The Journal of Transport and Land Use http://jtlu.org
Vol. 10 No. 1 [2017] pp. 743–762

JTLU

Transit-oriented development in China: Literature review and evaluation of TOD potential across 50 Chinese cities

Wangtu (Ato) Xu
Xiamen University
ato1981@xmu.edu.cn

Andrew Guthrie
University of Minnesota
guth0064@umn.edu

Yingling Fan
University of Minnesota
yingling@umn.edu

Yongling Li
Utrecht University
y.li2@uu.nl

Abstract: Transit-oriented development (TOD) has been widely accepted in recent years as an important urban development policy. This article reviews the existing TOD literature pertinent to conditions in China, introduces TOD practices in China, and evaluates land development impacts of TOD across 50 Chinese cities that either have metro systems already or expect to have operating metro systems by 2020. The evaluation analysis contributes to the existing literature because most research on TOD in Chinese cities has focused on large, national or provincial capitals such as Beijing, Shanghai, and/or Guangzhou. Based on simulation analysis, we evaluate TOD's land development impacts across all Chinese cities that are expected to have metro systems by 2020. Our results show that the second- as well as the third-class cities of China will have more potential for TOD implementation than the first-class cities in the next five years.

Keywords: Urban policy, transit-oriented development (TOD), land development, metro, China

Article history:
Received: May 9, 2017
Received in revised form: April 25, 2014
Accepted: May 10, 2017
Available online: August 22, 2017

1 Introduction

Transit-oriented development (TOD) is the creation of mixed-use, compact, walkable neighborhoods that encourage people to live near and use public transit. At their hearts, TOD neighborhoods typically feature a transit station and public spaces as well as a walkable street network connecting moderate- or high-density residential and commercial buildings to that station within a half-mile (800 m) radius (Feudo, 2014). Although concepts similar to TOD were promoted before the 1990s, intentional TOD became popular when Peter Calthorpe introduced it in his 1993 book "The Next American Metropolis" (Calthorpe, 1993).

TOD stands in contrast to conventional, auto-dependent development. Auto-dependent development became the prevailing development pattern in U.S. cities and regions since the Second World

http://dx.doi.org/10.5198/jtlu.2017.922
ISSN: 1938-7849 | Licensed under the Creative Commons Attribution – Noncommercial License 3.0

The *Journal of Transport and Land* Use is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies.

War, largely because of growing automobile dominance, transit disinvestment, highway expansion, and suburbanization. Decades of auto-dependent development led to negative societal outcomes ranging from traffic congestion, air pollution, and energy shortages, to urban sprawl, sedentary lifestyles, and impoverished social lives (Cervero, 2002; Cervero, 2003; Cervero, 2008; Curtis & Scheurer, 2017). Under these circumstances, U.S. cities and regions began promoting TOD along with concepts such as smart growth and new urbanism to encourage alternative development patterns and to improve the vitality and livability of urban and suburban communities (De Vos, Van Acker, & Witlox, 2014). Starting in the 1990s, almost every U.S. city and metropolitan region with major transit infrastructure adopted some form of TOD policy (Reconnecting America, 2010).

While TOD originated to address problems in U.S. cities and regions, the value of TOD has been recognized globally, especially in developing countries experiencing rapid urbanization and growing traffic congestion such as China. Faced with skyrocketing traffic demand and unbearable congestion, large Chinese cities began and accelerated the construction of urban rail systems in the early 2000s. In November 2011, the Ministry of Transport (MoT) of China initiated the Transit Metropolis Programme (gongjiao dushu 公交都市) and selected thirty-seven pilot cities as foci of rail transit expansion and TOD efforts (Gmbh, 2015). According to the latest city plans (NDRC, 2016), there would be 50 transit metropolises (defined as cities with urban rail transit systems) in mainland China by 2020. Figure 1 shows locations of these cities and the number of rail lines in each city. As shown in Figure 1, almost all capital cities (except Lasa—the capital city of Tibet) would have urban rail transit by 2020. And according to the China State Council's city classification, all firs class cities (cities with more than 10 million urban population) would have urban rail transit; many second class (5-10 million urban population), as well as third class (1-5 million urban population) cities, such as Baotou, Suzhou, Huizhou, Xiamen, and Nanning, would have their urban rail systems by 2020.

