Transit-Oriented Development (TOD) for Urban Sustainability: A Comparative Case Study of Beijing and Shenzhen, China

by

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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

A number of urban problems pose ongoing challenges to sustainable development, which includes urban sprawl, low rates of land utilization and increases in private vehicular ownership and related traffic congestion. Transit-oriented development (TOD) has been touted as one strategy to address these urban development challenges. Although TOD strategies have a relatively mature theory and practical system in the world, the development situation in China is still at a stage of trial and error. Moreover, many studies have been conducted to tackle the issues related to land use, transportation planning, and the feasibility of TOD, while few have investigated the implementation effects of TOD on a sustainable urban future. Therefore, this thesis reviews the basic concept of sustainable urban development and pioneering paradigms about TOD practices, then applies a Pressure-States-Response (PSR) evaluation framework to compare the implementation effects of TOD in two typical Chinese metropolises —Beijing and Shenzhen. Quantitative data collected from National Statistics are visualized using descriptive statistics to conduct the comparative analysis.

This study defines a sustainable city as one that achieves a balance between the three sustainability pillars of: economy, environment, and society. Within this definition of sustainability, the comparative implementation effects are assessed for the TOD, performance of Beijing and Shenzhen from the year 2010 to the year 2014. The research found that both Beijing and Shenzhen had faced an increasing pressure from population density, expenditure on housing and transportation, and the number of civil automobiles during the five years.

Shenzhen performed better than Beijing on the indicators of “disposable income of urban residents per capita”, “construction land per capita”, “area of roads per capita” and “GDP per acre”; while Beijing showed more positive effects than Shenzhen on the indicators of “urban residential gross floor area per capita” , “passengers traffic”, and “number of public vehicles”. For the economy response indicators, the Beijing government produced a more effective effect on “fixed assets per acre”, and “fixed investments in real estate industry”, while the Shenzhen government had a stronger performance on “fixed investments in transportation industry”. The key findings from this research support the building of muilti-mode transportation systems to enhance ecological, economic and social sustainability in rapidly growing cities.

The research contributes to the body of knowledge of the performance of metropolises towards urban sustainability by evaluating the implementation effects of TOD and demonstrating that government planning and development policy does impact TOD outcomes. Besides, this study makes a practical contribution to discussions on China’s urban planning and TOD supportive policies and decisions that urban planners and policy makers face as they work towards achieving more sustainable urban development.

Keywords: Transit-oriented Development; Implementation Effect; Sustainable Urban Development; PSR Evaluation Framework; Comparative Analysis; Descriptive Statistics; China

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List of Abbreviations

BRT	Bus Rapid Transit
CDB	Central Business District
DAC	Danish Architecture Center
GHG	Green House Gases
HKTDC	Hong Kong Trade Development Council
ILG	Institute for Local Government
IRES	Infrastructure Development and Real Estate-related Services
MITOD	Mixed-income Transit-oriented Development
MTRC	Mass Transit Railway Corporation
OECD	Organization for Economic Cooperation and Development
PCA	Principal Components Analysis
PSR	Pressure-States-Response
SEZ	Special Economic Zones
SGN	Smart Growth Network
TCRP	Transit Cooperative Research Program
TCSZM	Transportation Commission of Shenzhen Municipality
TOD	Transit-oriented development
TRB	Transportation Research Board
VMT	Vehicle Miles Traveled
WCED	World Commission on Environment and Development

1 Introduction

1.1 Problem Statement

An increasing urban population, the rise of new mega cities, and lack of available physical space are common challenges that different transport modes are faced with. Since the reform and opening-up policy putting in place, a large number of rural people have entered into first- and second-tier cities in China (Kamal-Chaoui et al., 2009; Chang, 2014). Metropolitan regions across the country are facing increasingly issues with respect to urbanization, transportation, and land use: traffic congestion, air pollution, greenhouse gas emissions, infrastructure costs, energy consuming as well as personal costs caused by urban sprawls (Huang & Kebin, 2012; He, et al., 2012; Shang & Wu, 2015).

The history of China is different to North America, South America and Europe, because China has been using TOD as its main system of transport until China joined the World Trade Organization (WTO) in 2001, its automobile industry has expanded significantly (Feng & Li, 2013). Consequently, the current challenges for China's TOD are large private vehicle volumes, insufficient public transit capacity, and incomplete urban transport facilities. Meanwhile, these TOD challenges could also cause environmental problems.

As for how to solve these problems, the government and academic world have made mixed contributions. Diverse academic research and advocacy are tending to address transportation and land use concerns (Sheng, 1997; Mena Report, 2013; Liu et al., 2014; Yang et al., 2015). Thus, plenty of hot topics have aroused discussion, including "new urbanism" (Holm et al., 2011; Trudeau, 2013; Wey, & Hsu, 2014), "smart cities" (LeRoy, 2002; Geller, 2003; Thite, 2011; Goodspeed, 2015; Meijer et al., 2016), “transit-oriented development” (Cervero, & Day, 2008; Loo et al., 2010; Cervero, & Sullivan, 2011; Mu, & Jong, 2012), “urban sustainable development” (Song, 2011; Edelman & Triantafillou, 2013; Aldegheishem, 2014), etc. Although many studies have been conducted to tackle the issues related to land use planning (Li et al., 2010; Handayeni, 2014; Dou et al., 2016), transportation planning (Gilat & Sussman, 2003; Falconer & Richardson, 2011), and the feasibility of TOD (Chen, 2010; Falconer & Richardson, 2010; Mu & Jong, 2012; Sharma et al., 2016), few have undertaken the implementing effects of TOD. With more and more countries have adopted the planning concepts of TOD and have put it into practice, the evaluation of TOD effects is required to determine whether those practices have made a success.

The study attempts to fill this gap by comparing the effects of implementation of TOD between two Chinese metropolises through the application of a modified evaluation index. Indicators are divided into three categories: pressure indicators, states indicators, and response indicators. Quantitative data have been collected to measure these indicators. Knowing whether TOD practices in Chinese cities help solve these transport issues, and how much progress they have made contributes to the academic literature on urban planning, governmental policies, and sustainability.

1.2 Research Purpose and Scope

The objective of this research is to measure the effects and outcomes of TOD to achieve urban sustainability. For the comparative case studies, two Chinese metropolises have been selected: Beijing and Shenzhen. Although TOD has also been applied in some other Chinese cities, it is still under development and in the phase of exploration and attempt. As China's first-tier metropolises, Beijing and Shenzhen have extensively applied TOD and arrived at a relative mature stage, thus it is more practicable and reasonable to measure the TOD's effects on them. Besides, Beijing and Shenzhen are facing many similar challenges of sustainable planning, involving super block phenomenon, housing and traffic pressures, and unbalanced land development. However, the two cities experienced very different histories: Beijing is a historic city and maintains a great variety of old districts, while Shenzhen is a booming city but grows rapidly. Therefore, it would be valuable to explore how the two cities respond to same development challenges within different contexts and situations.

The data are collected from the year 2010 to 2014, as this period is a transition from 11^{th} Five-year Plan to 12^{th} Five-year Plan in China, since it would be more significant to compare and draw a conclusion after five-year implementation. The quantitative data are obtained from the National Bureau of Statistics of the People's Republic of China, while some continuous variables (e.g. rates) are calculated by the author. Then the data analysis has been conducted by statistic graphs or tables to provide a visualized presentation.

1.3 Research Questions

The central research question this study aims to answer is:

- How does TOD work in China and what progress has been made?

In addition, the thesis addresses the following sub-questions:

- What transportation and sustainability challenges are Chinese metropolises faced with?

- What are the most useful indicators to measure the effects of the implementation of TOD? What kind of indicators can be selected to evaluate the implementation effects based on China's current situation?

- What policies have been enacted to apply the concept of TOD and in Beijing and Shenzhen? Whether the implementation of TOD has made progress? If so, which aspects have been successful? If not, which aspects have failed? What are the implications of these changes for urban sustainability?

1.4 Methods and Analysis

In order to assess what kind of indicators can be used to measure the implementation effects of TOD effectively, Pressure-States-Response (PSR) model has been adopted. The basic idea of this model is that 1) human activities exert pressures on the environment and transportation, and then resulting in changes in objective facts (e.g. environmental quality, traffic congestion degree, residential area per capita, etc.); and 2) how society and the government respond to these changes through policies, decisions or management measures to reduce these pressures.

After the PSR framework has been established, a comparative case study relying on quantitative data (population density, annual household expenditure on transportation and housing per capita, civil automobiles, disposable income of urban residents per capita, urban residential gross floor area per capita, area of urban construction land per capita, area of roads per capita, passengers traffic, number of public vehicles, GDP per acre, investment in fixed assets per acre, fixed investments in the transportation industry, fixed investments in the real estate industry) is carried out. The option of a comparative case study is justified by the research questions, which focus on how Chinese metropolises apply the TOD and whether the implementation is successful. Generally speaking, case studies are better appropriate to examine the role of causal mechanisms and address complex causal patterns than statistical methods (George & Bennett, 2005; Ragin, 2004; Yin, 2003; King *et al.* 1994). Subsequently, descriptive statistics are applied to conduct a comparison and to analyze findings.

1.5 Assumptions and Limitations

Assumptions are listed below to guide the scope and purpose of the research, and to address the utilization of the case study as a research methodology answering in part the research questions for this thesis.

- The underdevelopment of transit-oriented urban environments in China justifies the case study focus on Beijing and Shenzhen;

- Because the practice of TOD is more mature in North America and Europe than China, the selected implementation examples can provide valuable lessons for the practice in China, even considering some contextual differences exists, for example the ownership of the land in China versus the United States;

- The adopted evaluation index can effectively measure the implementation effects of TOD; and

- The selected case studies are more advanced in urban planning and implementing

TOD compared to other Chinese cities, and therefore can provide helpful recommendations for national urban development strategies.

Given that this is a graduate-level thesis and under the time constraints of a Master's program, the selection and investigation of case studies is limited in scope. This research is limited to two cases of China's first-tier cities to evaluate the implementation of TOD, while there are certainly more cases that can provide valuable insights and recommendations to China's sustainable urban development. Consequently, the findings from the thesis provide only a small set of helpful recommendations for sustainable urban planning and implementing TOD in China. Due to the limited amount of undertaken empirical research, findings from the comparative analysis may not be fully triangulated. Besides, a number of indicators related to the implementation of TOD are not involved in this research, including land use planning, transit station planning, and real-estate market analysis. For a fuller analysis, further research on these indicators should be undertaken when establishing a comprehensive evaluation system for TOD.

1.6 Significance and Contribution

This research investigates and contributes to current TOD implementation efforts within the City of Beijing and the City of Shenzhen. Recommendations generated from the thesis provide valuable insights to TOD supportive polices and urban sustainable development. These recommendations have particular importance for Chinese first-tier metropolises, considering their status as rapid-growth cities with relatively more financial resources, and currently undergoing an increasing number of transit-oriented initiatives and sustainable urban development strategies.

This thesis also contributes to the TOD evaluative methodology through the use of a modified PSR model. The PSR model is tested in the context of the TOD data available from Beijing and Shenzhen and this approach can be replicated in other urban contexts.

Given the focus on TOD plans and the Chinese metropolises contexts, the proposed recommendations particularly benefit to the State Council, Transportation Commission of Shenzhen Municipality, and the Beijing Government. The research can also supplement the current efforts of the departments to set and implement TOD strategies, and contribute to enhance the relationships between public transit and urban sustainable development in China. With the review of China's *Twelfth Five-Year Plan*, Beijing and Shenzhen's policy planning document, the research can make a timely contribution to the effects evaluation of TOD supportive policies. The comparative analysis system proposed in this research may also be applicable to other Chinese cities that have implemented transit-oriented development strategies.

1.7 Outline of the Document

Chapter 1 introduces the thesis by outlining the sustainability challenges facing cities and makes the case for evaluating a TOD approach to dealing with transit related development objectives, with a focus on two case studies in China. The chapter also articulates the key research questions, methods used and assumptions and limitations of the study.

Chapter 2 conducts a review of the literature and a discussion on the historical roots and excellent worldwide paradigms of TOD practices and related research. The chapter also highlights how the implementation of TOD contributes to smart growth and sustainable urban development. Research on the differences between western world and Chinese context, and the challenges of sustainable urban development new urban districts and old towns are faced with is presented to conduct the influencing factors of TOD implementation.

Chapter 3 presents the methodology of evaluation index and comparative case study. Based on the indicators of TOD success proposed in pioneer research, and integrated with China's current context, a modified PSR evaluation framework is adopted.

Chapter 4 contains background research on the city of Beijing and the city of Shenzhen respectively, and a comparative analysis using the quantitative data collected from the government statistics, while the qualitative data gathered form national development plans. A series of descriptive statistics are presented to visualize the data and conduct the comparative evaluation. Results and findings are presented to answer the research questions.

Chapter 5 is a summary of the research findings and conclusions. Recommendations are proposed to address the challenges of sustainable urban development and enhance the positive effects of TOD's implementation. Limitations of the research are presented and the chapter concludes with a discussion on the directions for further research.

2 Literature Review

2.1 Origins and History of TOD

TOD is both an old and new concept stemming from the streetcar suburbs and satellite rail towns that were developed throughout North America during the late 19th and early 20th century (Bernick & Cervero 1997; Dunphy et al. 2004). With the book *The Next American Metropolis: Ecology, Community and the American Dream* (1993), the architect and planner Peter Calthorpe is credited with introducing TOD into the broader discourse on smart growth and new urbanism. In his book, Calthorpe (1993, p.56) defines TOD in a community scope: "a mixed-use community within an average 2,000-foot walking distance" from a commercial center or transit stops. TOD is a kind of communities combines residential, commercial, public uses and open space into a walkable environment. Consequently, it is convenient for residents and employees to commute through transit, cycles, foot, or cars. The definition of TOD in the contemporary practice is still defined as a mixed-use and higher density form of development (Reaney, 2011), which presents same implication as what has been proposed by Calthorpe.

According to Bernick and Cervero (1997), the original intention of TOD and transit villages was to promote transit to a "respectable means of travel outside the village" (p.7); the nodal design of TOD and transit villages can be traced back to the earliest of rail suburbs of New York, where they formed "beads on a string" on a regional scale, and formed communities that circulate around a transit station on the neighborhood scale (Bernick & Cervero 1997). Each suburban community along the commuter rail-line included enough daily facilities to be self-sufficient, thus people could conduct most daily activities in their own communities; this walkable distance from rail stations provides convenience to residents, as at that time only the very rich could afford a vehicle to be able to live further into the countryside (Bernick & Cervero 1997, p.16).

TOD could be deemed as an ideological way to consider communities and a real-estate movement. In this context, TOD has gained remarkable popularity amongst municipalities in the United States (TCRP, 2002). Between 1992 and 2004, more than 30 countries and municipalities in the United States have adopted TOD regulations (TRB, 2004); while many typical forms of nodal development around transit exist in South America, Western Europe, and Australia (Bernick & Cervero 1997; TCRP, 2002). As stated by Dittmar and Ohland (2008): TOD is not a new concept, while how to apply TOD in auto-oriented metropolises is a new challenge.

In contrast, Transit Cooperative Research Program (TCRP, 2002) states that transit adjacent development is a term for characterizing development at station areas that does not have a "functional or meaningful relationship to the station". In this definition, development around stations is conventional single-use development patterns, with conventional parking requirements, so that the development is actually transit adjacent rather than transit oriented.

Scholars' discussion is focus on the planning of TOD, while the effects of TOD projects in are only starting to be evaluated. Proponents such as Calthorpe and Fulton (2001, p.218) indicate that the performance standards for TOD should:

- Decrease traffic congestion at a local- or regional- scale;
- Make investments in transit more efficient in costs and operations;
- Increase the pedestrian friendliness of neighborhoods through urban design; and
- Increase mobility by increasing options for walking and transit, and offering viable

housing alternatives to traditional suburban development.

Besides, a criteria of successful TODs has been proposed by Dittmar and Ohland (2008). They state that successful TOD requires being “mix-use, walkable, location-efficient”, and could balance the demand for sufficient density to support convenient transit service with the scale of communities. Moreover, techniques need to be developed to assure TOD also maintains mixed-income in character. Implementation of TOD remains the challenge under the conventional scope of planning worldwide. Implementation approaches and the challenges are investigated in the next two sections.

2.2 Definition of TOD

TOD is considered as one of the most sustainable urban development forms as its “compact, mixed-use, pedestrian-friendly development centered around transit stations” encourage the use of transit and reduce the use of automobile (Cervero et al., 2004). It is a concept that can help many governments’ urban policies realize more sustainable outcomes, more specific, it is a planning element which attempts to obtain a public transport (rail, bus, or ferry) can anchor a more eco-friendly and socially responsible urban form (Black et al., 2016). TOD is also one type of modern movements in urban design that aim to stimulate street life and diversify urban landscapes (Cervero & Murakami, 2008). One of the key theories in this urban design is for a quality and transit-friendly place which called “connectivity” (Awasthi et al., 2011); it emphasizes on the ability to interconnect to nearby places in an efficient, pleasant, and safe manner without restraint and seamlessly.

As shown in the published *TCRP Report 102: Transit-Oriented Development in the United*

States: Experiences, Challenges, and Prospects (Cervero et al., 2004), there are many and somewhat varying definitions of TOD. One definition which has been adopted by the State of California does a good job of capturing the essence of TOD. It highlights that TOD is moderately higher density development located within a walkabke distance (about half a mile) to major transit stations. And also the development is with mixed land use designed for residential, employment, and shopping opportunities without excluding the auto (California Department of Transportation, 2002, p.3).

On the other hand, TOD has been recognized as a model for integrating land use with transportation in the interest of "smart growth" (Calthorpe, 1993; Cervero, 1998; Newman & Kenworthy, 1999; Renne & Newman, 2002; Renne and Wells, 2004). According to Cervero et al. (2004), "TOD has gained currency in the United States as a means of promoting smart growth, injecting vitality into declining inner-city settings, and expanding lifestyle choices". Dittmar and Ohland (2004) state TOD is an essential part of the healthy growth and also involves the development of regional economies. Bukowski et al. (2013) also define TOD as "a walkable environment located around a rail transit station that hopes to provide a healthy lifestyle for its residents" in their study on the sustainability of TOD in Hong Kong. They believe that a sustainable TOD should be able to meet all the residents' needs within the walkable distance from the closest station or another station.

In *The New Transit Town: Best Practices in Transit-Oriented Development* (2008), authors Dittmar and Ohland have extended upon the work of Calthorpe et al. to develop a performance-based definition of TOD, based on five goals:

i. Location efficiency;

ii. Rich mix of choices;

iii. Value capture;

iv. Place making;

v. Resolving the tension between node and place.

The purpose of developing the performance-based definition of TOD was to create benchmarks for new TOD projects and evaluate the quality of past TOD projects. Given that not all practices can meet the standard of real TOD, but without a benchmark there will be no way to determine the quality of implementations or even to clearly consider of the trade-offs that could be made when conducting a project. Therefore, this performance-based definition has been used to evaluate case studies of TOD projects.

Besides, scholars propose five "D"s physical features of TOD, which are influential to travel behavior and the travel mode choice (Cervero & Murakami, 2008, p.23-24; Ewing & Cervero, 2010, p.267). The five "D"s are:

Table 1 Five "D" features of TOD.

"D" Features	Description
Density	Enough residents, workers, and visitors within reasonable walking distance around transit stations promote ridership
Diversity	Mixed land uses, housing types, and ways of moving around the neighborhood

Design	Walking-oriented design: physical features, site layouts, aesthetics, and amenities that encourage walking, biking, and transit riding as well as social engagement
Distance to transit	Distance from the transit stations
Destination accessibility	Whether the TOD is well-connected with the popular destinations

To sum up, the definition of TOD used in this research would be a planning strategy to integrate land use with public transportation (e.g. rail transit, bus transit) in the interest of sustainable urban development which is able to create walkable communities for people of all ages and incomes and provide easily-accessible transportation and housing options.

2.3 Sustainable Urban development

As a new concept presented after the construction of worldwide industrial cities, sustainable urban development makes up for the vacancy and deficiency of metropolises development theory and establishes new theories and techniques for the sound development of cities. The concept of sustainable development was initially introduced by the United Nations World Commission on Environment and Development (WCED) in 1987, which defined it as a pattern of development that "meets the need of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987). Since the 15th National Congress of the Communist Party of China in 1997, sustainable development has been identified as a strategy that "must be implemented in the modernization construction" of China (Yang et al., 2017). Whereafter, the first time sustainable development has been incorporated into the long-term planning of China's economic and social development is the publishment of the *Whitepaper on China's Population, Environment, and Development in the 21st Century* in 2000 (Yang et al., 2017). According to China's national situation, sustainable development has been identified as the development that considers not only current but also future development demands, and satisfies the interests of the current generation without causing future generations to pay the price of satisfying current interests.

Since the definition was proposed, scholars and practitioners have refined the conception of sustainability in many ways in order to make the notion more applicable to diverse policy areas. Overall, the appropriate ways of defining sustainability reflect the need of balancing competing interests, by introducing the triple-bottom line issues of environment, economy, and society. Meanwhile, scholars in China and abroad have a variety of opinions on sustainable development in cities. In particular, a general agreement states that sustainable development in cities is achieved by coordinated development of economy, society, environment, population, and resources in an urban system. The main findings of international and Chinese research are as follows.

Firstly, sustainable urban development is the coordinated development of three main systems: environment, economy, and society (Dias et al., 2014; Shaker & Sirodoev, 2016), because the foundations, conditions, and purpose of sustainable development are provided by these systems in cities (Guo, 2012); likewise, Xu and Zhang (2001) state that sustainable development in cities maintains the harmony among environmental support, economic profits, and social progress. This coordinated development can be attained by promoting social equity, environmental quality, and economic growth (Shaker & Sirodoev, 2016). Yang and Shi (2011) propose that sustainability in urban development involves changes in population, resources, and governance. Therefore, a sustainable city cannot be built without sound urban infrastructures, sufficient and affordable housing, and a livable environment.

