD model has been successfully implemented in both Hong Kong and Tokyo (Tang & Lo, 2008; Jiang & Han, 2009).

5. Cultural differences

The car-oriented lifestyle is rooted deeply in American culture, which emphasizes having a single detached house in the suburbs and driving to work, the mall and other places. In contrast to American cities, Chinese cities have been considered the heart of culture and economics since early in the country's history. Cities provide more opportunities compared to rural villages, and basic pubic services and infrastructure are much further developed in cities. Thus, many people desire to move to the cities. Shenzhen is one of the largest metropolitan cities in China, having a population of almost 12 million as of 2016, but 38 years ago, its population was less than 500,000. On average, Shenzhen has achieved a growth rate of 10.5% each year (Shenzhen Statistics Yearbook 2015, 2016). The rapidly growing populations in Chinese cities have created a compact, high density urban environment.

Due to the above-mentioned differences between Chinese and American cities, TOD in China is still in the research and planning stage, and a consolidated definition has yet to be determined. Most of the TODs implemented in Chinese cities are just in their beginning stages, and planners and researchers will continue to modify and learn from mistakes that have been made, and to search for a TOD model that can successfully work in Chinese cities.

3.2.2 Defining TOD and its current condition in China

The initial approach to designing and planning a Chinese TOD is very similar to the American TOD. Four principles which have been agreed upon by most planners and scholars are high density, mixed-use land development, walkable design and public transit services (Zhang & Liu, 2007). By drawing on further studies on the differences between Chinese and American cities, Wang (2016) has developed a more detailed definition that is suitable for China's current conditions. This definition has three main principles:

1. Appropriate development density

Since most Chinese cities have a high population density, it is unnecessary to set a density goal like in the American TOD. Instead, the density of the TOD should be determined by the maximum capacity of the transit system to avoid low density developments or transit-overloaded situations.

2. Rich mix of land uses

Wang (2016) states that a successful TOD should include the following three major land use functions: residential, public amenities that serve the community, and public amenities that serve the city. Within a TOD community, 30-60% should be dedicated for residential uses, 20-30% for public amenities that serve the community, and 10-40% for public amenities that serve the city. With a proper mix of the three land use functions, the TOD will be able to reduce the need of

residents to travel outside of the community and create a balance between arriving and leaving traffic during rush hours.

3. Continuity in pedestrian walking systems

Due to the high density of Chinese cities, conflicts between pedestrian and vehicles are much more severe compared to those in American cities. This has encouraged people to drive instead of walk or take the transit. Thus, it is important to build a continuous pedestrian system around the transit station to encourage residents to walk or bike within the TOD community and to the transit station.

Based on case studies of transit integrated land developments in Hong Kong, Taipei, and Shanghai, Professor Zhang Ming furthered developed a Chinese version of the 5Ds. Similar to the American 5Ds, Zhang believes these are the key components of a successful Chinese TOD. The Chinese 5Ds are a lot more detailed compared to the other definitions of TOD (Zhang, 2007):

1) Density Differential;

As mentioned earlier, the density in Chinese cities is much higher than in North American cities, and it is unnecessary to set density goals. Instead, Zhang (2007) suggests that the density within a TOD should be differentiated. For example, it is better to have higher density closer to the transit station to serve the residents that consider transit as their primary travelling method. The density will be relatively lower when the distance from the transit station increases. The residential units will be more spacious compared to the higher density units, and the residents that live in these types of community usually choose to drive.

2) Dockized District;

According to Calthorpe (1993), the conventional TOD district refers to a circle with a radius of approximately 400-500 m, and the transit station is the centre of the district. Due to the high density urban environment of Chinese cities, Zhang (2007) recommends expanding the coverage of the

conventional TOD by extending the entrances of the transit station through underground walkways, skywalks or building lobbies. Such a network would provide conveniences for direct pedestrian access to the transit station for residents or transit that is coming from outside of the TOD coverage. The downtown Toronto PATH system is a successful example of an underground pathway that connects office towers in the downtown core to the subway system.

3) Deluxe Design;

Zhang (2007) suggests that high quality design not only applies to the pedestrian environment, it should also apply to "vehicles, platforms, exit-entrance spaces, synchronization of feeder modes scheduling, station facilities, and landscape and buildings in the entire TOD district" (Zhang, 2007).

4) Diverse Destination;

Achieving mixed land uses has been recognized as one of the main objectives of American TOD; however, mixed-use is generally achieved in Chinese cities. Zhang (2007) suggests that Chinese TOD should focus on mixed-use on a regional scale. He further states that "diverse destination means that citizens have easy access by transit to various urban services and functions region wide if they chose to live in a TOD district" (Zhang, 2007). Also, TOD should aim to achieve a job-housing balance along the transit corridor instead of concentrating on a single TOD district.

5) Distributed Dividends.

Similar to "value capture", the idea of distributed dividends is to recapture increased property values due to the rapid transit development and redistribute them between the public and the private sector for transit financing in Chinese cities (Zhang, 2007).

Due to the high population density of most Chinese cities, subways and LRT have become the most popular rapid transit systems that have been adopted for their large capacity, high efficiency and low impacts on the surrounding environments (Hua et al, 2009). The subway was introduced

to most Chinese cities in the late 1990s, and the increasing wealth of China has made subway systems more common across the country in recent years. This means that in most cases, even before the planning stage of subway developments, the surrounding lands are often completely developed. Many of these lands are mixed with high density residential communities, offices, and retail stores, along with other amenities. Thus, in these cases, the stations are sometimes unable to be located in the ideal center of the high-density area. Even though the area could be redeveloped to partially change the density and land use composition, it would be difficult to achieve the ideal condition of TOD (Jin et al., 2011). Implementing TOD in built-up urban areas would have many limitations, and this would be one of the major and most unique challenges to Chinese cities. Other than the TOD discussed above, we can also see some more conventional TODs in many Chinese cities, usually in the suburbs or on city reserved lands. In this case, they are often located in green fields or relatively less developed lands, and land developments are intensified after the station sites are selected or constructed.

3.2.3 Typology for TOD in China

Similar to the original typology for TOD developed by Peter Carlthorpe, Wang (2016) has also identified two basic types of TOD in Chinese cities: “regional TOD” and “urban TOD”. In contrast to Calthrope’s typology for TOD, “neighbourhood TOD” is not applicable to Chinese cities as low density sprawl does not exist. Instead, “regional TOD” is more appropriate for the unique conditions of Chinese cities. According to Wang (2016), “regional TOD” refers to districts using high speed rail or intercity rail stations as the centre with a highly intensified mix of retail locations and offices which will eventually become the sub-centre or CBD of the city. “Urban TOD” refers

to districts using subways or LRT as the centre with a balanced mixed of residential, public services and amenities and commercial land uses.

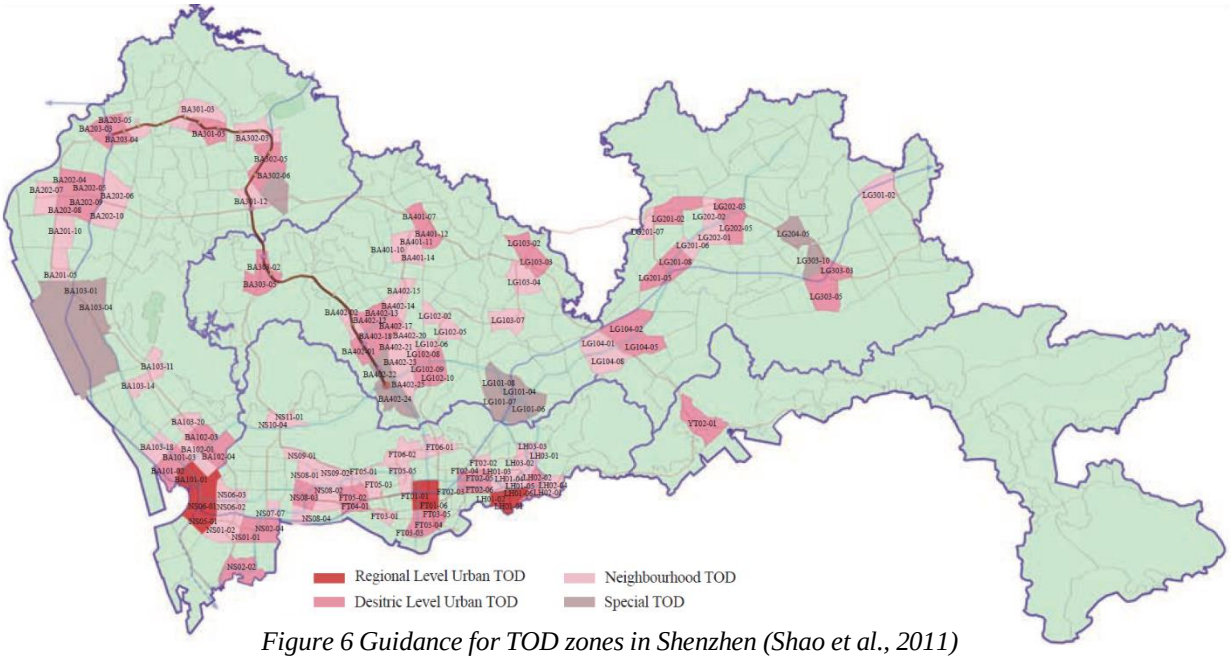

Figure 6 Guidance for TOD zones in Shenzhen (Shao et al., 2011)

The "one size fits all" theory for typology does not apply to Chinese cities as well, as all cities have different characteristics. The Shenzhen Urban Transportation Planning Center has developed a set of TOD typologies specifically tailored to Shenzhen's needs. The TOD districts can be categorized into three types (Shao et al, 2011):

1) Urban TOD

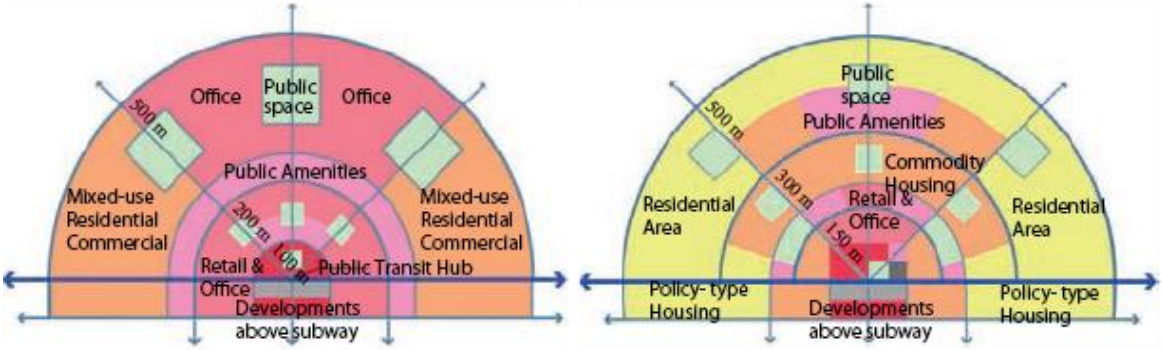

Figure 7 Urban TOD in Shenzhen (Zhao et al., 2011)

This type of TOD is located at the urban centres and sub-centres, and has direct access to the subway system and transit hubs. The urban TOD can be further categorized into "regional-level urban TOD" and "district-level urban TOD". Figure 4 illustrates the design of both types of urban TOD in detail.

2) Neighbourhood TOD

A neighbourhood TOD is located at the centre of several residential communities that should be well connected to surrounding neighbourhoods as well as the city centre and sub-centres. It can be located along the subway lines or other feeder lines. Please see Figure 5 for the structure and functions of this type of TOD.

Figure 8 Neighbourhood TOD in Shenzhen (Zhao et al., 2011)

3) Special TOD

A special TOD is located near large-scale integrated transit hubs, such as airports, high speed rail stations and intercity rail stations.

To sum up, the American TOD and its implementation does not apply to Chinese cities due to the differences between Chinese and American cities. Even though TOD is defined differently between the two, they still share similar goals. The Chinese version of TOD also intends to change the travel behavior of residents. It aims to encourage residents to take transit by providing diverse destinations along the transit lines; provide high quality design throughout the entire district; and

provide convenient pedestrian connections for residents that even live on the outskirts of the TOD to allow direct access to transit. Within the TOD, public amenities and retail locations will provide services and products to satisfy residents' daily needs.

3.3 Travel Behavior and TOD

Many have argued that the current car-oriented transport system is unsustainable, as many problems such as low density urban sprawl, high consumption, negative environmental impacts and traffic congestion are all caused by this style of transport system (Banister, 2011; Steg & Gifford, 2005). Scholars and researchers have been searching for a more sustainable approach and various strategies have been identified, such as demand management, investment in public transit, prioritizing walking and cycling and creating high quality urban design (Banister, 2011). In general, these strategies aim to achieve the following three objectives (Banister, 2011): 1) Reduce the need to travel (by automobile in particular); 2) Encourage greater use of public transit (including walking and cycling); and, 3) Reduce travel distances. These objectives can be achieved through behavioral and technological changes (Steg & Gifford, 2005). More specifically, behavioral changes in transport aim to reduce the level of personal automobile usage by converting to more sustainable travel methods and reducing the amount of travelling needed (Banister 2008). Technological changes focus on the shift from traditional fuel consumption to sustainable energy consumption in order to reduce the negative environmental impacts per car or per trip (Steg & Gifford, 2005). Energy-efficient and electric cars are considered a technological solution because they reduce the carbon emissions. Even though both behavioral changes and technological changes are necessary for achieving sustainable transport systems, many people are more accepting of technological solutions as behavioral changes are often perceived as resulting in a substantial reduction in people's freedom to move (Poortinga et al., 2003). According to Gardner and Stern

(1996), behavioral changes are often associated with additional effort or decreased comfort, and many people believe that technological solutions require less change to travel behaviors. However, the results of putting particular emphasis on high mobility and technology would not satisfy any of the objectives of the sustainable transport system mentioned above as it would not reduce the society's dependence on automobiles, and problems such as traffic congestion and long travel times cannot be solved by technological measures (Steg & Sievers, 2000). Thus, a combination of both behavioral and technological approaches would be ideal for achieving a more sustainable transport system, and policymakers should put more effort into persuading the public to make behavioral changes as it is a much more complicated and slower process compared to adapting new technologies.

TOD and its influence on travel behavior has been studied extensively in the literature. Much evidence has indicated that the use of more sustainable travel modes can be enhanced in TODs, as there are more people taking public transit, walking and cycling compared to driving or taking taxis (Arrinton & Sloop, 2009; Cervero, 2002; Lund et al., 2006; Kamruzzaman et al., 2013; Sung and Oh, 2011). Many believe that the key influence of behavioral changes is the urban form. In this case, TOD has illustrated a great example of influencing travel behavior through its urban form. The compact urban form with a rich mix of amenities, retail and employment available within the neighbourhoods allows residents to undertake local trips; the pedestrian-friendly urban design encourages the usage of active transportation (e.g. walking and cycling); and easy access to the rapid transit system consequently fosters the use of public transit (Curtis et al., 2009). However, there is opposition to this concept of urban form being the major factor for travel behavior changes as Kamruzzaman (2015) has argued that it neglects the importance of travel attitudes and residential self-selection. Many researches have indicated that individual travel

attitudes and living preferences show a much stronger influence on changing travel behavior compared to the urban form variables mentioned above (Olaru et al., 2011; Handy & Clifton, 2001; Cao et al., 2007). This means that people who are aware of environmental concerns and other negative impacts that driving a car has, or more simply people who prefer to take public transit would choose to live in TODs or similar neighbourhoods (De Vos et al., 2012). People who enjoy the car-oriented suburban life and do not need to take transit would still prefer to live in traditional suburban neighbourhoods. Exceptions also exist as there are people who prefer to live in TODs for the comprehensive public amenities and retail services rather than the convenient access to transit services (Lund, 2006). This in a way is also a change to travel behavior as residents' needs could be satisfied within walking distances. Further research by Kamruzzaman (2015) is confirmed that travel attitudes and residential area self-selection are significant factors that have a strong influence on travel behavior. TOD and its policies are proven to have successful outcomes in encouraging public transit and active transportation. Furthermore, the study suggested that traditional suburbs and other types of neighbourhoods can also be converted to have similar features as TOD neighbourhoods, and will also result in travel behavior changes.

Various studies have shown that the differences in travel behavior between TOD and non-TOD neighbourhoods is significant. Studies have compared two similar cities in Brazil. The cities of Curitiba and Brasilia share a similar size, population density and social economic status. The differences between the two cities is that high-density areas in Curitiba are concentrated in mixed land use areas along the BRT-served corridors while high-density areas in Brasilia are spread evenly across the city where the functional land uses are segregated from each other. A study by Belzer & Autler (2002) demonstrates the significant differences in travel behavior between the two cities. An average of 355 transit trips per person per year has been reported in Curitiba

compared to 97 in Brasilia. And the average number of vehicle kilometres travelled per person in Brasilia is more than twice the number estimated in Curitiba (Curtis et al., 2009). An evaluation of a number of TODs located across California conducted by Lund, Cervero and Willson (2006) shows that TOD neighbourhoods have higher rates of transit use compared to non-TOD neighbourhoods. The study further demonstrates the differences of the impacts on commute and non-commute trips for TOD residents, in which 26.5% of home-based work trips were made by public transit, and only 8.1% for home-based non-work trips. This means that the public transit access in TODs is more impactful on commute travel mode than non-commute mode choices.

3.4 Travel Behavior and TOD in Chinese Cities

Before the economic reform in 1979, current urban issues such as high density urban sprawl, long travel times between home and work, traffic congestion and air pollution did not exist as private vehicles were not provided in the central planned economic system. Even though the cities were extremely underdeveloped and the living conditions were much poorer compared to other developed countries during the time, ironically, some of the features of Chinese cities at the time were the ideal approaches that we are looking to implement today. During that time period, people had to travel to different places on foot, by bike or by bus, which is exactly what we are promoting today. Creating self-sufficient communities is one of the main objectives of TOD neighbourhoods. It is ideal to have TOD residents live, work and have all their living essentials provided within the neighbourhood to reduce the need to travel and to encourage walking and cycling. This seems unimaginable in today's society, but it was actually once achieved in Chinese cities. "Danwei" (work unit) generally refers to the socialist workplace in China before the reform (Bray, 2005), and some people today still use it to refer to the workplace in general. It was the only type of employment organization in China before the reform (Wang & Chai, 2009) and was also the basic

unit of economic, social and spatial organization in urban China (Bray, 2005). Danwei not only provided employment opportunities, but also a full package of welfare and services including housing, retail stores and cafeterias. Some danwei even had schools and hospitals located within the compound (Chai, 1996; Jiang & Han, 2009). Danwei is similar to a small-scale society that can be self-sustaining. People visiting or leaving the danwei was strictly controlled during the time, but since most daily activities could be accomplished within the compound, residents were needed to travel outside less frequently (Jiang & Han, 2009). Since the market-oriented economic reform began, the danwei system and its comprehensive package of welfare and services including housing accommodations has been gradually removed. As land transfer has been permitted in China, state-owned or collectively-owned danwei also decided to sell the residences and prioritized the housing needs of its own employees. The retail stores, schools and hospitals within danwei were all opened up to the public (Jiang & Han, 2009). As Chinese cities have been developing rapidly since the economic reform, the amenities and services within danwei can no longer fulfill living demands, and people have started to move away from danwei, as a more efficient transport system is needed to support the growth of the city. Other employment organizations have also emerged since the economic reform such as joint ventures and privately-owned companies. According to Wang & Chai (2009), 40% of the nation's workforce is employed by market-based employment organizations. Without the housing provisions provided by danwei, people have to move away from their workplaces. As the land value increases, the distance between the workplace and home have become further, which has significantly increased the need to travel as well as the travel distance. Even though danwei has become part of the past of Chinese cities, its experience of creating a sustainable community will be a helpful precedent for the future exploration of approaches that aim to realize a true sustainable neighbourhood that is similar to the compact city

concept in Europe or new urbanism concept in North America (Zhao & Chai, 2013; Wang & Chai, 2009).