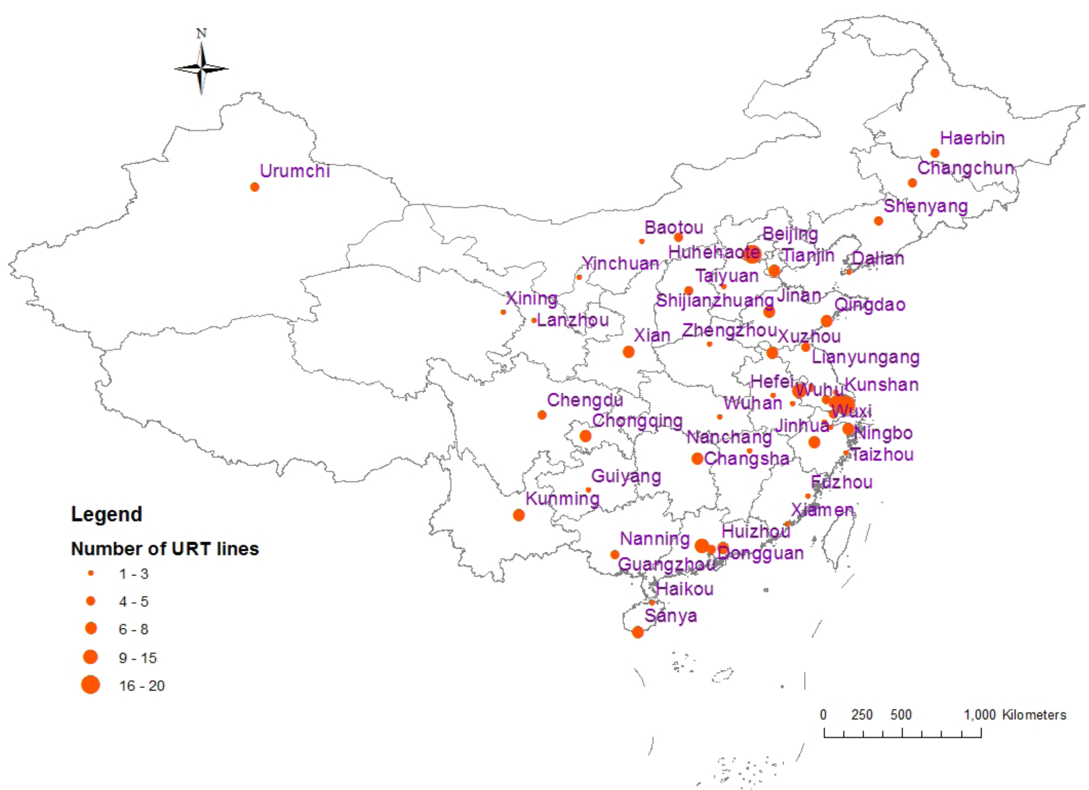

Figure 1: Cities with urban rail transit routes in mainland China by 2020

Despite Chinese enthusiasm for TOD, questions remain: Can the U.S. experience of TOD implementation and evaluation be directly imported and applied to Chinese cities? Do Chinese cities have unique planning and policy contexts that may require adjustments to implementation and evaluation techniques? Unlike U.S. cities, cities in China have not experienced the extremely high levels of urban sprawl and auto dependence. Much of the rail transit development in Chinese cities occurs in high-density, developed areas, which means that there is limited potential for the transit system to shape the urban structure. Further, the regulations, financing and taxation systems and planning processes for land development and redevelopment in China are not as advanced or well-developed as in the U.S. The lack of coordination between government agencies in China for TOD, such as between land-use planning agencies and transportation planning agencies, is more severe in China than the U.S. For the reasons above, the U.S. TOD experience may not be directly imported or exactly applied to Chinese cities. This paper is an attempt to introduce current TOD practices in China and evaluate the potential for TOD implementation in China.

2 Literature review

For this paper, we review three specific categories of TOD literature. First, we review existing empirical literature on TOD in China to establish the current state of Chinese TOD practice. Second, we consider TOD literature that offers concrete lessons to inform effective TOD policy transfer from the West to China. Finally, with a more global focus, we review the general methodological literature on TOD impact assessment to identify an appropriate technique to evaluate TOD potential (operationalized regarding expected future TOD impacts) in Chinese cities.

2.1 TOD in China

Given continuing growth in the capital cities and accelerating growth in second- and third-class cities as well as increasing rates of motorization and congestion, China has realized the importance of integrating land development with the construction of transit systems. TOD is considered as an increasingly important strategy for urban land use and transportation development. Accordingly, the research literature on TOD in China has dramatically increased. Figure 2 summarizes the number of journal articles resulted from keyword searches including “transit-oriented development” and “China” in the Elsevier database (Accessing date: June 17, 2016). It is clear that the recent TOD advances in China are associated with an increasing number of journal articles on TOD in China since 2001.

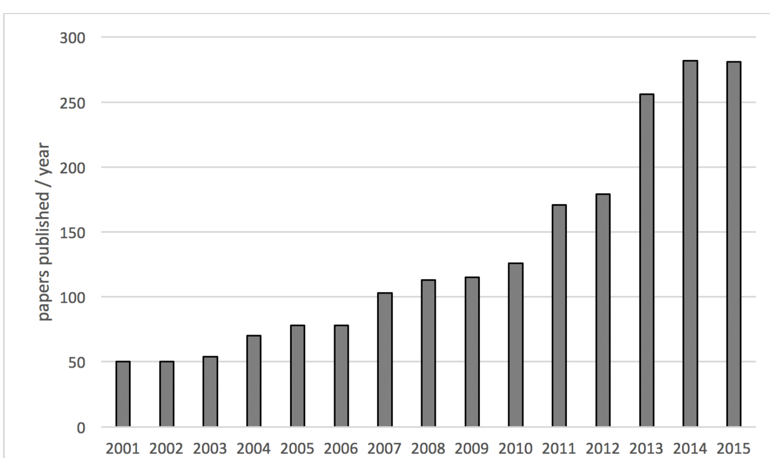

Figure 2: Papers published on Chinese study areas with keyword “transit oriented development” in the Elsevier database, 2001–2015

Although both the TOD concept and TOD studies are becoming more common in Chinese cities, there are many differences in TOD contexts between China and other countries. For instance, TOD implementation in U.S. cities was intended to solve a serious problem stemming from an overly low density of development, through increasing density and diversity around transit stations. Conversely, China attempts to solve problems of high density by building transit systems and compact, location-efficient communities to eliminate "access commuting trips," thus reducing traffic congestion.