Plenty of studies have been conducted to define sustainability and sustainable city, while the achievement of sustainability is always elusive, especially how to balance the interrelations among the three sustainability pillars. Bring people out of poverty is the only way for all urban development, Glaeser (2011) states that human capital makes city prosper, because educated people share knowledge and give rise to innovations which boosting productivity. By doing so, they expand urban wealth and attract more investment that creates more job opportunities. Consequently, cities continue to prosper as developers build more office buildings and residential dwellings. However, this kind of economic development promotes resource consuming, which is environmentally unsustainable in the environmental perspective. For instance in China, Shanghai is ranked the top economic city among all Chinese cities, but it is still unsustainable when it comes to socio-ecological factors (Jiang & Shen 2010; Pow & Neo 2013), because social and environmental aspects are often neglected in the fast-paced urbanization. Figure 1 demonstrates how traditional engineering could be expanded when considering environmental demands. The economic, environmental, and social issues are illustrated in the global context (Cibworld, 2014; Hassan & Lee, 2015). A comprehensive sustainable object is supposed to maintain a balance among economy, society, and environment despite of which scale: city, neighborhood, or just a building.

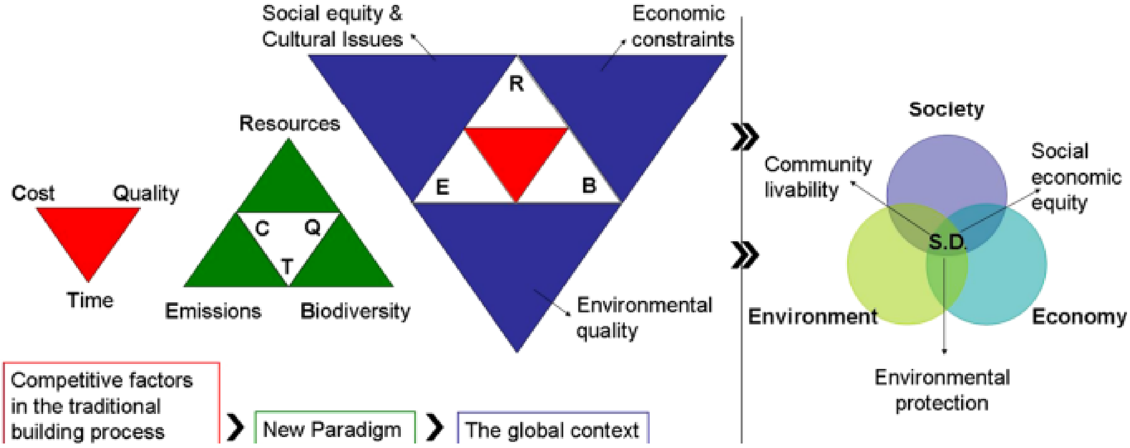

Figure 1 Pillars and requirements for sustainability, from a micro level to global level (Cibworld, 2014; Hassan & Lee, 2015)

As the Italian architect Giancarlo Di Carlo stated that, "Once we produced to consume; now we consume to produce." Theodoridou et al. (2012) consider that a sustainable city is self-sufficient, and can restore people to the first condition of "producing to consume" (Hawkes, 1995). The United Nations Sustainable Development Goals (2015) highlight that a sustainable city should be able to maintain the supply of natural resources when realizing economic, physical, and social achievements, in order to remain safe against the environmental risks that can undermine any development achievement. Hence, a trend towards this kind of sustainable urban development is "zero-carbon eco-city". The eco-city attempts to use "passive and active devices" that generate clean and renewable energy, reducing the emissions of carbon dioxide or green house gases (GHG) to zero (Hassan & Lee, 2015). New technologies involving renewable-energy-based tools such as PV power plant, concentrated solar power, wind turbines, geothermal technologies, and internal transportation based on electric light rapid transit or personal rapid transit (Masdarconnect, 2013), as well as waste management, can be applied to construct the zero-carbon city. This type of cities not only alleviates environmental problems but also contributes to improving the quality of life.

Although solving the environmental problems inside the city, the resource consumption and carbon emissions outside the city for resource used within the city also needs to be controlled. Food is a good example of ecologically damaging practices that occur outside the city, but this is done in order to feed cities (Frayne, 2017). In the US, the average food product travels nearly 2,400 kilometers from the farm where it is grown to the consumer's refrigerator (Goldenberg, 2016). Therefore, a tremendous amount of fossil fuel is used to transport food from such long distances. In spite of the environmental harm resulting from food processing, packaging or long-distance-transport, the industrial farms are major sources of air and water pollution (DAC, 2014). Therefore, how cities can produce food locally and in a sustainable way is also a question sustainable urban development need to address.

Therefore, sustainable urban development requires interaction among three dimensions: economic, environmental, and social. It can be considered as the strategies and processes that drive the progress in the field of sustainability. A sustainable city should meet the needs of economy, society, environment, culture, and polity, along with physical objectives, and ensure residents have equitable access to all services, without depleting the resources of other cities and the regions.

2.4 Smart City with TOD

Urbanization is the only way which must be passed to modernization, and has become a general trend of social and economic development across the world. However, many urban problems during the process of urbanization have been more and more serious: environmental pollution, resources shortage, irrational land use, and traffic congestion. Similar with that in western countries, the urbanization in China has caused great impacts on the state since China started to reform and opening up. Over the past 60 years, the global urbanization rate has increased 21%, more than 50% of the world population lives in urban area today; meanwhile, the ratio is predicted to be close to 60% by 2030 (United Nations, 2015). Recently in the worldwide context, "smart city" has been proposed as an effective approach to achieve sustainable urban development and better urban management. The core concept of smart city is to achieve the integration of municipal service, business, transportation, water, energy source and other urban sub-systems (Wu et al., 2017), which also be reflected in TOD.

Smart city is an ideal blueprint for a sustainable city, while smart growth is an effective strategy of long-term urban planning. As a transportation and urban planning theory, smart growth aims to concentrate growth in dense city centers and maintains urban transport accessibility to avoid urban sprawl (Boeing et al., 2014). To be more specific, smart growth advocates "compact, transit-oriented, walkable, bicycle-friendly land use" (Boeing et al., 2014) including easily-accessible supporting facilities (schools, hospitals, shopping centers, etc.), complete roads and streets, and a range of affordable housing choices. There is a set of smart growth principles presented by the Smart Growth Network (SGN):

Table 2 Smart growth principles.

Principle	Explanation
Mix Land Uses (P1)	Supporting the integration of mixed land uses in communities as a critical component of achieving better place to live.
Compact Building Design (P2)	Providing a means for communities to incorporate more-compact building design as an alternative to conventional, land-consumptive development
Variety of Housing	Providing a variety of housing types, sizes, and prices.

Choices (P3)	
Wakeable Neighborhoods (P4)	Creating walkable communities to live, work, learn, worship, and play.
Preserve Open Space and Critical Environmental Areas (P5)	Encouraging communities to craft a vision and set standards for development by promoting local economies, preserving critical environmental areas, improving community's quality of life, and guiding new growth into existing communities.
Strengthen and Direct Development Towards Existing Communities (P6)	Directing development towards existing communities already served by infrastructure, seeking to utilize resources that existing neighborhoods offer, and conserving open space and irreplaceable natural resources on the urban fringe.
Variety of Transportation Choices (P7)	Providing a wider range of transportation options to improve current systems.
Community-stakeholder partnership (P8)	Encouraging community and stakeholder to jointly making development decisions.
Cost Effective Development (P9)	Embracing the private sector to help make development decisions to be predictable, fair, and cost effective.

Source: The official website of Smart Growth Network, http://smartgrowth.org/smart-growth-principles/; Wey, 2015.

The core concept of TOD requires mixed-use, walkable, rich mix of choices, location-efficient development, and adequate density to support public transit services with the scale of the neighboring community. Therefore, it is one of the approaches to achieve urban smart growth. The notion of smart city, TOD, smart growth has been applied in worldwide urban planning projects, although land planners and growth management advocates are facing with many economic and political challenges, there is still much to be optimistic about those initiatives towards sustainable urban planning and development.

2.5 Experience of TOD Implementation

There are a couple of cases commendably dealing with the relationship between transit service and land use in cities across the world. This section mainly studies on the paradigms considered to be successful transit cities, and attempts to draw lessons for sustainable urban planning and development, desiring to create world-class transit systems and discern strategies for reducing automobile use and increasing the utilization rate of public transit.

2.5.1 Stockholm: multi-centered built form

Stockholm, Sweden's capital and largest city with around 795,163 (by the year of 2007) residents, is the best example of coordinated planning of rail transit and urban development. Half of inhabitants live in the central city, while half of remaining residents live in planned satellite communities that orbit central Stockholm and are rapidly linked to the core by a regional rail system, Tunnelbana (Figure 2.1). The star-shaped and multi-centered built form of the region is directly caused by a comprehensive planning campaign that targeted overspill growth after World War Two to rail-served suburbs (Cervero, 1998; Pandis & Brandt, 2011). Today, more than a half of Stockholm's residents and workers in new town commuting by train or by bus (Suzuki et al., 2013). Stockholm indicates that highly successful and sustainable transit systems can be mounted in an affluent region with a pretty high quality of life.

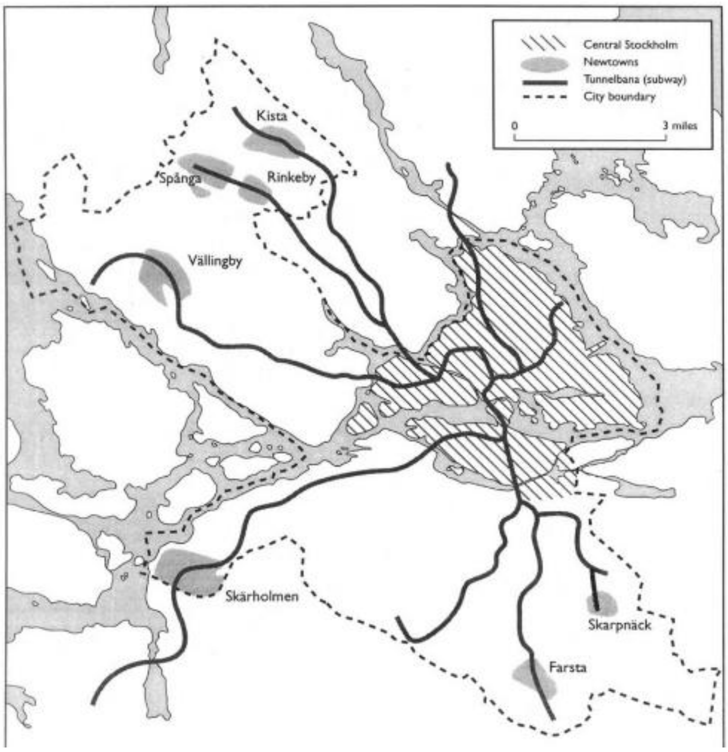

Figure 2 Stockholm's rail transit system and major satellite new towns (Cervero, 1998).

The blueprint for building Stockholm's transit metropolis came from Seve Markelius's *General Plan of 1945-1952*. The regional rail system Tunnelbana became the primary device to achieve Markelius's planning vision and was designed to focus on Stockholm's redeveloped core. The form of this rail system is radial, containing 100 stations in 110 kilometers (Stockholm Business Region, 2015). In the regional plan, the function of satellite in sub-centers is playing a role as complements to central area, and the traffic flows are bidirectional and well-organized (Cervero, 1995). The co-development of rail-served new towns and the Tunnelbana metro systems set the stage for a powerful transit-land use nexus. In Markelius's regional master plan, transit has become the instrument for linking city and suburb as well as for conserving green space and the surrounding countryside.

There are two generations of new towns in Stockholm. The first generation new towns were designed using a common formula: emphasizing on the balance between housing and employments, which means the planning of commercial, business, or residential land should based on the scale of population. That is why Cervero (1998) called them ABC towns (A stands for housing, B stands for jobs, and C stands for services). Unexpectedly, after new towns have been built, most residents in new towns do not work in these new areas, while most employees in new towns do not live in these new districts (Hall, 2002). Therefore, when build the later-generation new towns, planners stressed on the balance between different towns rather than the balance inside every new town, because each one has its own characters, and people can easily access to any new town by rail transit. Besides, the decoration of metro stations in Stockholm is known as its artistic creativity.

Figure 3 The artistic decoration of the Stockholm metro. The left one is the first metro station in Stockholm, and is also where the idea of bring artwork to the metro began. The right one contains Muhr’s 2.5 meters tall tulip sculptures appearing as they are also waiting for the train, which create a more pleasant environment for passengers. (Cox & Rodriguez, 2015)

Lessons learned from Stockholm can be summarized into four main aspects:

1) Setting a long-term urban plan

Stockholm has set long-term plans for urban development before more than half century:

advocating transit-oriented construction, striving to develop public transit, and integrating urban land use with transportation. This long-term plan not only formed multi-centered land layout, but also conserved green spaces among new towns. In this way, strategic planning contributes to sustainable urban development in economy and environment.

2) Creating unique new towns

Experience shows that a job-housing balance and self-containment are not essential in reducing automobile dependence. In order to be fully functional and self-contained, first generation new towns over focused on a job-housing balance and tried to decrease the rely on urban center; conversely, the planning resulted in heavy traffic pressures on city center. Therefore, later-generation construction started to expand own characteristics. For example, Spnga has been built as an immigrants town, Kista has emerged as a high technopolis, while Sharpnck has been designed as a neo-traditional community. These prove that transit-oriented communities need not to be isolated islands within the larger metropolis, and unique new towns are able to take full advantages of their resources, achieving low energy consuming.

3) Developing high-efficient commuting patterns

One of Stockholm's most remarkable transit achievements is its incredibly balanced two-way traffic flows. During peak hours, "directional splits of 45:55 percent" (Cervero, 1998, p.126) are demonstrated in Stockholm which is not uncommon on many rail lines. Workers commuting to jobs in rail-served suburbs have produced this noteworthy balance. Moreover, although Stockholm is a prosperous region where most households own cars, which means Stockholmers enjoy high levels of automobility but many of them prefer to leave cars at home, instead taking transit for the daily routine of traveling to and from work. Highly efficient transit patterns not only benefit the society but also contribute to create an eco-friendly city.

4) Government support

The physical integration of suburban development and rail transit is not the sole reason behind transit popularity in Stockholm. Diverse supportive public policies have been essential as well. Stockholm officials have opted to reward environmentally sustainable transport by setting transit fares low. With adult cash fares of US$1 to US$1.5 per trip and deeply discounted multi-trip strips available. By contrast, parking and taxi fares are expensive especially in central Stockholm. Reasonable allocation of transport charge is helpful to control the traffic pressure, achieving economic, environmental and social sustainability.

In conclusion, Stockholm's strong built form with regional core orbited by transit villages deserves much of the credit for low automobile dependence. A handful of transit villages in a landscape of sprawling development will not yield significant mobility or environmental benefits. Only community-based planning and design can a sustainable transit metropolis start to take form.

2.5.2 Copenhagen: hand-shaped land-use transport plan

The City of Copenhagen, located in eastern Denmark on the island of Zealand, has a population of about 763,908 (601,448 live in the Municipality of Copenhagen) while the larger urban area has a population of 1,280,371 within its 615 square kilometers urban land area (Denmark Statistik, 2016). The city of Copenhagen is the nation's capital as well as its commercial, industrial, and cultural center. To ensure the greater Copenhagen's development supports broader national interests, the Danish government has enacted much of the regional planning that has taken place during the post-World War Two era. As in Stockholm, a strong regional land-use vision has induced a radial rail system that efficiently links master-planned suburbs.

The urban development of Copenhagen is a paradigm of rail transit's role as an instrument for creating a special built form—a hand-shaped cityscape with radial corridors, like figures—that radiates from central Copenhagen, separated by green wedges of woodlands, farmlands, and public recreational space (Danish Ministry of the Environment, 2015). In 1947, Copenhagen planners introduced the Figure Plan, adopting the image of a hand with five fingers that emanate from urban center to the north, south, and west with each finger aligned in the direction of historical Danish marked town. The city has been organized on the basis of an overall regional structure where urban development is concentrated along city fingers linked to the railway system and radial road networks and where the city fingers are separated by green wedges which are kept exempt from urban development (The Danish Nature Agency, 2015).

Figure 4 The finger plan in Copenhagen (Knowles, 2012)

Copenhagen's hand-shaped built form is the outcome of integrated rail transit and urban development under the 1947 Finger Plan and its subsequent updates. Most urban expansion has occurred along the five fingers and central Copenhagen remains easily accessible by train, while green wedges have not been devastated until now (Cahasan & Clark, 2004). Of course, Copenhagen is not simply a story of constructing rail-oriented new towns and urban growth by enhancing the viability and aesthetic qualities of the traditional city center, meanwhile, streets and curbsides have been dedicated to pedestrians and bicycles (Peters, 2015). Most transit users today reach central city train stations by bike or on foot.

Figure 5 Copenhagen downtown pedestrian street. Strøget in downtown Copenhagen is believed to be the longest pedestrian-only shopping street in the world. (Rodriguez, 2013)

Figure 6 Copenhagen green bicycle routes. These peaceful cycle-ways are not intended to be a substitute for existing cycle-ways, but a supplement where bikers can ride free of automobile traffic. (DAC&LIFE, n.d.)

2.5.3 Curitiba: trinary road concept

Curitiba is a pioneering example of integrated transportation and land use planning around a Bus Rapid Transit (BRT) system which is one of the most sustainable transit systems created in the medium-size metropolis in south Brazil. Curitiba has applied highly ingenious low-cost strategies to cope with rapid growth through visionary planning and brilliant leadership. And it was one of the first cities to close off downtown streets to cars and return this space to pedestrians.

Curitiba is the capital of Parana which is a mainly agriculture state in southern of Brazil and located near the coastal mountain range. In 1965, there were 400,000 residents within a 431 square kilometers area, while its population surpassed 1.8 million in 2015 (TCRP, 1996). Due to the rapid population growth, Curitiba was poised to become a sprawling and uncontrollable city. But through integrating transportation and land-use planning, comprehensive urban planning strategies have been adopted to change the city.

A crucial step toward creating Curitiba's structural axes is the establishment of the "trinary road concept" (Transportation Research Board, n.d.). This unique Curitiba innovation symbolizes the essence of integrated mass transit, roadways, and land uses. The trinary road system is comprised of three main routes shown in Figure 1. The route in the center also consists of three roads (shown in Figure 2): dedicated lanes in the center exclusively used by the express buses bringing people to and from downtown, two surrounded lanes for local traffic as to allow access to the local area by car. Running parallel to this center route are two, one-way direct line routes (shown in green and blue). These routes have dedicated lanes for direct line buses and also lanes for local traffic allowing access to downtown (Karis et al., 2006).

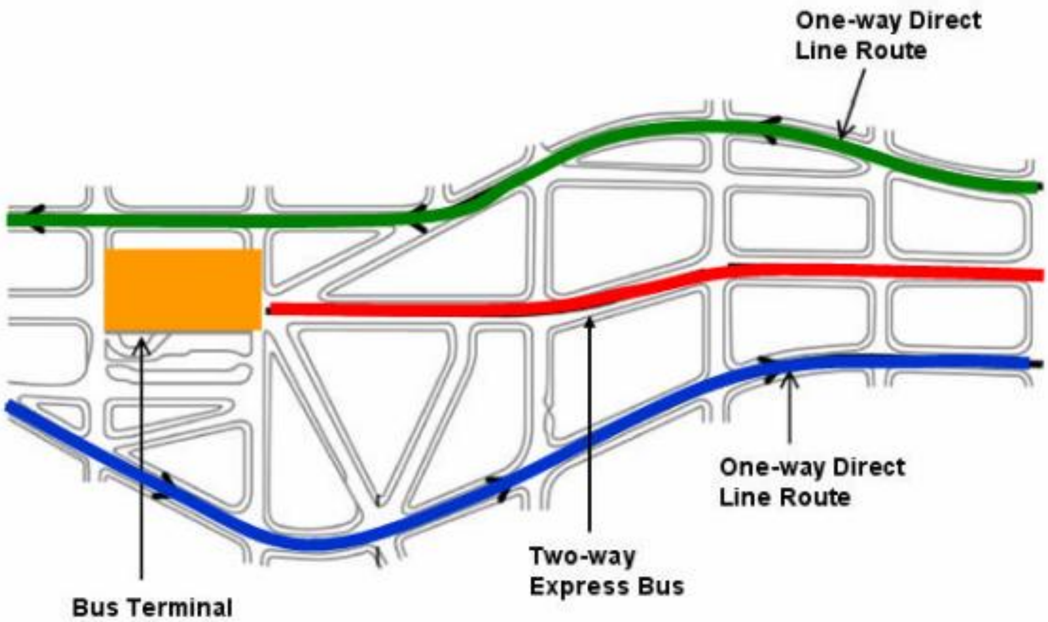

Figure 7 The Trinary Road System (Karis et al., 2006)

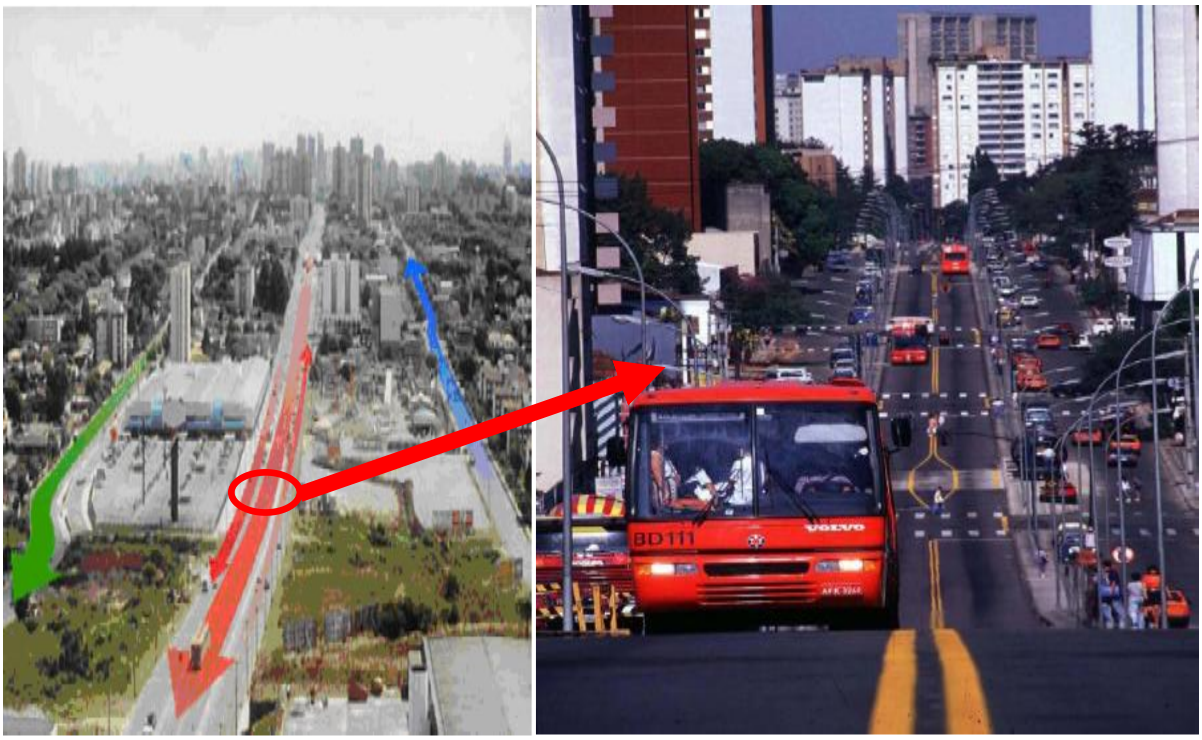

Figure 8 The central avenue in the trinary road system also consists of three roads. (Jian, 2010)

The trinary concept also clearly ensures that land uses and roadways are also compatible. Land uses that benefit from exposure and busy traffic (including retail shops and consumer services) occupy the ground and first floors of the auxiliary lanes and one-way couplets. Curitiba encourages intensively high-density development on both sides of BRT axes; population density and plot ratio are decreasing along the axes. High-volume roads are buffered by high-rise buildings from low-density residential neighborhoods.