The economic reform has also allowed for the widespread private ownership of automobiles, along with the increased need to travel, and as a result the transport systems in Chinese cities are facing an unprecedented challenge. To quickly accommodate the rapid growth of the cities, the car-oriented system was first adopted, which has brought many urban issues that are similar to those seen in western countries, such as air pollution and traffic congestion. According to China Today (2004), driving in some of the areas in major cities such as Beijing, Shanghai and Guangzhou is slower than riding a bike. Since the economic reform, after only less than a decade of transformation, the travel behavior of people in urban China has changed drastically. In 1990, the total automobile ownership of Shenzhen was less than 50,000, and the total number increased to almost 300,000 by 2000 (Shenzhen Statistics Yearbook 1990, 1991; Shenzhen Statistics Yearbook 2000, 2001). As of 2015, there were over 3 million automobiles registered in Shenzhen (Shenzhen Statistics Yearbook 2015, 2016). As of 2006, the public transit mode share in major Chinese cities was extremely low, and the average number of people traveling by public transit in these cities was less than 10%. As illustrated in Figure 6, most cities are showing a public transit mode share of less than 40%, Shenzhen is right at 40%, Beijing is at 30%, and Shanghai is only at 19% (Song & Tang, 2016). According to Chris Hale (2014), only cities with a public transit mode share higher than 50% can be considered as successful TODs. To encourage public transit use and reduce the number of people traveling by car, researchers have identified the following causes of the low public transit mode share (Song & Tang, 2016): 1) improper administration and cooperation between different government departments; 2) inappropriate land use structures; 3) a lack of policies that limit the total number of cars; and 4) extremely poor transit services. Jiang & Han

(2009) stressed that poor transit services is the main cause of low transit ridership, and a lack of government attention and investments is the reason for the inadequate transit services. Due to this under investment in public transit, the transit service could not meet the travel demands. According to a public transit satisfaction survey conducted in 2007 in Beijing, 78% of the 3000 participants agreed that the public transit is always too crowded, and they strongly recommended increasing

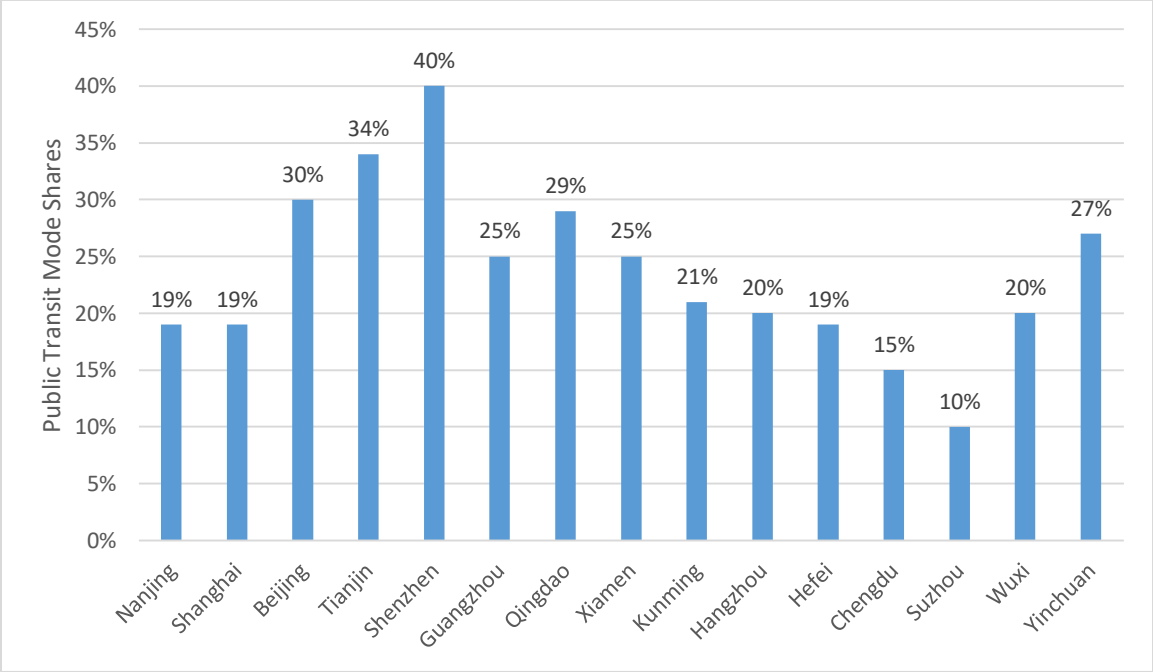

Figure: 9 2006 Public Transit Mode Shares in Major Cities (Jiang et al., 2009).

the frequency of the transits (Jiang & Han, 2009). Without a comfortable travel environment and guaranteed scheduling of public transit, many people choose to drive instead of taking transit, which has significantly increased the traffic volume and travel time. With the TOD concept being adopted across Chinese cities, the main focus will not be on low density urban sprawl or mixed-use development like in North American cities; instead, the key challenge for Chinese planners and policymakers is to identify key features of TOD or other types successful sustainable community developments that would help persuade car drivers to convert back to public transit or other sustainable travel methods.

As mentioned earlier, even though TOD was introduced to Chinese cities almost two decades ago, it is still in the research and planning stage in many cities, and subjects regarding the impact or evaluation of TOD in Chinese cities have yet to be studied in detail. The most recent research study by Zhao et al. (2016) examined the built environment of TOD in Beijing and its impact on TOD residents' travel behavior. According to this study, TOD in Beijing has a significant positive influence on TOD residents' travel behavior, which has successfully reduced long distance travel and the need to travel by car. Based on the result, he further identified three improvements to TODs that would help to influence residents' travel behavior: 1) increase the ratio of non-residential developments to encourage residents to work close to home, which would improve the job-housing balance within the TOD; 2) offer diversified retail and land use functions. In addition to large-scale supermarkets and shopping centres, TOD should also include convenience stores, fast food restaurants and other types of affordable retail and entertainment facilities to satisfy the needs of residents from different income levels; and 3) avoid creating "super blocks" within TOD as narrower roadways and high density pedestrian walkway networks would improve residents' access to surrounding amenities and encourage TOD residents to travel by walking or cycling.

3.5 Literature Gap

After examining studies on TOD and its relationship with travel behavior in different contexts, the following major literature gaps have been identified. This research study will attempt to explore these gaps further.

1) Research studies associated with TOD often focus on statistical analysis in aspects such as property value, land-use variety and transit ridership (Sung & Oh, 2011; Lau, 1997; Renne, 2009). China's urban landscape is constantly changing, and Shenzhen in particular is one of the frontier

cities of urban development. TOD is one of the newly adopted and intensively used development strategies in Shenzhen, and studies of current practices are required for future improvements. Studies regarding TOD and its impact on local residents' travel behavior for both work and non-work trips in TOD in Shenzhen should be further explored.

2) Unlike North American cities, TOD in Chinese cities has been utilized as a guideline for regional developments, and it is often studied at the policy and regional level. But these studies sometimes can be very descriptive and lack empirical analysis at the neighbourhood level.

3) As discussed earlier, travel attitudes and personal preferences play an important role in people's travel behavior. Even though this topic has been extensively studied in western literature, existing literature on how travel attitudes and self-selection influence travel mode choices in Chinese TODs is relatively weak. It is necessary to further explore and understand the key reasons for why residents would choose to live in the TOD and what qualities are they seeking within the TOD to facilitate the shift in travel modes from driving to sustainable travel options.

4) As discussed earlier, a unique challenge that the Chinese cities are facing is to incorporate TOD in a high density, built-up urban environment, such as old urban centres. This type of TOD has already been implemented across the country in different cities; however, few studies have examined the results and compared them to conventional TOD, which is usually applied to green fields or less developed areas. Its ability to influence TOD residents' travel behavior compared to conventional TOD should be further explored.

4 Methodology

This section focuses on research questions and research design. This research is an exploratory study using case studies. The methodology consists of the analysis of secondary data, a short questionnaire and neighbourhood observations.

4.1 Approaches to the Research Questions

The key focus of this study is to understand how travel behavior has been impacted by Transit-Oriented Development at the neighbourhood level. Based on the literature review, studies on this specific topic are limited in China; therefore, this research intends to explore further the case of Shenzhen's subway-led TOD practices. The three major research questions raised in Chapter 1 can be answered through the following approaches:

1) How has residents' travel behavior changed since having access to the subway within the two study areas?
    a. Subway ridership data at the two study stations have been acquired from Shenzhen subway authorities. The data have been further analyzed to understand the changes in subway ridership at both stations in the time they have been in operation.
    b. Field observation of the physical environment within the study areas has been performed. The current land use condition of the study areas has been compared to the original land use condition before having access to a subway to identify the changes to the physical environment which are most likely to be caused by introducing a subway into the areas. It has also been compared to the land use plan to understand what has been changed from the plan during the implementation.

c. A short questionnaire regarding the travel methods for work and non-work-related activities has been completed by roughly 200 residents from each of the study areas. The results can tell us about how the residents' travel methods have changed since having access to the subway at both study areas.

2) Are there any differences between the results of the two study areas?
    a. The subway ridership data and the results of the questionnaire are compared to identify and understand the differences between the two study areas, in terms of the physical environment and travel methods used.
3) Based on the results and the different urban characteristics of the two study areas, what key elements of the two TOD cases can be identified that would improve subway ridership and encourage residents to choose other sustainable travel methods (e.g. bus, walking and cycling)?
    a. Based on the results of the study and the differences found between the two study areas, key factors that would reduce the need for driving and encourage subway ridership and other sustainable travel methods have been identified in the Discussion section.

4.2 Study Areas

Two cases have been closely studied for this research: Grand Theatre Station and Houhai Station. The neighbourhoods selected at both study areas have used the coverage of TODs as the reference, which is a circle with a 500-600m radius using the station as the centre. The neighbourhoods located within the circle or right at the edge of the circle are selected (See Appendix 1 &2). At Houhai Station study area, the reference circle has shifted to the left to include neighbourhoods on the west side of the existing commercial core considering the station is located at the east end of the core developments (it is set up for connections to future commercial developments on the east side of station). The reasons for including these neighbourhoods is that the shopping centres should

serve as a connection or extended entrance to provide subway services for residents that are located adjacent to the commercial core. At Grand Theatre Station, the reference circle has shifted to the right to include neighbourhoods situated adjacent to the old financial centre as the subway station is not located in the centre. The boundary of the study areas (the dash lines illustrated in Appendix 3&4) is finalized based on the physical features that would be considered as barriers for residents to have access to the selected stations. For instance, at Grand Theatre Station study area, the side boundary lines are located along Hong Ling Zhong Road and Bao An South Road as both roads are major arterial roads with heavy traffic. It would be too far for residents that live outside of selected boundary lines to take the subway at Grand Theatre Station especially when there are other stations located closer to them. Similar process has been utilized when finalizing the boundary of Houhai Station study area as well. The 200 residents from 8 neighbourhoods within each study area have been randomly selected to complete the questionnaire. The two study areas are selected for the following reasons:

1) According to "The Comprehensive Plan of Shenzhen City (2010-2020)", both study areas are located within the only two core centres of the city. Houhai Station is located within the Qianhai Centre and the Grand Theatre Station is located within the Futian-Luohu Centre.
2) According to Shao et al. (2011) and as illustrated in Figure 3, both stations are located within areas that are designated as district-level urban TODs;
3) As discussed in Literature Review, we have identified the following qualities of TODs that are shared in both Western and Chinese contexts. These qualities can be found in both study areas:
    a. High density as both stations are located within the urban core;

b. Highly mixed of commercial, residential and institutional uses.;
c. High quality urban design around station and new developments;
d. Both areas provide a diverse destinations for its residents or visitors, such as employment, housing, shopping, schools, and other entertainments.
e. Both subway stations locate within a walkable distance from the residential area and commercial core, and also provides a variety of options for its residents to have access to other TODs along the subway line.

4) Both stations have two large-scale mixed-use developments located close to the subway satiations;
5) Both stations have a similar number of residential communities around the subway stations; and
6) Both cases are unique, but are still able to resemble TODs in two different types of urban environments which can be found in Shenzhen and most cities across China. The Grand Theatre Station TOD is implemented in a high-density, built-up urban environment. Houhai Station was developed following the conventional TOD models, which are mostly implemented in green fields or less developed areas.

4.2.1 Case 1: Grand Theatre Station

Grand Theatre Station is on Subway Line 1 (Luobao Line) which is located in the old financial center of Shenzhen, and became accessible to the public in 2004. According to "Transit-Oriented Development Framework and Planning Strategies of Shenzhen", the station is categorized as urban TOD at the district level, and the radius of coverage for this type of TOD is 500-600 m, with the station as the center point (Shao et al., 2011). The station has been in operation for over 10 years, and the developments and redevelopments happening around the station area are mostly complete.

This means the majority of the residents should have already adapted to the new environment, including subway service and other amenities, which means the data collected will be richer. There are two large-scale mixed-use developments located within the study area, the Kingkey Financial Centre located on the north of the subway station and the MXIC Centre located on the south, and both mixed-use centres have a direct connection to the station. Please see Appendix 1 for a boundary map of the study area. The data collection is towards the neighbourhoods within the TOD coverage of the station, which includes the following residential communities (Please see Appendix 3 for a boundary map of the study area and the location of the selected neighbourhoods):

Table 3 Residential Communities in Grand Theatre Station Study Area. Source: http://shenzhen.anjuke.com

Residential Community	**Built Year**	**Residential Type**	**Total Units**	**Letting Rate**	**Distance to Subway**
Xinfuli	2009	High-end	768	49%	500 m
Kingkey 100 Residence	2007	High-end/Moderate	1664	80%	450 m
Caiwuwei Xinba Jiufang	1998	Urban Village/Low-end	N/A	80%	250 m
Caiwuwei Xinshi Fang	1998	Urban Village/Low-end	409	80%	360 m

Caiwuwei South Village	Late 1980s	Urban Village/Low-end	164	80%	550 m
Mingshige	1999	Moderate	751	56%	50 m
Square North Street Residential Community	1998	Moderate	650	80%	300 m
Bingyuan Residential Community	1986	Moderate	300	80%	550 m

4.2.2 Case 2: Houhai Station

Houhai Station is part of Subway Line 2 (Shekou Line) and located in Nanshan district. Many stations on Line 2 were designed according to the conventional TOD model, including Houhai Station. Shortly after the completion of phase 1 (part of Line 1 and Line 4), the local officials directed its focus away from subway developments. Without the support of local authorities, phase 2 (Lines 2, 3 and 5) of the subway development was delayed until 2008 (Nanfang Daily, 2007). Houhai Station was opened on December 28, 2010, and due to the delay of the subway development, many of the residential areas and much of the commercial core was developed before the completion of the station. The neighbourhoods within the study are include (Please see Appendix 4 for a boundary map of the study area and the location of the selected neighbourhoods):

Table 4 Residential Communities in Houhai Station Study Area. Source: http://shenzhen.anjuke.com

Residential Community	**Built Year**	**Residential Type**	**Total Units**	**Letting Rate**	**Distance to Subway**
The Window of Binghai	2004	High-end/Moderate	1400	58%	550 m
Yang Ri Wan Pan	2003	High-end/Moderate	1133	48%	300 m
Hai An Ming Zhu	1995	Moderate	482	54%	700 m
Nan Yue Ming Zhu	2002	Moderate	457	80%	600 m
Hai Yin Chang Cheng	2003	High-end/Moderate	1801	31%	700 m
Wei Lan Hai An 3rd Phase	2002	High-end	2580	52%	450 m
Lang Qing Yu	2004	High-end	600	59%	520 m
Guan Hai Tai Garden	2002	High-end	929	51%	300 m

4.3 Research Methods

4.3.1 Secondary Data

As discussed in literature review section, ridership impact is the most studied field when it comes to travel behavior in TOD. Information on transit ridership can give us a brief idea of whether there have been changes in travel mode. This research first looked at the changes in MRT ridership at both study areas. Grand Theatre Station has been in operation since December of 2004, and the research focuses on data collected from 2005 to 2015 and Houhai Station focuses on data collected from 2011 to 2015 as the station opened at the end of 2010. By studying transit ridership over time,

we are able to determine whether there is an increasing number of residents in the area choosing the subway as their travel mode since access to the subway is now available. The data sample for this part of study is mainly acquired from the Shenzhen subway authorities.

4.3.2 Primary Data

4.3.2.1 Field Observation

To explore the current urban landscape and to become familiarized with the study area prior to more in-depth studies, field observation has been conducted. Major shopping centers, grocery stores, employment clusters, restaurant clusters, schools, hospitals, and other entertainment facilities within the study area will first be studied on an online map (Baidu map), and these locations are then verified and noted on the map printouts through the field observation. Locations that are not shown on the online map will also be identified and marked on the map printouts. New developments that are currently under construction are noted as well. The estimated distance from these locations to the selected neighbourhoods is measured through online mapping tools (Baidu Map). A walking tour from Grand Theatre Station to the neighbourhoods was taken to identify major activities, services and the overall walking experience (walkway conditions, streetscapes, etc.) along the walk. This exercise aimed to identify the locations and the availabilities of different amenities within the study areas.

4.3.2.2 Questionnaire

The questionnaire further explores the impacts of TOD on residents' travel behavior in the study areas. It focuses on their travelling mode for going to work and non-work activities, travel experience with the MRT, and experience with the major shopping centres that were developed after the subway service was made available. Residents in the study areas were asked to complete a short questionnaire. The questionnaire has 9 questions that take approximately 5 to 10 minutes

to complete. For each neighbourhood, the study is expecting to have 200 participants. The participants were randomly selected from pedestrians who are residents in the two selected study areas. The participants are preferably adults and their age was recorded. The study was conducted from 5 pm to 8 pm during the weekdays. Please see Appendix 3 and 4 for the full questionnaire.

The questionnaire consists of three sets of questions. Questions 1 and 2 are on the basic information of the participants, including the number of years they have lived in the area and the reason why they chose to move to their current home. Questions 3 to 6 aim to understand the travel methods used by the participants to go to work and non-work activities such as shopping and dining. They also aim to understand what would be the reasons if they are not using the subway. Questions 7 to 9 aim to understand whether the retail locations and amenities provided in the study areas are sufficient for the daily needs of the participants. They also aim to further understand whether the participants use the major shopping centres in the study areas, and what are the reasons if not.

4.3.2.3 Data Analysis

Data collected are first analyzed by categorization, percentage calculation and comparison between traveling to work and to other activities. To further investigate the relationship between the different variables and understand the reasons for the differences between the two study areas in terms of travel methods and the usage of major commercial centres, the research will use a Chi-square Test and Cramer's V Test to analyze the relationship and the strength of the relationship.

Chi-square Test

The Chi-square Test is one of the most useful and most widely used tests in statistics. There are two types of chi square tests that are most commonly used by researchers: the goodness of fit test and the chi square test for the independence of two variables. This study uses the chi square test for the independence of two variables, which can determine the dependency of two variables at

different levels and is suitable for most circumstances. The chi square test determines the relationship between variables by rejecting the null hypothesis, which is that the two variables are independent, and accepting the alternative hypothesis, which is that the two variables are related. The obtained sample data are considered as observed value. The observed value can be organized by using the contingency table based on the categories of the two variables. For this test, if the null hypothesis is correct, an expected value for each category can be calculated. The chi square test is based on the difference between the observed value and expected values for each category.

The chi square statistic is defined as the following equation:

$$\chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$$

where χ^2 represents chi squared value, O_i is the observed value in category i, and E_i is the expected value in category i. The chi squared value is calculated by finding the difference between the observed and expected value in each category, which is squared and divided by the expected value in that category. The sum of these values for all the categories is the chi squared value.

Each chi squared value has a degree of freedom associated with it, and based on the chi squared value and the degree of freedom associated with it, we will be able to find the corresponding level of significance *P* value on the chi square distribution table (see Appendix 5). The significance represents the possibility of the null hypothesis, which is that the two variables are independent, being correct. For instance, if the corresponding significance is 0.01, then there is 0.01 chance that the two variables are independent from each other. In this study, we will be using 0.05 as the level of significance to reduce type I error. This means that if the corresponding *P* value is smaller than 0.05, then the null hypothesis is rejected. Even though the chi square test is very useful and is widely used in statistics, it has one disadvantage, which is that it does not show the type or strength

of the association between the two variables. To understand the types of the association between the variables, we will need to carefully study the sample data and find out whether it is positive or negative. To understand the strength of the association, we will need to perform a Cramer's V Test.

Cramer's V Test

The chi square test can determine whether two variables are related, but it does not show the strength of the association. The Cramer's V Test will determine the strength based on the chi square value developed by using the chi square test to determine the independence of two variables. Cramer's V is defined as:

$$V = \sqrt{\frac{\chi^2}{nt}}$$

where V is the Cramer's V, χ^2 is the chi squared value and n is the sample size. The same contingency table that has been used to determine χ^2 will be used here as well, where t is the smaller of the number of rows minus one or the number of columns minus one. The value of Cramer's V is in the range between 0 and 1. The strength between the two variables is strong when the value is closer to 1, and weak when the value is closer to 0.

5 Findings

5.1 Analysis of Secondary Data

According to the ridership data acquired from Shenzhen MRT authorities, subway line 1 shows a much higher ridership compared to subway line 2. The ridership of subway line 1 reached over 50 million in 2005, and by 2015, the ridership for the year reached almost 4 billion. Compared to subway line 1, the ridership of subway line 2 reached only 50 million in 2015. Subway line 1 is located along the main axis of Shennan Avenue. Most of the early developments of the city are located along this road including the urban centre, several commercial centres and the city government. Since subway line 1 was completed, it has become the busiest subway line in the city.

As illustrated in Figure 7, the ridership at Grand Theatre Station has grown exponentially since it opened in 2004, and the average annual growth rate is 11.3%. From the graph, we can see a drop in ridership in 2009 and 2010. This could be because of the opening of subway lines 2 and 3, which has diverted some of the passenger volume on subway line 1. When the Kingkey Financial Centre opened in 2010, the ridership started to climb again. This means that the new development has a significant impact on the subway ridership at Grand Theatre Station. Compared to Grand Theatre Station, the ridership at Houhai Station is much lower, as illustrated in Figure 7. However, it has a higher average annual growth rate of 16.1% compared to Grand Theatre Station. Based on the increasing ridership and the high annual growth rate of ridership at both stations, it is clear that the TODs at both locations definitely have a significant positive impact on travel behavior as there are more and more people choosing to use public transit.

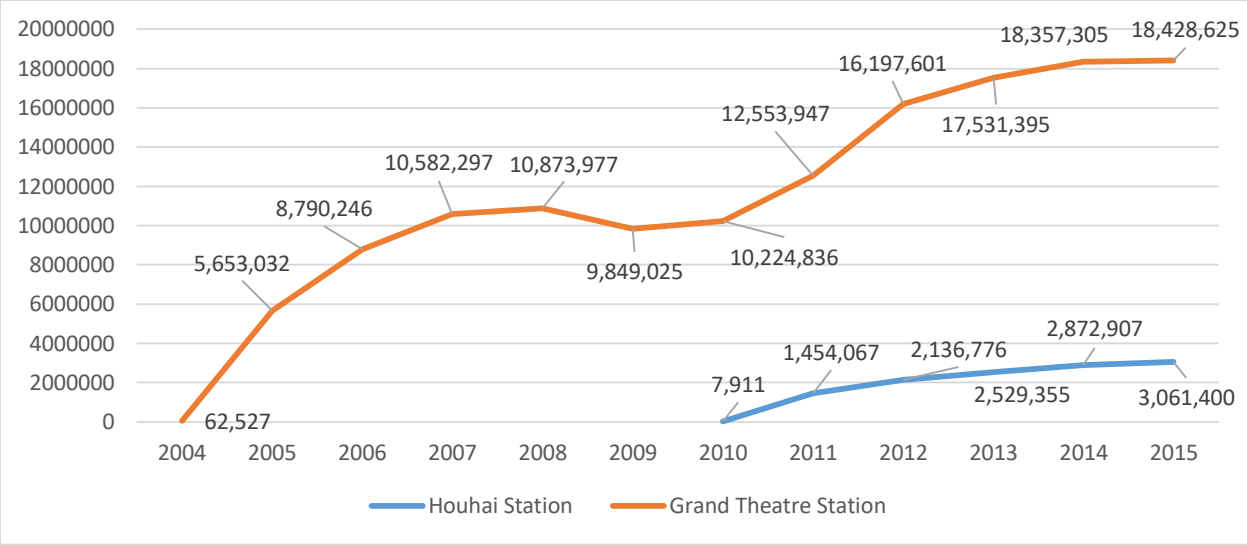

Figure 10 Subway ridership at Grand Theatre Station and Houhai Station each year since opening

5.2 Analysis of Primary Data

5.2.1 Field Observation

The main purpose of the field observation is to explore the current urban landscape of the two selected study areas and identify the changes compared to the condition before the subway was developed. The 2001 land use map of the area has been compared to the land use plan from the previous City Comprehensive Plan (1998 – 2010) and the current land use condition which was recorded during the field observation to understand what has changed and how it is different from the original plan. The locations of major activities and services available within the study areas, including shopping centres, grocery stores, schools, hospitals, restaurant clusters and other entertainment facilities have been identified by studying the satellite map on the Baidu Map and field observations. The distances between each residential community and the identified primary locations for activities and services have also been roughly measured by using the measuring tool in the Baidu Map. Finally, from a personal perspective, the overall walking experience in the two

study areas will be described and discussed based on the physical condition of the walkways and streetscapes.