Of the studies included in Figure 2 on TOD in China, we read all abstracts and found that many studies focus on how to transplant the "successes" of TOD implementation from American or European cities to Chinese cities (Arrington & Cervero, 2008; Jiang, Zegras, & Mehndiratta, 2012; Mu & Jong, 2012; Cervero & Dai, 2014; Handayeni, 2014; Noland, Ozbay, DiPetrillo, & Iyer, 2014; Noland & DiPetrillo, 2015; Dou et al., 2016; Xu & Zhang, 2016; Doulet & Delpirou, 2017). These studies do not offer original empirical evidence on TOD implementation and impacts in China. After careful reading of the abstracts, we were able to identify 15 studies on TOD in China (listed in Table 1) that offer first-hand empirical evidence.

Table 1: Literature on TOD in China

	Issues				
Author (year)	**Community & Social**	**Real Estate**	**Traffic & Mobility**	**Data**	**Study Area**
(Cervero & Dai, 2014)	x			BRT network and land use data	Mainland China
(Cervero & Day, 2008)			x	Job location change data	Three communities of Shanghai
(Dou et al., 2016)			x	Urban carbon emission data	Shanghai
(Huang, Cao, Cao, & Yin, 2016)			x	Transit trip data	Xi'an
(Jiang et al., 2012)			x	Walking accessibility data	Jinan
(Li et al., 2010)		x		Land use data	Shenzhen
(Li, Luan, Yang, & Lin, 2013)		x		Funding and urban planning data	Pearl River Delta
(Mu & de Jong, 2012)	x	x		Transit ridership data	Dalian
(Pan, Shen, & Liu, 2011)	x	x		Resident travel behaviour data	Shanghai
(Thomas & Deakin, 2008)		x		Land use data	Jinan
(Yang, et al., 2016a)		x		Land development data	Shenzhen
(Yang et al., 2016b)		x		Land transaction data	Beijing
(Zhang, Meng, Wang, & Xu, 2014)		x		Housing price data	Beijing
(Zhang & Wang, 2013)		x		Housing price data	Beijing

From Table 1, we could see that most TOD research in China is more or less related to real estate market issues. In fact, in many Chinese cities, advocacy for TOD projects often aims at profits stemming from increased land values in station areas. At the same time, few Chinese cities have realized genuinely "transit-oriented" as opposed to "transit-adjacent" development because of their lack of long-term planning, with most planning aimed to solve immediate practical problems—oriented heavily towards market-based development. Apparently, specific mechanisms or systems of implementing TOD in the U.S. or Europe were not (or could not be) directly copied to Chinese cities. From this perspective, the concept of TOD has only been superficially applied in China in the past two decades. In the end, TOD might become little more than a publicity stunt staged by the government or a real estate developer. Current issues to address include combining TOD in China with affordable housing and/or congestion-reduction strategies.

2.2 Policy transfer examples for China

China has a unique set of legal and financial conditions. This situation complicates the process of transferring successful TOD practice from the West. Chinese cities' urban planning approaches still more or less follow the Soviet model, i.e., the project-oriented mode (Wei & Li, 2002; Wei, 2005). Furthermore, urban land is owned by the state in China. This situation differs greatly from the private developer-driven context of TOD in the US (Guthrie & Fan, 2016.) As a result, if a TOD wants to be successful in China, it must alter the planning, design, and operation of TOD projects.

Thomas (2014) investigated how two Chinese cities – Jinan and Kunming incorporated sustainable transportation policies into their transportation systems. She pointed out that once the urban planning system attains a higher legal status, the second-tier cities such as Jinan and Kunming would have more potential to produce a sustainable transportation system and TOD program. Chen (2010) contrasted TOD in the U.S. and China, with an eye towards the implications of U.S. TOD practice for Chinese cities. One of the most important issues he documented was the higher urban population density in Chinese cities than U.S. cities. Thus, Chinese cities could not directly use the population density thresholds used in U.S. TOD projects. Loo and du Verle (2016) demonstrated that job density around transit stations affects the travel behavior of workers in Hong Kong, echoing Cervero (1995). Mu and de Jong (2016) addressed the complexity of the policy process and negotiations connected with TOD in China. They proposed a network governance approach to deal with the sharp interactions between the involved actors in China's urban planning system, and pointed out that possible financing and funding approaches for TOD development designed for the rich East China were not necessarily practical for the second and third tiers of cities in Western China. Venhoeven (2014) transferred the best TOD practices in Netherlands to Beijing, and proposed a new standard for Beijing's new TOD projects – to pay more attention to the pedestrian experience. Straatemeier (2009) listed the implications of TODs in the U.S. for Germany, including enhancing public-private trust and emphasis on "place making" rather than "money making." For this reason, Chinese TODs should avoid the objective of "making money." Historical conditions in Chinese cities, however, are substantially different from those in other countries with an established track record of TOD projects. As a result, some scholars, such as Mu et al. (2013) called for decades of observations of TOD practices in other sister-cities in different countries, such as Singapore, India, the U.S., Netherlands, the U.K., Germany, etc., to identify the most appropriate TOD theory and practical examples, leading to a sustainable transportation system for Chinese cities.