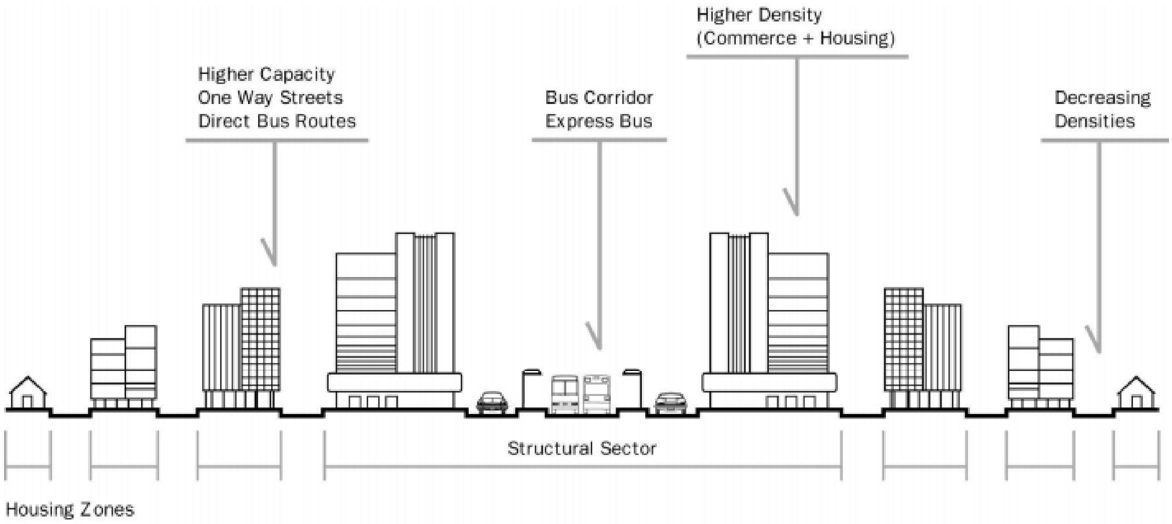

Figure 9 Land use and densities along trinary roads (TRB, n.d.)

Curitiba's patented boarding tubes and high-capacity buses are one of the excellent speedy services. These tubes function as mini-stations for direct line and conventional buses, allowing passengers to pay fares before buses arrive and board without having to step up (CTS-Brasil, n.d.). Bus tubes are extremely convenient and efficient. They allow eight passengers to enter and exit buses per second limiting delay time between stops (Karis, B. et al., 2006). Except for a person only needs to pay once when entering the bus tubes or terminals, this single charge allows passengers to exchange buses and move throughout the city, which greatly reduces the travel time and delay between stops.

Figure 10 Curitiba's bus boarding tubes. Left, the interior of downtown multi-bus tubes look and function like a metro station; right, downtown bus tubes support five-door boarding, and a folding ramp allows same-level boarding and alighting. (Jian, 2010; Karis, B. et al., 2006)

The current settlement pattern and transit system in Curitiba are not a series of lucky events or the result of a never-to-be-repeated visionary plan. Conversely, early master plans set out broad visions for the future. Actual implementation began with small steps, often occurred in fits and starts, and on a trial-and-error basis. More importantly, mistakes were made, providing lessons that were later put into better use. By implementing low-cost and fast-turnaround solutions to urban unsustainable issues, as well as keeping the urban development process simple and transparent, Curitiba has been able to achieve development goals rapidly.

2.5.4 Hong Kong: rail + property development

Hong Kong is worldwide known for its successful integration of rail transit investments and urban development. Enduring extremely high densities, the city could not operate smoothly without worldclass railway services. Hong Kong is one of the few cities in the world where public transport makes a profit. More than half of all income to the railway operators comes from property development (McKinney Company, 2016).The city has insistently pursued transit value capture to finance railway infrastructure through its “Rail + Property” (R+P) development program.

Hong Kong’s urban densities and built form are contributing to railway profits. Nearly 7 million inhabitants live within Hong Kong’s total land area of 1,107 square kilometers. The vast majority of residents live in the city’s built-up coastal areas, producing the highest net urban densities (more than 26 000 inhabitants per square kilometer) (Cervero & Murakami, 2008). Although Hong Kong’s population growth rate has slowed since 2000, economic activities have not shifted from a traditional manufacturing to a more service-based economy (HKTDC, 2007). Presently, Hong Kong is the recipient of more direct foreign investments than greater Tokyo and Singapore combined (Kawai & Naknoi, 2015). Visitors to Hong Kong directly recognize that public transport is the lifeblood of the city. Hong Kong boasts a rich offering of public transport services including a high-capacity railway, surface-street trams, an assortment of buses and minibuses, and ferries.

Figure 11 Hong Kong’s high-density housing and heavy street flow. (Romainjl, 2015; Romainjl, 2011)

The R+P model is one of the best examples of applying the “value capture” (Cervero & Murakami, 2008) principle to finance railway investments, which is implemented by the Mass Transit Railway Corporation (MTRC), the owner-operator of the city’s largest rail service. MTRC’s central mission is to construct, operate and maintain a modern, safe, reliable and efficient mass-transit railway system (MTRC, 2005 Annual Report). The railway has also played an essential city-shaping role. In 2002, around 2.8 million people (41 per cent of Hong Kong’s population) lived within 500 meters of an MTR station; and one in five households lived within 200 meters of a station (Tang et al., 2004).

One of the good practices of R+P in Hong Kong is Maritime Square, which is part of the development of Tsing Yi station on the new Airport Express Line, designed and managed by

MTRC. A 50-year development right for the site has been granted to MTRC, while MTRC directly sold the right at a considerable premium to underwrite the costs of building the station (Cervero & Murakami, 2008; Ascher & Krupp, 2010), then a private developer used the development right to build residential towers and a shopping center adjacent to the rail station (Hong & Lam, 1998). The resulting mixed-use Maritime Square R+P project embodies a seamless integration between the railway station and shopping centre as well as the above-station residential towers (Figure 3). The towers provide a "temperature-controlled" (Cervero & Murakami, 2008) environment so that residents can go to the shopping mall from their apartments and then directly into the metro station without stepping outdoors. The integration of physical characters which were determined at the master planning stage made Maritime Square become to reality (Tang et al., 2004).

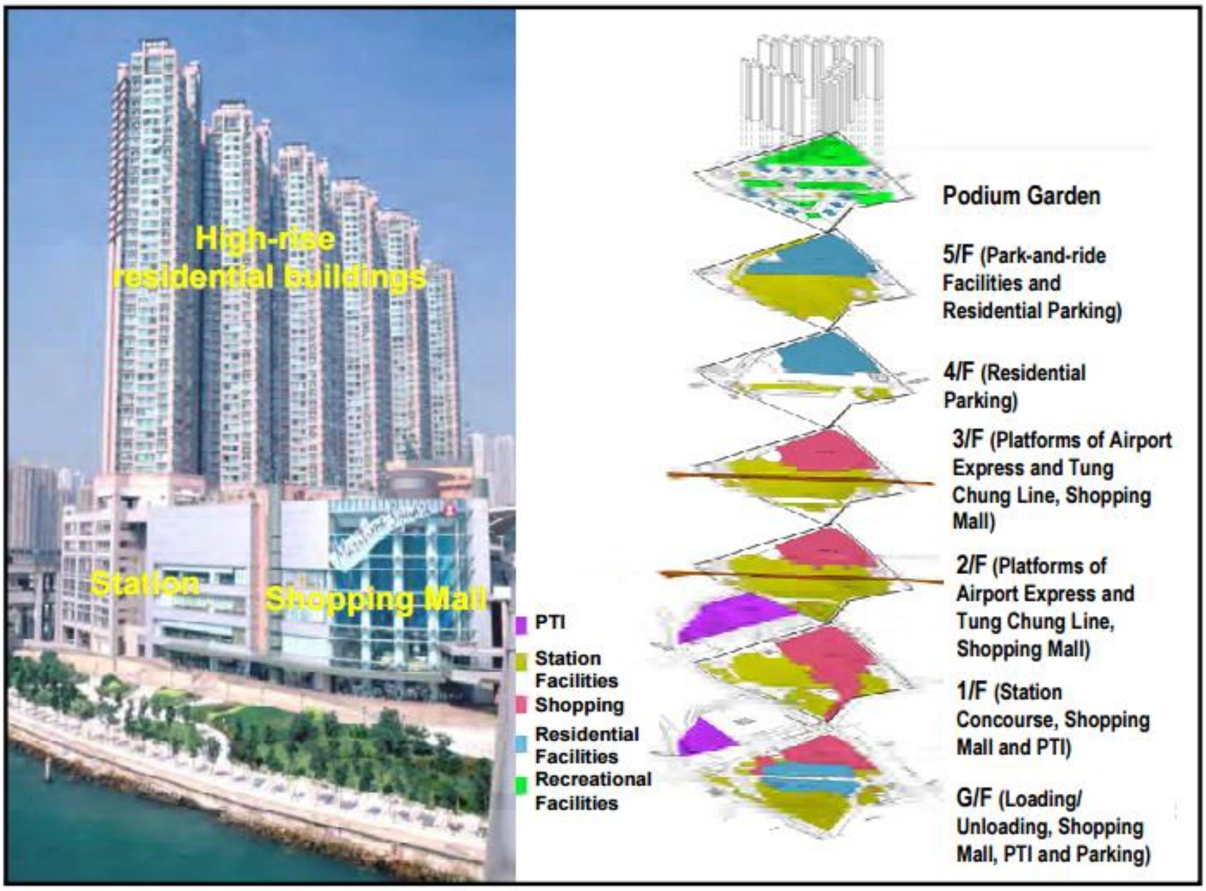

Figure 12 Maritime Square residential-retail plan above Tsing Yi Station. Maritime Square boasts hierarchically integrated uses: the shopping mall expands from the ground floor to the 3rd level; the station concourse is on the 1st floor, with rail lines and platforms above and auxiliary functions (like public transport/bus interchange and parking); above the 4th and the 5th floor, residential parking and a podium garden provided. (Cervero & Murakami, 2009)

The granting of exclusive development rights is what fuels MTRC's R+P program. The Hong Kong government does not give any cash subsidies to MTRC for the railway construction; instead MTRC is offered "an in-kind contribution in the form of a land grant that provides the company exclusive development rights for land above and adjacent to its stations" (Ascher & Krupp, 2010; Hang-Kwong, 2011). The grants make MTRC relieve from purchasing expensive land on the open market. Moreover, in order to generate more income, MTRC takes full advantage of real estate development potential of its stations. This kind of property development has been described as the "jewel in the MTRC's crown" (Ho, 2001).

The benefits yield by R+P projects should be reflected by gains in both ridership and real estate prices. Because of their generally high-quality designs, good intermodal connectivity and efficient on-site and off-site circulation, one would expect a considerable increase in ridership at R+P stations compared to others (IRES, 2015). Ridership gains are mainly public benefits to the perspectives that they reduce traffic congestion, air pollution and energy consumption. And as long as R+P projects are desirable places in which to live, work or run a business, property prices will rise as people and institutions compete for limited supplies of floor space (Suzuki et al., 2013). Rent premiums reflect private benefits due to the demand for high-quality development and accessible locations in such a dense urban setting.

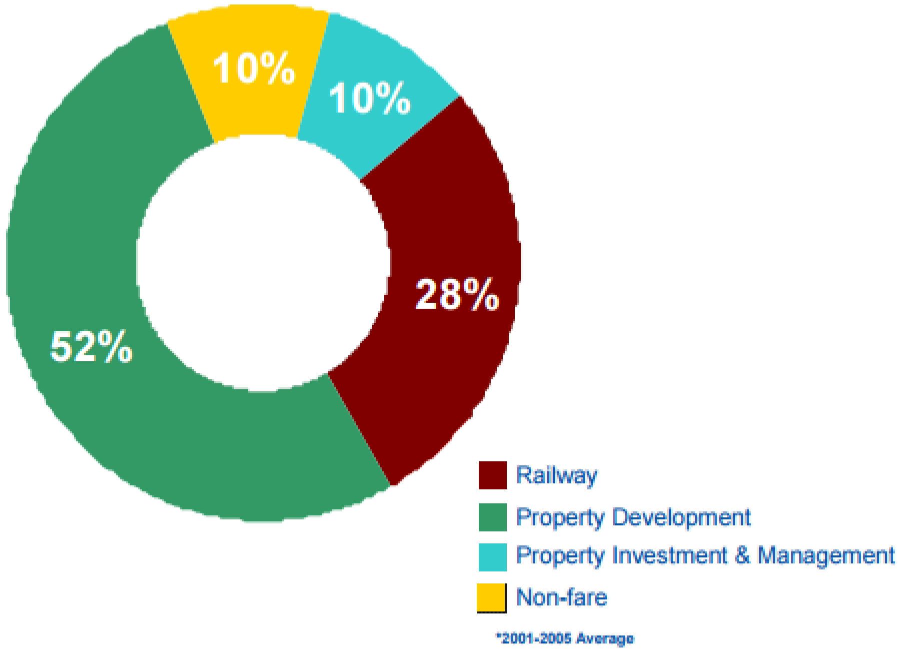

Figure 13 MTRC revenue sources, 2001–2005 average. (MTRC financial accounts, 2008; Cervero & Murakami, 2009)

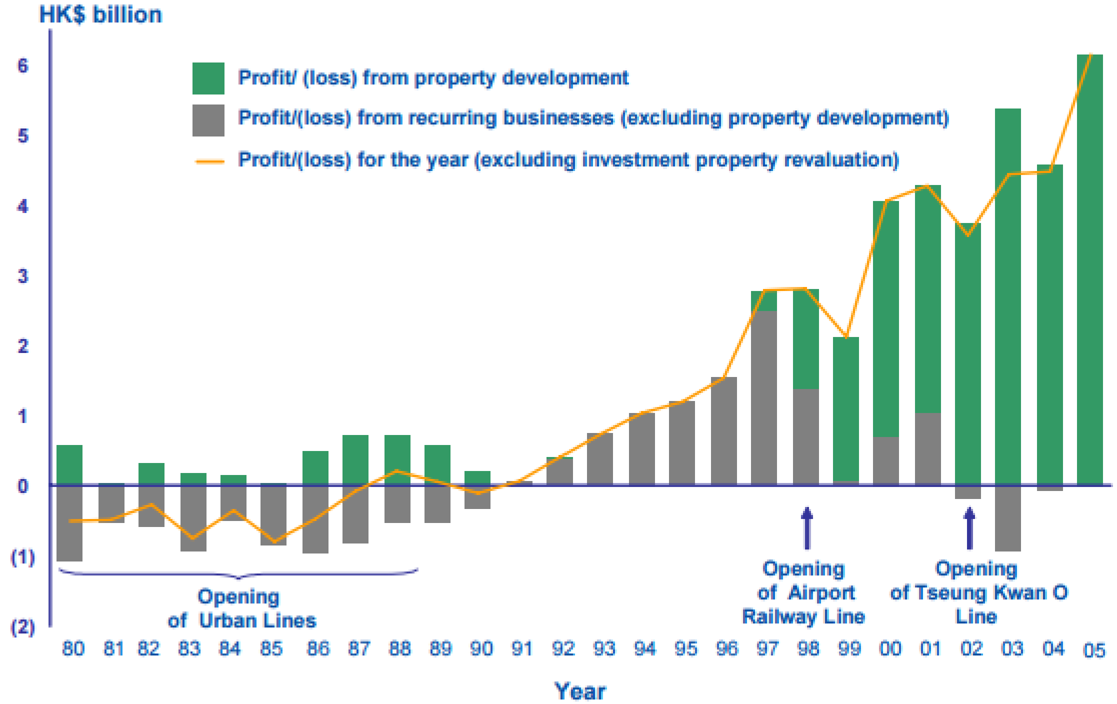

Figure 14 Trends in MTRC's profits and losses from property development and recurring businesses for the 1980–2005 period (Cervero & Murakami, 2009)

Hong Kong's experience with the R+P program shows that transit value capture is certainly a viable model—not only for sustainable finance, but also sustainable urbanism. MTRC is able to offer shareholders substantial returns on investment by means of property development, which currently generates over half of the company's income. Streams of income from past R+P projects are helpful to finance future railway extensions; these expansions will in turn have their own R+P projects that finance capital investments even further downstream. The Hong Kong style rail and property development has formed a virtuous cycle of feasible railway operations and a highly transit-oriented built form.

2.5.5 Lessons for China

Although the numbers of populations of Stockholm, Copenhagen, and Curitiba are very small compared to that of the two Chinese metropolises, Beijing and Shenzhen, the planning concepts of TOD applied in these paradigms can still provide many valuable insights to China's urban planning and TOD implementation. For example, the trinary road concept of Curitiba is helpful to address the traffic congestion in Chinese metropolises; the multi-centered built form of Stockholm can be implemented in China's TOD planning; and the idea of Copenhagen's hand-shaped land-use plan encourages Chinese cities to be built following the urban public transit lines. Therefore, these TOD practices are relevant to the selected Chinese case studies.

Many Chinese cities are approaching the size (roughly 5 million inhabitants) and dense thresholds (15 000 inhabitants per square kilometer in the urban core) often thought necessary to justify railway investments (Cervero, 1998). And many are becoming more and more automobile-oriented. Approximately twice as large in population, Beijing has 2.8 million registered vehicles compared with Hong Kong's 0.5 million (Tang et al., 2004).

A first step to absorb the models like R+P is to emphasize the importance of integrating public transport and urban development more generally. To a large extent, there has been a disconnection between the two. Beijing currently operates nineteen rail transit lines, with a total track length of 574 km (Beijing Subway, 2016). Beijing's rail transit expansion has been accompanied by a real estate boom. Yet there is a lack of integrated planning and development, although new buildings might be spatially proximate to rail stations. Housing projects followed Beijing's rail transit networks, but jobs and service have not (Zhang, 2007). Many new communities developed along rail corridors have become veritable dormitory communities. Skewed commuting patterns have resulted. A study of three residential new towns in Beijing's rail-served northern suburbs found as many as nine times the number of rail passengers heading inbound in the morning peak as heading outbound (Lin & Zhang, 2004). Poor integration of station designs with surrounding development has led to chaotic pedestrian circulation patterns and long passenger queues at suburban stations like Xizhimen on Beijing's Line 2 (Zhang, 2007).

However, experience with R+P and other approaches to transit joint development cannot be directly applied in Chinese mainland cities as private companies cannot own land outright, thus the government's ownership and control of land is one prospective stumbling block. The trend towards single-use, master-planned projects with repetitive architecture on superblocks in suburban settings could also work against TOD, as could the emphasis on lacing Chinese cities with massive thoroughfares and expressways in an apparent attempt to mimic Western patterns of infrastructure and suburbanization. Still, the theory of value capture is an idea that resonates with many Chinese officials. Many recent urban rail projects (Beijing Line 4, Chengdu Line 18, Shenzhen Line 6, etc.) start to apply the public–private partnerships to develop urban railways. As rapid urbanization continues to choke the streets of many Chinese cities with traffic and threatens environmental quality locally and on the global stage, it is crucial that arguably the most sustainable form of urbanism—the linkage of land use and public transport—be aggressively pursued. Hong Kong's R+P model is believed as the best template available for sustainably financing transit and building cities.

2.6 TOD in China

2.6.1 Differences with North America

After experiencing car-oriented development, the developed cities in North America are facing serious suburbanization, functional decline of old city center, massive private cars, low land utilization, and dispersed urban spatial layout. The spread of private cars has made the residents in North America adapt to car travel and single detached homes, to a large extent, they would not prefer public transportation and high density accommodations. Based on this situation, the implementation of TOD is affected by the adjustment of market mechanism, and may confront enormous risk and uncertainty.