5.2.1.1 Case 1: Grand Theatre Station Study Area

i. Comparison of the Urban Environment before and after the TOD

Original Land Use (2001):

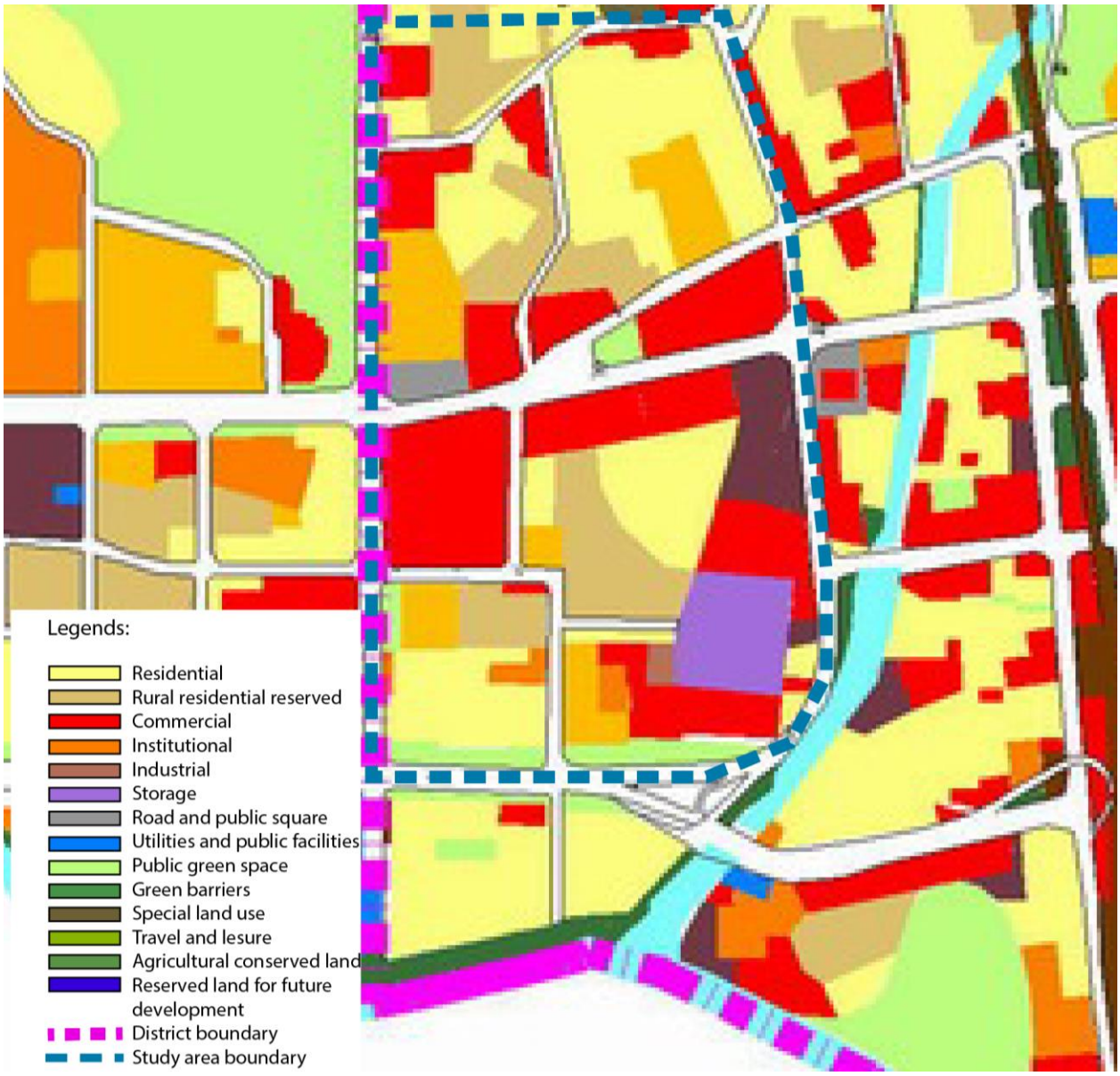

Figure 11 Grand Theatre Station Study Area Land Use Condition of 2001. Source: http://www.szpl.gov.cn

Figure 8 shows the land use map of Luohu District created in 2001 as part of the 'Luohu District Comprehensive Plan 1998-2008', which can help us understand the land use condition of the study area before the subway was fully in service. According to the map, the land use composition within the study area mainly consists of residential, commercial, institutional land uses and rural residential reserved lands. Most of the commercial land uses are located along Shennan Avenue (深南大道); this includes several office towers which form the old business centre of the city. The triangle piece of land in the centre of the study area on the north side of the Shennan Avenue is occupied by the tallest skyscraper in the city at the time, Diwang Skyscraper. And land along the south side of the avenue is occupied by several towers for banks, financial institutes and retail stores, one of which has several floors dedicated to the largest book store in the city at the time, which has become the main attraction of this area. Residential and rural residential reserved lands are located beyond the business centre to the north and south. The residential lands are mostly occupied by residential communities that were built in the late 1980s and early 1990s. Some significant features of the residential communities built during that time are that the buildings are mostly less than 7 floors, the unit size and layout are unified across the entire community, and there are many green spaces throughout the community. Rural residential reserved land is occupied by urban villages, which are rural lands located within the urban boundary due to the rapid growth and expansion of the city. Urban villages are very common in Guangdong Province, especially in rapidly growing and expanding cities like Shenzhen, Guangzhou (广州), Huizhou (惠州) and Dongguan (东莞). On rural residential reserved land, the land is collectively owned by the village, and each of the villagers will receive a piece of land on which to build their own houses. But because there are no standards and regulations for the residential buildings they build on rural land, and to maximize the profits of the land, many villagers have decided to build their own apartment

buildings that take up the entire lot and leave very little separation between the buildings. Compared to the regular residential communities that were mentioned previously, the build quality and the living quality of each unit are poor and the community is lacking in green spaces and public amenities. Each apartment building is owned by one or several households, and additional units are rented out to people. Because of the cheap prices and prime location of these types of communities, rental units are extremely popular and easily rented out by young laborers and service workers that work in close-by areas that are often in walking distance.

Land Use Plan (2001):

The land use plan of Luohu District was also created as part of the 'Luohu District Comprehensive Plan 1998-2008' (see Figure 9). This map plans out the different land use developments of the district for the next 10 years. According to the comprehensive plan, within the study area, using the subway station as the core and along Shennan Avenue, the area has been designated as the main commercial and business development axis for the city, which means business and commercial developments will be expanded along this axis. The plan also emphasizes the redevelopment and transformation of urban villages to control any new developments of illegal residential apartment buildings on rural residential reserved lands and to improve the living quality and urban environments of the urban villages. Compared to the land use condition of the district at the time, there are several significant changes proposed to the land uses within the study area. A significant amount of land along Shennan Avenue has been planned to be used for public green spaces which could be reserved for the subway stations that were still under construction when the map was created. The lot (lot 1) located in the northeast of the study area that is bounded by Jiefang West Road (解放西路) in the south, Caiwuwei 1st Street (蔡屋围一街) in the west, Caiwuwei 5th

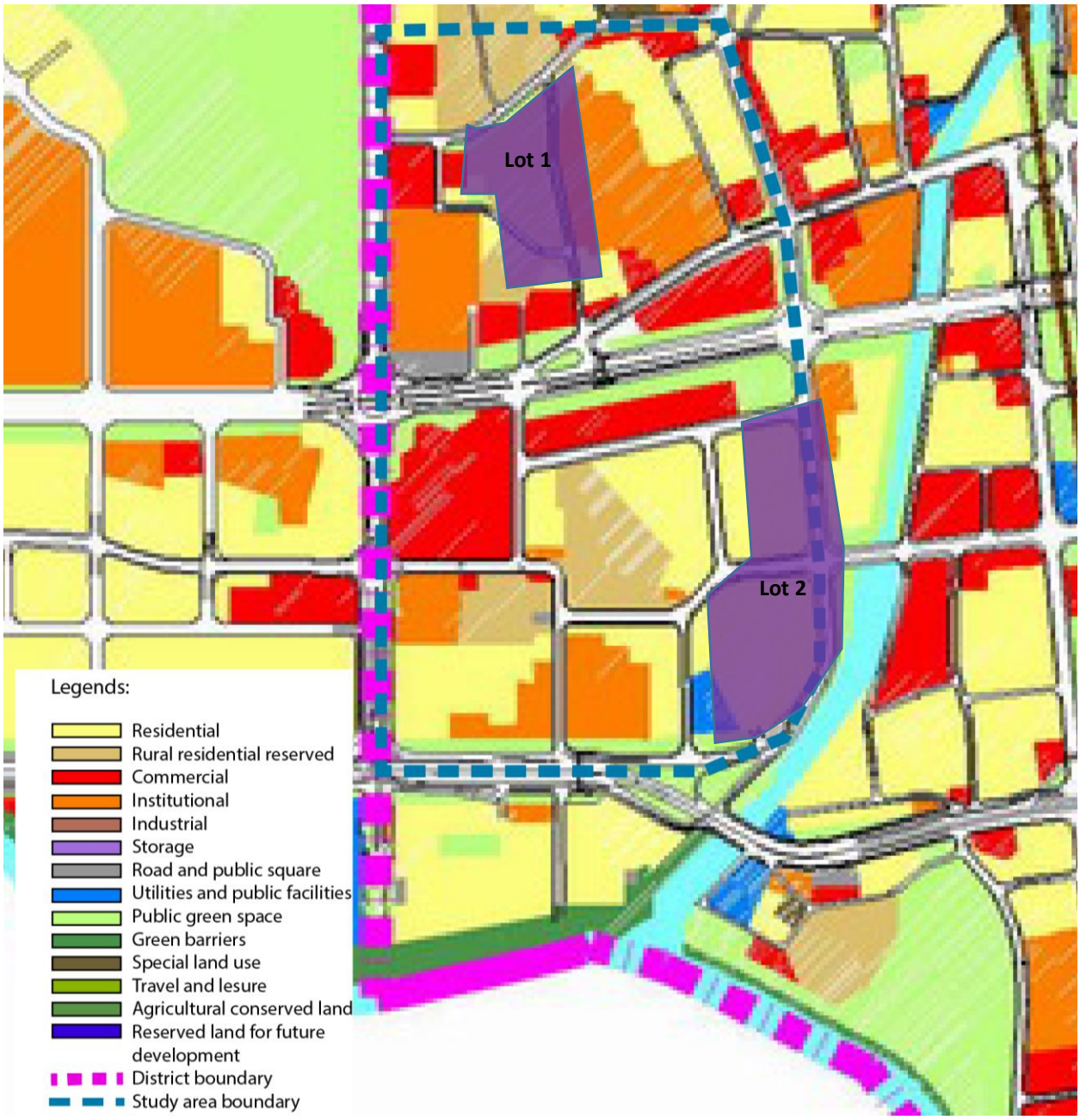

Figure 12 Luohu District 1998-2010 Land Use Plan of the Grand Theatre Station Study Area. Source: http://www.szpl.gov.cn

Street (蔡屋围五街) in the east, and Hongbao Road (红宝路) in the north has been planned to become rural residential reserved land. The lot (lot 2) located in the southwest corner of the study area bounded by Book City Road (书城路) in the north, Baoan South Road (宝安南路) in the

south and east, and Wanxiang Street (万象街) on the west has been dedicated for residential land use.

Current Land Use Condition:

Based on the field observation, we have identified several differences between the actual land use condition and the land use plan. As mentioned earlier, lot 1 of the study area has been planned as

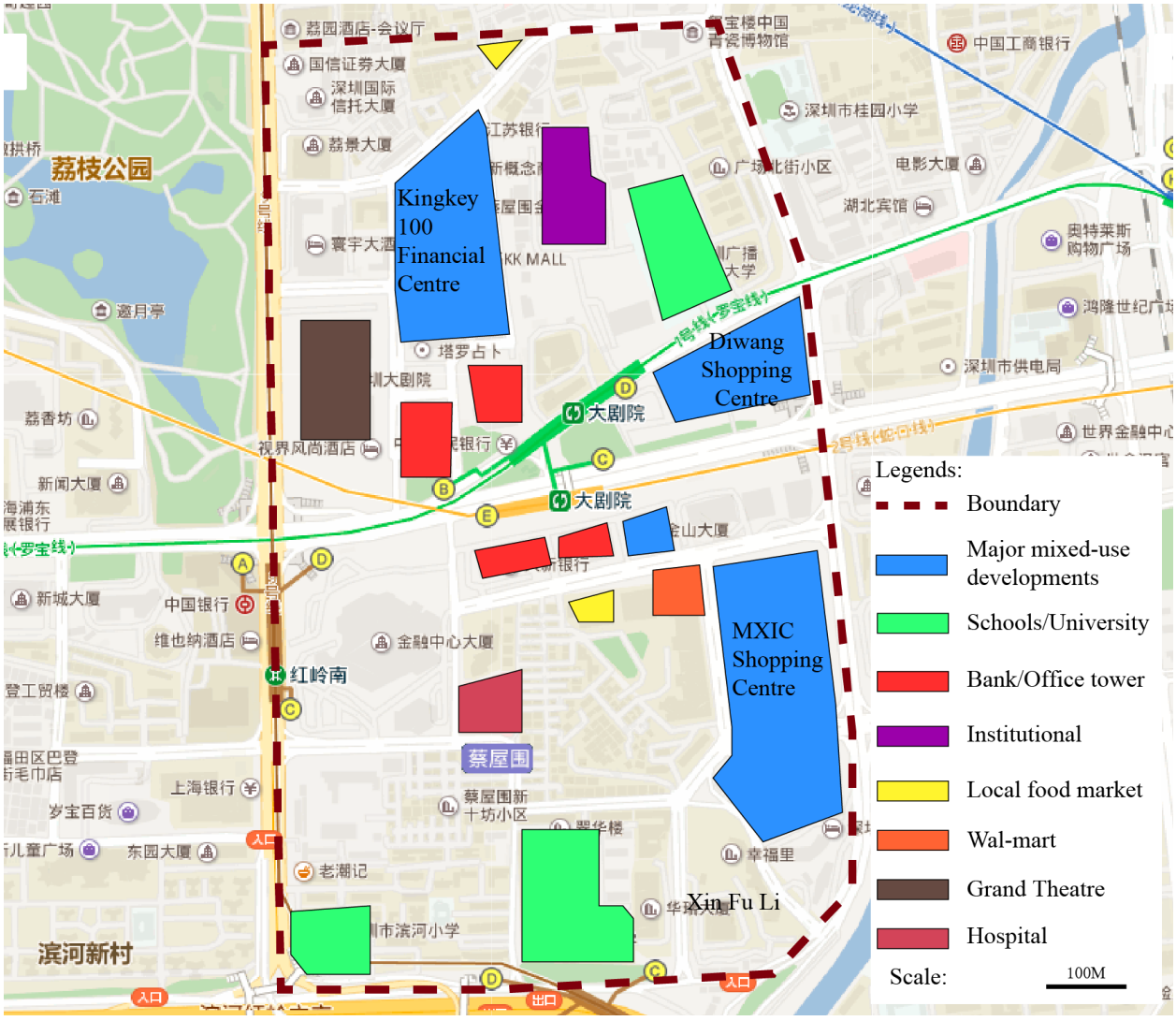

Figure 13 Major amenities and services offered at Grand Theatre Station study area.
Source: Compiled by author. Base map: Baidu Map.

rural residential reserved land. But currently, the land is improved by a mixed-use development 'Kingkey Financial Centre'. The development includes a 100-storey-tall office tower, which is

currently the second tallest tower in Shenzhen, and eleventh tallest in the world. Other than the office tower, the development also includes a large-scale shopping centre as the podium and several high-rise apartment buildings on top of the shopping centre.

According to the land use plan, lot 2 of the study area has been designated for residential land use. But the land is currently occupied by another mixed-use development 'MIXC', which also includes a large-scale shopping centre and a residential complex 'Xinfu Li', which was selected as one of neighbourhoods for data collection. Other than the changes mentioned above, the current land use condition generally complies with the land use plan that was developed in 2001 as part of the 'Luohu District Comprehensive Plan 1998-2008'.

ii. Major Retail Locations and Amenities

Based on the field observation, several major retail locations and amenities are identified in the study area (see Figure 10). The two large-scale shopping centres are the key retail locations and amenities in the study area that serve residents that live in the area and visitors from across the city and even from outside of the city. During the construction of the subway station, one of the two large-scale Mixed-Use developments 'MXIC' was being constructed simultaneously. The development is located in the south-east direction from the subway station, and the distance between the station and the closest entrance of MIXC is approximately 250 m. The commercial portion of the development includes an ultra-size mall and office towers on top. MIXC mall is the largest mall in Shenzhen with a site area of 18.8 Ha, and one of the most successful ultra-size malls in China. The construction of the development was broken down into two phases, phase 1 of which was finished several months before the operation of the Grand Theatre Station in 2004, and phase 2 started in 2005 and was completed in 2008. Xingfuli residential community, which is the residential portion of the phase 2 development and located south of MIXC, was completed in 2009.

The community consists of three 49-storey apartment buildings and provides 768 residential units designed in various sizes and layouts. In 2010, KK-Mall (KingKey Financial Center), another mixed-use development located within 500 m of the Grand Theatre Station was also opened. The development consists of a large-scale mall that occupies the atrium space, several residential towers on top of the mall that provide 1,664 residential units and a 441.8-m tall office tower. The office tower is currently the second tallest tower in Shenzhen, and the eleventh tallest in the world.

Figure 14 On street storefronts condition at the Grand Theatre Station study area.
Source: Compiled by author. Base map: Baidu Map.

Other than the two shopping centres, there are also individual storefronts scattered throughout the entire area that provide products and services for residents that live in nearby communities. As

illustrated in Figure 10, within the study area there is a Walmart and a local food market that sells food and daily essentials that are more affordable to the residents with middle and lower income levels. There are also domestic retail stores and restaurants scattered across the entire study area, especially on the narrower streets, and many retail spaces are directly facing the streets, which has improved and attracted pedestrian movements. This will be further discussed in the next chapter. Figure 11 illustrates all the storefronts that are facing the streets within the study area based on the field observation.

iii. Overall Walking Experience

The Grand Theatre Station TOD area is located within an older district, and many sections of the sidewalks are old and in need of repair. Other than the avenues running across the area, the sidewalks along local streets are often narrow and not very clean. When walking in the areas around Grand Theatre Station, it gives pedestrians a sense of security and enjoyment, as there are many other people using the sidewalks from early in the morning until very late at night. Especially at night, the stores, restaurants and small street vendors along the streets become the main contributors for the pedestrian movements, as they are the source and destination for many street users. The street users include both the residents that live within the area, and visitors from outside of this area that come for shopping, dining and other forms of entertainment.

5.2.1.2 Case 2: Houhai Station Study Area

i. Comparison of the urban environment before and after the TOD

Original Land Use (2002):

Figure 12 shows the land use map of Nanshan District, which demonstrates the 2002 land use condition of the district. According to the map, most of the lands within the study area were undeveloped in 2002. The areas in grey are railroad and roadway-reserved lands. On the East of Houhai Avenue (后海大道) and the south of Chuangye Road (创业路) the land is mainly occupied

Figure 15 Houhai Station study area land use condition of 2002. Source: http://www.szpl.gov.cn

by residential land use. On the west of the Houhaibin Road (后海滨路) is the sea shore of Shenzhen Bay. In conclusion, the study area is a green field compared to the Grand Theatre Station study area, as there are no commercial land uses and most of the lands are undeveloped within the study area.