As addressed above, the primary objective of TOD is to solve urban problems such as traffic congestion, affordable housing shortages, air pollution, and incessant sprawl (TCRP, 2002). In this study, we may draw lessons from TODs in American cities. Successful TOD experiences of the U.S. have fast spread to different countries such as Japan, Singapore, and Seoul between 1990 and 2010 (Doulet &

Delpirou, 2017). Early American cities were also "TOD." Before the 1920s, American suburbanization was driven in tandem by streetcar companies and real estate developers. According to Doulet and Delpirou (2017), "the Chinese context seems well suited to the implementation of TOD principles in many aspects." After the rapid urbanization and urban growth in the last decades, China's primary problems in urban development lie in the "finance of land." In China today, the land around transit stations is often developed as upmarket residential and commercial uses. In such cases, the people who depend most on transit cannot afford to live in TOD communities. Coincidently, the U.S. and other English-speaking countries have confronted the same dilemmas in urban development as Chinese cities (Doulet & Delpirou, 2017). Consequently, this aspect of the U. S. TOD experience is highly relevant to TOD planning in China today.

2.3 TOD impact assessment techniques

The secondary objective of this paper is to evaluate the potential for TOD (i.e., future impacts of TOD) in different tiers of cities in China. The potential for TOD refers to a city that has a chance of promoting "livable communities" and "smart growth." For this consideration, evaluating the potential of TOD in different tiers of cities in China could help determine a more appropriate urban land development policy for different cities. Crucially, it could also help determine how to apply TOD practices of other countries to China in the next decade. To identify an appropriate technique to evaluate the potential of TOD in Chinese cities, we first review the general methodological literature on TOD impact assessment.

Techniques for measuring TOD impacts can be divided into analytical and simulation-based (Taeihagh, Bañares-Alcñantara, & Millican, 2009; Macharis & Bernardini, 2015). Analytical methods frequently draw on cost-benefit analysis, cost-effectiveness analysis and multi-criteria decision analysis techniques (Browne & Ryan, 2011). In addition, the prediction of land-use changes in the context of accessibility to transit stations, residential property value changes, residential/commercial permitting rates in station areas and neighborhood environmental pollution reductions are also based in the framework of analytical methods (Geurs & van Wee, 2004; Hatzopoulou & Miller, 2009; Guthrie & Fan, 2013). Analytical techniques can also be divided into aggregate and disaggregate models. Aggregate models analyze the effect of transport policy at the level of the entire study area. Disaggregate models, on the other hand, tend to explore policies' effects on individuals. As a result, surveys are critical tools for the disaggregate approach (Eboli & Mazzulla, 2011; Idris, Nurul Habib, & Shalaby, 2015).

Simulation-based methods aim to measure the effect of transport policy according to the simulation results. Simulation models are commonly constructed based on a series of input/output data. The input data consists of the policy scenario, present land utilization data, etc. The output data often include the functional indicators of the study area, such as housing prices, transportation mode split, accessibility and/or walkability of the area, land use mix, etc. Popular simulation models include Cellular Automaton models, multi-agent models, system dynamics models, social force models, discrete event simulations, etc. (Ku, 2016). Recently, the evaluation of TOD is increasingly applying new and emerging analysis techniques such as geographical information system tools, visualization technology, remote sensing, etc. (Heeress, Tillema, & Arts, 2012; Mishra et al., 2014). Some of these tools, such as the tool developed by Nelson and Niles (1999) and Jeihani et al. (2013), were combined with the urban simulation techniques, to predict whether the TOD project could be successfully implemented. Indeed, these tools to some extent enabled us to use the simulation technique to identify the future impacts of TOD.

To date, no research has explored how to predict or evaluate the effects of future TOD policies in China. Foremost among the reasons for this is that future land use—an important data point for most simulations—is difficult to predict in Chinese cities. Measures of TOD impacts are strongly related to the effects of transit access on nearby land uses (Puget Sound Regional Council, 2015). In this research, we propose to evaluate the future impacts of TOD policy in different tiers of Chinese cities using a Cellular Automaton simulation model. The Cellular Automaton technique allows us to evaluate the impacts of TOD based on the current land use situation in Chinese cities. The technique has been proven effective in predicting the effects of transportation policy (Lagarias, 2012; Aljoufie, et al. 2013; Tian et al., 2016).

3 Evaluation of TOD potential across 50 Chinese cities

3.1 Methodology

To evaluate urban growth and TOD practices for all Chinese transit metropolises, we employ the simulation approach with a Cellular Automaton (CA) model. Because we aim to evaluate future TOD policies of all transit metropolises in China in 2020, we collect the land use data of the 50 metropolises of mainland China from the 2012 Chinese City Construction Statistics Yearbook (MOHURD, 2013). The metropolises include cities with rail transit systems currently (through December 2015), as well as the cities with planned rail systems set to open by 2020. As Chinese cities contain both rural and urban land uses, in this research, we examine how much rural land near transit stations would be urbanized through development. The geographic location of rail transit stations was collected from the database on China City Metro Website (http://www.ccmetro.com/).

In this case, the methodology of future urban land use simulation could be referred in (Liu & Long, 2016; Long & Wu, 2017). We refer to converted parcels as "TOD parcels" in this paper. At the very beginning, all land parcels' status was set according to the real data of each city in 2012 (MOHURD, 2013). The state-change model using the CA technique is represented as:

$$S_a^{t+1} = f(S_a^{t+1}, \Omega_a^{t+1}, Con, N) \quad (1)$$

Where:

f is the state-change function of the land parcel.

$S_a^t = \begin{cases} 1, \text{urban land} \\ 0, \text{rural land} \end{cases}$ denotes the state of land parcel at the time step t.

Ω_a^{t+1} is the TOD parcel evaluation function;

Con is the constraint condition on urban expansion;

N is the total number of cells (land parcels).