Compared to that in North America, the urbanization in China is still at an accelerating development stage. Because of high population density and relatively short land resource, private cars have not played a leading role among the means of traveling. Therefore, the implementation of TOD in China mostly depends on the controlling and support of the government. The differences between the cities in China and the United States are listed as follows:

Table 3 The differences between the cities in China and the United States (Kong, 2013)

Compared Items	**China**	**America**
Urban spatial structure	● Poly-centric ● Passive expansion ● Compact space layout ● High land development density ● Inner city with cohesive function	● Multi-centric ● Active expansion ● Incompact space layout ● Low land utilization ● Inner city with declining function
Residents travel modes	● Comparatively low rate of car ownership ● Urban transport is transforming	● Car is the dominating travel mode ● Car-oriented is developed
Living habits	● High population density ● High density living environment	● Low population density ● Single detached homes
Land policy	● The state owns the land; and the land-use right can be granted or allotted through bid inviting, auction and listing	● Private land ownership
Regulatory authority	● Urban planning, transportation system and land development are managed by three different departments	● Metropolitan planning organization (MPO) coordinates the relations among urban development, transportation and land use
TOD policy	● The Chinese government has advocated giving priority to developing public transport	● Many policies has been issued to promote TOD implementation, including *Growing Smart Legislative Guidebook*

Through contrast analysis, although there are obvious differences among different states, China with its special national conditions and current situation has more advantages when implementing TOD mode to achieve urban sustainability.

1) The land development in China is mainly mixed development, and also residents have adapted to the high density housing style.

2) The state owns the land and has autonomy in planning and development, which provide convenience to implement TOD.

3) Although the number of automobiles is continuous increasing, not every home has owned a private car. Meanwhile, the car-oriented development has not developed.

4) Considered of the huge passenger flow during the rush hour, low-volume public transportation cannot satisfy the demand of travelling. *The Priority to the Development of Urban Public Transportation under The State Council's Guidance* in 2012 states that, “on the premise of low income level, the priority to develop urban public transportation is a primary initiative to build resource conservation and environment friendly society” (The State Council, 2012). Driven by the policy, the construction of high-capacity urban transit and bus rapid transit in the countrywide is gaining steam.

5) The research of TOD concept and practice in North America is relatively comprehensive, which could provide some valuable insights and experience to China.

2.6.2 TOD Planning Conception

In order to promote a coordinated development with land use, public transportation must play the leading role sufficiently in macro-level urban development, middle-level regional development and micro-level community development. The research attempts to explain the planning conception of TOD in these three levels.

1) Macro level

Macro-level planning should take city development status (including city spatial structure, urban land use data, demographics, industrial distribution, geographical conditions, etc.), future goals, and TOD conception and principles to set urban master planning. Meanwhile, urban planning should combine transport planning with land planning.

Transport planning is supposed to select which mode of urban public transit system firstly, and then determine the primary public transport corridors. Following measures should be taken to promote the implementation of the planning and to coordinate all kinds of transportations. By contrast, land planning should be based on urban public transport system and its particular development plan; land use guidelines and adjustments are needed. There are four main modes in urban public transport system:

Table 4 Four main modes in urban public transport system (Zhao, 2008):

Modes	Description
Basic Mode: walking +bicycling + conventional bus transit	Normal bus transit is the backbone of urban public transport system; it can satisfy most traveling demands.
Elementary Mode: walking +bicycling +	Compared to the basic mode, elementary

conventional bus transit +exclusive bus lane	mode emphases on the priority of buses.
Intermediate Mode: walking +bicycling + conventional bus transit +exclusive bus lane +urban rail transit	Multiple urban public transit systems provide more travel choices to ease traffic pressure.
Advanced Mode: walking +bicycling +conventional bus transit +exclusive bus lane +urban rail transit +comprehensive transfer hub	Comprehensive transfer hubs realize the transfer between rail transit and normal buses. The mode has formed a multidimensional consummate system.

When selecting the modes of urban public transport, the scale of city, economic condition, population and specific demand are the main determinants. For small-scale city with small population and relatively lower economic level, the Basic Mode is the best choice. By contrast, Elementary Mode suits medium-size city, while large cities suit Intermediate Mode and megalopolis suit Advanced Mode.

When setting the guidelines of land use, urban land development strategies should be based on the public transport corridors, attending to walking-friendly and high-efficient. For example, “Land development intensity is inversely proportional to the distance bus lines” (Zhang, 2012) is principle which should be followed in land planning. Therefore, commercial estate and the third industry are preferably developed near the public transport corridors; conversely, the enterprises occupying a huge area are usually far away the public transport corridors. At the same time, controlling construction land, conserving agriculture land and protecting cultivated land are helpful to build eco-environment and achieve sustainable using of land resource.

Combining land planning and transport planning, a balanced develop model can lead the urban space continuously stretching with multicenter groups (Kong, 2013). The model is a combination of radial urban rail transit and annular bus transit, and the intersections of radial urban rail transit routes converge to Central Business District (CBD) integrating residential, commercial, medical, education and recreational function districts. One advantage of this model is complete living facilities, which can satisfy the basic needs of living, decrease unnecessary trips, and ease the pressure of traffic and housing.

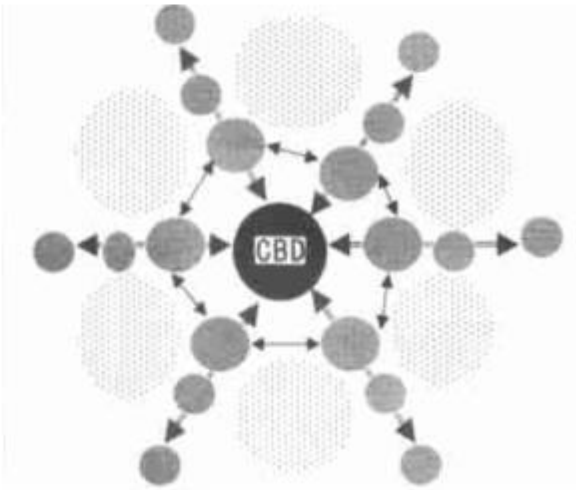

Figure 15 Urban space continuously stretching with multicenter group model (Kong, 2013)

2) Middle level

Although macro-level planning is overall consideration for urban development strategies, it cannot be detailed to every specific project. Thus, middle-level planning is required to formulate regional plan and implement overall planning, which can make urban planning more refining and thorough. Regional planning mainly contains the setting up of regular buses and the connection between bus routes and urban rail transit. A complete urban public transit system is necessary for travel conditions.

Some common problems exist in China's public transit system: for passengers' perspective, the heavily overloaded buses with unpunctual schedule are much crowed and with poor service, and also the station facilities are rudimentary; for urban development perspective, private cars always interfere with buses owing to lack of bus-only lanes, furthermore, some bus companies occupy carriageways or roads for pedestrian rather than using parking lots. These problems result in lower commuting efficiency and constraining the development of public transit. To solve these problems, the government can adopt experience from Curitiba by building drum stations and exclusive bus lanes, or from Copenhagen by applying low bus fare system and improving car purchase tax to promote the usage rate of buses.

Due to the limited coverage area for urban rail transit which can only solve the main road passenger flow, seamless connection between rail transit and regular bus transit is very necessary, because regular buses can be an assist or supplement to rail transit. It proves that the routes of regular buses should be built into every TOD district, and vertical intersecting with rail transit routes is better than parallel.

3) Micro level

On a micro level, based on the middle-level planning of urban transport, the internal layout of TOD communities includes the establishment of comfortable pedestrian environment, multiple and compact land development, and the systematic design of roads. One aim of the TOD communities is encouraging people to choose walking or bicycling and reducing the use of private cars.

Firstly, the design of internal roads and intersections should ensure safety and comfort of walking and bicycling, and then integrate the general motorway with exclusive bus routes. For example, sidewalks have to be built on both sides of main roads or two-way traffic lanes, but for one-way lanes, sidewalks are not required on both sides. Besides, benches can be sited on pedestrian streets if it is necessary, and a pedestrian crosswalk is a must on intersections.

Secondly, to keep every road well-organized, the main roads should be connected to core commercial districts or bus stations; and other streets are supposed to connect with open space or residential areas.

Lastly, the exits of buildings should try to face streets and the distance to streets should be proper. Diversified design along the streets is helpful to ease the sense of fatigue during walking and short psychological distance.

Multiple and compact land development is not only the core of TOD community internal design, but also the key to successful TOD planning. The multiple and compact land development proves that different function land is centralized developed near the urban rail transit stations. More specific, commercial estate or office buildings are allocated near or upon the stations; residential districts are divided into different patterns including multistory buildings and high-rise buildings, while social affordable housing and low-rent housing are allocated secondary areas. Meanwhile, land development density along the rail transit gradually reduces outward. Applying this planning conception can effectively control the extension directions of cities, preventing chaotic urban sprawl.

2.6.3 The Implementation of TOD

According to the development situation and history, Chinese cities generally contain old town and new urban districts. Old town refers to the original district before expanding; it is not only the center of politics, economy and culture, but also a gathering place containing commercial estate, education, medical and transportation services. By contrast, new urban districts are the areas built after expanding, which are generally away from old town. Recently, old town and new urban districts in China are encountering many unsustainable issues during the urbanization process. The following section attempts to discuss issues and approaches to implement TOD in a sustainable way.

2.6.3.1 TOD in Old Town

Old towns are the inheritance of historical civilization and also the gathering place of modern civilization; hence, they not only protect cultural heritage but also satisfy the modern living demands. Planners realized that it is infeasible to develop old towns without protecting cultural heritages, and it is also impossible to keep still without any development. Therefore, the renewal of old towns should follow the principle called "Protection for development, development for protection" (*National 12th Five-year Plan*, 2011). However, after dozens of years' renewal, most urban old towns are tending to chaotic sprawl without achieving the requirements for urban civilization.

1) Superblock phenomenon

Superblock is a widespread urban layout with large scale and internal spatial characteristics in most Chinese cities, which refers to the districts surrounded by city main roads or loop lines. Many old towns after reconstruction have become to this type (Deng, 2015).

After expanding, the roads between different original blocks have been transferred into new blocks, hence an increasing number of gated communities have formed. Superblock and gated communities decrease the density of urban road network and reduce the walking accessibility of external urban space. Consequently, more and more residents rely on private cars; traffic pressure is increasing; isolated communities reduce the links with other blocks. Although transport departments are trying to broaden roads to ease the traffic pressure, a vicious cycle results in the broader roads the more cars. Besides, under the impacts from isolation and land value, the wealth gap and social stratum polarization is becoming greater.

2) Housing and traffic pressure

Compared to the newly built districts, old town has complete supporting facilities involving commercial, educational, medical, and recreational fields. Thus, old town is more convenient for people living; more and more people pour into urban center, resulting in original buildings cannot satisfy the living demand. Land developers take the advantages of old town rebuilding to develop enormous real estate markets and raise housing price. Now plenty of people cannot afford the continuous increasing housing price, while they have to purchase cheaper residence in suburb. The commuting between urban center and suburb has increased the cost in transportation, and also the traffic pressure is undoubtedly increasing.

3) Land derivational problems

Many unreasonable phenomena exist in old town development projects. Firstly, the land development is unbalancing. That is to say, only the districts with high-density population or enterprises are developed intensively, while other districts face lower land utilization rate.

Besides, it is not hard to see that along-street areas are full of sprouting skyscrapers, while the internal districts are usually idle or with low-density land usage. In addition, there are also plenty of urban villages inside the city; although they were built intensively, their plot ratio is relatively low.

Not only is the transportation demand in old town the largest, but also the most complex. Some common transport problems exist in old towns: incomplete public traffic systems, unpleasant environment for walking or bicycling, weak road traffic facilities, an increasing number of private cars, daunting traffic jams, and mutual interference between automobiles and pedestrians.

Furthermore, unreasonable land development and traffic problems result in a series of environment and energy problems. For example, partial intensive land development reduces green coverage rate; along-street development neglects the harsh environment of urban villages; the increasing number of private cars need more energy consumption, meanwhile, emitting more carbon dioxide would make worldwide climate change.

In order to solve the problems listed above, three main strategies can be applied:

1) Return to human-scale community

The aim of this strategy is developing neighborhoods that promote walking by narrowing down supper blocks to small scale blocks. Based on the structure of blocks, dividing a supper block to subdivisions can strengthen the connection between different districts, avoid social isolation and reduce the usage of private cars. According to Lynch, city performance can be measured solely by its urban spatial form. A good city form can produce appropriate settlements and qualities that allow "development within continuity via openness and connection" (Lynch, 1984). Therefore, a human-scale community ought to meet these requirements: "vitality, sense, fit, access, and control" throughout efficiency and justice (Llynch, 1981). Associated to China's context, opening the internal roads within residential super communities to municipal path is a recommendable strategy. To keep smooth traffic flow, the internal roads can be as one-way if they are too narrow. To keep walking safety, the roads should be classified to sidewalks, motorways and non-motorized vehicle lanes. And also, in order to reduce the chance to travel, the ground floor of buildings can be reformed to retail stores and satisfy the basic needs of residents.

In addition, more public transit lines are supposed to be built to support transport services for residents. In fact, the idea of small-scale blocks is one kind of humanistic design; it avoids the disadvantages of "super block, broad road" (Tan, 2016) and improves the walking accessibility. Therefore, this strategy completely meets the urban spatial requirement of TOD mode. Confronted with increasingly heavy traffic congestion, people might think the broader the road, the smoother the traffic. Actually, only broadening roads cannot solve traffic congestion, while more "one-way binary roads" (Calthorpe, 2002) are helpful to ease the traffic jams. For example, avenues could be divided into two one-way streets setting a block apart, creating an urban grid of pedestrian scaled streets.

2) Mixed-income TOD development strategy

Mixed-income TOD development (MITOD) refers to the transit-oriented communities combined with different income levels of residents. This strategy can provide different income classes with diverse and affordable housing in a specific transit area.

To apply this strategy, firstly, the allocation standards of affordable housing should be based on urban demographic statistics, income surveys, per capita housing area, etc. And then the number of affordable housing should be properly allocated according to TOD community location and neighboring employment units. Furthermore, the TOD communities should be mixed developed: upscale housing and commercial stores are supposed to be built inside the service radius of public transit stops, while the affordable housing should be located in secondary areas. At the same time, the TOD communities are supposed to be opened to the public with particular sidewalks and bicycle lanes; the accessibility of passing through is convenient for the low incomes to reach bus stops, commercial stores, and employment areas.

The establishment of MITOD communities can not only reduce the social isolation between the rich and the poor but also provide low-income people with affordable housing and better employment opportunities. It contributes to a relatively balanced traffic flow and a stable employment environment.

3) Multimodal public transit system

Attributing to a diverse and complicated characteristic, the urban public transit system in China consists of rail transit, conventional bus transit, bus rapid transit, bicycling, etc. Only by coordinating these diverse traffic modes could the urban public transit system achieve optimal benefits.

Firstly, the construction of a complete urban transit corridor should rely on urban rail transit and bus rapid transit. What's more, this corridor is supposed to be built follow the intensive passenger flow, in order to undertake a large proportion of urban traffic flow.

Secondly, the establishment of feeder bus routes should be based on conventional bus transit to assist the urban rail transit and bus rapid transit. A complete urban transit system can improve the coverage rate of public transportation, and an integrated transfer hub can achieve the seamless connection between different transportations.

Lastly, a comfortable bicycle system is needed to support the public transit. The bicycle system is divided into two forms:

a) Public bicycle system

A public bicycle system is a service in which bicycles are made available for shared use to individuals on a very short term basis. Bike share schemes allow people to borrow a bike from point "A" and return it at point "B". Many bicycle-sharing systems offer subscriptions that make the first 30–45 minutes of use either free or very inexpensive, encouraging use as transportation (Shaheen, 2015). This allows each bike to serve several users per day. In most bicycle-sharing cities, casual riding over several hours or days is better served by bicycle rental than by bicycle-sharing. For many systems, smartphone mapping apps show nearby stations with available bikes and open docks.

Figure 16 Public bicycle-sharing system in Kunming, China. (The author, 2017)

For the purpose of proving affordable and convenient access to bicycles for short-distance trips in an urban area as an alternative to motorized public transport or private vehicles, thereby reducing traffic congestion, noise, and air pollution, a series of public mobile bikes have been applied in most cities in China. People can navigate the exact locations of these bicycles using an installed APP in their smartphones, and find an available bike in a short time. Bicycle-sharing systems have also been cited as a way to solve the "last mile" problem and connect users to public transit networks (ILG, 2011), and also a good way to promote nationwide fitness.

b) Private bicycle system

However, with limits on the number of places where bicycles can be rented or returned, the bicycle-sharing service has therefore been criticized as less convenient than a privately owned bicycle used door-to-door (May, 2010). Hence, a private bicycle system should provide specific parking lots for private bikes near the bus stations or subway stations. With lock stud and management device, the safety of private bikes has been ensured.

No matter which form of the system to be applied, in order to maintain a comfortable bicycling environment and avoid the interference with automobiles, the establishment of bicycle lanes is necessary. Multimodal transit system encourages people to choose low-energy transportation alternatives, which are helpful to reduce traffic congestion, noise, and air pollution.

2.6.3.2 TOD in New Urban District

With a large number of rural population crowded into cities, urban land resources no longer satisfy the people's living demand, resulting in housing shortage. Considering of overloaded traffic and the deteriorating living environment, the government has started to lead real estate developers to develop suburbs and establish a new urban district. However, the construction of new city region has not achieved anticipated goals, many problems exist:

1) Unbalanced land use

The land development in new urban district has two patterns: developing greenfield and expropriating cultivated land. Many uncertain factors existing in the expropriation and demolish process increase the difficulty for development, and it is hard to balance the interests among farmers, the government, and developers. By contrast, it is easier to obtain virgin land. Consequently, the land which is easier to be obtained has been developed to commercial centers, residential areas, or industrial districts; while other land which is difficult to be expropriated is still in idle. This unbalanced situation not only cannot share the burden of old town, but also affects the expansion of the urban land and the scale benefit of urban land use.

2) Simplex industrial structure

New urban districts in China have been divided into two categories: construction-oriented and project-oriented. The construction-oriented urban development mainly follows the conventional pattern, in which the types of industry are too simplex, thereby the economy in this area is hard to be sustainable. By contrast, the project-oriented development invites investment through the government by constructing a large number of productive projects. Although these productive construction projects have promoted economy growth, the construction of basic living facilities (evolving medical, educational, commercial, and recreational) has been neglected.

3) Incomplete public transit system

The connection between old town and new urban districts mainly relies on highways. Long distance and incomplete public transit system stimulate people's car-purchasing desire. In addition, there are generally short of direct road connection between different new urban districts; thereby old town has to be a transit point, which would increase the traffic pressure of old town. Moreover, it is inconvenient for people to take bus with low coverage rate of feeder bus routes, far away bus stations, and long time intervals.

There are three suggestions to solve the above problems:

1) Scientific exploitation and utilization

Before planning a new urban district, the relationship with old town must be clear: with saturated population and limited land resources, residences and industrial factories cannot be over built in old towns, while the communal properties involving education, culture, and commercial should be developed. Therefore, the construction of new urban districts is supposed to focus on livable amenities and industrial bases to share the burden of old town. By doing so, the complementary relations between the old and the new have been based on the independence of living and producing.

In addition, an integrated planning and a comprehensive arrangement are required to balance the land use. The government should urge the process of idle land development and withdraw the overdue, ensure the intensive development of construction land, avoid the waste of land resources, and promote the coordinated development. Meanwhile, the government must enact relative preferential policies or provide subsidies to the farmers whose land has been expropriated. Only by considering of farmers' basic interests, can the difficulties in land expropriation be solved. And the social stability is maintained.

Besides, planning for new urban districts cannot ignore the construction of eco-environment. The planning should prevent developing greenbelts to construction land, reject the construction projects which would cause severe pollution, and protect pleasant living conditions. Avoid making the same mistakes treatment after pollution.

2) Diversified industrial structure

New urban districts should depend on diversified industrial structure to achieve population transfer. Through expanding industrial fields, optimizing the industrial structure, and emphasizing on own core industries, the development of new urban districts can be sustainable. At the same time, in order to enhance the service function of new urban centers, the supporting facilities should be gradually completed, because people are willing to a livable and well-finished district.

3) Priority to public transit

In order to maintain the connection between old town and new urban districts, the development should give a priority to public transit. The linking transit system generally includes mass rail transit and rapid exclusive buses. The route settings are always along the intensive traffic flow to decrease the transportation costs. Besides, the internal transit system should also be completed. Increasing the coverage rate of general buses and shortening the distance between two stops is helpful to provide a convenient commuting condition for new urban residents. In conclusion, according to TOD conceptions, public transit is playing a leading role in new urban development. And the advantages of public transit promote new urban real estate development, which provide an economic support to the new urban development.

2.6.4 Influencing Factors of Implementation

Based on the analysis of the problems existing in old town and new urban districts, there are three different kinds of influencing factors when implementing TOD: pressure factors, state factors, and response factors. The pressure factors include urban sprawl, inefficient land use, traffic congestion, human pressures. The state factors indicate the states of land, traffic, and human under these pressures, while the response factors are the government measures aiming to these pressures. The three kinds of factors directly decide the effectiveness of TOD implementation, and have direct bearing on sustainable cities.

2.6.4.1 Pressure Factors

1) Population

The selection of urban public transit, the determination of public transportation corridors, and the land layout are based on the population. The size of population can affect the effectiveness of TOD implementation. For example, when the scale of a city is invariable, the increase of population will decrease per capita land resources, per capita residential housing areas, and per capita road areas, which will cause a huge pressure on residence, transportation, and land use, and constrain the implementation of TOD.

2) The number of private cars

TOD modes advocate public transit leads urban development, and take the advantages of public transit (including high-capacity, speediness, convenience, etc.) to ease urban traffic congestion. However, the increasing number of private cars will cause more traffic jams and prevent the implementation of TOD.

2.6.4.2 State Factors

1) Construction land area

TOD requires high-efficiency and intensive land use. The area of construction land can reflect the land use situation under the pressures; when construction land area is larger, the density of land use is higher, which means the land use is more rational and intensive, thereby the land is tending to a virtuous circle.

2) Road area

TOD modes emphasize constructing the routes of walking, cycling, and buses. Road area is one of the indicators to measure the maturity level of urban transportation system. The larger the road area, to some extent, the more comfortable the commuting is, and the city is more humanistic.