Land Use Plan (2002):

The land use plan of Nanshan District was included as part of the 'Nanshan District Comprehensive Plan 2002-2010'. According to the Comprehensive Plan, the study area has been dedicated as the Recreation Business District (RBD), which is the Commercial and Cultural Centre

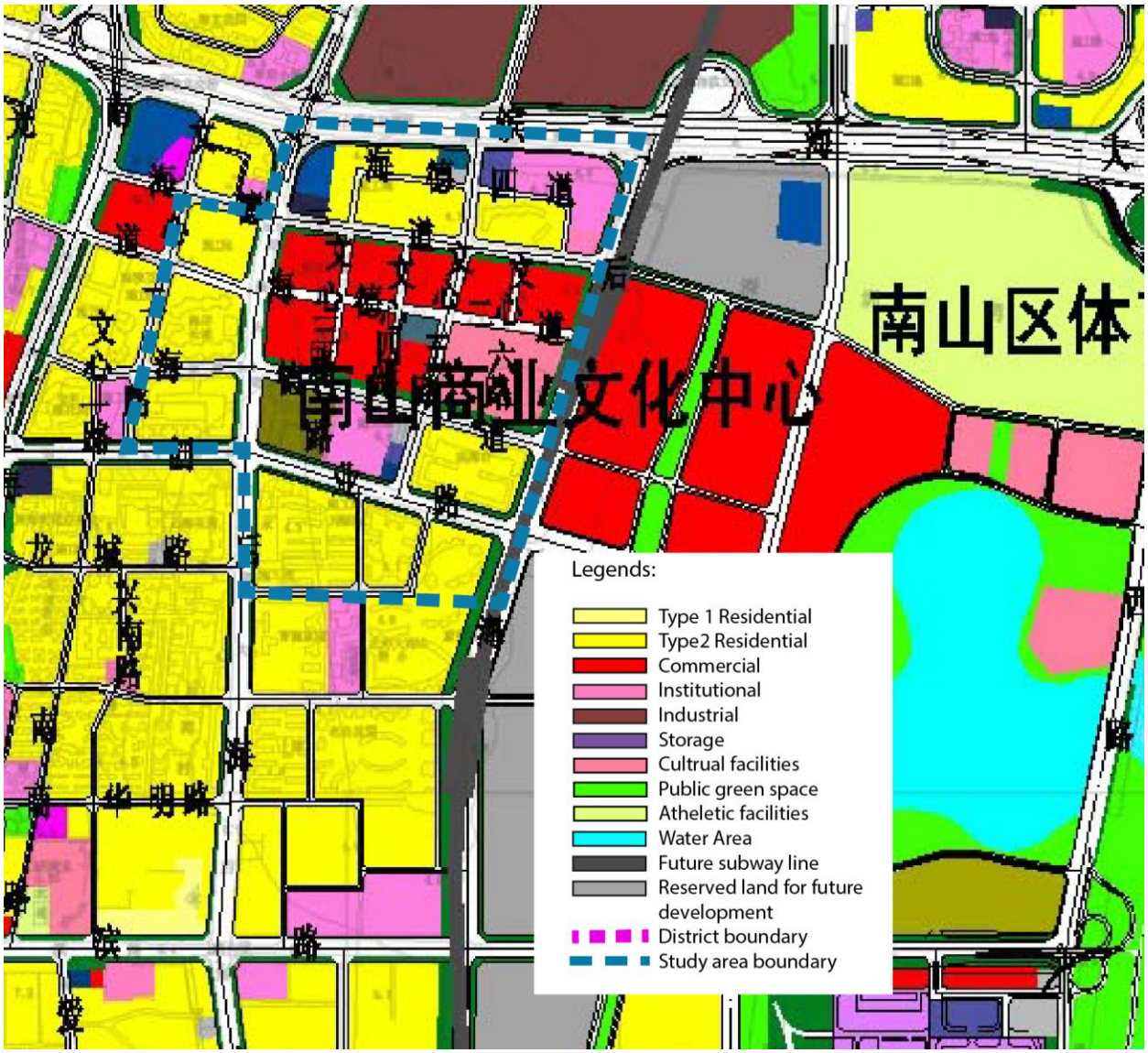

Figure 16 Nanshan District Land Use Plan (2002-2010) of Houhai Station Study Area. Source: http://www.szpl.gov.cn

for Nanshan District, and the land use has been changed from railway and roadway-reserved lands to commercial, institutional and residential lands. The commercial lands are concentrated in the area bounded by Houhai Avenue (后海大道) in the west, Haide 3rd Avenue (海德三道) in the north, Houhaibin Road (后海滨路) in the east, and Chuangye Road (创业路) in the south. West

of Houhai Avenue and south of Chuangye Road, the land use continues to be residential. According to the Comprehensive Plan, in the north of Haide 3rd Avenue, the land has been dedicated for high-end residential use. On the east side of Houhaibin Road, the ocean has been planned to be filled to expand developable lands eastwards and extend the Commercial and Cultural Centre on the East side of Houhaibin Road. This has also been planned to be used to create space for an athletic and recreational centre to host the 2011 Summer Universiade. On the south part of the land, the filled area has been dedicated to become another entry port for both people and logistics that will directly connect to Hong Kong. This would shorten the travel time from Shenzhen to Hong Kong International Airport compared to the other two original entry ports, Huanggang and Futian (皇岗口岸和福田口岸). As mentioned earlier, the plan for subway line 2 and the station locations were carefully studied and approved in 2004. Even in the 2002 District Comprehensive Plan, the subway line and Houhai Station were clearly indicated on the land use map and the transportation master plan of the district (see Figure 13), and the subway station was named Nanshan Commercial Centre instead of Houhai.

Current Land Use Condition:

Based on the field observation, we found that the actual land use condition generally complies with the land use plan. The Nanshan District Business and Cultural Centre has been developed according to the plan. The area on the west side of Houhaibin Road has been completely developed and the area on the east side of the road is currently under construction. As mentioned earlier, this

Figure 17 Major amenities and services offered at the Houhai Station study area.
Source: Compiled by author. Base map: Baidu Map.

Recreational Business District (RBD) serves the entire Nanshan District. The area includes several office towers and two large-scale shopping centres, the Baoli Cultral Square and Coastal City. The only difference between the current land use condition and the land use plan is that the landscape buffer has been increasing along Haide 3rd Avenue and Haide 1st Avenue to separate commercial

and residential land uses. Haide 3rd Avenue and Haide 1st Avenue are the north and south boundary of the Business and Cultural Centre, respectively, and for both the landscape buffer is about 50 metres wide which includes four rectangular artificial lakes on each side. The athletics and recreation centre has been completed and is currently serving citizens from across Nanshan District and the city. The new entry port that connects to Hong Kong has also been fully in service since 2015.

ii. Major Retail Locations and Amenities

As mentioned in the above section, there was no commercial land use within the study area before 2002. And based on the 'Nanshan District Comprehensive Plan 2002-2010', the area is designated as the RBD of the Nanshan District, which will become the Business and Cultural Centre of the district. According to field observations and research, major retail locations and amenities have been identified in the area to provide daily essentials for the residents that live in the study area and surrounding areas. Baoli Cultural Square is located in the core area of the Business and Cultural Centre right next to Houhai Subway Station; it is also the first commercial development of this area with a site area of 5.4 Ha and a total floor area of 15 Ha. This large-scale shopping centre is divided into four sections: Section A contains restaurants and bars; Section B is the movie theatre and recreational area; Section C contains department stores, supermarket and other retail stores; and Section D is the Baoli Theatre, the most well-known landmark in Nanshan District (see Figure 14). It is one of the first integrated shopping centres in Shenzhen that has used the concept of combining different functions such as theatres, entertainment and retail amenities, supermarkets, restaurants and bars. This development was approved by the city in 2004 and opened in 2008.

In 2004, the city also approved the development of the Coastal City commercial complex. This complex makes up the rest of the commercial land uses of the Business and Cultural Centre on the

East side of Houhaibin Road, which is currently the largest integrated commercial complex in the west region of Shenzhen, and is also the largest indoor shopping, recreational and entertainment

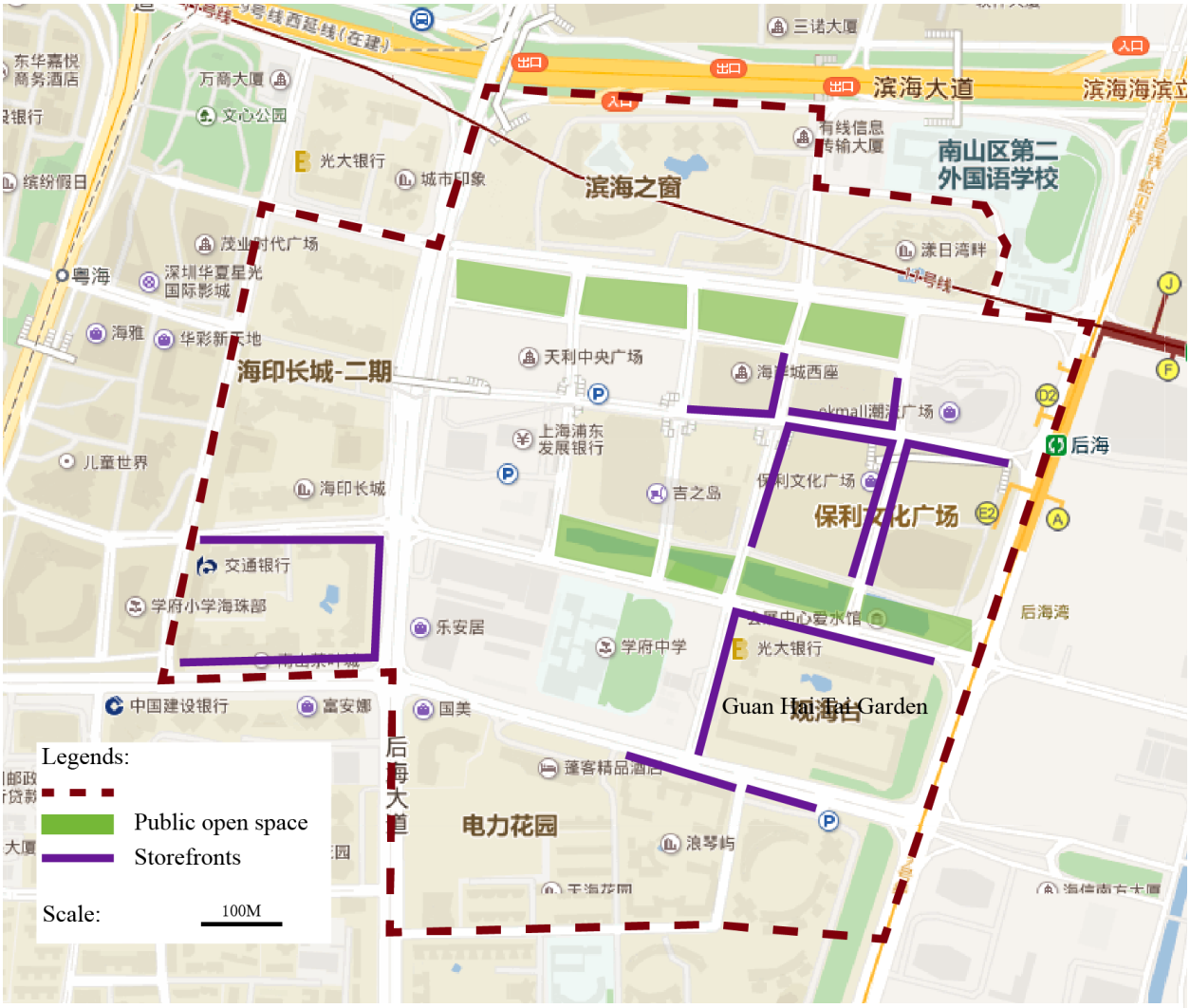

Figure 18 On-street storefronts condition and public open space at the Houhai Station study area. Source: Compiled by author. Base map: Baidu Map.

centre in the city. The complex is comprised of three major areas: the shopping centre, office towers and a pedestrian shopping street. Three significant elements of the commercial complex should be noted here. First, both the shopping centre and the pedestrian shopping street offer a variety of dining selections, as there is an international gourmet food street located within the complex which contains hundreds of restaurants that offer different types of cuisine from all over the world and has attracted many residents that live in nearby communities as well as visitors from

across the city. Second, one of the main aspects of the design of this development is to create two large open spaces on both the south side and north side of the complex along Haide 1st Avenue and Haide 3rd Avenue. The purpose of the open space is to provide space for performances and other public activities, the public is encouraged to use the space for walking, jogging and, most importantly, square dancing, which is a very popular outdoor fitness activity among middle aged and elderly females in China. The open space also includes eight artificial lakes, with four on each side of the complex to emphasize the main theme of the Coastal City. Third, to provide a pedestrian-friendly outdoor shopping environment, the design has adopted the concept of separating pedestrian movements and vehicular movements vertically, with the outdoor pedestrian street located on the second level and the roadway located on the ground level. The pedestrian shopping street is approximately 800 m in length, and 710 m has been used in this design, which not only provides a safe walking environment but also saves a lot of usable space.

iii. Overall Walking Experience

Compared to the Grand Theatre Station TOD area, the sidewalks within the Houhai Station TOD area are in a much better condition. The road and the sidewalks are much wider and cleaner, with trees and greeneries planted along the sidewalks and eight 50 m-wide artificial lakes located along Haide 1st and 3rd Avenue. The walking experience at the two locations is very different as well. When walking within the Houhai Station TOD area, it does not offer similar qualities and experiences to the Grand Theatre Station TOD area. In areas that are closer to the shopping centres, the sidewalks are much wider, and there is a wide public space between the shopping centres and the sidewalks (see Figure 15), which makes the pedestrians feel like walking closer to the roadway than to the store fronts, where most pedestrian activities and interactions are happening. The wide landscape creates a buffer zone between the commercial area and road, which also creates a barrier

that isolates the retail stores and amenity spaces from the residential area by increasing the walking distance. Even though the sidewalks and public spaces are well designed in terms of landscapes and pavements, pedestrians still get the sense that the space is out of human scale. In the residential areas, there are also stores and restaurants located at the street level, but they do not offer enough variety compared to Grand Theatre Station TOD area.

5.2.2 Questionnaire

The purpose of the questionnaire is to understand the impact of TOD on residents' travel behavior within the study areas. As mentioned earlier, the questionnaire can be broken down into three categories: 1. To understand the basic information of the participants including how long they have been living in the area and why did they move into the area if they have been living in the area for less than 10 years; 2. To identify the travel methods the participants are currently using for going to work and other daily activities such as shopping, dining and entertainment. To identify the shifts in travel methods due to the development of subways by identifying the travel methods used by participants before having access to a subway. And to understand why participants would not choose the subway as their primary travel method; 3. To identify whether the services and amenities provided within the study areas are able to fulfill the daily needs of the participants. To identify whether the key commercial developments that were developed as part of the TOD have accomplished its significant role as the main services and amenities provider for the residents within the study areas and if it is unsuccessful to understand why from the participants' perspectives. This and the following sections have answers to research question 1 and 2, to find out how has residents' travel behavior changed since having access to the subway within the two study areas and whether if there are any differences between the two areas. The differences have been further discussed in Discussion section.

The data collection was performed from 5 pm to 9 pm on each day from June 10, 2016 to June 16, 2016. The participants were randomly selected pedestrians within the residential communities that were previously selected (see Methodology Chapter). For those communities that were not allowed to enter without permission and, participants were approached while they were entering or coming out from the main gate of the selected communities. As a result, 407 samples were collected in total for both study areas, of which, 205 samples were collected at the Grand Theatre Station study area and 202 samples were collected at the Houhai Station study area. As mentioned earlier, one of the key goals is to understand the travel methods used for work, which is why we have purposely excluded children, students and elderly individuals that are unlikely to be working currently during the sample selection process for a more accurate comparison between the travel methods used before and after having access to the subway. The average age of the participants at the Grand Theatre Station study area is 31 years old, and the median is 30 years old with 18 years old being the youngest and 52 as the oldest participants. The average age of the participants at the Houhai Station study area is 34 years old, and the median is also 34 years old, with 21 years old being the youngest and 60 as the oldest participants. As we can see, for both cases, the average age and the median age of the participants are very close, which means the samples are evenly distributed around the average age.

5.2.2.1 Basic Information

Question 1 of the questionnaire tries to identify the years of residency of the participants within the study areas, and we found that most of the participants from both study areas are relatively new to the area, arriving there less than five years ago (See Figure 16). At the Grand Theatre Station TOD area, out of 205 participants, 105 of them were residents in the area for less than 5 years. And at the Houhai Station TOD area, 88 out of the 202 participants have lived in the area for less

than 5 years. 54 participants from the Grand Theatre Station TOD area and 71 participants from the Houhai Station TOD area have lived in the corresponding areas for about 5 to 10 years. And 31 participants from the Grand Theatre Station TOD area and 40 participants from the Houhai Station TOD area have lived in the corresponding areas for about 10 to 15 years. 15 participants and 3 participants from the Grand Theatre Station study area and Houhai Station study area, respectively, have lived in the corresponding areas for more than 15 years. Even though the Grand Theatre Station study area was developed a lot earlier than the Houhai Station study area, based on the results of the questionnaire, the length of residency of the participants from both study areas is very similar. As described in the previous section, a considerable portion of the land in the Grand Theatre Station study area is occupied by a land use type called rural residential reserved land (a.k.a. urban villages). In Shenzhen, most of the residential buildings within urban villages were built in the late 1980s and early 1990s during the initial stages of the city's development. The buildings were built by the villagers themselves and do not meet the proper standards for residential buildings, and the living conditions are very poor and not properly maintained. But because of the prime location of these "illegal" apartment buildings and relatively cheaper rents, they have become the best housing options for labourers and service workers who cannot pay for regular apartments and work within the area or nearby areas. Another portion of the land is occupied by residential communities that were developed by the government during the initial stage of the city's development. This type of residential building was built properly, following government standards and requirements. But the buildings have been getting older and without proper maintenance, the living condition and the size of the units no longer satisfy many of the original residents. They will then move to newer and larger apartment units, and rent out their old apartments. People living in rental housing are likely to move very often, which is why more than

half of the participants at the Grand Theatre Station study area have only resided here for less than five years. Most of the residential communities at the Houhai Station study area were developed within the past 10 years, which is why most of the participants from this area have lived here for less than 5 years or 5 to 10 years.

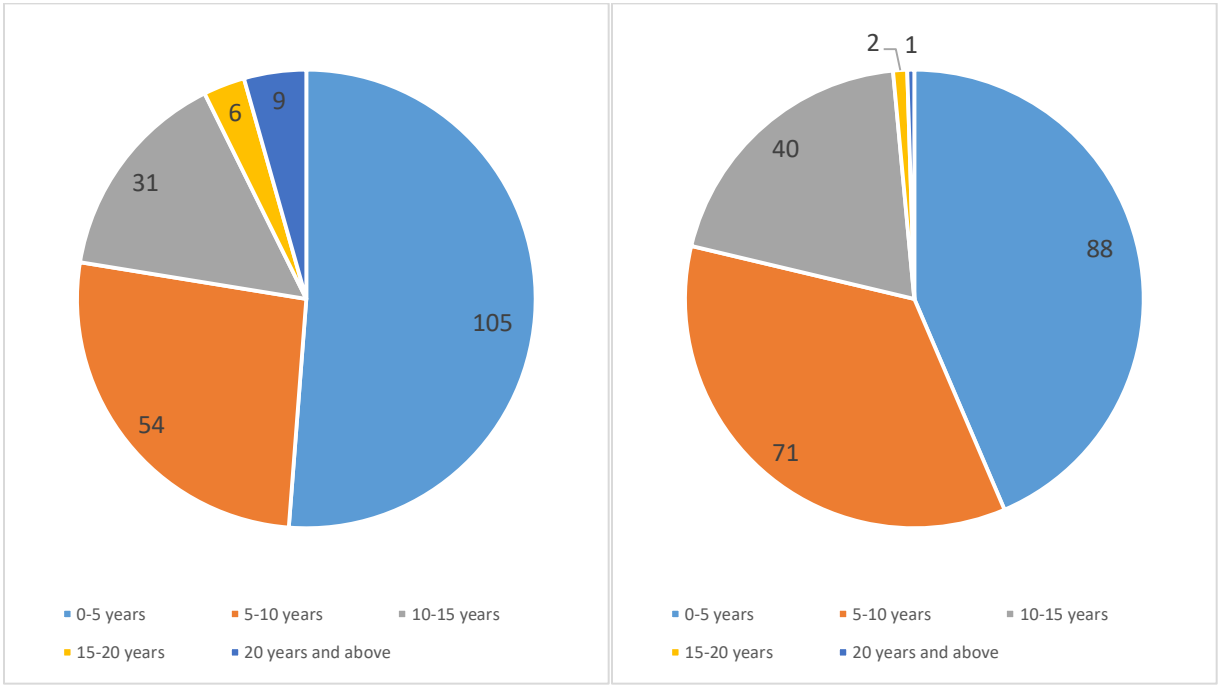

Figure 19 Breakdown of participants by years of residency within the study areas. Grand Theatre Station Study Area (Left) and Houhai Station Study Area (Right).

The second question of the questionnaire tends to identify the major reasons for participants to move into the study areas within the past 10 years. As we can see in Figure 17, being close to work, having good services and amenities and being close to a subway station are the three deciding factors for participants to move into communities within the Grand Theatre Station study area. In the Houhai Station study area, being close to work is the major reason selected by most participants, followed by having good services and amenities in the area. Even though being close to a subway station is also heavily weighted, it is definitely not valued as highly as the other two factors. An interesting finding which should be noted here is that even though much of the Grand Theatre Station study area has been occupied by "illegal" urban villages and old residential apartments, a

considerable number of participants at the Grand Theatre Station study area still decided to move here because of the safe and comfortable living environment. But at the Houhai Station study area, the safe and comfortable living environment is the reason least selected by the participants. This will be further discussed in the next chapter.