Finally, every discrete time t in the *CA* is a year.

And for each parcel, we would use the potential probability function to determine the state-change function:

$$P_a^{t+1} = P_a^{N,t} \times P_a^{\Omega,t} \times P_a^{Con,t} \times P^{\xi} \quad (2)$$

Where:

P_a^{t+1} is the potential probability of land parcel a for changing the state from "rural land" to "urban land."

$P_a^{N,t}$ is the fixed probability with which land parcel a could be converted from state "rural land" to "urban land" within its neighborhood in the end of time step t. In this study, the neighborhoods of a land parcel would be chosen according to a buffer radius of 1500 meters and according to the land-use boundary condition. In this study, once more than half (50%) percent of land parcels within the neighborhood of land parcel a is "urban land," we set the $P_a^{N,t}$ value as 0.9. Conversely, for the parcel far away from (out of 1500 meters' scope) the transit station, its $P_a^{N,t}$ value would be assigned with a random small probability (generating from range (0, 0.1]).

$P_a^{\Omega,t}$ is the probability which responds to the TOD parcel evaluation function Ω_a^{t+1} in equation (1). The parcel within a buffer area of the transit station with a radius of 1500 meters would have a relatively large probability of being converted to an urban parcel. We set the $P_a^{\Omega,t}$ value as 0.9. Conversely, for the parcel far away from (out of 1500 meters' scope) the transit station, its $P_a^{\Omega,t}$ value would be assigned a random small probability (generating from range (0, 0.2]).

$P_a^{Con,t}$ is the constrained development function. Once the land parcel cell locates within (with a 1500-meter buffer radius) the restrictive development areas, e.g., the water, mountains, customs and culture, historical sites, we set $P_a^{Con,t} = 0$; and otherwise, $P_a^{Con,t} = 1$.

P^{ξ} denotes the stochastic disturbance in the model. In this case, we set $P^{\xi} = 0.95$. That is, we would set 95% as the confidence interval for the total probability value.

In summary, we could use a threshold probability to determine the state for each land parcel as follows:

$$f = \begin{cases} 1, P_a^{t+1} \geq P \\ 0, P_a^{t+1} < P \end{cases} \quad (3)$$

Where: P is the threshold probability which controls the change of land parcel state. That is, P could be deemed as the predefined "urbanization rate" in a given period. In this case, we set $P = 0.55$.

In Figure 3, there is an example that shows how the simulation model is used to determine whether a land parcel would change its state from the "rural land (0)" to "urban land (0)".

Land parcels A and B shown in Figure 3 are located in the same neighborhood. On the other hand, 5/9 of the land parcels within the neighborhood are urban land. As a result, we could set $P_A^{N,t} = P_B^{N,t} = 0.9$. At the same time, if we suppose that the development within the neighborhood is unrestricted, we have $P_A^{Con,t} = P_B^{Con,t} = 1$.

Suppose that the distance between land parcel A and the closest transit station is 500 meters and that the distance between land parcel B and the closest transit station is 2000 meters. As a result, according to the method presented above, we could set the probabilities responding to the effect of TOD as follows: $P_A^{\Omega,t} = 0.9$ and $P_B^{\Omega,t} = .01$.

According to equation (2), we could obtain the potential probability of changing the state from "rural land" to "urban land" at the next time step for the two land parcels in Figure 3 as follows: $P_A^{t+1} = 0.9 \times 0.9 \times 1.0 \times 0.95 = 0.7695$ and $P_B^{t+1} = 0.9 \times 0.1 \times 1.0 \times 0.95 = 0.086$. For this sake, once we have set the threshold probability P as 0.55 in equation (3), we could determine the states of the two land parcels of the next time step according to equations (1) and (3) as: $S_A^{t+1} = 1$ and $S_B^{t+1} = 0$.

It could be learned from the case presented in Figure 3 that the land parcel's distance to the closest transit station would play an essential role in determining the state-change probability. As a result, it could well reflect the effect of the TOD scenario on urban land use change. Finally, as for of the calibration of the simulation model, we use the data in 2012 as a benchmark, and the land use data of each city in 2015 to calibrate the input parameters accordingly.