3) The number of public transportations

Giving priority to public transit is the core conception of TOD. The number of public transportations indicates the maturity level of public traffic facilities. The larger the number, the higher the maturity level, and people have more alternatives.

2.6.4.3 Response Factors

1) Fixed investments per acre

Fixed investments in land is the best fiscal measure adopted by the government to respond TOD modes. The more fixed investments in land, the more intensive the land development is, hence traffic facilities would be more complete.

2) Fixed investments in transportation industry

The high costs of urban rail transit and the terrible situation of general buses require the government to allocate more investments in transportation industry. To build a pleasant, rapid, and convenient commuting environment, *The Priority to the Development of Urban Public Transport* published by The State Council in 2005 indicates that "China should give a priority to the development of urban public transport, and improve the basic public service level."

3 Methodology

3.1 TOD Effects Evaluation

Over the past decade, TOD has gained in popularity as a planning tool to promote smart growth. Although not all new urban planning projects are TODs, most TODs seek to promote the basic concepts of new urbanism. Many articles, books, reports, and plans have discussed the potential benefits of TOD, which vary broadly. But except for studies focusing on transit ridership and land value near stations (Cervero et al., 2004), little empirical research, especially in China, has been conducted to holistically measure the outcomes of TOD.

Across china, various people and organizations are encouraging TOD, not only because it may lead to higher levels of transit ridership but also because it is believed to promote sustainably economic development and environmental conservation, and to increase social diversity not only in the community but also across the region. Therefore, a study on evaluating the effectiveness of TOD is necessary to be conducted.

3.1.1 Indicators of TOD Success in America

TOD outcomes are difficult to define and evaluate, while a survey of scholarly and professional sources in the United States has been presented to begin developing a list of indicators to measure the success of TOD. The Transit Cooperative Research Program (TCRP) provided a good starting point because it contains a stakeholder survey on TOD from 90 transit agencies. These municipalities and agencies were invited to identify any and all possible indicators that could be used to measure the success of TOD. As a result of this research, 56 indicators were identified and were then categorized into five groups (Cervero et al. 2004):

- Travel behavior—parking and traffic flow
- Economic—public and private investment
- Environmental—air quality and energy use

- Built environment—design quality, pedestrian friendliness, and land use

- Social—diversity, safety, and affordability

And the most commonly noted indicators of TOD are listed as follows in descending frequency (Renne et al., 2005):

Table 5 Travel Behavior Indicators

Category	Indicator
Parking	Number of parking spaces for shoppers only
	Number of parking spaces for commuters only
	Number of parking spaces that are shared
	Number of parking garages
	Number of bicycle racks or lockers provided
Traffic Flow	Transit ridership
	Number of shuttle or jitney services provided to and from the transit station
	Vehicle miles traveled (VMT) for residents/employees
	Number of single-occupancy-vehicle trips for residents/employees
	Bicycle activity counts
	Number of traffic control or flow improvements (including traffic calming devices)
	Amount of bicycle lanes
	Pedestrian activity counts

Table 6 Economic Indicators

Category	Indicator
Public Investment	**Municipal Funds**

	State funds:	—Grants
		—Loans
	Federal funds:	—Grants
		—Loans
	Tax abatements given	
	Total public investment	
Private Investment	**Commercial**	
	New or substantially rehabilitated retail/office space	
	Number of convenience retail establishments (e.g., dry cleaning, video rental)	
	Estimated private investment	
	Estimated new property taxes generated	
	Housing	
	New or substantially rehabilitated housing units	
	Minor housing improvements	
	Estimated private investment	
	Estimated new property taxes generated	
	Estimated increase in property value	
	Configuration	
	Studio/one bedroom	
	Two bedrooms	
	Three or more bedrooms	
	Tenure	
	For sale	
	For rent	

	Subsidized units (with income limits)	For sale
		For rent

Table 7 Environmental Indicators

Category	**Indicator**
Air Quality	Amount of air pollution (NO_x, CO_2, PM)
Energy Use	Consumer gasoline consumption

Table 8 Built Environment Indicators

Category	**Indicator**
Design Quality	Presence of pedestrian orientation/human scale
Pedestrian Friendliness	Length of improved streetscape
	Number of improved intersections/street crossings for pedestrian safety
	Length of façade improvement
	Amount of brownfield properties remediated under a DEP-approved plan
	Number/size of vacant buildings rehabilitated or replaced
	Number/amount of underutilized vacant lots reclaimed for construction or green/recreation space
	Number of new or improved park areas
Land Use	Number of mixed-use structures

Table 9 Social Diversity/Quality Indicators

Category	**Indicator**
Social	Amount of crime
	New cultural/artistic institutions or establishments
	Number of neighborhood associations
	Public perception (administered survey)

	Household diversity
	Increase in household disposable income
	Number of affordable housing units

3.1.2 PSR Evaluation Framework

Urban development in China is still in a transition period, and there is a huge distinction in both national conditions and background between China and North America. Thus, the selection of the indicators to evaluate TOD effectiveness should be based on not only the experience from Western countries but also the fundamental realities of China.

The PSR framework was initially proposed by the Organization for Economic Cooperation and Development (OECD) to evaluate the world environmental situation (Adriaanse, 1993). The basic idea was that human activities exert pressure on the environment and natural resources. Consequently, it changes the environmental quality and quantity of natural resources, and society responds to these changes through policies, decisions or management measures of the environment, economy and land use to reduce pressure on the environment and maintain environmental health. The PSR model answers three basic questions, i.e., “What happened? Why did it happen? What do we do?” (Wang et al., 2015). An evaluation index system (Kong, 2013) is adopted and modified based on a pioneering research, combined with the economic, environmental, and social indicators to measure the implementing effects of TOD.

Table 10 TOD implementation effects evaluation index system

Target Layer A	Criterion Layer B	Indicators	Indicators Characteristic
TOD Effects A	**Pressure Index B1**	Population density **X1** (people/sq.km)	Reflect the population pressure on land use
		Annual household expenditure on transportation and housing per capita **X2** (yuan)	Reflect the housing and transportation pressure
		Civil automobiles **X3** (unit)	Reflect urban traffic pressure
	States Index B2	Disposable income of urban residents per capita **X4** (yuan)	Reflect residents' economic status
		Urban residential gross floor area per capita **X5** (sq.m/Person)	Reflect residents' dwelling environment
		Area of urban construction land per capita **X6** (sq.m/person)	Reflect urban land use degree
		Area of roads per capita **X7**(sq.m/person)	Measure traffic facilities perfect degree
		Passengers traffic **X8** (ten thousand person-times)	Reflect the utilization rate of urban public transport
		Number of public vehicles **X9**	Measure traffic facilities perfection degree
		GDP per acre **X10** (100 million yuan/sq.km)	Measure the economic benefit of land
	Response Index B3	Investment in fixed assets per acre **X11** (100 million yuan/sq.km)	Urban sustainable development measures
		Fixed investments in transportation industry **X12** (10 thousand yuan)	Traffic facilities perfect degree measures
		Fixed investments in real estate industry **X13** (10 thousand yuan)	Residents' dwelling environment measures

The explanation of indicators is listed below:

Table 11 Indicators explanation:

Indicators Layer B	**Indicators Explanation**
Population density **X1** (people/sq.km)	=urban residential population/urban built-up area Urban residential population is the number of population of the whole city including all municipal districts. When X1 is lager, the pressure on land is higher.
Annual household expenditure on transportation and housing per capita **X2** (yuan)	=annual household expenditure on transportation and housing/residential population When X2 is lager, the pressure of housing and transportation on residents is higher.
Civil automobiles **X3** (unit)	The more private cars, the higher pressure on urban transportation is.
Disposable income of urban residents per capita **X4** (yuan)	The part of cash incomes to arrange daily life. When X4 is lager, the economic status of residents is better.
Urban residential gross floor area per capita **X5** (sq.m/Person)	=urban residential gross floor area/residential population When X5 is lager, the dwelling environment and the quality of life are better.
Area of urban construction land per capita **X6** (sq.m/person)	=urban construction land area/urban population Urban construction land area includes residential land, industrial land, land for public facilities, land for transportation, municipal utility land, green space and special land. The lager X6 is the more urban construction land is, thus urban land use degree is higher.
Area of roads per capita **X7**(sq.m/person)	=urban road area/urban population X8 indicates the perfection level of urban traffic facilities. To some extent, the more X7 the higher the perfection level is.
Passengers traffic **X8** (ten thousand person-times)	X9 is the total times of passengers taking urban public transportation. The lager X9 is the higher rate of public transportation using is.

Number of public vehicles **X9**	X9 is the total number of urban public traffic vehicles. The more public traffic vehicles indicate the higher perfection traffic facilities.
GDP per acre **X10** (100 million yuan/sq.km)	=urban GDP/urban built-up area When X10 is larger, the more economic output the urban built-up areas have produced.
Investment in fixed assets per acre **X11** (100 million yuan/sq.km)	= fixed investments/urban built-up area Per acre fixed investment can effectively measure the sustainability of urban development.
Fixed investments in transportation industry **X12** (10 thousand yuan)	X12 is the fixed investments made by the government in the transportation industry. The more investments in the transportation industry, the higher perfection of traffic facilities.
Fixed investments in real estate industry **X13** (10 thousand yuan)	X13 is the fixed investments made by the government in the real estate industry. The larger X13 is, the more developed the real estate industry is; thus there are more alternative housing.

3.2 Comparative Case Study

3.2.1 Rationale for the Design

The mixed method research use a case study design for a number of reasons. Firstly, the study attempt to answer "how" and "why" questions (Yin, 1994) regarding the implementation effects of TOD. Such type of questions is a typical characteristic for case study designs, especially in urban development. Secondly, case study designs are suitable for dealing with "specific, complex, functioning" (Stake, 1995, p.2) phenomenon. This approach allows the research to capture the complexity in the TOD settings. Thirdly, the aim to determine the similarities and differences across different Chinese cities necessitates a comparative case study, because this design can provide a visualized perspective to optimize the understanding of variations.

While research questions are broad, cases can ensure that the study remains reasonable in scope. With respect to the selection of cases, many scholars suggest placing limits on research objectives: a) limitation on time and place (Creswell, 2003); b) limitation on activities (Stake, 1995); and c) limitation on definition and context (Miles & Huberman, 1994). In this research, cases are bounded by two Chinese metropolises—Beijing and Shenzhen—and the topic of TOD implementation.

Once the cases have been determined and the boundaries have been placed upon them, another additional component required to design and conduct a rigorous case study should been considered—propositions. Yin (2003) states that propositions can lead to the establishment of a conceptual framework and to guide the research. Propositions can be generated from previous literature, experience (personal or professional), and theories. Stake (1995) presents propositions as issues, which are not simple and pure, but combining political, social, historical, and especially personal contexts. The compound analysis of TOD planning and implementation effects requires multiple layers of understanding, involving historical, economic, political, cultural, academic, experimental, emotional etc.

In addition, the data collected from cases are analyzed by descriptive statistics in the following section. The author initially adopt principal components analysis (PCA) to process the data using SPSS Statistics, but the validity of results cannot be guaranteed in terms of these reasons: 1) sample size should be sufficiently large to provide the validity; 2) the collected data are time series data instead of cross-sectional data, and variables are across different cities, thus it would be problematic to use PCA. Finally, the study conducts descriptive statistics to present findings.

3.2.2 Key Evaluation Questions

The goal of case study is to answer the following questions:

- What TOD initiatives have been implemented in Chinese cities and how these initiatives have been conducted? What transport issues and challenges of urban sustainability are the cities faced with?

- Based on the evaluation index system, what kind of effects (positive or negative) has been made on urban development after implementing TOD? If it is positive, what progress has been made? If it is negative, which aspects have been failed? What are the implications of these changes for urban sustainability?

- Through analyzing the implementation effects of TOD, what recommendations can be provided to urban planners, policy makers, and individuals to achieve more sustainable urban development?

3.2.3 Selection of Cases

For the purpose of answering these research questions, Beijing and Shenzhen have been selected as two case studies. The first reason why the two cities are selected is that Beijing and Shenzhen are both first-tier cities in China, as one is the capital city of China and one is the special economic zones of China, which means they are on a comparable scope. Besides, these two cities also have many differences, involving urban history (Beijing is an ancient city while Shenzhen is a booming city), city size, population density, the policies on transportation and planning, development status, etc. Therefore, it would be feasible and meaningful to conduct a comparison and analysis between the two metropolises to figure out what progress has been made respectively by the implementation of TOD.

4 Case Study

4.1 TOD in the City of Beijing

4.1.1 Background

Beijing is the capital of the People's Republic of China and also one of the world's most populous capital cities. The city with 16.41 thousand square kilometers, located in northern China is governed as a direct-controlled municipality under the national government with 16 urban, suburban, and rural districts and is the nation's political, cultural, and educational centre (Beijing Statistics Bureau, 2015). Beijing is an ever-changing megacity rich in history but also truly modern, exemplified in its extraordinary global influence in politics, economy, history, culture, education, language, architecture, and technology. Regarding to transport, Beijing is a major hub for the national highway, expressway, railway, and high-speed rail networks, with five ring roads, nine expressways, eleven National Highways, nine conventional railways, and two high-speed railways converging on the city. As of 2016, the city's metro network is the busiest and second longest in the world, after Shanghai's metro system.

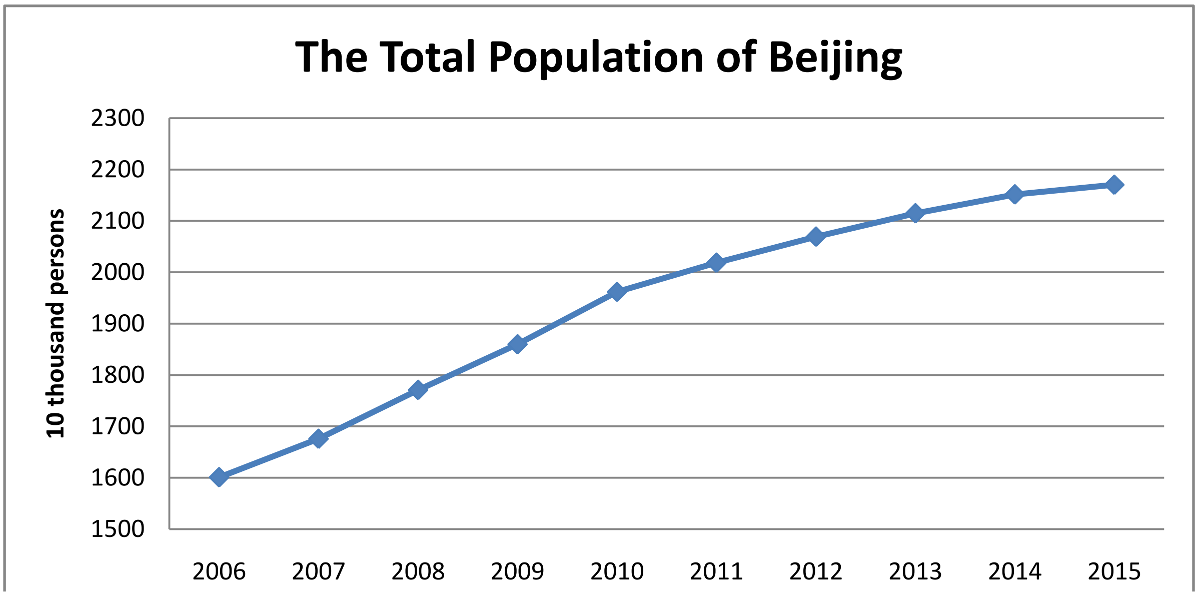

Figure 17 The total population of Beijing (unit: 10 thousand)
Source: Beijing Statistical Information Net (http://www.bjstats.gov.cn/)

There are nineteen metro lines in Beijing. Based on the data from *Beijing Statistical Yearbook* (Beijing Statistics Bureau, 2015), annual passenger volume of Beijing subway in 2016 is 3, 025, 800, 000, while the daily passenger volume reaches 8, 270, 000, in which, weekday passenger volume is counted as 9, 350, 000 with a year-on-year growth of 7.5%. The highest daily passenger volume in the year 2016 is on October 21st (Friday), with the number of 1, 052, 360, 000, which hits record highs (Beijing Subway, 2016).

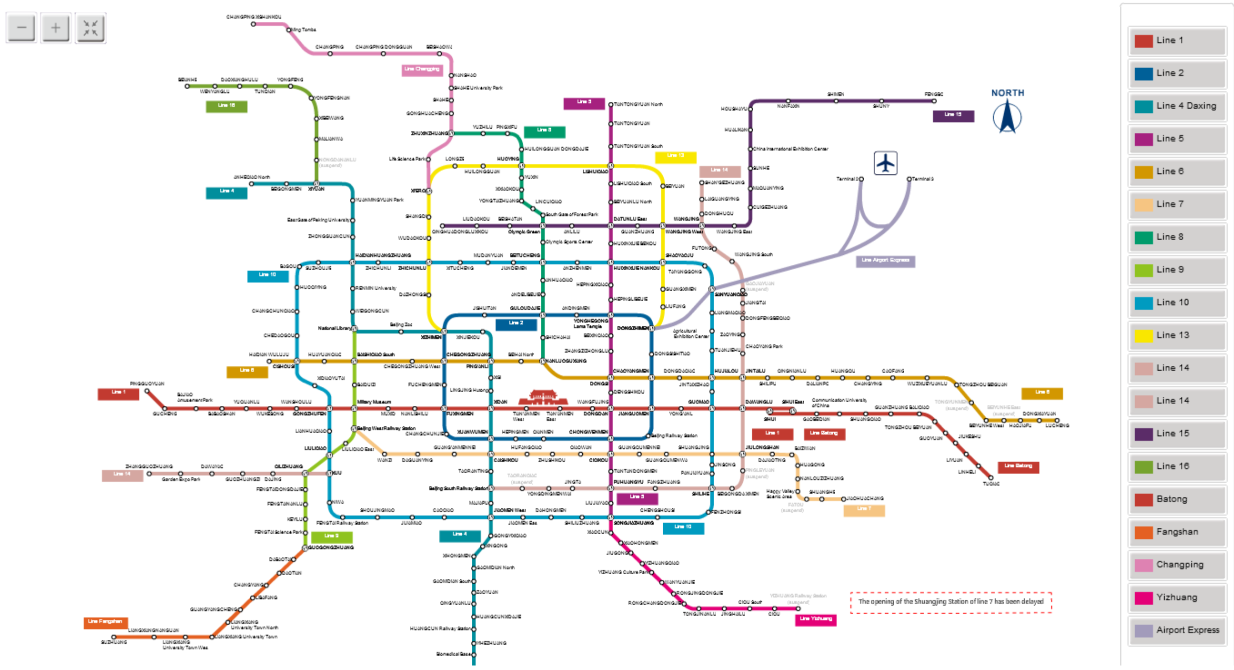

Figure 18 Route Map of Beijing Subway in 2016

Source: Beijing Subway (http://www.bjsubway.com/en/subwaymap/station_map.html)

Beijing's urban design layout further exacerbates transportation problems. Within the urban core, city streets generally follow the checkerboard pattern of the ancient capital. The authorities have introduced several bus lanes, which only public buses can use during rush hour. In the beginning of 2010, Beijing had 4 million registered automobiles; by the end of 2010, the government forecast 5 million; while in 2010, new car registrations in Beijing averaged 15,500 per week (China Daily, 2011). Towards the end of 2010, the city government announcedn a series of drastic measures to tackle traffic jams, including limiting the number of new license plates issued to passenger cars to 20,000 a month and barring cars with non-Beijing plates from entering areas within the Fifth Ring Road during rush hour (ChinaAutoWeb, 2010). More restrictive measures are also reserved during major events or heavily polluted weather.

4.1.2 Beijing 12th Five-Year Plan for Transport

The five years of *The 11th Five-Year Plan* (2006-2010) were extraordinary in the history of China’s development. Under the sound leadership of the Central Committee of the Communist Party of China and the State Council, people from various social strata have conscientiously studied the scientific development concept and have put it into practice; in doing so, they have carried out tenacious struggles, and they have overcome many difficulties, including successfully hosting an unrivalled Olympic Games and preparing for the celebratory activities of the 60th Anniversary of the Founding of New China. Likewise, the next five years (2011-2015) are supposed to be an important and opportune time for fully developing China’s abilities, especially in transport industry, with new opportunities and conditions favorable for its development.

Hosting the 2008 Olympic Games helped Beijing achieve leap-forward development in infrastructural facilities. During *The Twelfth Five-Year Plan for the National Economic and Social Development of Beijing* (The Beijing Government, 2011) (hereafter referred to as *Beijing 12th Five-Year Plan*), proceeding from the strategic height of promoting the city’s sustainable development, the municipality will strive even more to promote the city’s normal operations and to ease traffic jams, resolve problems in resource supplies and garbage disposal, which are major concerns of almost all citizens. The focus on urban construction will be shifted from an emphasis on facilities to that of functions. The systemization, safety and reliability of infrastructural facilities will be considerably promoted to meet the needs of socio-economic development and to better serve residents daily living needs.

During *Beijing 12th Five-Year Plan* (The Beijing Government, 2011), priority should be given to its public transportation development strategy. Efforts should be made to direct the rational use of private automobiles, accelerate the construction of the transportation infrastructure, improve comprehensive management and services, promote proper commuting conduct so as to alleviate traffic congestion in the central urban area, especially the core area, and to ensure safe and smooth transportation services. The strategy of giving priority to public transport will be carried out strongly to “increase the public transport services accessibility in the central area to at least 50 percent” (The Beijing Government, 2011). Beijing aims to set up an easy-transfer public transportation network with rail transportation as the backbone and ground public transpiration as the main force.