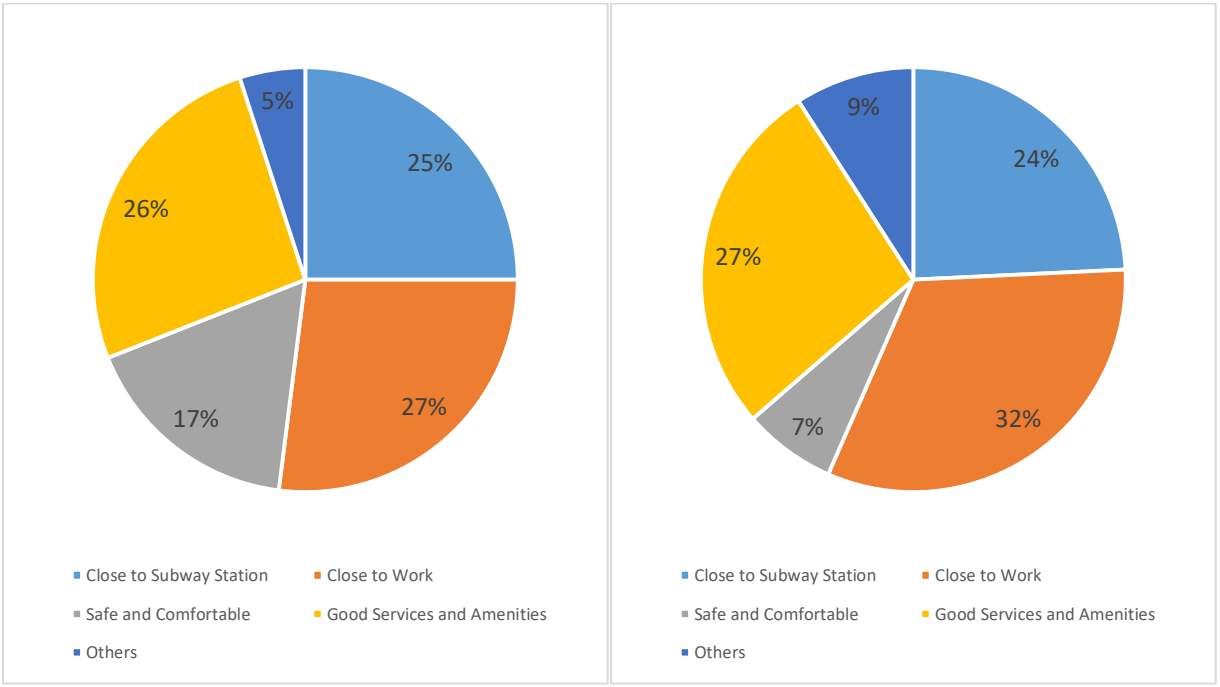

Figure 20 Reasons for participants to move here by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

5.2.2.2 Shifts in Travel Methods

According to the findings (see Figure 18), at the Grand Theatre Station study area, 14.1% of the participants currently drive to work, 46.3% of the participants take the subway, and 17.1% of the participants walk to work. At the Houhai Station study area, 28.8% of the participants currently drive to work, 35.1% of the participants take the subway and 7.4% of the participants walk to work. As we can see, the percentage of residents choosing to drive to work is significantly higher at the Houhai Station study area, and the Grand Theater Station study area has a significantly higher percentage of participants taking the subway and walking to work.

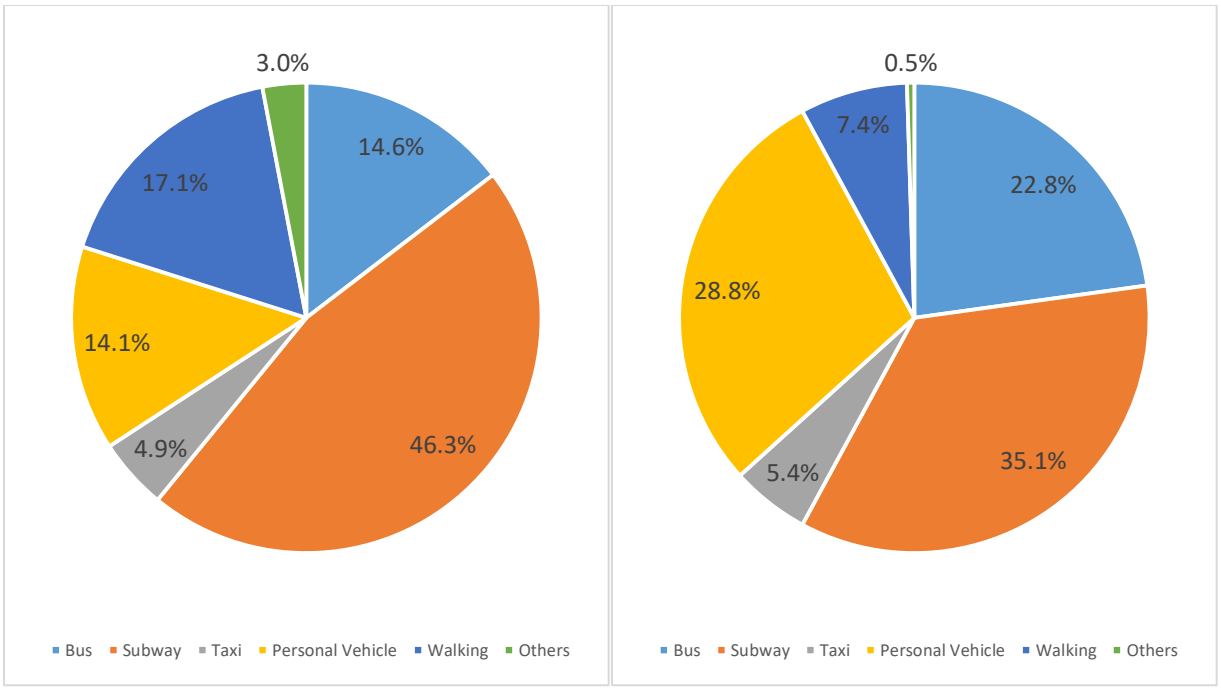

Figure 21 Travel methods used to go to work by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

To understand the shifts in travel methods since the opening of the subway service, we have also asked the participants to provide the primary methods they used to travel to work before having access to a subway. The results show that the majority of the participants from both study areas used to take the bus to go to work prior to having access to the subway (see Figure 19). Different from after having access to the subway, the participants at the Houhai Station study area actually show a higher percentage of using the public transit than participants at the Grand Theatre Station study area, with 56.9% of the participants at the Houhai Station study area compared to 42.4% of the participants at Grand Theatre Station study area taking the bus. But participants at the Houhai Station study area still show a higher percentage of using personal vehicles and a lower percentage of participants choosing to walk to work compared to participants at the Grand Theatre Station study area.

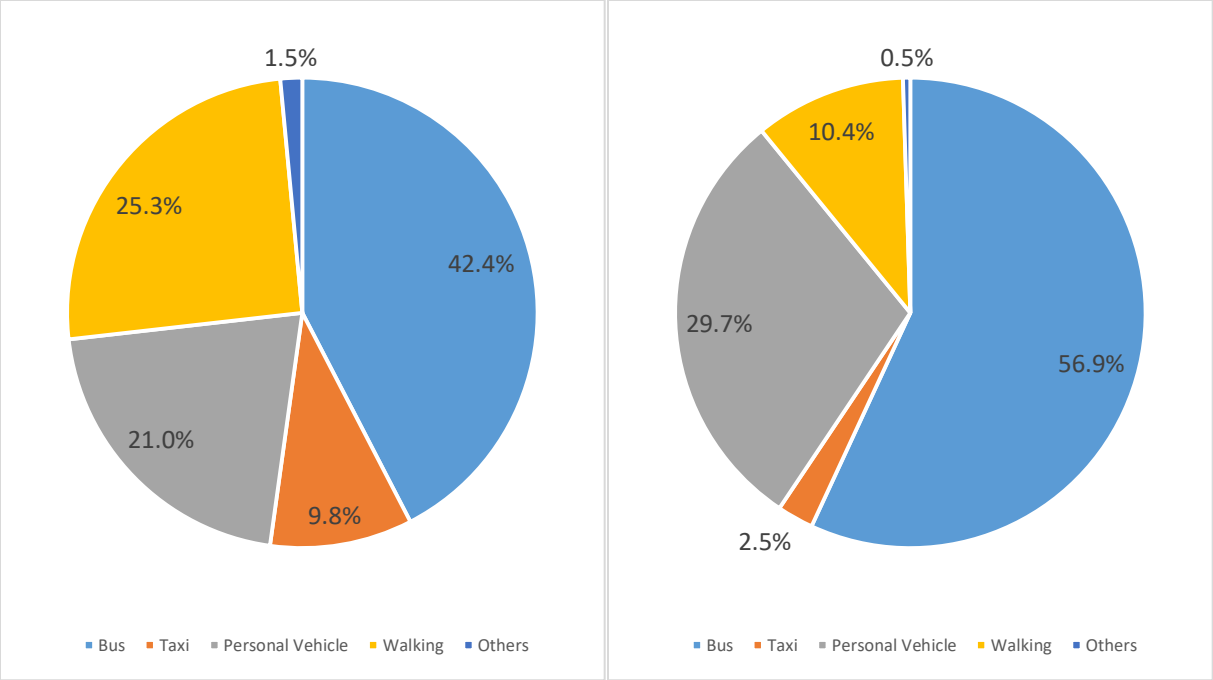

Figure 22 Travel methods for going to work prior to access to a subway by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

As discussed earlier in the literature review, it has been agreed by most scholars that one of the benefits of TOD is to change people's travel methods, which could reduce automobile usage, and increase the ridership of subways or other types of sustainable travel modes. To further study the shifts in travel methods, we have compared the travel methods of each participant before and after having access to a subway. As a result, we found that there are more participants at the Grand Theatre Station study area who converted to taking subway to go to work compared to the Houhai Station study area since the opening of subway services (see Figure 20). Unsurprisingly, in both cases the majority of the subway riders used to be public transit riders as well, as about 25% of the participants used to take the bus to work and are currently taking the subway. Both areas have participants converted to driving or continued to drive after having access to the subway, and the number of participants that drive is much higher at the Houhai Station study area compared the to Grand Theatre Station study area. There are also a lot more participants who started to walk or

continued to walk to work at the Grand Theatre Station study area compared to the Houhai Station study area.

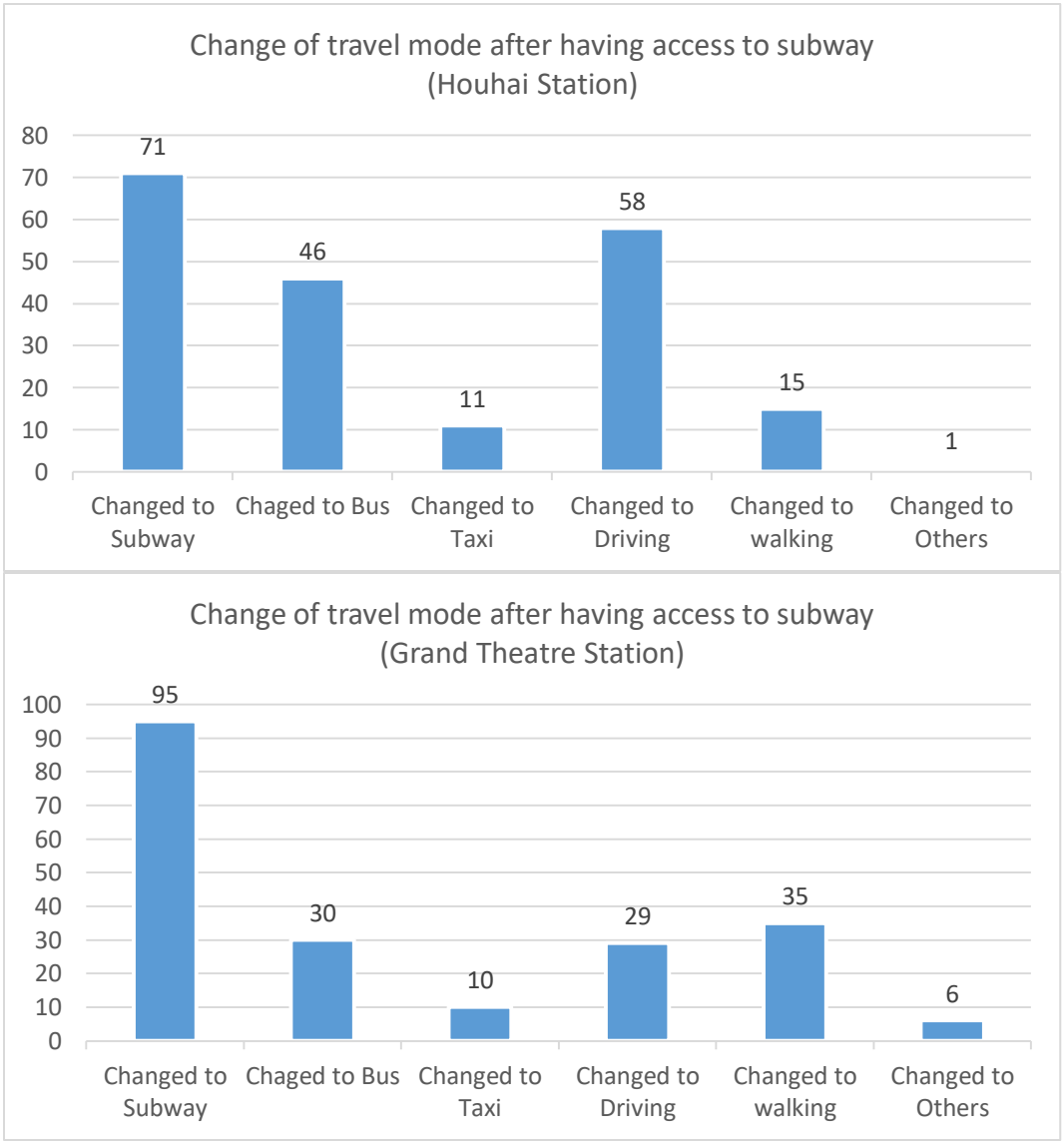

Figure 23 Change of travel methods after having access to a subway. Grand Theatre Station study area (top), Houhai Station study area (bottom).

Question 5 of the questionnaire is intended to identify the major reasons of participants for not taking the subway to work. According to Figure 21, we can see that both study areas share the same top two reasons which are most selected by the participants. The subway being too crowded as the main reason for not taking the subway has been selected by 30% of participants at the Grand Theatre Station study area and 25% of participants at the Houhai Station study area. About 20%

of the participants from both study areas would not take the subway to work because the walking distance to the station is too far. 17% of the participants from the Grand Theatre Station study area and 13% of the participants from the Houhai Station study area have to transfer too many times between the subway lines and buses. 14% of the participants from the Grand Theatre Station study area and 18% of the participants from the Houhai Station study area would not take the subway because there are not enough seats provided on the subway. Based on the results, except for the walking distance to the station being too far, the other top reasons that are mostly selected by the participants are related to subway services, such as the subway being too crowded, not enough seats being provided, and having to transfer many times between different transit lines or types of transit. There are several participants from both study areas that selected "Others", and indicated that they do not have a particular reason and just do not feel the need to take the subway because they can drive. But as we can see, most of the participants have provided an explanation as to why they do not take the subway, which means that even though they are currently not taking the subway, they do have expectations of the subway services, and there are residents who would be willing to take the subway if their concerns were properly addressed. Improvements regarding the quality of subway services will be further discussed in the next chapter.

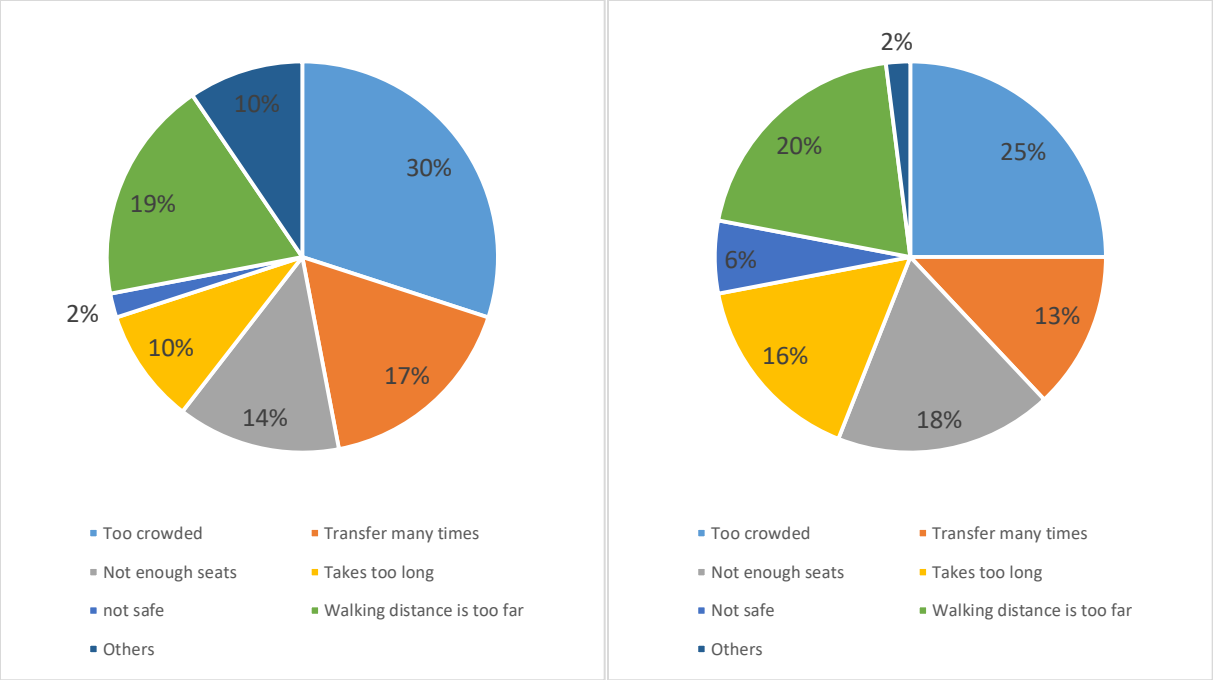

Figure 24 Break down of reasons for not taking subway to work by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

5.2.2.3 Services and Amenities

The travel methods used by the participants at the two study areas for non-work-related activities such as shopping, dining, and other types of entertainment show a much more significant difference than for work (see Figure 22). 16.1% of the participants at the Grand Theater Station study area choose to drive for non-work related activities, which is a little bit higher but still consistent with the result we have for traveling to work. But the Houhai Station study area shows a significantly higher result, as 45.5% of the participants choose to drive for non-work-related activities. 11.0% of the participants choose to walk, which is significantly lower compared to 33.7% at the Grand Theatre Station study area. And 15.8% of the participants choose to take the subway, which is also much lower compared to 30.2% at the Grand Theatre Station study area.

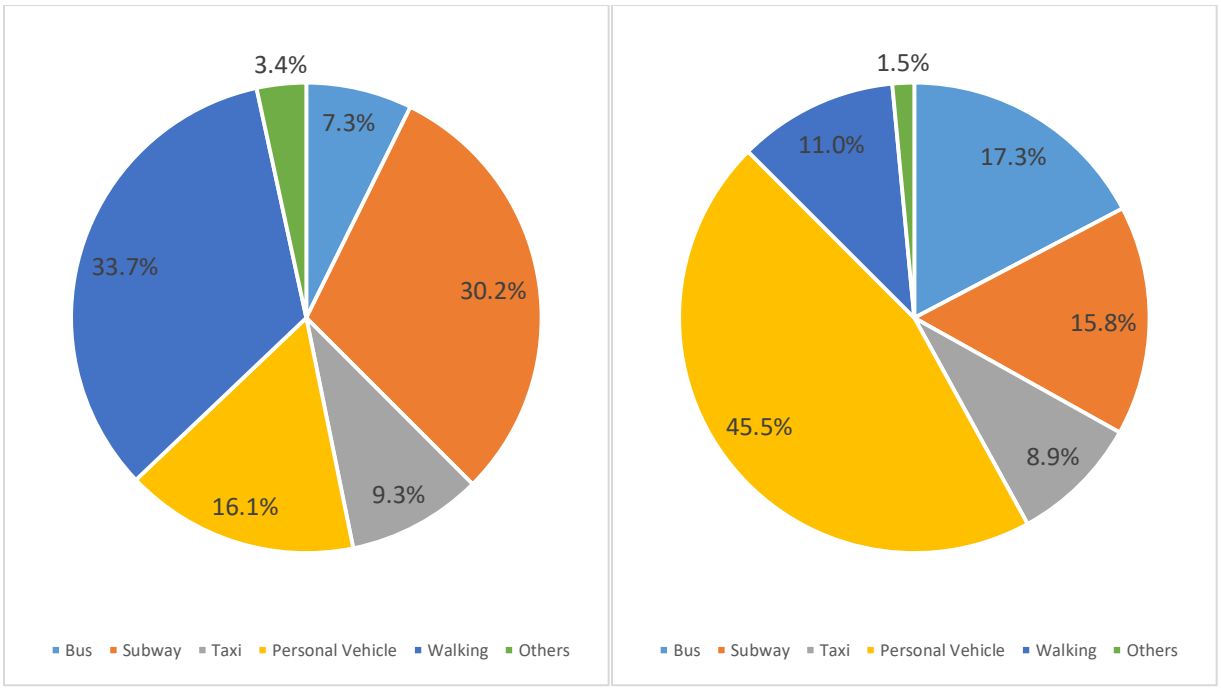

Figure 25 Travel methods for non-work activities by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

It is important for a successful TOD to provide enough services and amenities to sustain the daily needs of the residents within the area. According to the results from question 7 of the questionnaire, most of the participants in both study areas think the area they are living in provides enough services and amenities for their daily needs, with 81% from the Grand Theatre Station study area, and 94% from the Houhai Station study area (see Figure 23). But the results of whether participants would go to the two recently developed large-scale shopping centres is significantly different between the two study areas (see Figure 24). Only half of the participants at the Grand Theatre Station study area would go to the two shopping centres within the area on a regular basis for dining, shopping and entertainment purposes. In comparison, 88% of the participants at the Houhai Station study area would go to the two shopping centres within the area on a regular basis. According to the results of question 9, the majority of the participants from both areas think the services and merchandise provided at the shopping centres are too

expensive (see Figure 25). 26% of the participants from the Grand Theatre Station study area selected “others”, which is the second most selected option in this area. Many of them have further explained that despite the shopping centres being too expensive, it is actually not necessary to go there because the services and amenities provided outside of the shopping centres are enough to provide for their daily needs.