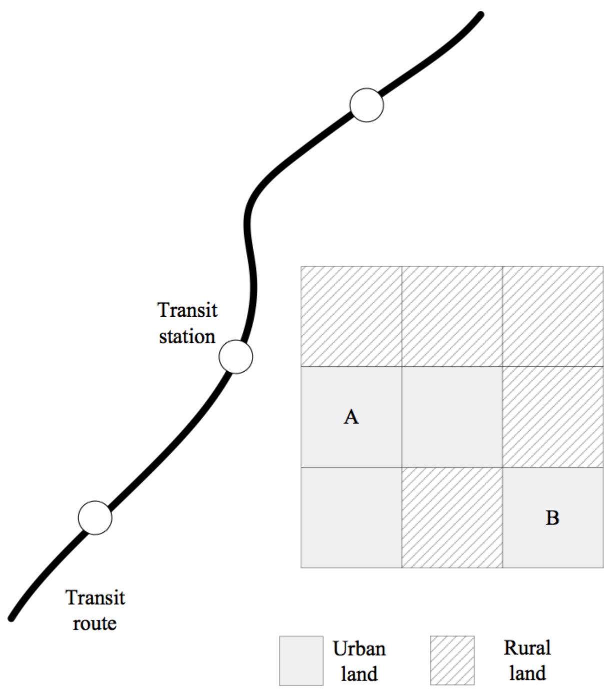

Figure 3: Example to demonstrate the state change of land parcels

3.2 Results

After several rounds of simulations, we calculate the average "urban" land parcel sizes for each transit metropolis. To evaluate urban expansions and TOD effects in each transit metropolis in more quantitative detail, we propose some additional indicators: Urban Land Parcel's Size (ULPS, e.g., Built areas), Expanded Land Parcel's Size (ELPS), Expanded Land Parcels Size Ratio (ExR = ELPS/ULPS), TOD Parcel's Size (TODPS), TOD Parcel's Ratios (TODR= TODPS/ULPS) and a ratio of TOD parcels to expand land parcels (TOD/Ex = TODR/ExR). ULPS denotes the built areas of each transit metropolis in 2020; ELPS denotes the expanded urban areas during 2015 and 2020 according to each metropolis's recent land-use planning under the NTU scenario (Liu & Long, 2016; Long & Wu, 2017); and ExR demonstrates the ratio of the expanded urban areas to the total urban built areas in 2020; TODPS represents the expanded urban land areas close to metro stations in each transit metropolis, and TODR denotes the percentage of TODPS relative to the total urban built area; finally, TOD/Ex is used to demonstrate the ratio of urban land areas expanded due to TOD practices to the total expanded urban land areas. TOD/Ex offers a direct measure of TOD effects on urban expansion. For instance, for two cities (we may call them A and B), both have a TODR of 5%. However, City A's ExR is 30% and City B's is 10%. We might then conclude that City B would be affected by TOD practice more than City A, since TOD/Ex of City A is 1/6, while TOD/Ex of City B is 1/2. This pattern implies that City B would undergo more urban land expansion along with the transit system in 2020.

For the simulation, we first collected the status quo data of urban land parcels for each transit metropolis. Based on the TOD scheme of each transit metropolis, we then simulated the distribution of TOD land parcels (shortened TOD parcels hereafter) by 2020. For illustration, we select 12 representative transit metropolises as demonstration – the relevant results are shown in Figure 4.

In Figure 4-1, we show urban expansion of several typical capital cities of China. In each panel, we find that the metro network configuration as well as details of urban land parcels by 2020 for a typical first-class city (a city with more than 10 million urban population). The simple-hatch denotes the current urban land parcels, the cross-hatch blocks denote the expanded urban land parcels, and the coral blocks are the TOD parcels. Taking Beijing and Shanghai as examples, we could see that the expanded land parcels as well as TOD parcels are distributed throughout the suburbs (i.e., the outskirts) of the cities. Due to overdevelopment (extreme high density) in the central business districts (CBDs) of Beijing and Shanghai, urban land expansion and TOD can only occur in the suburbs from 2015 to 2020 instead of the CBDs, although these two cities have already been aware of and stressed the importance of TOD. The same situation is not present in Tianjin, Guangzhou, and Xi'an. Besides the suburbs, TOD can also be constructed in the CBDs. These cities are still quite active regarding CBD redevelopment projects. Some run-down zones in the old CBDs of these three cities would be redeveloped as TOD communities in this simulation. Compared to other cities shown in Figure 4-1, TOD parcels are wretchedly inadequate in Wuhan (presented in Panel F) in 2020 despite the large number of expanded land parcels on the outskirts of this city. Several metro lines of Wuhan city will be still under construction by 2020. The local government also does not establish any policies to encourage land development around the constructing metro stations. As a result, there would be a serious deficiency of TOD implementations in Wuhan, compared to other capital cities.