The Beijing Government (2011) emphases that priority will be given to rail transportation facility construction in the central urban area, and Beijing will complete 561 kilometers long rail network in 2015 and increase the total length of rail transportation to 660 kilometers in 2015. Besides, the Bus Rapid Transit (BRT) commuting network will be built, and planned bus lanes at rapid transit roads and trunk roads in the central urban area will be designated to increase the total length to more than 450 km to improve public transit efficiency during rush hours. On the other hand, public transportation conditions will be optimized: bus line, rail transport lines, and connections between rail transit and bus transport lines are supposed to be extensively improved; meanwhile, the compliance of norms and standards will be enhanced and parking facilities cannot be neglected while the rail traffic lines being constructed.

The comprehensive transport management is supposed to be strengthened during the five years. The total number of motor vehicles will be controlled and the rapid momentum of motor vehicle growth be restrained in Beijing (The Beijing Government, 2011). The government aims to encourage rational use of motor vehicles by differentiating parking charges. And also, transport capacity building is supposed to be strengthened to advance services in the central urban area, and road networks will be improved. Moreover, bicycle lanes and sidewalk networks will be enhanced to facilitate pedestrians and cyclists green traffic.

In addition, intelligent traffic management will be promoted to increase traffic efficiency. And an integrated rapid traffic system will be built to provide the rural and urban areas with rapid traffic resources. The *12th Five-Year Plan* (The Beijing Government, 2011) indicates that the area within Beijing Fifth Ring Road will be covered with an intelligent traffic system and intelligent control of traffic signals, which meets the requirement of smart cities. Moreover, intelligent dispatching of urban rail transit, buses and taxies will be realized. Dynamic traffic information will be disclosed in real time, such as the road conditions and available parking spaces, to improve efficiency. Coverage of the electronic toll collection system will be expanded and speedy passage at expressway toll stations will be assured.

The Beijing Government has realized the importance of rail transport availability relying on suburban and inter-city rail lines in all districts. Therefore, the building of expressway passages between the central urban area and new towns and among new towns will be accelerated. Roads linking expressways so as to connect all the key towns and functional areas will be built. The trunk roads and highways of counties, towns and villages will be strengthened and improved. Construction of the road network in suburban hilly areas will be accelerated to form a structure consisting of one ring road, 11 radial roads and numerous linking roads. Possibilities of increasing highways in the northwestern part of Beijing will be studied. In 2015, the total mileage of Beijing highways will reach 21,500km (The Beijing Government, 2011).

Based on the planning policies discussed above, it is not hard to conclude that the Beijing Government has realized the significance of TOD, and has put the conception of TOD into urban plan. The *12th Five-Year Plan* for the transport development of Beijing focuses on public transportation development strategy, urban rail transportation facility construction, intelligent traffic management, and connection between central urban area and new towns. As for whether these goals have been achieved and how much progress has been made, the paper conducts a descriptive statistic analysis relying on the established evaluation index.

4.1.3 Beijing Data Collection

The quantitative data of evaluation indicators are collected from *Beijing Statistical Yearbooks* (Beijing Statistics Bureau, 2015) on the Beijing Statistics Bureau website, and are listed in the following table.

Table 12 Beijing TOD implementation effects evaluation index

Criterion	**Indicators**	**2010**	**2011**	**2012**	**2013**	**2014**
Pressure Index	Population density **X1** (people/sq.km)	1195	1230	1261	1289	1311
	Annual household expenditure on transportation and housing per capita **X2** (yuan)	3950	4407	4697	5232	5395

	Civil automobiles **X3** (unit)	4809000	4983000	5200000	5437000	5581000
States Index	Disposable income of urban residents per capita **X4** (yuan)	29073	32903	36469	40321	43910
	Urban residential gross floor area per capita **X5** (sq.m/Person)	28.94	29.38	29.26	31.31	31.54
	Area of urban construction land per capita **X6** (sq.m/person)	70.35	70.64	69.83	71.16	73.73
	Area of roads per capita **X7**(sq.m/person)	4.79	4.54	4.46	4.54	4.65
	Passengers traffic **X8** (ten thousand person-times)	689788	722552	761578	804775	815849
	Number of public vehicles **X9**	24011	24478	25831	27590	28331
	GDP per acre **X10** (100 million yuan/sq.km)	11.74	13.20	14.18	14.93	15.39
Response Index	Investment in fixed assets per acre **X11** (100 million yuan/sq.km)	4.16	4.44	4.64	4.86	5.00
	Fixed investments in transportation industry **X12** (10 thousand yuan)	7205000	6807000	7120000	6645000	7402678
	Fixed investments in real estate industry **X13** (10 thousand yuan)	29011000	30363000	31534000	34834000	39113000

4.2 TOD in the City of Shenzhen

4.2.1 Background

Shenzhen is an emerging city in Guangdong Province and is one of the four largest and wealthiest cities (also including Beijing, Shanghai, and Guangzhou) in China. The city is 1996.85 square kilometers, located immediately north of Hong Kong Special Administrative Region and holds sub-provincial administrative status, with powers slightly less than a province. Shenzhen was a market town of 30,000 people on the route of the Kowloon–Canton Railway, while it changed in 1979 when Shenzhen was promoted to city-status and in 1980 designated China's first Special Economic Zone (SEZ). According to *Shenzhen Statistical Yearbook 2015*, Shenzhen had transformed into a city with a population of 10,778,900 and a metropolitan area population of over 18 million. Shenzhen was one of the fastest-growing cities in the world during the 1990s and the 2000s (U.S. Commercial Service, 2007).The population of Shenzhen approximately slowed down to less than one percent per year by 2013 with growth spilling over the municipal border and forming a contiguous urban area with southern Dongguan City and Huizhou City (NewsGD, 2013).

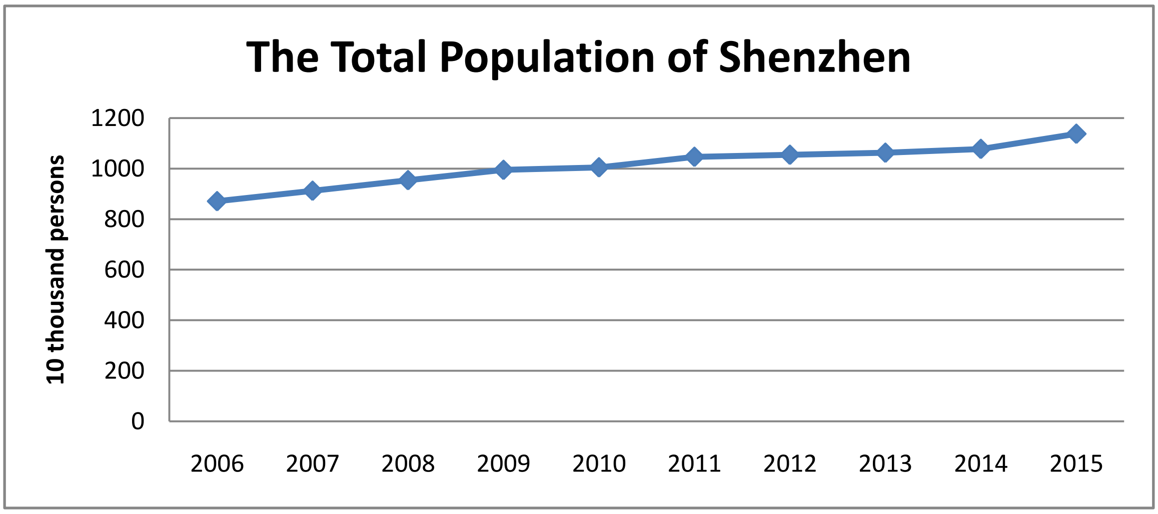

Figure 19 The total population of Shenzhen (unit: 10 thousand)

Source: Shenzhen Statistical Information Net (http://www.sztj.gov.cn/xxgk/tjsj/tjnj/)

Shenzhen is an important railway terminal in South China, the regional center of the Pearl River Delta and the primary supporting point in the planned transportation network. By March 2015, Shenzhen had 88 road passenger transport companies, 35 regular bus companies, 73 chartered vehicle companies and 20 companies operating regular buses and chartered vehicles (The Shenzhen Government, n.d.). Shenzhen has long-distance buses to all major counties and cities in Guangdong, Hong Kong and Macao, as well as more than 20 provinces, municipalities and autonomous regions, including Hainan, Guangxi, Hunan, Jiangxi, Fujian, Shanghai and Liaoning (NewsGD, 2013).

Shenzhen has played a big role as a road transport hub in the pan-Pearl River Delta area with the integration of delta cities and the expansion of the expressway network. By the end of July 2016, eight metro lines (Line 1, 2, 3, 4, 5, 7, 9, 11) with over 200 vehicles were being operated in Shenzhen, forming a 229-km Metro network (The Shenzhen Government, n.d.), while . In 2015, Shenzhen Metro transported 1.12 billion passengers and a maximum of 3.07 million people each day, accounting for 31.3% of the total public transportation. Rail traffic has become an important part of public transport in the city. By the end of 2015, about 10 million passengers used public buses daily. About 94.96% residents could walk to a bus stop within 500 meters of their home. The city owns 15,120 public transport vehicles and has 903 public transport routes under operation which extended about 965 million kilometers. The total number of new-energy vehicles used for public transport has reached 9,085, among which 6,650 are buses and 2,435 are electric taxis (The Shenzhen Government, n.d.).

Figure 20 Route Map of Shenzhen Subway in 2016
Source: Shenzhen Metro (http://www.szmc.net/page/html5.html)

4.2.2 Shenzhen 12th Five-Year Plan for Transport

The same as Beijing, the Shenzhen government has established a set of development plan for the city's growth. Based on *The Twelfth Five-Year Plan for the National Economic and Social Development of Shenzhen* (TCSZM, 2011), a specific plan for Shenzhen's transportation development has been published—*The Twelfth Five-Year Plan for the Comprehensive Transportation of Shenzhen* (TCSZM, 2012) (hereafter referred to as *Shenzhen 12th Five-Year Plan*). The plan summarizes progress made during last five years and proposes new goals that need to be achieved in the following five years.

The core development goal is to create a higher-standard comprehensive transportation system, and to build Shenzhen as a traffic hub city, a worldwide logistics hub city, and a transit metropolis in the international level (TCSZM, 2012). By the year 2015, Shenzhen will build 156 kilometers long urban rail transit, and will increase the total length of bus lanes to more than 700 kilometers; meanwhile, the coverage rate of bus stops within 500 meters will be more than 93%. For the punctuality rate, urban rail transit aims to achieve 99%, while buses attempts to reach 90%. Besides, for the daily motorized travel, the allocation proportion of public transportation should be more than 56%. The average speed of automobiles in the urban central area during rush hours should more than 25km/hour. Moreover, the pollution emission of automobiles should not exceed that of existing level (TCSZM, 2012).

To achieve the goals more efficiently, the plan highlights a development strategy—Intelligent Transportation Systems (ITS). ITS are modern comprehensive transportation systems contain a wide variety of technologies applied to transportation infrastructures to enable users experience safer, smarter, more efficient, more reliable, and more eco-friendly use of available transport networks, while decreasing traffic congestion and traffic accidents, and reducing the environmental impact caused by travelling. The establishment of this system requires diverse disciplines including transportation planning, engineering, computer science, finance, telecommunications, electronic commerce, automobile manufacturing, etc.

The plan also advocates enhancing the cooperation between rail transit and conventional buses, and promoting a coordination development. Around the rail transit network, optimize and adjustment the layout of conventional bus network. Further improve the “rapid -trunk-branch” structure (TCSZM, 2012), forming a suitable-size network which is matching the capacity of rail transit. One the other hand, bus connection station should be reasonably planned. The construction of public transport hub, station and supporting facilities should be simultaneously carried out to achieve the seamless convergence between rail transit and conventional buses. Besides, bus lanes should be constructed on the newly built expressway, while transit signals should be adopted at crossroads (TCSZM, 2012).

Shenzhen 12th Five-Year Plan (2012) emphasizes fully tapping the potential of existing facilities, coordinating traffic operation management with traffic demand management, creating intelligent, efficient, convenient, accessible, and low-carbon urban transport systems, providing safer, more comfortable, and more punctual green traffic services. By the year 2015, Shenzhen promotes the use of new-energy buses more than 7000, and pure electric taxies more than 3000 (TCSZM, 2012). In order to guide people to choose public transportation, new parking policies will be enacted depending on different regions.

4.2.3 Shenzhen Data Collection

The quantitative data of evaluation indicators are collected from *Shenzhen Statistical Yearbooks* (Shenzhen Statistics Bureau, 2015) on the Shenzhen Statistics Bureau website, and are listed in the following table.

Table 13 Shenzhen TOD implementation effects evaluation index

Criterion	**Indicators**	**2010**	**2011**	**2012**	**2013**	**2014**
Pressure Index	Population density **X1** (people/sq.km)	5201	5256	5282	5323	5398
	Annual household expenditure on transportation and housing per capita **X2** (yuan)	5609	5571	7058	9766	9803
	Civil automobiles **X3** (unit)	1669674	1939653	2210821	2583869	3111488

States Index	Disposable income of urban residents per capita **X4** (yuan)	32381	36505	40742	44653	40948
	Urban residential gross floor area per capita **X5** (sq.m/Person)	27.03	27.94	27.91	27.58	21.10
	Area of urban construction land per capita **X6** (sq.m/person)	92.53	89.61	89.28	90.07	89.83
	Area of roads per capita **X7**(sq.m/person)	8.60	10.10	10.10	10.80	10.80
	Passengers traffic **X8** (ten thousand person-times)	244329	269720	306434	311893	329414
	Number of public vehicles **X9**	12456	15365	14546	14617	15074
	GDP per acre **X10** (100 million yuan/sq.km)	11.78	13.69	15.03	16.73	17.98
Response Index	Investment in fixed assets per acre **X11** (100 million yuan/sq.km)	2.34	2.45	2.54	2.75	3.05
	Fixed investments in transportation industry **X12** (10 thousand yuan)	3650747	3362286	2400099	4064413	3458632
	Fixed investments in real estate industry **X13** (10 thousand yuan)	5683900	6921631	9266212	11998082	13740589

4.3 Comparative Analysis

1) Pressure Index

a Population density

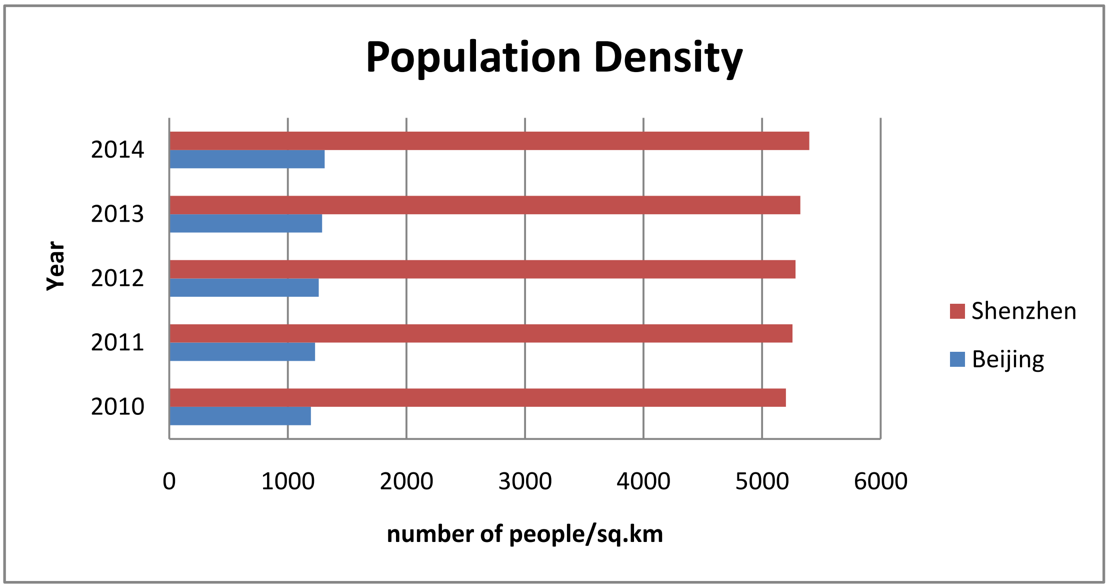

Figure 21 Population density comparison

The bar chart indicates the average population densities of Beijing and Shenzhen from 2010 to 2014. Based on the data collected from the national statistical yearbooks (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015) and also listed in the Table 12 and Table 13, the population density of Beijing in the year 2010 was 1195 people per square kilometers of land area, and in the following four years it has been slightly growth, reaching 1311 people/sq.km in the year 2014. Compared to that of Beijing, the population density of Shenzhen is much larger and it was 5201 people/sq.km in the year 2010, almost five times that of Beijing. Therefore, it can be determined that the city of Shenzhen sustains higher population pressure than the city of Beijing, owing to Shenzhen's insufficient land space (Shenzhen is a coastal city with 1996.85 square kilometers land area, which is only 1/8 of Beijing). But the same is, the population densities of core urban areas of Beijing and Shenzhen are both more than 10,000 people/sq.km (ShenzhenNews, 2016). Overall, the population pressure of Beijing and Shenzhen both increased by years during the five years, while Shenzhen's population pressure on the environment is higher than Beijing's, thus it could be harder for Shenzhen to achieve environmental sustainability.

b Annual household expenditure

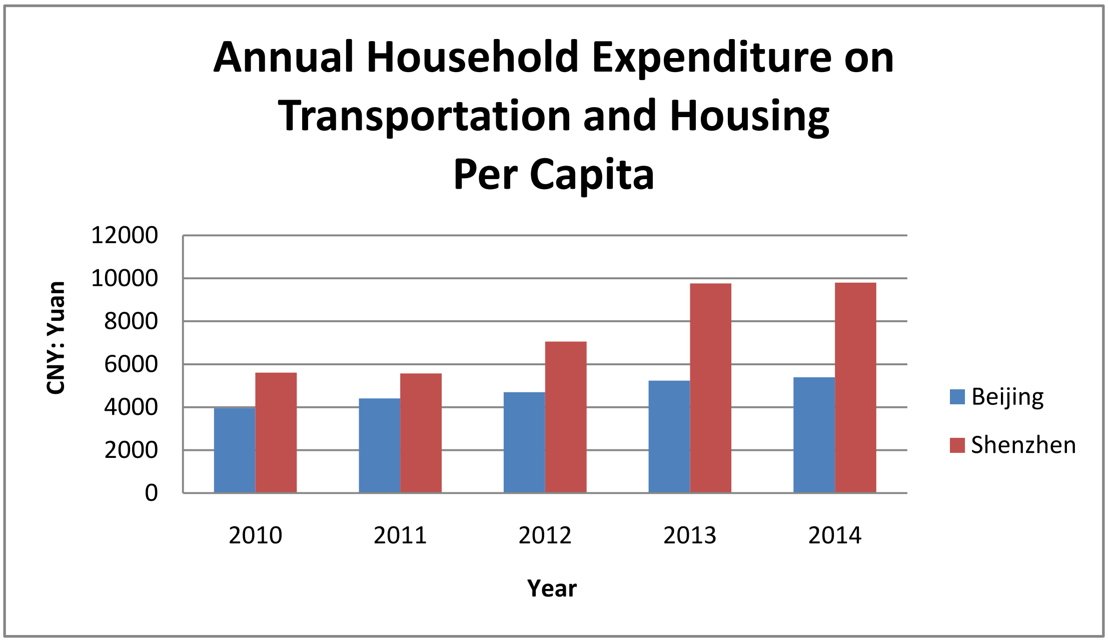

Figure 22 Annual household expenditure comparison

This graph deals with the two cities' annual per capita household expenditure on transportation and housing during the five years. It is apparent that people in Shenzhen spent more money on housing and transportation than people in Beijing. The household expenditure of Shenzhen people dramatically increased since the year 2012, and it almost doubled by the year 2013. By contrast, people in Beijing only spent 4,000 to 5,500 yuan on housing and transportation per year during this period (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). These data indicate that people's expenditure on housing and transportation in Beijing was relatively stable, perhaps because of its lower public transportation fees. For example, in Beijing, buses cost ¥2/person within 10 kilometers, while citizens can get 50% off discount and students can get 75% off discount; in Shenzhen, buses cost ¥2/person within 11 kilometers, while citizens can only get 20% off discount and students under 18 years old can get 50% off discount (Travel China Guide, 2016; Travel China Guide, 2017). It shows that Beijing provides more incentives for people to choose public transportations, while Shenzhen attempts to do but have to consider its expensive construction costs caused by marine reclamation land. Given that the living quality of people would be decreased if they spend more money on transportation and housing, thus urban social sustainability would be impacted.

c Civil automobiles

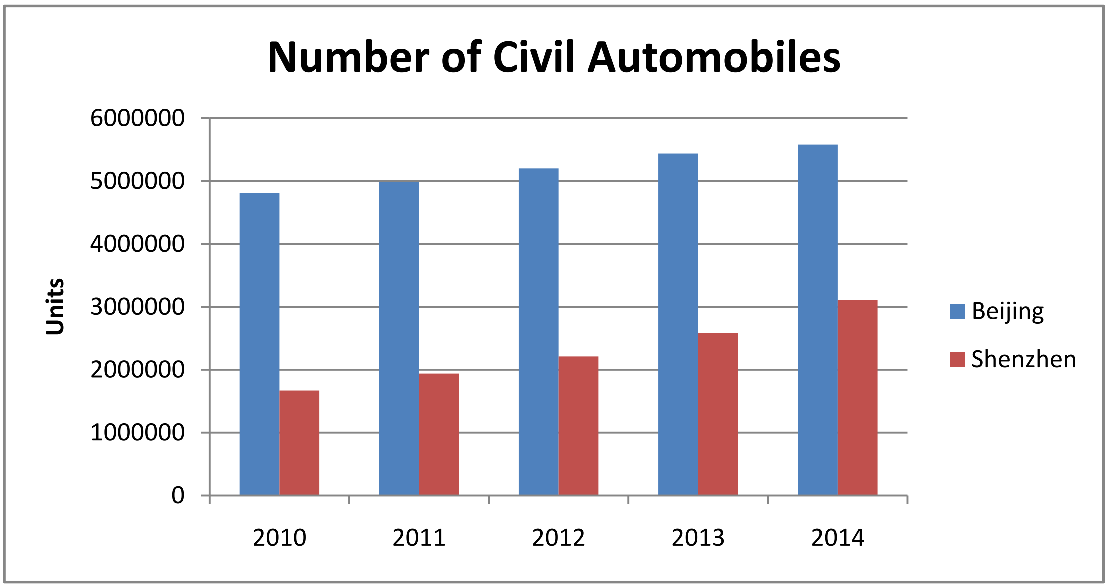

Figure 23 Civil automobiles comparison

This graph shows that the numbers of civil automobiles in Beijing and Shenzhen are both increasing during the five years. The reasons may come from growing populations, the improvement of living standards, and the popularity of cars. Obviously, the number of civil automobiles in Beijing was twice larger than that of Shenzhen; one of the reasons may be that the total population of Beijing is twice as many as Shenzhen's. The land area of Shenzhen is only 1/8 of Beijing's, but the number of civil automobiles Shenzhen have to sustain has reached a half of Beijing's (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). It can be seen that Shenzhen's urban transport system is facing more pressures from automobiles than that of Beijing, although Beijing encounters more motor vehicles which could cause more environment issues including air pollution, carbon dioxide emissions, or noise pollution.