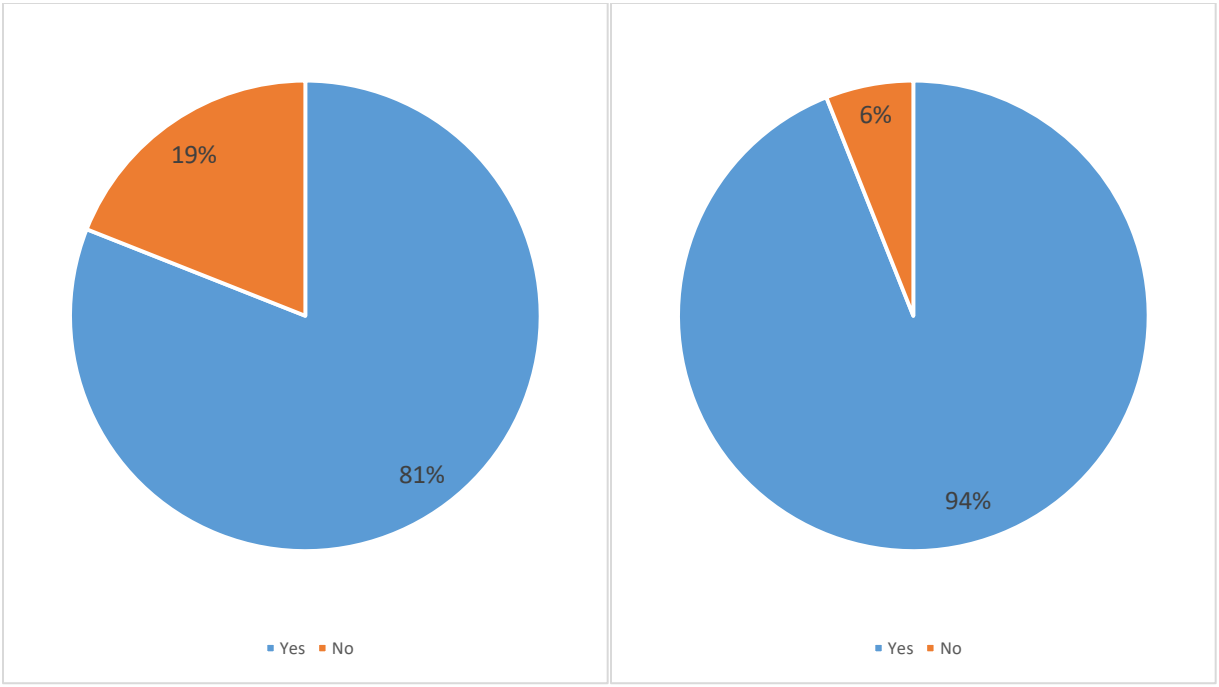

Figure 26 Satisfaction with services and amenities provided by the commercial and retail facilities within the study areas. Grand Theatre Station study area (left), Houhai Station study area (right).

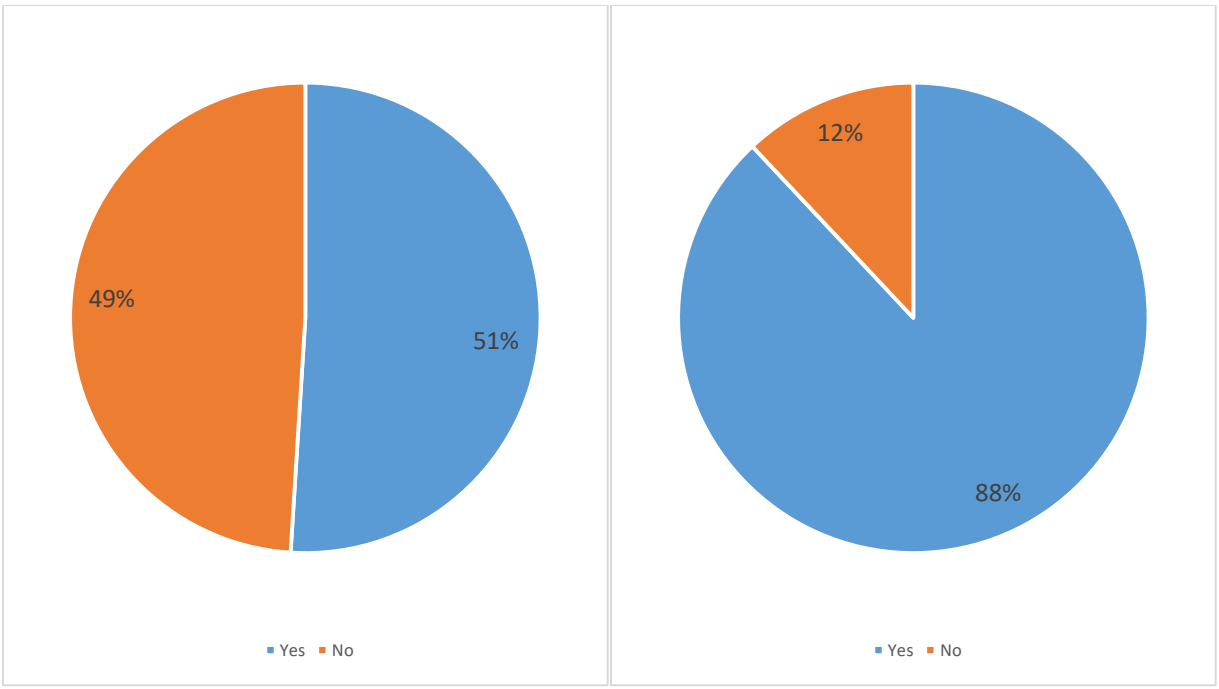

Figure 27 Whether participants would go to the recently developed shopping centres by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

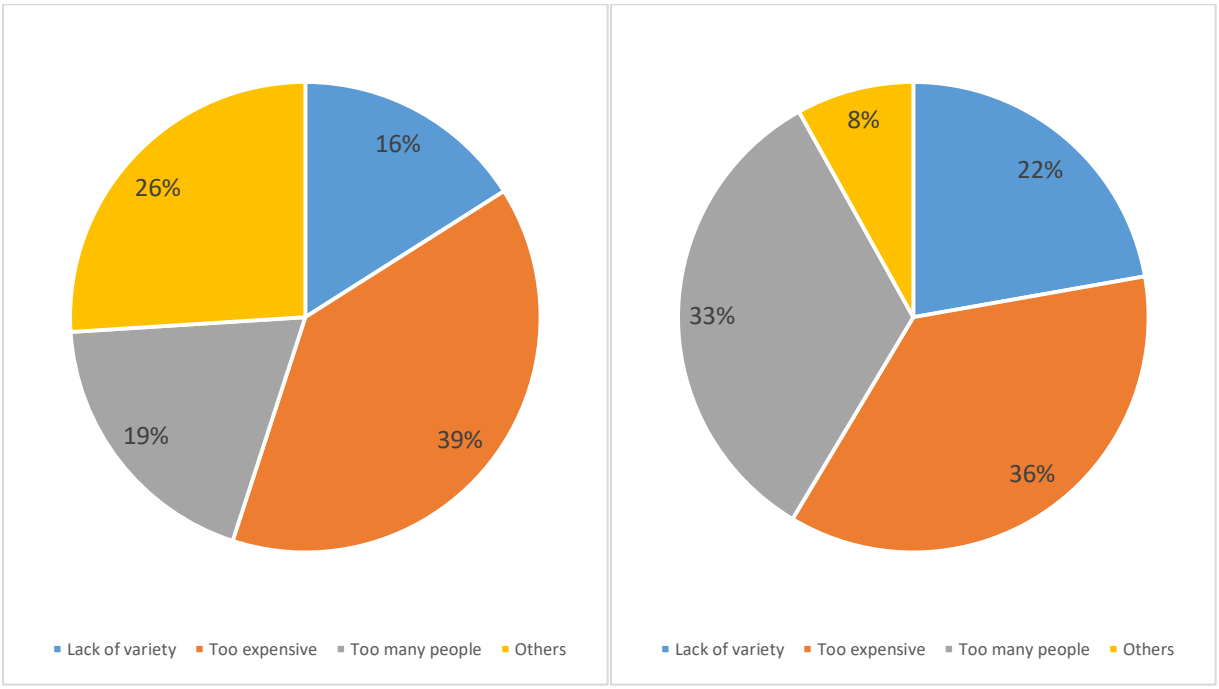

Figure 28 Reasons for not going to the recently developed shopping centres by percentage. Grand Theatre Station study area (left), Houhai Station study area (right).

5.3 Analysis of the Primary Data Using Chi Square Test and Cramer's V Test

We have analyzed and compared the answers from each question of the questionnaire by using Chi Square Test and Cramer's V Test to determine the association and the strength of the association between different questions. The following table illustrates all the variables that are proven to be related to each other by the Chi Square Test. As mentioned earlier, the Chi Square Test tests the association between two variables and whether they are related or independent, and the Cramer's V Test identifies the strength of the association between the two related variables. However, the result does not tell us whether the association is negative or positive, and we will need to investigate further to understand the relation. Out of all the results, there are several related variables showing a relatively strong association and these should be further analyzed.

5.3.1 Age and Travel Methods:

According to the table below, age is associated with the travel methods used by the participants to get to both work and non-work-related activities at both study areas. With further analysis comparing the different travel methods used against the age of the participants, we found that most of the younger participants tends t take public transit, including the subway and bus, and as the age of the participants increase, there are more participants that drive instead of taking public transit. If we take a further look at the travel methods used to go to work against the age of the participants, we find that at the Houhai Station study area, out of the 65 participants that are below age 30, 23 of them take the bus to work, 30 of them take the subway and only 4 drive to work. Out of the 71 participants from age 30 to 39, 19 of them take the bus to work, 28 of them take the subway, and 22 participants drive to work. For the participants age 40 and above, out of the 56 participants only 4 take the bus and 13 of them take the subway, but there are 32 participants that

drive. Based on this set of data, we can clearly see a progressive decrease in the number of participants that take the bus and subway to work and an increase in the number of participants that drive to work as the age increases. The result is very similar to that of the Grand Theatre Station study area as well.

5.3.2 Neighbourhoods and Travel Methods:

The results of the Chi Square Test also show that the travel methods used by the participants to go to work and non-work-related activities are both related to the location of the neighbourhoods the participants are currently living in. According to further analysis, we found that the travel methods used by the participants are related to housing types. At the Grand Theatre Station study area, we took a closer look at participants' responses to the questionnaire from each neighbourhood individually. It was found that older neighbourhoods that are currently comprised of mostly rental housing have a higher rate of participants taking public transit or walking compared to recently developed high-end residential neighbourhoods. According to the responses of the questionnaire, 70% of participants from the Guangchangbeijie (广场北街) residential neighbourhood take public transit to work, the rest of the participants walk or bike to work and none of them drive. This is compared with the Xinfuli (幸福里) residential neighbourhood, in which 54% of the participants take public transit, and more than 30% of the participants drive to work. We found that the travel methods used by participants are different between neighbourhoods of different types of rental housing as well by comparing the Guangchangbeijie residential neighbourhood and the Caiwuwei New 8th and 9th Lane (蔡屋围新八九坊) residential neighbourhood. Both of the neighbourhoods are currently mostly comprised of rental housing, and the difference is that the Guangchangbeijie residential neighbourhood was developed in 1998 and built in accordance with government design guidelines and standards, while the Caiwuwei New 8th and 9th Lane residential neighbourhood is

an urban village developed in the 1980s and was rebuilt and renovated in 1998. The buildings in the urban village are considered "illegal" as none of the buildings comply with the design guidelines and standards as mentioned earlier. Therefore, even though the Guangchangbeijie residential neighbourhood was built in the same year as the Caiwuwei New 8th and 9th Lane residential neighbourhood, Guangchangbeijie provides a much better living environment than the Caiwuwei New 8th and 9th Lane residential neighbourhood, and the rent of the units are a lot cheaper at the Caiwuwei New 8th and 9th Lane residential neighbourhood. Cheaper rent would attract a lot of younger workers that work in nearby restaurants, retail stores and shopping centres, who can walk to work instead of spending extra money on transit. According to the responses, more than 50% of the participants from the Caiwuwei New 8th and 9th Lane residential neighbourhood walk to work, and more than 40% of participants take public transit, which is a lot lower than the 70% at the Guangchangbeijie residential neighbourhood.

With further analysis, we also found that at the Grand Theatre Station study area, as the location of the neighbourhoods becomes further away from the subway station, there are fewer participants taking the subway, as instead participants take the bus or drive. This trend is very similar at the Houhai Station study area as well; the only difference between the two study areas is that Houhai has more participants who choose to drive and it is not influenced by the distance between the neighbourhoods they live in and the subway station. The Kingkey 100 residential neighbourhood is the residential portion of the Kingkey Financial Centre mixed-use development which was developed in 2007 along with the Kk Mall and Kingkey 100 office tower. As mentioned earlier, the Kingkey Financial Centre is directly connected to the Grand Theatre Station subway station with less than a 5-minute walk between them. The residential portion of the Kingkey Financial Centre is considered a high-end residential neighbourhood, but based on the responses to the

questionnaire, 67.5% of the participants from this neighbourhood would take the public transit to work, which is the second highest among all the other neighbourhoods within the area. In conclusion, both housing types and the location of the neighbourhood are the major contributing factors to subway ridership.

Table 5 Selected Results of the Chi-Square Test and Cramer's V Test

The relationship between	Study Areas	Chi Square χ^2	P Value	Cramer's V
Current work travel methods and age groups	Grand Theatre Station	$\chi^2 = 34.5$	P<0.0001	*V*=0.29
	Houhai Station	$\chi^2 = 45.4$	P<0.0000001	*V*=0.34
Current work travel methods and the location of the neighbourhoods	Grand Theatre Station	$\chi^2 = 37.3$	P<0.00001	*V*=0.30
	Houhai Station	$\chi^2 = 72.8$	P<0.0000001	*V*=0.35
Current work travel methods and number of years living in the neighbourhood	Grand Theatre Station	$\chi^2 = 34.5$	P<0.05	*V*=0.22
	Houhai Station	$\chi^2 = 40.1$	P<0.0000001	*V*=0.32
Current work travel methods and reasons for moving to the neighbourhood	Grand Theatre Station	$\chi^2 = 151.2$	P<0.0000001	*V*=0.47
	Houhai Station	$\chi^2 = 67.0$	P<0.0000001	*V*=0.31
Current work travel methods and work travel methods used before having access to a subway	Grand Theatre Station	$\chi^2 = 74.1$	P<0.0000001	*V*=0.46
	Houhai Station	$\chi^2 = 120.7$	P<0.0000001	*V*=0.57
Current work travel methods and non-working travel methods	Grand Theatre Station	$\chi^2 = 80.3$	P<0.0000001	*V*=0.40
	Houhai Station	$\chi^2 = 93.1$	P<0.0000001	*V*=0.43
Willingness to shop at the recently developed shopping centres and the location of the neighbourhoods	Grand Theatre Station	$\chi^2 = 0.27$	P>0.05	*independent*
	Houhai Station	$\chi^2 = 6.2$	P<0.05	*V*=0.18
Non-working travel methods and number of years living in the neighbourhood	Grand Theatre Station	$\chi^2 = 15.4$	P>0.05	*independent*
	Houhai Station	$\chi^2 = 23.4$	P<0.005	*V*=0.24
Reasons for moving to the neighbourhood and the location of the neighbourhoods	Grand Theatre Station	$\chi^2 = 9.04$	P>0.05	*independent*
	Houhai Station	$\chi^2 = 14.1$	P<0.05	*V*=0.17
Reasons for moving to the neighbourhood and age groups	Grand Theatre Station	$\chi^2 = 17.0$	P<0.01	*V*=0.19
	Houhai Station	$\chi^2 = 25.1$	P<0.001	*V*=0.23
Non-working travel methods and age groups	Grand Theatre Station	$\chi^2 = 23.6$	P<0.005	*V*=0.24
	Houhai Station	$\chi^2 = 38.7$	P<0.0000001	*V*=0.31
Non-working travel methods and the location of the neighbourhoods	Grand Theatre Station	$\chi^2 = 16.5$	P<0.05	*V*=0.20
	Houhai Station	$\chi^2 = 39.5$	P<0.0001	*V*=0.26

6 Discussion

In this chapter, the research will continue to explore the differences between the two study areas and understand the rationale based on knowledge and understating of the local urban context and traveling habits. This chapter will also summarize and recommend a series of qualities that a TOD should aim to achieve based on the descriptive analysis of the two selected study areas.

6.1 Shifts in Travel Modes

It is understandable to assume that the station area and its surrounding land use are designed and built based on the idea that a conventional TOD design (Houhai Station) will have a greater impact on residents' travel behaviors than adopting and integrating the new TOD concept in a fully built-up urban environment (Grand Theatre Station). However, the results show the opposite; in fact, the TOD implemented at Grand Theatre Station is more successful in terms of its ability to influence the travel methods used by the residents within the TOD when compared to the TOD at Houhai Station. The Grand Theatre Station study area shows a higher rate of residents taking the subway and walking, and the Houhai Station study area shows a much higher percentage of participants using personal vehicles to go to work as well as for going out for non-work-related purposes such as shopping, dining, and other recreational activities. After comparing different aspects of the two station areas, it was found that two significant different characteristics between the two TODs could be the main cause of the result.

The first set of significant differences between the two TODs are the demographics and housing types. At Houhai Station, almost all the communities are gated and are comprised of residents that have a relatively higher income compared with many other parts of the city. Most of these residential communities are considered as higher end or luxurious commodity housings, with

security services, full amenities and other services. The residents living in this area are mostly homeowners and rentals are extremely uncommon due to the exceptionally high rental prices that many young professionals are unable to afford. The average age of residents living in this area is also higher, as their income would be higher and more stable compared to young professionals. The Grand Theatre Station on the other hand has very different demographic characteristics. Compared to the Houhai Station, the Grand Theatre Station has much more variety in terms of housing types. Because it is the old financial centre of the city, many of the residential communities were built by the government in the 1980s and early 1990s. Many of the original residents have already moved out of these buildings because the size, the amenities, and condition of the housing units can no longer satisfy their needs, and they often move to places such as Houhai and suburban areas for newer and larger housing units in residential communities with better security, services and amenities. Their old apartment after a quick renovation can be easily rented out to young professionals that work in the area or work close to a subway station. The government has recently carried out an incentive program to support rental companies to rent out the old apartment buildings and provide free renovations to turn them into rental units. Other than the government-built residential communities, the Grand Theatre Station is surrounded by urban villages. Urban villages consist of apartment buildings built illegally on rural lands and are owned by the villagers individually. Although the living conditions in these urban villages are very poor, they are still one of the most popular forms of rental housing for lower wage labourers that work in the malls, shops and restaurants within the area because of their low price. As discussed earlier, the age composition of the residents in two study areas are also different, which residents at Houhai Station study area tend to be older and residents living in Grand Theatre Station study area are mostly young professionals. According to our findings, age and travel methods in both study areas found to be

related as older residents would prefer to drive and younger residents would mostly take the public transit or walk. This could be one of the main reasons for the difference in travel methods used between the two study areas.

The second set of differences between the two stations are the characteristics of the built environment of the station area. The design of the Houhai Station area shows the station as the centre point of the development area, with commercial land use and residential land use expanding out 500 metres. The commercial land uses including offices, retail locations and other commercial services stay within the centre or middle part within the 500 m range, and the rest of the space will be occupied by residential communities. In the case of Houhai Station, the central space for commercial land uses is a long rectangular strip that extends out approximately 500 metres from the subway station. The area is bounded by Houhai Bin Road in the east, Haide Third Road in the North, Houhai Avenue in the West and Haide First Road on the South. It consists of several office towers, two large-scale shopping centres and a performance centre (theatre). The residential communities are located around the commercial land on the north, south and west. As mentioned in the previous chapter, the location of the station and the station's surrounding area were planned and designed in 2002 and the station was expected to be completed in 2005. However, the construction of Houhai Station was not finished until 2010 due to the minimal effort and support from the local authorities, and most of the surrounding commercial and residential developments were finished before the construction of the station had even started. Because of the delay in completing the subway station, there was no direct connection between the commercial spaces or residential communities and the station. Subway riders have to walk outdoors to exit or enter the station, and this is often not desirable during summer and typhoon seasons. In comparison, the Grand Theatre Station and its surrounding areas have a very distinct physical character. As

mentioned in the previous chapter, the station was placed in the old city centre, where the communities, offices and amenities were fully developed. Even though the Grand Theatre Station was built within a previously developed urban space, it demonstrates a much better integration between the station and adjacent land uses compared to Houhai Station.

The Grand Theatre Station and its surrounding mixed-use developments are connected at the underground level. It takes about 2 minutes to walk to KK Mall and a nearby mixed-use building Diwang Skyscraper, which was completed in the late 1990s. It takes less than 5 minutes to walk to MIXC Mall through the underground connection. With another 5 minutes of walking through the mall and exiting from the south entrance, Xingfuli community and other residential communities can be reached nearby. The underground pedestrian pathway provides retail spaces that are currently occupied by convenience stores, small vendors and restaurants. The underground pathway has not only shortened the travel distance for transit riders, but also provides a variety of services for the convenience of transit riders. The businesses will also be improved by the increasing number of transit riders using the underground connection and passing through the mall. The benefits are mutual between the two parties. With the underground connection, research shows that even residents that live further (at a 600 to 700-m range from the station) would take the subway as their preferred travel method. The best example would be Xingfuli Community; its straight-line distance from the station is about 600 m, but according to Baidu Map the walking distance on at-grade streets would be close to 1 km, which would take around 15 minutes to walk. With the underground pathways and by walking through the mall, the travel time from the station to Xingfuli Community has been shortened to less than 10 minutes.

The pedestrian underground connections between Grand Theatre Station and the malls provide a great walking experience for the transit riders through the well-designed interior spaces. The

commercial units within the pathway are owned by the government subway management company. To create a smoother visual and commercial transition between the subway station and the malls, the subway management company has allowed the malls to extend their underground entrances and to connect with the retail spaces within the station. With clearly indicated signage pointing out directions, transit riders often do not notice that they have already exited the station and entered the mall.

At grade level, Houhai Station area provides newer and cleaner streetscapes with wider roads and sidewalks, a lot of opens spaces and green spaces, and the height of the architectures are generally lower compared to Grand Theatre Station area. Compared to the Houhai study area, the Grand Theatre study area has narrower streets, fewer green spaces and open spaces, and a mixture of tall office towers, recently developed tall residential apartment buildings, mid-rise apartment buildings

Figure 30 Local retail stores along streets at the Grand Theatre Station study area. Source: Photo by author.

and urban villages that were built in the late 1980s and early 1990s. But most differently, the Grand Theatre Station area consists of many retail spaces at grade level that open directly towards the street (please see Figures 11 and 15). These retail stores can completely support residents living in the surrounding areas and visitors with their daily needs, including restaurants, convenience stores, grocery stores, hardware stores, barber shops and many more. The services and amenities provided at these retail stores have facilitated a lot of on street activities, which creates natural public surveillance on the street and protects the safety of transit riders and local residents. This is why our findings show that 17% of the participants at the Grand Theatre Station area considered a safe and comfortable walking environment as their main reason for living in this area, and only 7% of the participants at Houhai Station area feel the same about their area.