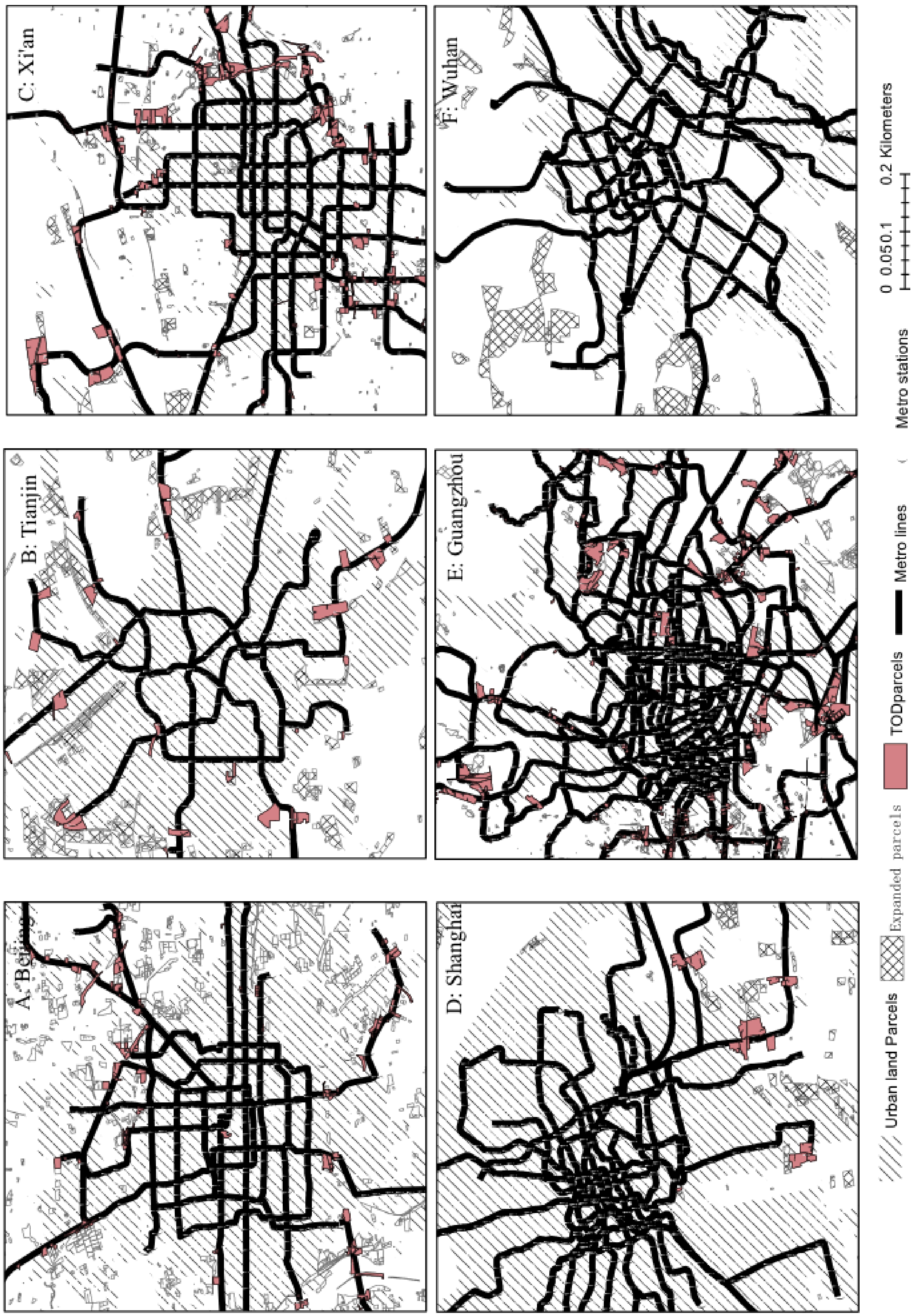

Figure 4-1: The existing urban land parcels, the expanding parcels and TOD parcels of representative metropolitans of China, 2020

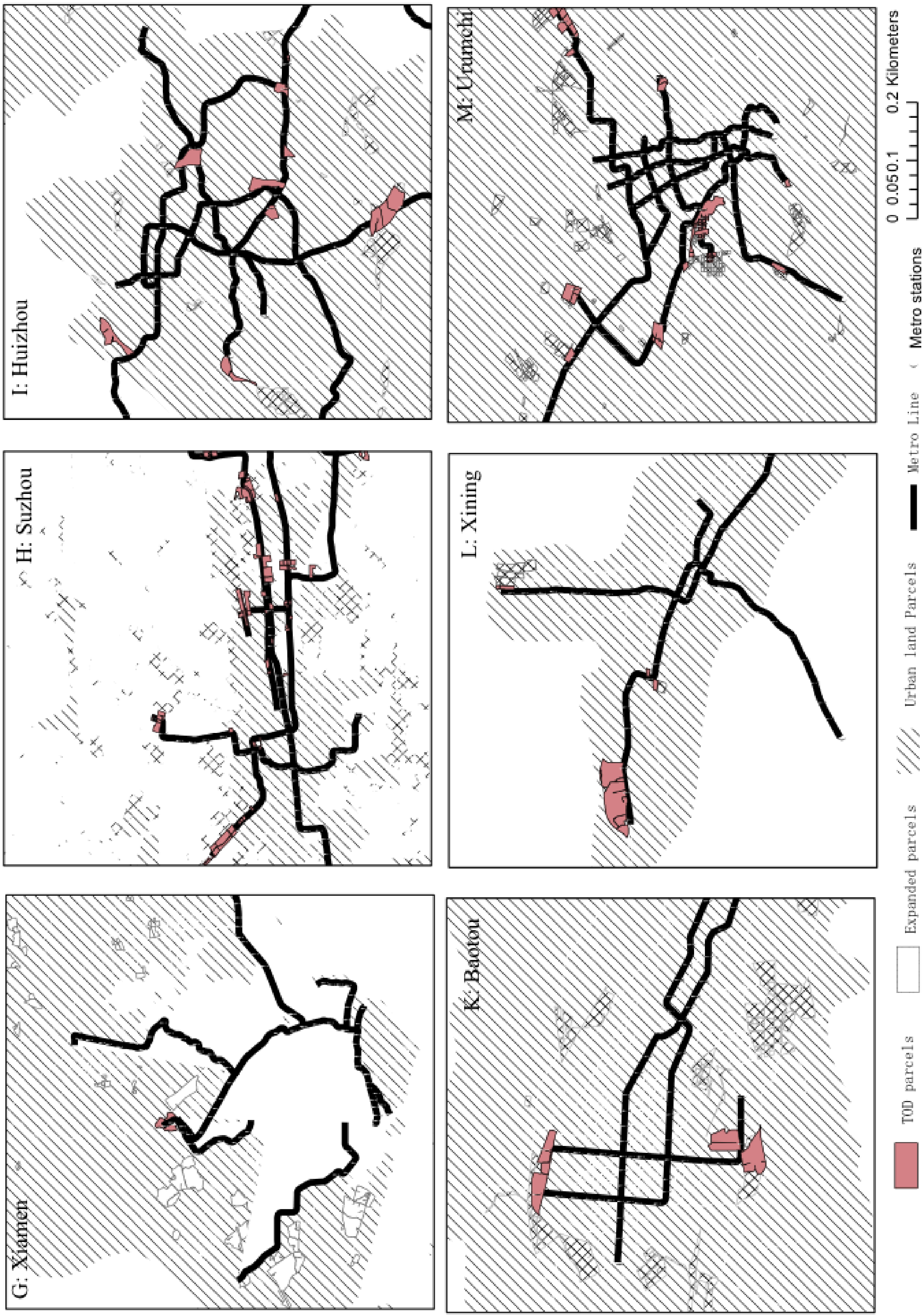

Figure 4-2: The existing urban land parcels, the expanding parcels and TOD parcels of representative metropolitans of China, 2020