2) States Index

a Disposable income

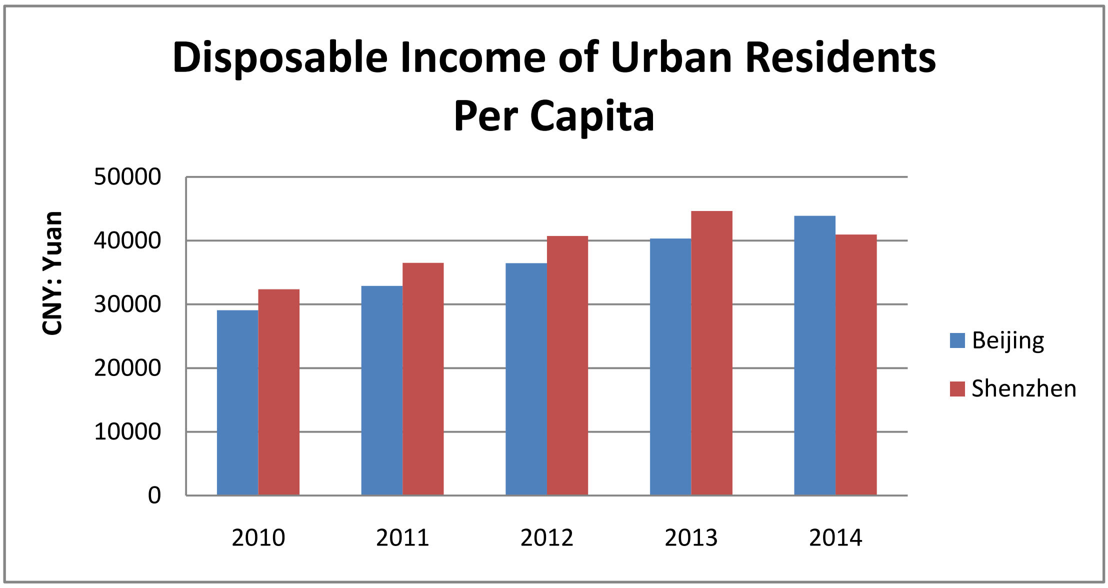

Figure 24 Disposable income comparison

This graph shows the average disposable income of urban residents in Beijing and Shenzhen. During the five years, the average disposable income of Beijing's urban residents was stably rising, from around 29,000 Yuan in the year 2010 to 44,000 Yuan in the year 2014; likewise, that of Shenzhen's slightly increased from 31,000 Yuan in the year 2010 to around 45,000 Yuan in the year 2013, but it dropped to 40,000 Yuan by the year 2014 (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). On the whole, the income gap between Beijing and Shenzhen is not huge; hence people's economic status and living standard in the two cities are to some extent on a same level. People have more disposable income to arrange daily life, which seems the society tends to be more sustainable.

b Housing area per capita

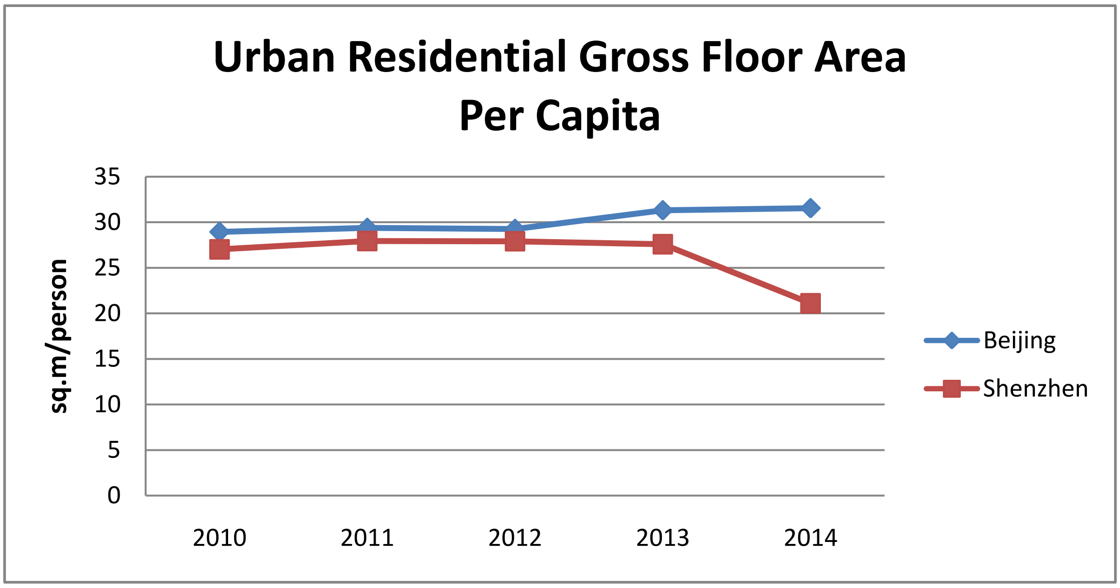

Figure 25 Housing area comparison

From the year 2010 to the year 2012, the per capita housing area in Shenzhen and Beijing was both around 28 square meters per person and kept stable, considering the populations in the two cities had increased during this period (referring to Figure 17 in 4.1.1 and Figure 19 in 4.2.1), thus it can be inferred that the per capita housing area in the two cities were both increased, which means more housing had been supplied in the market. The data of Beijing had slightly increased to 31 square meters per person in the year 2013 and kept stable in the next year, while the data of Shenzhen dramatically dropped to about 20 square meters per person in the year 2014 (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). The total population of Shenzhen had increased from the year 2013 to the year 2014, accordingly it can be deduced that the growth rate of housing area could not match that of population. It is obvious that if people have more space to live, the urban development would be more sustainable.

c Area of urban construction land

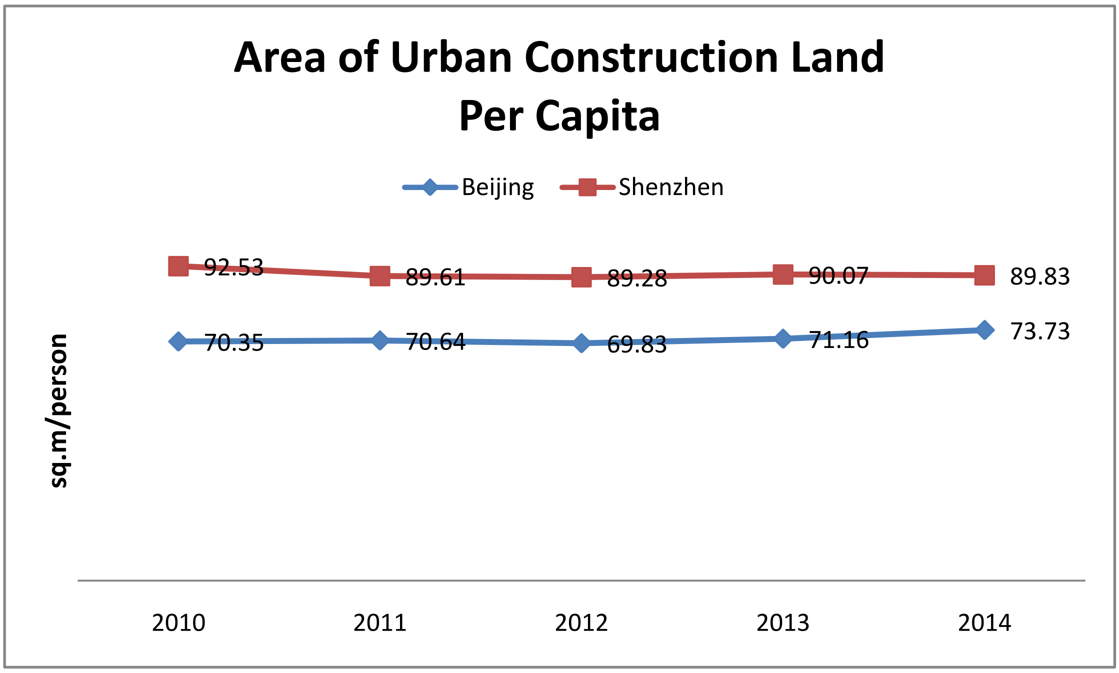

Figure 26 Area of urban construction land comparison

Area of urban construction land refers to all kinds of construction land including residential land, industrial land, land for public facilities, land for transportation, municipal utility land, green space, and land for special uses. Per capita area of urban construction land reflects the degree of urban land use. From the year 2010 to 2014, the data of Beijing and Shenzhen were both maintaining stable; meanwhile, the per capita area of urban construction land of Shenzhen was always around 20 square meters more than that of Beijing (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). Although Shenzhen sustained larger population density than Beijing, people in Shenzhen could enjoy relatively more construction land to conduct activities, thus its urban land use degree was higher than Beijing's. More construction land may benefit the development of economy and society, but could cause more environmental pollution.

d Area of roads

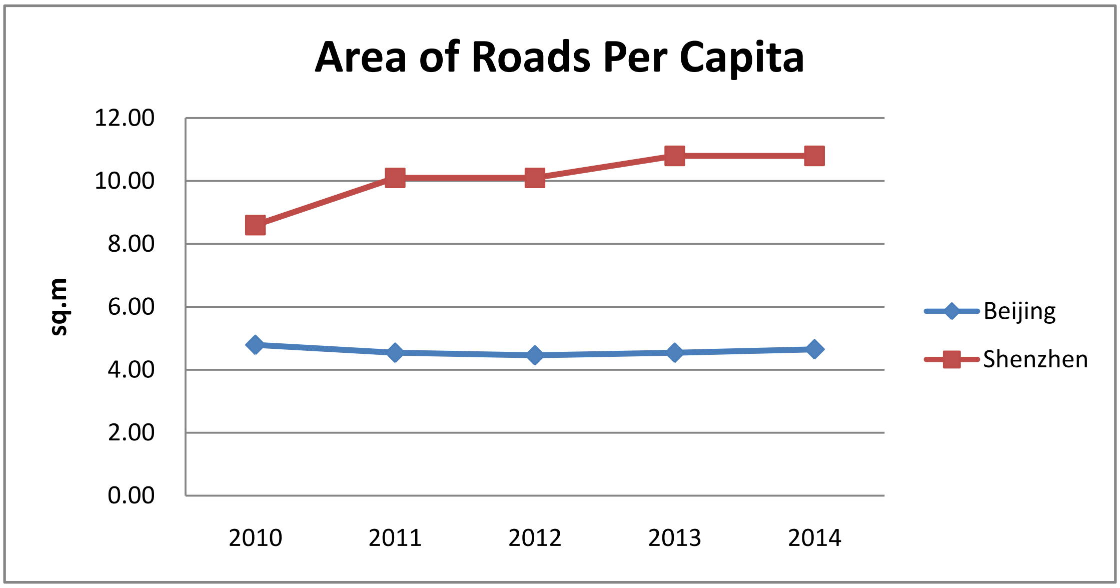

Figure 27 Area of roads comparison

This line chart deals with per capita area of roads in Beijing and Shenzhen. It shows that per capita area of roads in Beijing was steady in the five years, while the data in Shenzhen was on an upward trend, thus it indicates that more roads had been built both in the two cities year by year, but the growth rate of built roads in Shenzhen was much higher than the growth rate of Shenzhen's population. Unexpectedly, the area of roads per capita in Beijing was only half of that in Shenzhen, despite Shenzhen sustains a larger population density (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). Considering the area of urban roads is one of the indicators to measure the perfection level of urban transportation facilities, Shenzhen has reached a comparatively higher level of perfection than Beijing, and this level had kept improved during this period. Therefore, in this perspective, the implementation of TOD brought a positive effect on Shenzhen, and the city of Shenzhen had made a big progress to achieve sustainable urban development.

e Passengers traffic

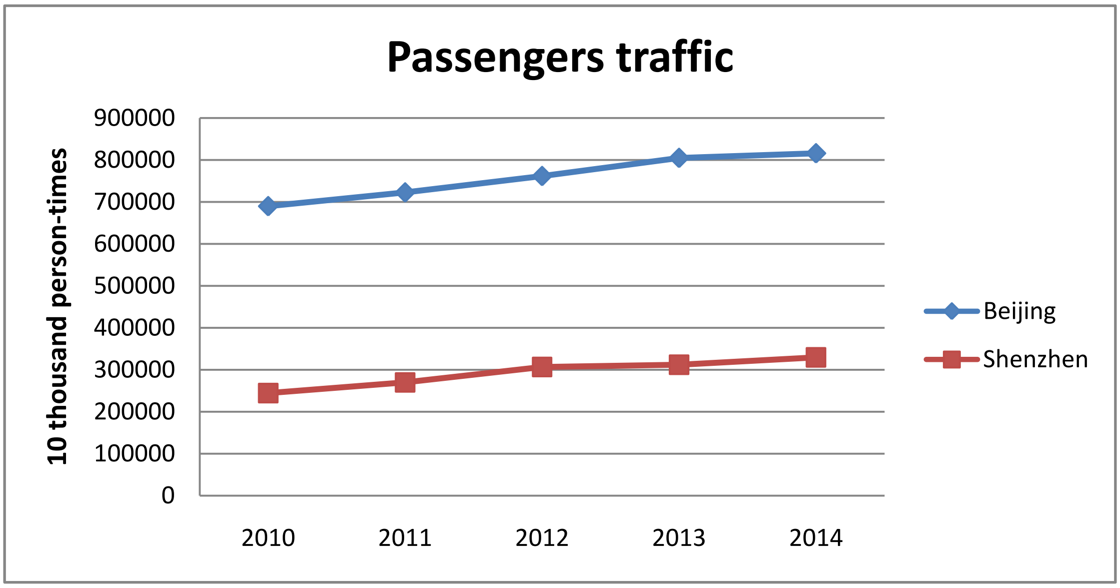

Figure 28 Passengers traffic comparison

This line graph demonstrates the total times of passengers taking urban public transportation from the year 2010 to the year 2014 in Shenzhen and Beijing. Apparently, passengers traffic in Beijing was more than twice that of Shenzhen. Considering the population of Beijing was around twice as many as that of Shenzhen, the frequency of people traveling with public transportations in Beijing is higher than that of Shenzhen (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). The higher utilization rate of public transportation indicates that Beijing had made more success in encouraging people to use public transportations compared to Shenzhen, in this way the city of Beijing had made more contributes to achieve environmental sustainability. By contrast, Shenzhen still need to make more progress to achieve the goal—increasing the utilization rate of public transportation—made in *the 12th Five-Year Plan* (TCSZM, 2012).

f Number of public vehicles

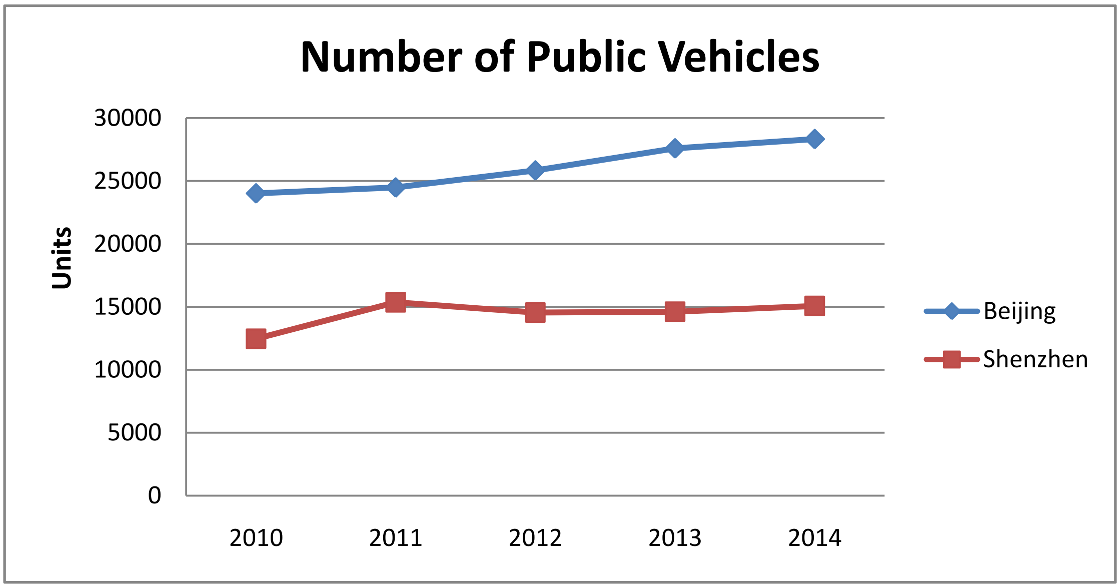

Figure 29 Number of public vehicles comparison

The number of public vehicles in Beijing had a continuous growth in the five years, from 24,011 to 28,331 (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). By contrast, the number of Shenzhen had a steep growth in the year 2011, but experienced a slight drop in the year 2012, then tending to steady. It is reasonable that Beijing owns more number of public vehicles than Shenzhen, owing to its larger population and more land space. More significantly, the increasing number of public vehicles in Beijing reflects that Beijing had made a big effort to achieve the goals in the *12th Five-Year Plan* (The Beijing Government, 2011): priority should be given to public transportation development strategies through "increasing the public transport services accessibility in the central area to at least 50%". By 2014, the total number of public vehicles in Beijing had been increased 18%. In contrast, the goal "allocation proportion of public transportation should be more than 56%" (TCSZM, 2012) established in *Shenzhen 12th Five-Year Plan* requires more data to determine how much progress it had been made.

g GDP per acre

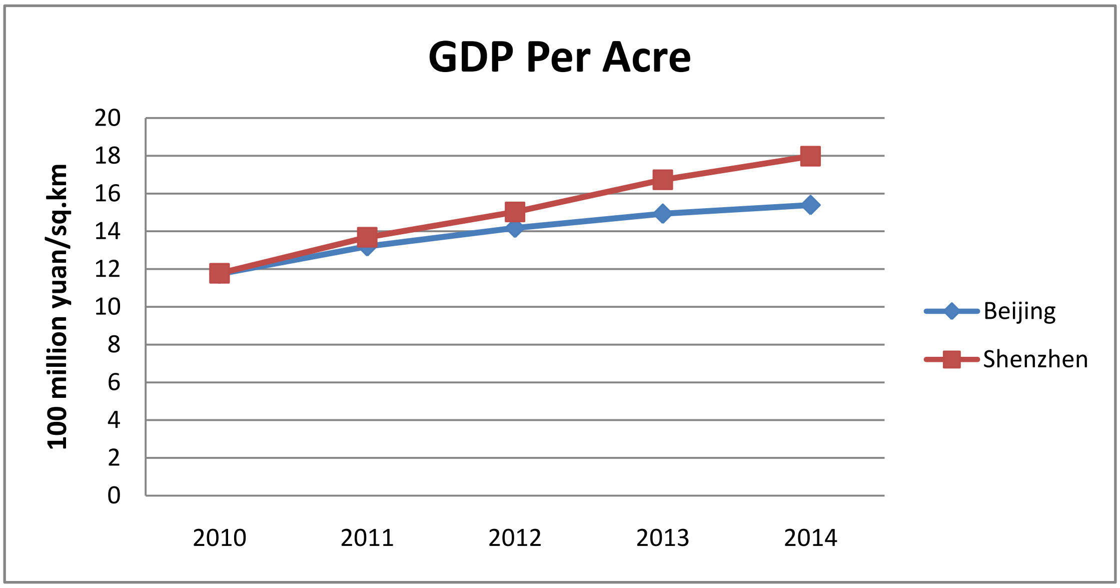

Figure 30 GDP per acre comparison

Per acre GDP is an indicator to measure the economic benefit of urban land, thus higher per acre GDP indicates more economic outputs have been produced on the built-up urban land area. In the year 2010, Beijing and Shenzhen shared a very similar GDP per acre, around 1200 million per square kilometers (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). In the following four years, the growth rate of per acre GDP of Shenzhen was faster than that of Beijing. Both the cities yielded growing economic benefits during the five years and the cities tend to be more sustainable in economy, while the performance of Shenzhen was better than Beijing's.