Figure 33 An example of a new mixed-use development Kingkey Financial Centre (right) and old urban area (left) at Grand Theatre Station. Source: Photo by author.

6.2 Differences between travel modes for commute and non-commute trips

According to the research, TOD has a much stronger influence on residents' travel modes for commute than non-commute trips. As mentioned earlier in the research findings, 45.5% of participants drive to go to non-work-related activities compared to 28.8% of participants who drive to work, and the percentage of participants taking the subway to work is 35.1% and to non-work activities 15.8% at the Houhai Station area. The differences between travel modes for commute and non-commute trips at the Grand Theatre Station area are not as significant, but there is a significant increase in the percentage of participants who choose to walk, which increased from 17.1% for commute trips to 33.7% for non-commute trips. One of the reasons for the increase in participants choosing to drive to non-work-related activities is that driving is more convenient than taking the subway when going out for shopping as cars can carry a lot more items. Parking discounts are also another major factor that encourages people to drive for non-work-related activities. For example, in most of the restaurants or shopping malls, if your purchase has reached a certain amount, a free parking ticket or discounted parking will be provided by the store. Therefore, sometimes even when the shopping centre is located within walking distance people will still choose to drive and park at the shopping centre. The increase in the percentage of participants walking to non-work-related activities at Grand Theatre Station has further indicated that the amenities and services provided within the area have successfully reduced the need of residents to travel by cars and encouraged walking.

6.3 Usage of the New Commercial Developments

According to Peter Calthorpe, a successful TOD will be able to provide enough amenities and services for the residents living within the area to self-sustain without traveling elsewhere. If the

amenities and services do not meet the needs of local communities, residents can take the subway or other rapid transit to another TOD for their needs (Calthorpe, 1993). Based on the research, we found that the participating residents at both study areas are generally satisfied with the services and amenities provided by the commercial and retail locations within the study areas, with 94% of the participating residents at the Houhai Station study area and 81% of the participating residents at the Grand Theatre Station study area. As mentioned in the previous sections, both stations are in close proximity to two newly developed large-scale shopping malls. The MIXC Mall and KK Mall are connected to Grand Theatre Station directly through an underground pedestrian pathway, and the Coastal City and Baoli Cultural Square are located right next to Houhai Station. Surprisingly, the research shows a very different usage rate of the new developments between the two study areas. At the Houhai Station study area, the research shows that out of the 94% of the participating residents that think surrounding services and amenities can support their daily lives at Houhai Station, 88% of them would go to the Coastal City Mall and Baoli Cultural Square on a regular basis. Compared to the Houhai Station study area, the MIXC Mall and KK Mall show a much lower utilization rate by the residents living within the study area. Out of the 88% of the participating residents that think surrounding services and amenities can fully meet their daily needs, 49% of them would not go to the two newly developed malls. This result can also be interpreted as them not needing to go to the two newly developed shopping malls to satisfy their daily needs; instead, the amenities and services provided in existing developments are sufficient.

Based on the answers from the questionnaire, we found that the expensive price of merchandise and services is the main reason for the residents at both study areas choosing not to go to the above-mentioned new malls for dining, shopping and entertainment purposes. The newly developed malls at both locations are considered as high-end shopping malls selling expensive consumer goods,

including clothing, accessories, electronics, etc. The malls consist mostly of upscale restaurants and several fast-food restaurants that do not offer many options. As mentioned earlier, the demographics between the two study areas are very different. A large portion of the residents living at the Grand Theater Station study area are renting. They are young professionals that have recently started working and labour workers with low incomes. Compared to the Grand Theater Station study area, residents living at the Houhai Station study area have a much higher income. As mentioned earlier, many of the communities located within this area are considered luxurious, with relatively lower letting rate. Because of the differences in income, the living standards of residents at the Grand Theater Station study area are considerably lower than those of residents living at the Houhai Station study area. This is the main reason why newly developed high-end malls are not preferred destinations for many residents living at Grand Theater Station. But the rest of the 51% that has agreed that they do go to the two newly developed shopping centres at Grand Theatre Station have demonstrated the ability of this TOD area to provide amenities and services that can accommodate residents of all income levels.

6.4 Qualities to be improved in TODs

This section answers to the third research question. Based on the research findings and comparison between the two study cases, we have identified the following aspects that would contribute to creating a more successful TOD that would reduce the need to travel and travel distance and encourage the use of public transit and other sustainable forms of transportation:

6.4.1 Rich Mix of Residential and Commercial Types

According to Peter Carlthorpe, mixed-use development is the key to a successful TOD (Calthorpe, 1993). Due to the car-oriented urban environment and ongoing urban sprawl in many North

American cities, mixed-use developments have been identified as a key method for achieving healthy growth through land intensification by combining a broad array of residential uses, offices, retail and services, institutions, entertainment, recreation and cultural activities, and parks and open spaces. Because of the high density of Chinese cities, communities often have a mix of residential and retail units. But as we can see in the case of Houhai Station, even though it is designed according to TOD standards, it does not have a significant impact on encouraging residents to shift from driving to using the subway. Compared to the Grand Theatre Station study area, the communities in the Houhai Station study area are lacking variety in housing types that can be offered to residents with different levels of income. Most of the housing units located within the Houhai Station study area are considered luxurious and high-end, and the residents that live there have higher incomes. With higher incomes and living standards, residents here often prefer to drive rather than using the public transit because driving provides a more comfortable travelling environment. Based on the results of the survey, comfort-related concerns such as the subway being too crowded, a lack of seats, and it not being safe are the primary reasons why participants at both study areas do not take subway to work. From comparing the two cases, it is safe to assume that in order for the TOD to encourage residents to take the subway, the residential development should provide a mixture of different housing types, such as rental housing, social housing and affordable housing aside from commodity housing. A mixture of housing types in a TOD can attract residents with different income levels and improve the subway ridership at this location.

In addition to including a mixture of housing types, improving the commercial developments with a mixture of retail locations that provide a variety of services and amenities for residents with different income levels would be necessary for achieving a successful TOD. As mentioned earlier, both cases have two new commercial developments that consist of shopping malls and office

towers. According to the findings, the commercial and retail amenities located within both study areas are successfully attracting residents living in the surrounding areas, as participants from both cases are satisfied with the services and amenities provided within the study areas for daily essentials. However, this assumption is not accurate, as if we take a closer look at the answers to questions 8 and 9 from the survey, we are able to identify some major underlying issues at both locations.

According to the findings, 88% of the participants at Grand Theatre Station think that the services and amenities provided in the surrounding areas are sufficient for supporting their daily needs, but 49% of them do not actually go to the two new shopping malls. This means that residents living in the Grand Theatre Station study area do not need the services and amenities provided by the new commercial developments for their daily needs, or the services and amenities provided by the new commercial developments are insufficient for residents' daily needs. Based on the answers provided for question 9 at this study area, we find that among the participants that do not shop at the new malls, 39% of them think the products and services are too expensive at the two new shopping malls. In this case, the high-end new shopping malls are not only serving higher-income residents within the study area but also visitors from outside of the study area. But as we have discussed earlier, because the Grand Theatre Station TOD has provided a range of housing types, and a large portion is rental housing, the distribution of income levels is relatively balanced compared to the Houhai Station study area. Since a large portion of the residents living in the Grand Theatre Station TOD area are the tenants of rental units and have lower incomes, the new shopping malls should consider their needs and purchasing abilities, and provide services and amenities that are affordable for lower-income residents as well.

At the Houhai Station study area, 94% of the participants were satisfied with the services and amenities provided within the coverage of TOD. Among them, only 12% do not normally go to the two new developments at the Houhai Station TOD area for dining, shopping, and entertainment purposes. Comparing both cases, the commercial developments at the Houhai Station TOD area are clearly more successful in terms of providing adequate services and amenities for the residents living within the coverage of TOD. As mentioned earlier, the new commercial developments at both cases are very similar high-end shopping centres that provide more luxurious products and services. But these new developments are more successful at the Houhai Station TOD area because the majority of the residents that live in this area have higher incomes, and they are willing to and able to afford the products and services provided by high-end shopping malls. However, if the Houhai TOD area is improved through a mixture of housing types such as rental, social and affordable housing as suggested earlier, the high-end shopping malls will no longer satisfy the needs of residents with lower incomes, as they will be too expensive for them.

In conclusion, a successful TOD should not simply look at mixing residential and commercial uses; instead, we should further understand the importance of including a rich mix of different residential housing types and a mixture of commercial retail locations that can provide a full range of services and amenities for residents with different income levels. With a mix of different housing types, there will be more residents within the TOD coverage taking the subway and other public transits instead of driving. And the mix of high-end and regular retail and amenities will be provide a variety of options to fulfill the daily needs of residents with different income levels within the TOD.

6.4.2 Walkability/Connectivity

Subway riders often walk to the station from home, work or shopping malls; therefore, the walking condition of the area around the station is essential for improving subway ridership. The overall aesthetic, cleanliness and physical condition of the street and sidewalks are important aspects to be considered when measuring walkability. But in both study cases, physical qualities are not the major factors that influence the walking experience. Instead, it is the atmosphere created by the on-street activities and pedestrian movements that strongly influence the walking experience. Compared to the new, wide pedestrian walkway at Houhai Station study area, the old and narrow streets at the Grand Theatre Station study area actually provide a much more enjoyable walking experience. As mentioned earlier, the Grand Theatre Station study area gives pedestrians a sense of security and enjoyment of walking in the area, as there are always many people using the street from early in the morning until very late at night. According to Jane Jacobs's three main qualities of streets of successful city neighbourhoods, having eyes on the street and pedestrians on the sidewalk continuously is exceptionally important (Jacobs, 1961). But to have eyes on the street and pedestrians using the sidewalks continuously, providing a vibrant walking environment for the residents and visitors is essential. Based on the field observation, we found that there are many domestic retail storefronts facing the streets at the Grand Theatre Station study area and they have become the main contributor of the street users. This kind of street environment not only promotes walking and having more users on the street, but also encourages more residents to use the subway. In the morning, subway riders walk past breakfast shops before getting on the subway. In the afternoon after work, subway riders can go to the grocery store, banks, restaurants and other activities on their way home. At night, many of the restaurants and stores will still be open even after the shopping centres are closed, which provides a safe walking environment for residents that

are coming home late. Compared to the Grand Theatre Station study area, the Houhai Station study area does not have similar characteristics. Even though the sidewalk and street space at the Houhai Station study area are designed to encourage public usage, the result is not as good as expected. The landscapes, new pavement and more than 50-m-wide artificial lakes do not give pedestrians a sense of human scale and have become a barrier between the residents in the study area and the commercial spaces. When the two are separated, there are fewer people using the street. Without street users, the street will lose the qualities of being a successful city neighbourhood as mentioned by Jane Jacobs. According to the result of the survey, 17% of the participants moved to the Grand Theatre Station study area is because of the safe and comfortable environment compared to 7% at the Houhai Station study area.

Connectivity between the residential communities, commercial developments and the subway station is the key quality of a successful TOD. Improving the connectivity will allow the expansion of the service coverage of the subway station. Grand Theatre Station is directly connected underground to the KK Mall and MXIC Shopping Centre as well as another commercial development developed in the late 1990s. The connections with the shopping centres serve as an extension of the subway entrance for residents that live further away from the station. In comparison, Houhai Station does not offer similar connectivity, as it does not have a direct connection with the shopping centres, and subway riders have to walk outside to be able to enter the station. This has a significant influence on both stations in terms of subway ridership. For example, Caiwuwei South Village (蔡屋围南村) residential community is located on the north end of the KK Mall shopping centre (see Appendix 1) which is about 560 m away from the Grand Theatre Station subway entrance. Subway riders usually enter through the north entrance of the shopping centre and walk inside the shopping centre to have direct access to the station. In

comparison, the Wei Lan Hai An (蔚蓝海岸) residential community is located at a similar distance from the Houhai Station subway entrance (see Appendix 2), but subway riders have to walk outdoors on the street to enter the subway station. As a result, 70% of the participants from Caiwuwei South Village take the subway to work compared to 50% of participants from Wei Lan Hai An. The importance of connectivity is also mentioned by Professor Zhang Ming, which has been referred to as the Dockized District, which has been explained in the literature review.

6.4.3 Quality of Subway Services

Other than the qualities mentioned above, the quality of the subway services is also one of the major aspects that directly influences the subway ridership. As mentioned in the literature review, Jiang et al. (2009) stated that the major cause of low public transit ridership in Chinese cities is the poor transit services. A passenger satisfaction survey was conducted in 2015, and the result showed that the subway service of line 2 is generally satisfied by the riders, and line 1 was among the

Figure 36 Subway riders waiting in line during rush hours at Grand Theatre Station. Source: Photo by author.

subway lines that has received the lower scores (Shenzhen News, 2015). We asked the participants in question 5 to select no more than two of the listed options to understand what would be the major concerns for not wanting to take the subway, and five out of the seven options are related to the quality of subway services. The returned answers from both study areas are very similar. The subway being too crowded was the most selected reason by the participants at both study areas, followed by the subway not providing enough seats. When selecting travel methods, personal comfort has always been at the top of the list for considering the pros and cons. During the rush hours and weekends, the subway lines are always very crowded, and sometimes subway riders will have to wait for several trains until there is enough more space. Getting on the train is already challenging, and finding seats is extremely difficult. The subway being so crowded brings many inconveniences to the subway riders, especially for riders with special needs, such as people with disabilities, mothers with infants and the elderly. Under these circumstances, personal vehicles are more comfortable and more convenient for people with needs compared to the crowded subway. As discussed earlier, the age and income level of residents at the Houhai Station TOD area are generally higher than the Grand Theatre Station TOD area, and there are more residents that have access to personal vehicles at the Houhai Station TOD area who would prefer to drive instead of taking the subway, especially when going out for recreational activities, such as shopping, dining and other types of entertainment.

Other than the subway being too crowded, and it being hard to find seats, a significant number of participants also identified that the inconveniences of taking the subway include having to transfer too many times and taking too long to reach their destination. The average speed of the subway is usually set from 35 km/h to 40 km/h, so it is understandable that it is not as fast as cars when there is no traffic. With spending time stopping at each station and for unexpected delays, the travel time

on the subway could often be longer than expected. Without an exceptional amount of time potentially being saved, many car owners would not be willing to switch to the subway as their primary travel method. Sometimes, the amount of transferring between the subway lines and bus routes for subway riders could also extend the travel time, and the transferring between the subway and buses in particular can be extremely frustrating. If the bus or subway is not on schedule, the riders could spend a lot of time waiting for the next available subway or bus. As discussed previously, the subway station should provide clear signage and other visual aids to improve the connectivity of the station, which would guide the riders to take the correct train, arrive at their destination and find the correct platforms for transferring. Most people can easily lose their sense of direction within the subway station, and the unclear signage for exits and directions can be very confusing. After leaving the station, riders can very often find themselves on the wrong side of the street or a completely wrong area. A well-designed station with clear signage and other visual aids

Figure 39 Crowded subway during rush hours. Source: Photo by author.

such as aerial maps and information about the bus routes that are connected to each of the exits would save a lot of time for subway riders.

To improve the above-mentioned qualities of subway services, the subway authorities should improve the coverage of the subway network and increase the frequency of the subway service. Tokyo has demonstrated a great example of providing quality public transit services and the ability to influence transit ridership. Tokyo has the world's largest rail transit network. There are 119 rail transit lines including subways and at-grade rail lines serving the great Tokyo region and the mode share of the rail transit system in Tokyo has achieved over 90%. The trains are always kept clean and on time, which makes them very reliable for transit riders. In urban areas, if you missed a subway train, the next one will arrive in less than 2 minutes, and the schedule of the rail lines at the suburbs of Tokyo during rush hours is every 6 to 8 minutes (Jiang & Han, 2009). Learning from the experience of Tokyo and other successful cases across the world, the comprehensive plan of the city has indicated that there will be 20 subway lines by the year 2040. The construction of the Shenzhen subway is currently in phase three, which will include 5 new subway lines and several extensions of the existing lines, and it is planned to be finished in 2020. At the same time, the city is already in the process of developing a detailed plan for the fourth phase of the subway development in Shenzhen. The fourth phase will develop 3 extension lines and 8 new lines, and line 14 will connect Shenzhen and the city of Huizhou. With a complete subway network, some of the riders on the current subway lines will be diverted to the new lines that are less crowded and the travel time will become much shorter as more places and sub centres will be connected by subway.

7 Conclusion

7.1 Summary of Research

The purpose of this research is to understand the impacts of TOD on residents' travel behavior in Shenzhen, China. It also sought to identify the key qualities that would improve TODs in Shenzhen to have stronger influence on residents' travel behavior to reduce driving and encourage public transit and other sustainable travel methods.

In the literature review, the evolution of the TODs and its impact on travel behavior in both China and western countries were identified through academic and technical resources. Furthermore, the research consisted of case studies of TODs at two subway stations in Shenzhen: Grand Theatre Station and Houhai Station. The two stations are located in different urban environments, as Grand Theatre Station is located within an old urban centre and Houhai Station is located within a newly developed urban area. Unsurprisingly, increments of subway ridership were found in both TODs. With further research, it was shown that the TOD at Grand Theatre Station has a stronger impact on residents' travel behavior compared to the TOD at Houhai Station. The results of the questionnaire indicated that there is a significantly higher number of participants at the study area of Grand Theatre Station starting to use more sustainable travel methods (subway, bus and walking) and fewer participants have been choosing to drive since having access to the subway.

The research also found that both TOD cases in this study demonstrated a much stronger influence on residents' commute travel modes than non-commute travel modes. Compared to going to work, both study areas showed a higher percentage of participants driving to non-work-related activities (e.g. shopping, dining, and entertainment). But a significant portion of participants at the study area of Grand Theatre Station would walk to non-work-related activities, which is very different

from the study area of Houhai Station as most participants still prefer driving. With further analysis and comparison of the results of the questionnaire and field observations of the two study areas, key qualities of TOD that would help reduce driving and encourage transit rides or other sustainable travel methods were also identified. Some of the key qualities have already been raised in different literatures in both China and western countries, but these qualities are often hard to achieve in both contexts. China planners should not only focus on the so called "good design" illustrated in new urban developments like the Houhai practice, but also look into the good qualities that are offered in old urban areas such as the Grand Theatre practice. Maybe like many researchers have suggested, planners might also look back to the danwei system (Zhao & Chai, 2013; Wang & Chai, 2009). Though it does not provide any experience in integrating transit into existing urban landscape, the danwei offers an example of planning model that has successfully offered people a sustainable way of living that we admire today. Based on the key qualities identified in the research, relevant recommendations are given in the following section.

7.2 Recommendations

As mentioned in Chapter 1, TOD is currently being widely adopted in many cities across China, and it is important for these cities to learn from the experiences of existing TODs to improve the design and implementation strategies for their own TODs. Based on the literature review, studies of the impacts of TOD in Chinese cities are limited, even though the TOD concept has already been implemented for over a decade in many cities such as Shenzhen, Shanghai, Beijing and Guangzhou. This study offers the opportunity to explore and investigate existing TOD implementation in the City of Shenzhen. In this study, we have also identified the challenges for TOD practices in Shenzhen that may also apply to other cities across China. On one hand, planners and decision makers should seek a better design and implementation strategy for TOD practices

in new urban spaces and to transform neighbourhoods like Houhai Station study area to become more effective in changing people's travel behavior. And on the other hand, we should also learn from existing TOD practices in built-up urban spaces which can be a huge asset in improving future TOD practices in both old urban areas as well as newly built-up urban spaces. The following recommendations are generated from this study which would be helpful for other cities in China and across the world to design better TODs.

1) Rich mix of residential and commercial types

The literature review has identified the need to provide a variety of residential and commercial types within TODs. As Zhang (2007) has stated, one of the 5Ds of the Chinese edition of TOD is Diverse Destinations, which suggests that the TOD and other TODs on a regional scale should provide different types of destinations that would satisfy the needs of TOD residents as well as those of other transit riders. Our analysis also shows that TODs with more types of residential and commercial developments will encourage their residents to take transit and walking. Residents who live in residential types such as rental housing and government subsidized housing are more likely to take transit to work or other non-work-related activities. And different commercial types should provide sufficient amenities and services for residents with different income levels, which would reduce the need to travel outside of the TOD area.

2) Improve walkability/connectivity

Both North American and Chinese literature has identified the importance of walkability within TOD, which can encourage more walking and transit riding. Zhang's (2007) 5Ds specifically explain the importance of connectivity within the TOD district. He suggests that different connections (e.g. bridges, skywalks, underground walkways and building lobbies) to the transit

station should be provided within TOD to encourage people, even those outside of the TOD district, to take transit as direct access is provided. The field observations and analysis of both case studies show that the study area of Grand Theatre Station has a higher number of participants that would take transit as it provides a much better connection to subway stations through underground walkways, shopping malls and building lobbies.

3) Improve Public Transit Services

The Chinese literature stresses the importance of public transit services. Jiang & Han (2009) stated that the poor public transit services provided in Chinese cities are the major reason for the low transit ridership. According to the research, most participants at both study areas do not take the subway because it is too crowded. Other common transit services-related issues also include long travel times and delays. Transit services can be improved through increasing the frequency and the coverage of the transit network. This has been successfully achieved by the rail transit system in Tokyo. Transit stations should also provide accurate schedule information that is visible to transit riders by using updated technologies, such as information LCD screens and cellphone apps.

4) Transport policies to encourage public transit

As identified in the study, parking discounts are normally provided for people at shopping malls and restaurants if a certain number of purchases have been made. This would significantly encourage driving as it would be much more convenient when buying many items. To reduce driving, parking restrictions should be enforced. Measures such as providing less parking space or increasing parking fees should be adopted in TODs.