3) Response index

a Investment in fixed assets

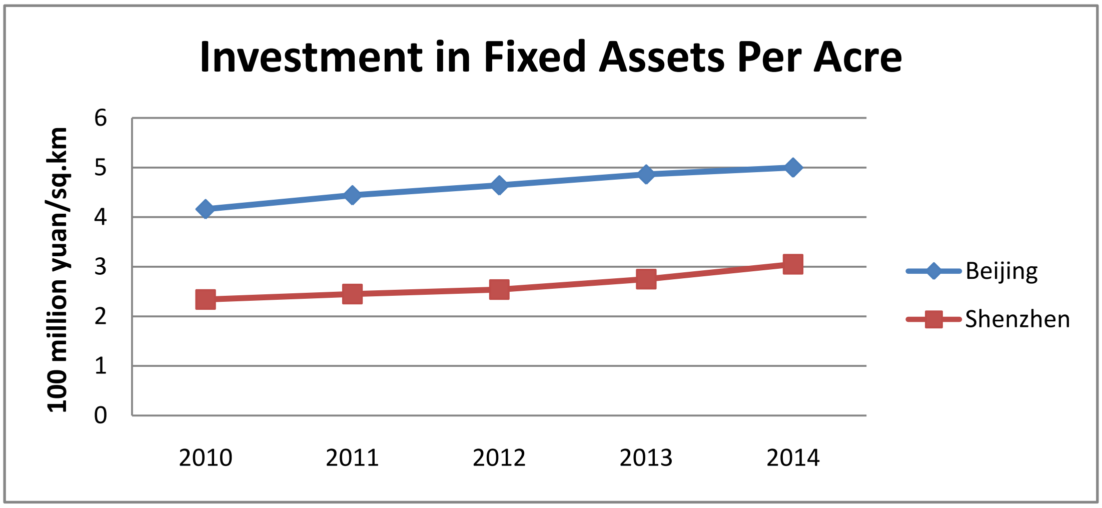

Figure 31 Investment in fixed assets comparison

Investment in fixed assets per acre is the government fixed investments divided by the area of urban built-up land. It can be considered as an indicator to measure the sustainability of urban development. During the five years, the investment in fixed assets per acre of Beijing and Shenzhen were both on a rising trend, which indicates the urban economic sustainability of the two cities were improving in this respect. To be compared, Beijing had a larger investment in each built-up land area than Shenzhen, thus it can be assumed that Beijing has more fixed assets to maintain its sustainable urban development.

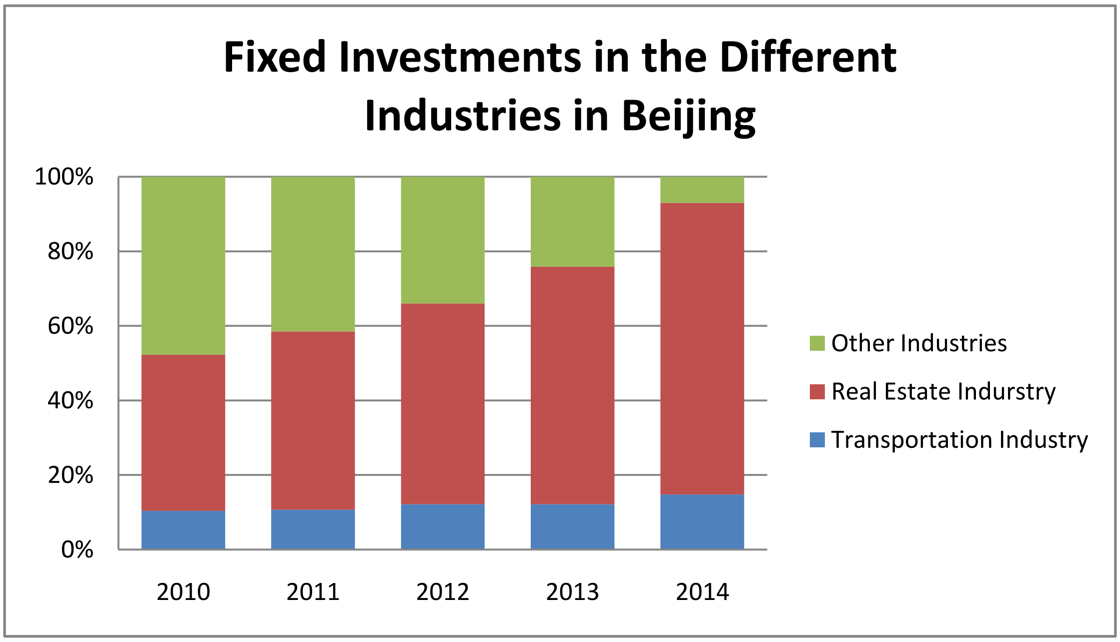

Figure 32 Fixed investments in the different industries in Beijing

This stack graph demonstrates fixed investments made by the Beijing government in the different industries. In the year 2010, the fixed investments in the real estate industry was only 40%, while the data showed a steady growth and arrived at almost 80% by the year 2014 (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). By contrast, the fixed investment in the transportation industry accounted for a small part, but it was still on a rising trend.

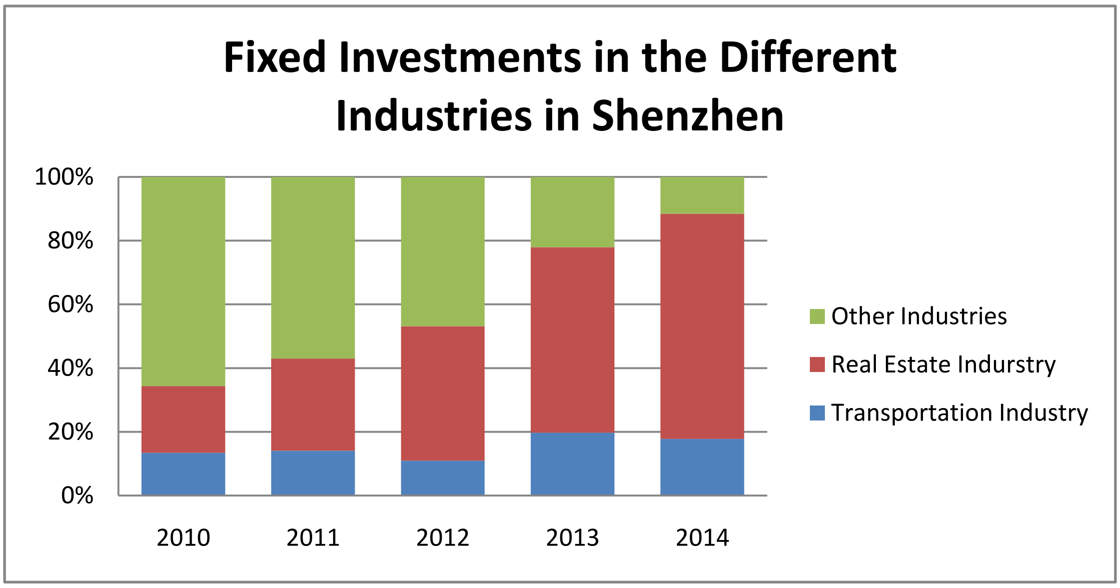

Figure 33 Fixed investments in the different industries in Shenzhen

Likewise, the proportion of fixed investments in the real estate industry of Shenzhen was on a steep increasing trend, from 20% in 2010 to 70% in 2014, the whole amount of increased proportion was even larger than Beijing's (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). During this period, the proportion of fixed investments in the transportation industry was showing a fluctuation; in the year 2010 and 2011, the proportion was around 13%, while it dropped to 10% in the year 2012, and then increased to around 20% in the year 2013 and 2014 (Beijing Statistics Bureau, 2015; Shenzhen Statistics Bureau, 2015). To be compared, the proportion of Shenzhen's fixed investments in the transportation industry were generally larger than that of Beijing, which means the Shenzhen government laid a little more emphasis on transportation than Beijing.

b Fixed investments in transportation industry

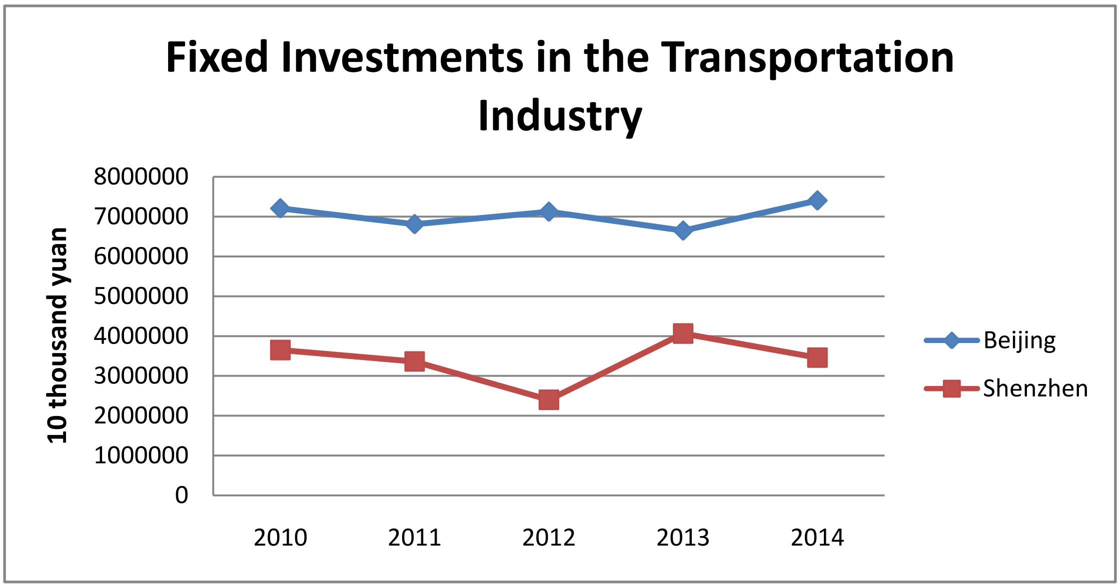

Figure 34 Fixed investments in the transportation industries comparison

When it comes to the exact number of investments in the transportation industry of the two cities, the Beijing government invested more money than Shenzhen's. In this perspective, the scale of investments put into Beijing's transportation industry was larger than Shenzhen's, which may caused by Beijing's large urban size, strong governing capacity, and high degree of economic development.

c Fixed investments in real estate industry

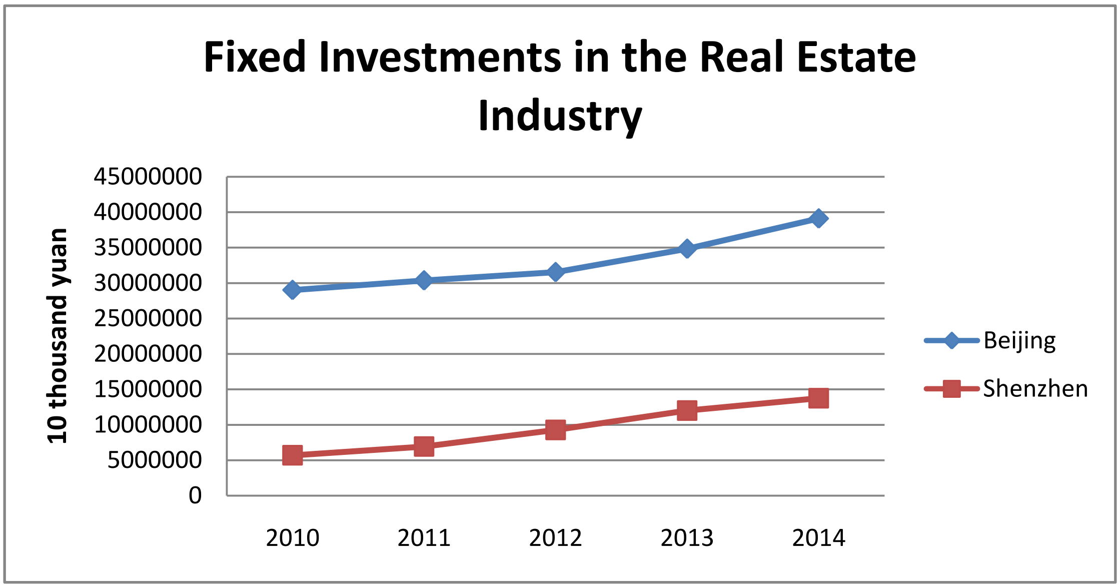

Figure 35 Fixed investments in the real estate industries comparison

Since the year 2010 (may before 2010), both the Shenzhen government and the Beijing government had highly increased the investments in the real estate industry. The investments could be influenced by the national macro control: after the financial crisis in the year 2008, the Chinese government had invested four trillion yuan in the real estate industry (Xinhua News, 2008), striving to develop China's urban infrastructures, including the construction of indemnificatory housing, the construction of rail transit, roads, and airports, and the construction of medical, educational, and cultural social undertaking. Therefore, the increasing fixed investments in the real estate industry are helpful to achieve the goals of TOD. More investments in the real estate industry resulting in more construction and buildings, it could achieve urban economic sustainability, but the environmental sustainability would be impeded as constructions cause carbon emissions and pollutions.

4.4 Findings and Results

To summarize the findings from comparative analysis, the paper uses "increasing", “dropped”, or “fluctuation” to describe the changing pattern of these indicators in the five years. The words “negative”, “positive” or “no obvious effect” present the implementation effect of TOD in Beijing and Shenzhen respectively. The comparison results between the two cities are explained following each indicator. The results are listed as below.

Table 14 The comparison results

Criterion	Indicators	Beijing	Shenzhen
Pressure Index	Population density **X1** (people/sq.km)	Steadily Increasing (negative)	Steadily Increasing (negative)
		Beijing’s performance was better. Shenzhen’s population density was five times that of Beijing, thus higher pressure on TOD.	
	Annual household expenditure on transportation and housing per capita **X2** (yuan)	Slightly increasing (negative)	Steeply increasing (negative)
		Beijing’s performance was better. People in Beijing spent less money on transportation and housing than people in Shenzhen, thus Beijing’s people had less pressure to afford transportation and housing.	
	Number of civil automobiles **X3** (unit)	Steadily Increasing (negative)	Steadily Increasing (negative)
		Beijing’s performance was better. Beijing had twice as large number of civil automobiles as Shenzhen, but the land area of Shenzhen is only 1/8 of Beijing’s.	
States Index	Disposable income of urban residents per capita **X4** (yuan)	Steadily Increasing (positive)	Increasing and dropped (positive)
		Shenzhen’s performance was better. Overall, people in Shenzhen had more disposable income than Beijing’s, although the data dropped below in the last year.	
	Urban residential gross floor area per capita **X5** (sq.m/person)	Steady and increasing (positive)	Steady and dropped (negative)
		Beijing’s performance was better. Similar start, Beijing’s increased while Shenzhen’s decreased in the end.	

	Area of urban construction land per capita **X6** (sq.m/person)	Steady (no obvious effect)	Steady (no obvious effect)
		Shenzhen’s performance was better. The data of Shenzhen were always larger than that of Beijing.	
	Area of roads per capita **X7**(sq.m/person)	Steady (no obvious effect)	Increasing (positive)
		Shenzhen’s performance was better. The data of Shenzhen were always larger than that of Beijing.	
	Passengers traffic **X8** (ten thousand person-times)	Increasing (positive)	Increasing (positive)
		Beijing’s performance was better. The frequency of people traveling with public transportations in Beijing is higher than that of Shenzhen.	
	Number of public vehicles **X9**	Steeply increasing (positive)	Slightly increasing (positive)
		Beijing’s performance was better.	
	GDP per acre **X10** (100 million/sq.km)	Steeply increasing (positive)	Slightly increasing (positive)
		Shenzhen’s performance was better.	
Response Index	Investment in fixed assets per acre **X11** (100 million/sq.km)	Increasing (positive)	Increasing (positive)
		Beijing’s performance was better.	
	Fixed investments in transportation industry **X12** (10 thousand yuan)	Fluctuation (positive)	Fluctuation (positive)
		Shenzhen’s performance was better. Although Beijing’s investments were larger, Shenzhen’s investment proportion was larger.	
	Fixed investments in real estate industry **X13** (10 thousand yuan)	Increasing (positive)	Increasing (positive)
		Beijing’s performance was better. Beijing’s investment proportion was always larger than Shenzhen’s.	

Based on the comparative analysis, the study found that for the pressure index—indicators

X1, X2 and X3—the implementation of TOD in both Beijing and Shenzhen had faced an increasing pressure from population density, expenditure on housing and transportation, number of civil automobiles during the five-year period. The sates index reflecting how the urban development objectives of Beijing and Shenzhen changed, Shenzhen did a better performance on the indicators X4, X6, X7, and X10; while the implementation of TOD in Beijing showed more positive effects on X5, X8, and X9. As for how the government's response for the pressures is, X11 and X13 reflects that the Beijing government produced a more effective effect on the implementation of TOD, while the Shenzhen's government made a better performance on X12.

The evaluation of TOD implementation effects indicates that TOD supportive initiatives are helpful to solve the urban development issues involving urban sprawls, traffic congestion, and inefficient land use, leading the growth of metropolises to be smarter and more sustainable. In China's current situation, under the growing number of population and auto vehicles, transit-oriented city are facing huge pressures. Although the government increased the investments in urban infrastructures, especially in the transportation industry and the real estate industry, and some states indicators have slightly improved, the majority of development issues have not been solved.

5 Conclusion

5.1 Summary of Research

As stated in Chapter 1, the purpose of the research is to investigate how TOD has been implemented in China, and what challenges for sustainable urban development the Chinese cities are faced with, and what effects and outcomes of TOD have been produced.

Research consisted of a literature review, one comparative case study on two Chinese first-tier metropolises: Beijing and Shenzhen. The literature review utilized academic and technical resources to investigate the history and paradigm practices of TOD. The opportunities and challenges for TOD implementation were examined in old town and new urban districts in China, including superblock phenomenon, housing and traffic pressures, unbalanced land use, incomplete public transit systems. Meanwhile, some relevant strategies have been proposed to address these issues.

In order to measure the implementation effects of TOD in China, a PSR evaluation index has been adopted from the Organization for Economic Cooperation and Development, while indicators are selected from pioneer research and modified with China’s current context. The quantitative data are collected from the government statistical yearbooks, processing by descriptive statistics to conduct a visualized comparative analysis. Comparison results and findings have been presented to answer the research questions. Relevant recommendations and directions for further study are illustrated in the following section.

5.2 Recommendations and Contributions

The study makes a contribution in many ways to the various fields of literature presented in the review, with a particular emphasis on urban sustainable development and the politics of transportation planning. It proposes the opportunity to explore and investigate current TOD implementation efforts within the City of Beijing and the City of Shenzhen. Although the research concentrates on Chinese cities, the insights which are presented can be used to understand other urban centers implementing TOD initiatives in China or around the world. Recommendations generated from this comparative case study contribute to provide valuable insight to TOD supportive policies, urban planners, and individuals.

In order to build a smarter city and make more positive effects on urban development, four main recommendations are provided as follows:

1) **Establish multi-mode public transportation systems**

For the purpose of increasing the passengers traffic, a complete multi-mode public transportation system is needed: building rail transit and rapid bus transit along urban main roads to share the most proportion of passenger flow; establishing a large-scale public transit network based on the connection between the conventional bus routes or rail transit and branch bus lines to increase the coverage rate of buses; and creating a more comfortable environment for walking and cycling to maintain the accessibility to transportation hubs. Lessons can be learned from the practice of Curitiba, multi-bus tubes as multi-functional bus modes contribute to improve riding environment and attract more passengers.

2) **Improve the operating efficiency of public transportations**

One main reason why the number of civil automobiles is increasing is inefficient operation of public transportations. It always takes more time to commute using public vehicles, because of unpunctual transit schedules, low coverage rate of bus routes, or long distance between stations. Therefore, in order to encourage people to choose public transportations for travel and constrain the number of private cars, the construction of urban public transportation system including rail transit, bus transit, stations and stops should be enhanced. More significantly, vehicles and facilities should be updated to be more intelligent and efficient.

3) Increase the investments in urban transportation industry

In order to relieve human pressures on roads, the per capita area of roads which reflects the reasonability of roads construction and the perfection degree of transportation facilities is supposed to be increased. It is a common phenomenon that bikes and non-automatic vehicles are using same roads with pedestrians, due to the lack of bicycle lanes. Therefore, the government should increase more investments in the transportation industry to achieve these goals.

4) Enhance the quality of passengers' behaviors

The government has adopted a series of measurements leading people to choose green travelling methods, such as raising parking fees in the central urban area, providing more discounts for public transportations, and applying public bicycle sharing systems. However, there are many uncivilized behaviors existing in many Chinese cities: vehicles are parking in an unallowable area just for a contemporary convenience; public mobile-bikes are destroyed for personal occupancy; and uncivilized driving behaviors including occupying non-motor vehicle lanes. When the government makes more efforts to create a sustainable urban environment, individuals also need to conduct a good manner.

5.3 Limitations

Overall, the research design, methodology and analytical framework built for the study have demonstrated to be valuable because they are allowable to answer the research questions. The evaluation index is modified based on antecedent research considering of being flexible enough to meet the challenges of data availability and maintaining practicability on the field. Although the indicators are adopted from previous research on China's TOD implementation, the validity of these indicators to measure the effects of TOD still requires further testing; moreover, more indicators to measure environmentally sustainability need to be involved. As for the internal validity of the indicators, the data are collected from China's government statistics yearbooks, and processed by some mathematical calculation (e.g. rates, per capita data), thus the reliability of these data is guaranteed.

Another limitation of the research is the scope of the case study. The two selected cities, Beijing and Shenzhen, can only represent the most advanced metropolises in China. How other cities' performance on TOD implementation is still requires further investigation and analysis. Consequently, the recommendations generated from case study may or may not be appropriate to applied in other cities. Besides, the comparison between Beijing and Shenzhen mainly relies on a simplex perspective, while the performance of each indicator could be influenced by multiple factors, thus the comparison results may be not comprehensive.

Besides, the sample size is too small. Considered of a longer time frame of data for each case study could result in different outcomes from the analysis, which in turn would influence the recommendations made. Therefore, a longer time frame could be more persuasive, for example, collecting data from 10 years instead if 5 years.

5.4 Directions for Further Study

Given the limited scope of this study, the evaluation of TOD implementation effects presented in the case studies was not always accurate or complete. Therefore, further studies would be conducted from the following respects.

1) Expand the case study scope. Collect statistics on multiple cities or more years so that the sample size is large enough to use principal components analysis (PCA) to process data. Only when multiple variables are measured at the continuous level, there is a linear relationship between all variables, and generally a minimum of 5 to 10 cities per variables, can the study be conducted by PCA using SPSS Statistics. In this way, the research would contribute a strong analysis to the present research field, and fill the gap of previous studies.

2) Create a comprehensive evaluation index. Considered of the adopted indictors in this study are kind of narrow and some of them may be overlapped. For example, the number of public vehicles and passengers traffic attempt to indentify a similar effect which could be combined. Therefore, further research is required to integrate these TOD factors and explore more essential indicators to establish a complete and valid evaluation index system.

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