Relevant policies should also be adopted to reduce the number of private cars in the city. Major cities such as Beijing, Shanghai, and Shenzhen have started to limit the number of license plate

that can be registered within the city. However, the results are often unsatisfying as traffic congestion still exists and is getting worse. Polices that can successfully reduce driving and encourage public transit have been adopted in other cities. The removal of highways in Seoul, Korea has successfully reduced the number of people driving into urban centres and increased subway ridership. Singapore has adopted a toll strategy called “congestion charges”, where cars that drive through roads that are often congested are charged. There is no cap for the charges, and the price can be raised as much as possible until the road is not congested anymore, which has successfully reduced the number of cars on the road and solved the road congestion problem. To encourage public transit riding, discounted transit tickets should be provided by the government for lower income families.

7.3 **Limitations**

The research design, methodology and analysis for the study have proven to be able to answer the research questions. However, several limitations of the study can be identified. The sample size of 200 participants at each study area can only provide a general idea of its residents’ travel behavior as this number is quite small and may or may not be representative of the entire TOD neighbourhood. One limitation of the research is the scope of the case studies. The two selected TOD areas, the Grand Theatre Station study area and Houhai Station study area, cannot represent any other TODs in China, as every TOD is different. Other TODs within Shenzhen or in other cities across China require further studies. Also, the recommendations generated through this study may or may not be able to be applied in other cities. Another limitation of the research is the simplicity of the survey questions, as travel behaviors can be influenced by many different factors, but the coverage of survey questions is very limited. Travel time and travel distance in particular was not discussed in this study, thus the results of the questionnaire may not be comprehensive.

The two selected stations were completed 6-years apart from each other, which may have also created research limitations for this study. Residents living close to Houhai Station may already have purchased cars before they moved in or before the subway was completed. In contrast, residents living close Grand Theatre Station may not feel the need to purchase cars because they have had access to the subway since 2002. The 6-year difference in the completion time between the two stations may be the cause of residents' different travel altitudes, as residents living close to Houhai Station may rely on driving more and residents from the Grand Theatre Station study area are more used to and more comfortable with taking the subway. This limitation may affect the accuracy of finding the key factors of TODs that can effectively change its residents' travel behavior.

One of the original objectives of the study is to understand the differences between residents' travel behavior before and after having access to subway. But during the statistical analysis of the collected survey results, we found that many of the participants at Grand Theatre Station study area did not live in the area before the subway service was available. Thus, the comparison between the travel experiences may not be accurate, as the travel behavior used by these participants may not reflect the travel behavior used in this study area. This is mainly caused by two reasons: 1) Grand Theatre Station has been operated since 2004, it is very likely the residents that lived in the area before having access to subway have already moved away; 2) As mentioned in the study, the housing type in this area is mostly rental housing with high letting rate, the residents here are likely to move away and new residents moving in to the area very frequently.

Another limitation would be the difficulty in conducting in-person survey. Studies have found that low response rate of surveying has been a challenge for most academic studies (Baruch & Holtom, 2008; Kennedy & Vargus; 2001; Sax et al., 2003). With limited resources, this study has also faced

similar challenges during the data collections stage using the questionnaires. A test survey with 30 questions was distributed in Grand Theatre Station study area, and there were no participants willing to stay for more than 2 to 3 minutes to answer the questions. Thus, the survey has been shortened to the current length in order to achieve a higher response rate. And even with the current survey, many participants have complained about the survey being too long. The limitation of a shorter questionnaire has been discussed earlier. The research design has specified the target participants to be residents of the two study areas that are currently working, and the best time to reach this population within the study areas would be after work from 5pm to 9pm which is often the busiest time around the subway station. During this study, most people were rushing to go home and negative altitudes were often given when they were stopped for a survey. Gated communities are the most common residential type in Chinese cities. During the study, most of the communities did not allow surveying to be conducted within the boundaries of the communities, and most participants were reached at the gate while they were entering or exiting the communities which may have caused the results of this study to have bias.

7.4 Future Studies

The challenges associate with this research mean that there are limitations on the findings and results of the study. Future research can build on this work, conducting studies that improve on it in the following ways:

1) Increase the sample size of the study. The data should be collected from a larger sample size to obtain more complete results. With a larger sample size, the study can use regression analysis to have a more comprehensive understanding of the relations between different variables.

2) Increase the number of case studies. The study should include several more TODs that have similar urban characteristics to Grand Theatre Station and Houhai Station. With more similar cases, the findings and results of the study can be more representative of TODs in a certain type of urban area. Also, the recommendations generated from the study will be more applicable to similar urban environments in different Chinese cities.
3) Expand the range of questions of the survey to cover more perspectives of travel behavior, such as the travel time and travel distances required to go to work and other non-work-related activities. With more variables, the study will be able to have an overall understanding of the impacts of TOD on different aspects of travel behavior.
4) Future site selections should look at stations that were built within five years, as one of the objectives of the study is to understand the different travel experiences of the residents before and after having access to the subway. Thus, studying stations that were built within five years will make sure most of the participants would have the travel experience to fulfill the requirements of this research. By increasing the sample size and the number of case studies would be also helpful for finding suitable participants.
5) A standardized tool for evaluating the quality of the walking environment within the TOD should be developed. In this way, the evaluation of the walking environment can be a combination of quantitative and descriptive analysis, which would provide more complete information for comparison between different case studies.

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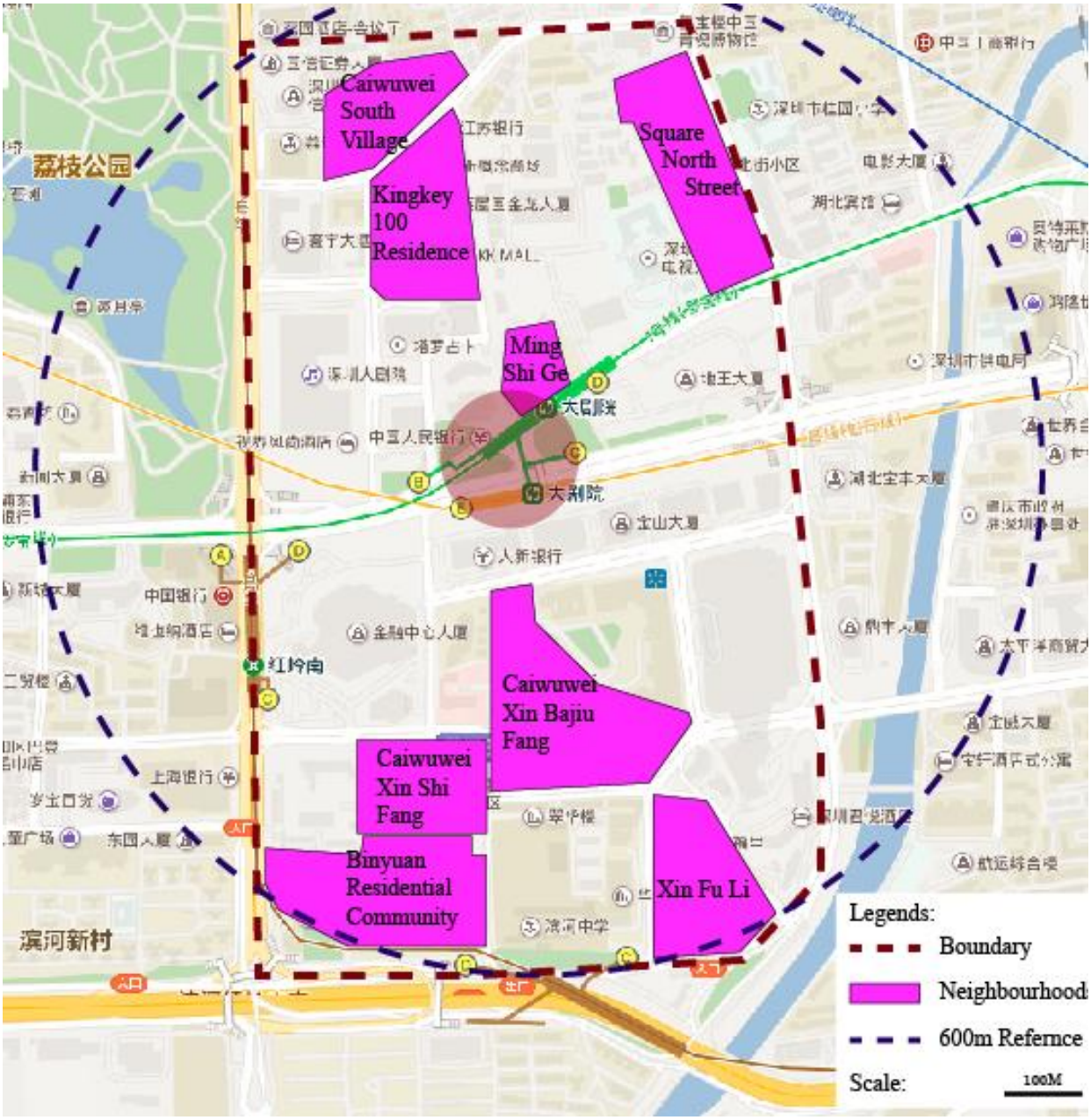
Appendices

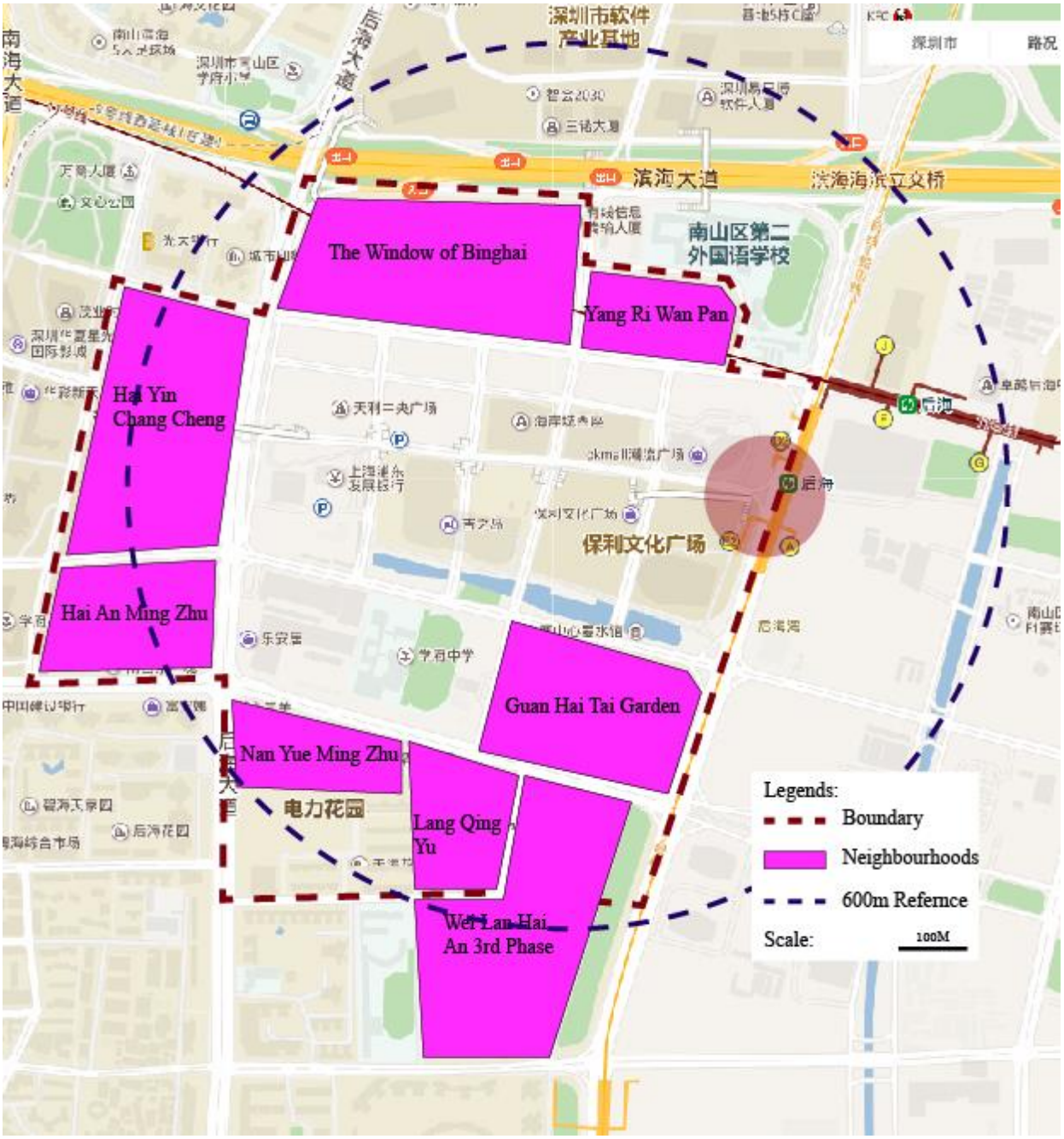
Appendix 1:

Boundary of Grand Theatre Station study area and reference boundary.



Appendix 2:

Boundary of Houhai Station study area and reference boundary.

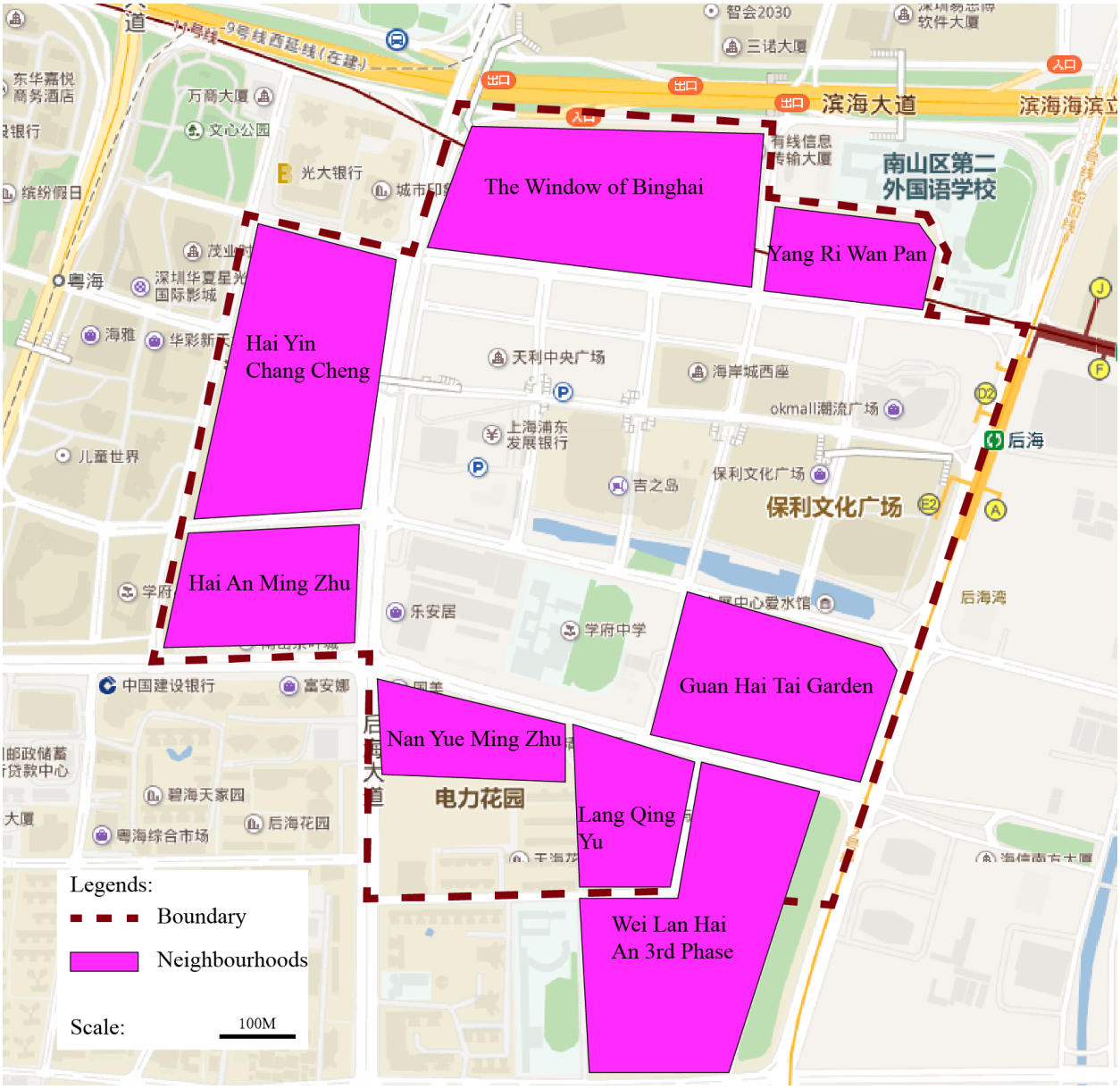


Appendix 3:

Boundary of Grand Theatre Station study area and locations of the selected neighbourhoods.

Appendix 4:

Boundary of Grand Theatre Station study area and locations of the selected neighbourhoods.



Appendix 5:

Grand Theater Station TOD Residents' Travel Behavior Survey

Time: Neighbourhood: Participant's Age:

1. How long have you been living in your current neighbourhood?

☐ 0-5 years □ 5-10 years □ 10-15 years □ 15-20 years □ above 20 years

2. If you have been living here for less than 10 years, what was your reason for moving?

☐ Close to subway, great access to public transit □ Close to work □ Safe and comfortable living environment

☐ Surrounding commercial areas are well developed，diversified retails and amenities (e.g. restaurants，shopping malls，and other entertainments）

☐ Others_____

3. How do you currently go to work?

☐ Bus □ Subway □ Taxi □ Personal vehicle □ walking

☐ Others_____

4. Before having access to subway (or before moving to this location), how did you go to work?

☐ Bus □ Taxi □ Personal vehicle □ Walking □ Others_____

5. If you currently do not take the subway to work, what would be the reason?

☐ Too crowded □ Have to transfer several times □ Limited seats □ Takes too long □ Not safe

☐ The station is too far

☐ Others_____

6. Which of the following travel methods do you usually use for non-work related activities (e.g. dinning, Shopping and other entertainments)?

☐ Bus □ Subway □ Taxi □ Personal Vehicle □ Walking □ Others_____

7. Does the commercial services and amenities around your neighbourhoods satisfy your daily needs? (e.g. dinning, Shopping, and other entertainments)

☐ Yes □ No

8. Do you often go to Kingkey 100 (kk mall) and MCIX Shopping centre for dinning, shopping and other entertainments?

☐ Yes □ No

9. If you do not go, what would be the reasons?

☐ Lack of diversity □ Too expensive □ Too crowded □ Others_____

Appendix 6:

Houhai Station TOD Residents' Travel Behavior Survey

Time: Neighbourhood: Participant's Age:

1. How long have you been living in your current neighbourhood?

☐ 0-5 years □ 5-10 years □ 10-15 years □ 15-20 years □ above 20 years

2. If you have been living here for less than 10 years, what was your reason for moving?

☐ Close to subway, great access to public transit □ Close to work □ Safe and comfortable living environment

☐ Surrounding commercial areas are well developed，diversified retails and amenities (e.g. restaurants，shopping malls，and other entertainments）

☐ Others_____

3. How do you currently go to work?

☐ Bus □ Subway □ Taxi □ Personal vehicle □ walking

☐ Others_____

4. Before having access to subway (or before moving to this location, how did you go to work?

☐ Bus □ Taxi □ Personal vehicle □ Walking □ Others_____

5. If you currently do not take the subway to work, what would be the reason?

☐ Too crowded □ Have to transfer several times □ Limited seats □ Takes too long □ Not safe

☐ The station is too far

☐ Others_____

6. Which of the following travel methods do you usually use for non-work related activities (e.g. dinning, Shopping and other entertainments)?

☐ Bus □ Subway □ Taxi □ Personal Vehicle □ Walking □ Others_____

7. Does the commercial services and amenities around your neighbourhoods satisfy your daily needs? (e.g. dinning, Shopping, and other entertainments)

☐ Yes □ No

8. Do you often go to Baoli Cultural Square and Coastal City Shopping Centre for dinning, shopping and other entertainments?

☐ Yes □ No

9. If you do not go, what would be the reasons?

☐ Lack of diversity □ Too expensive □ Too crowded □ Others_____

Appendix 7: Percentage Points of the Chi-Square Distribution

Source:
http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447119&topicorder=8&maxto=16&minto=1

Percentage Points of the Chi-Square Distribution

Degrees of Freedom	Probability of a larger value of x^2								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.004	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.61	5.99	9.21
3	0.115	0.352	0.584	1.212	2.366	4.11	6.25	7.81	11.34
4	0.297	0.711	1.064	1.923	3.357	5.39	7.78	9.49	13.28
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	15.09
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.48
8	1.647	2.733	3.490	5.071	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21
11	3.053	4.575	5.578	7.584	10.341	13.70	17.28	19.68	24.72
12	3.571	5.226	6.304	8.438	11.340	14.85	18.55	21.03	26.22
13	4.107	5.892	7.042	9.299	12.340	15.98	19.81	22.36	27.69
14	4.660	6.571	7.790	10.165	13.339	17.12	21.06	23.68	29.14
15	5.229	7.261	8.547	11.037	14.339	18.25	22.31	25.00	30.58
16	5.812	7.962	9.312	11.912	15.338	19.37	23.54	26.30	32.00
17	6.408	8.672	10.085	12.792	16.338	20.49	24.77	27.59	33.41
18	7.015	9.390	10.865	13.675	17.338	21.60	25.99	28.87	34.80
19	7.633	10.117	11.651	14.562	18.338	22.72	27.20	30.14	36.19
20	8.260	10.851	12.443	15.452	19.337	23.83	28.41	31.41	37.57
22	9.542	12.338	14.041	17.240	21.337	26.04	30.81	33.92	40.29
24	10.856	13.848	15.659	19.037	23.337	28.24	33.20	36.42	42.98
26	12.198	15.379	17.292	20.843	25.336	30.43	35.56	38.89	45.64
28	13.565	16.928	18.939	22.657	27.336	32.62	37.92	41.34	48.28
30	14.953	18.493	20.599	24.478	29.336	34.80	40.26	43.77	50.89
40	22.164	26.509	29.051	33.660	39.335	45.62	51.80	55.76	63.69
50	27.707	34.764	37.689	42.942	49.335	56.33	63.17	67.50	76.15
60	37.485	43.188	46.459	52.294	59.335	66.98	74.40	79.08	88.38