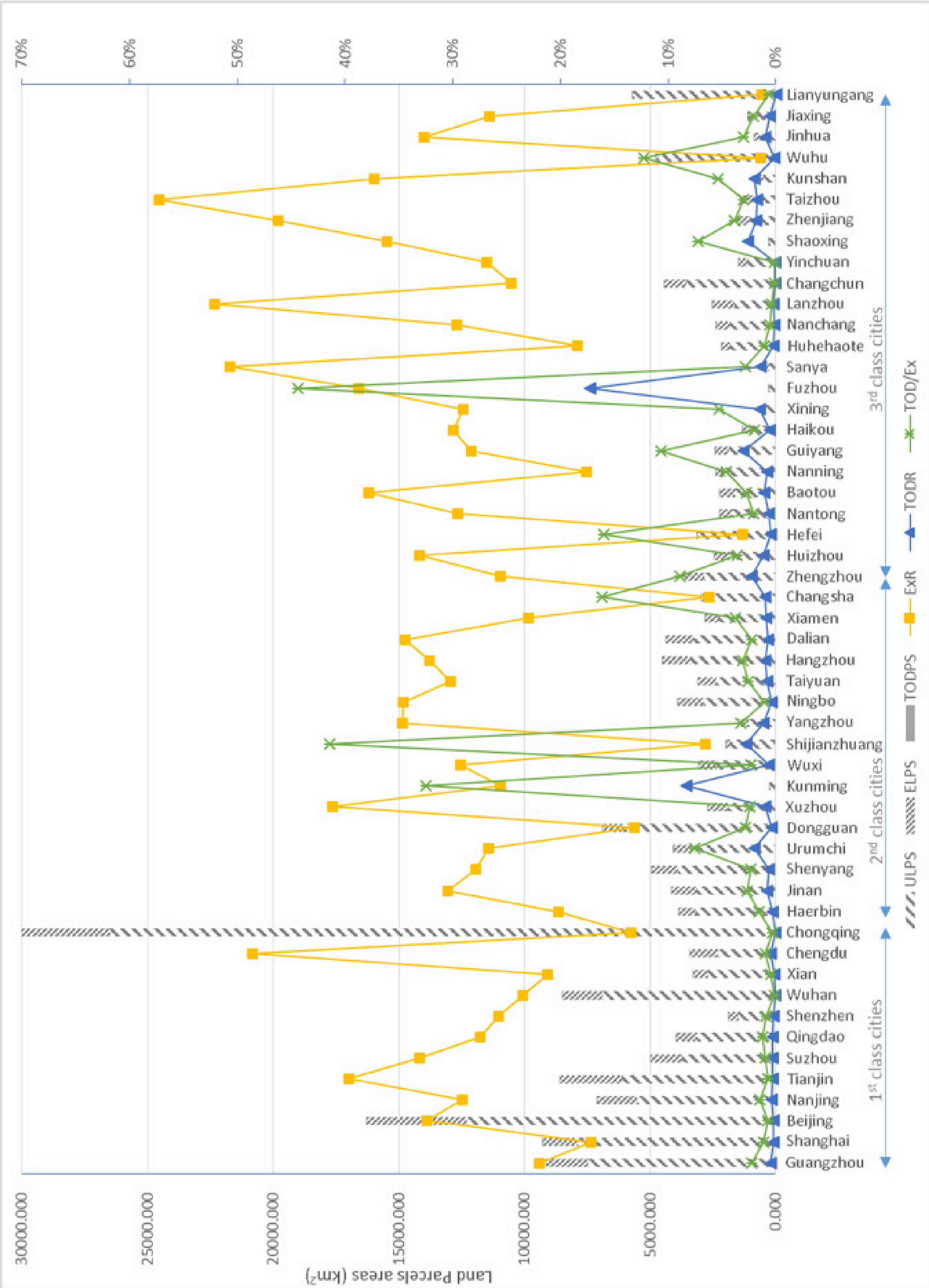

Figure 5: The urban land parcels, expanded land parcels and TOD parcels and the corresponding ratios of all metropolises by 2020

Figure 4-2 presents the results of urban expansions and TOD practices in the typical second-class cities (those with 5-10 million urban population) of China. Panels G, H and I present three typical second-class cities—Xiamen, Suzhou and Huizhou—spanning locations from north to south China. Correspondingly, Panels K, L and M show three other typical second-class cities—Baotou, Xining and Urumchi—from east to west China. A large body of research examines TOD projects in the typical capital cities of China (Mu & Jong, 2012; Atkinson-Palombo & Marshall, 2013; Xu & Zhang 2016). However, the study of TOD practice in the second-class cities of China is relatively rare, let alone the second-class cities in Western China. Figure 4-2 shows that the typical second-class city in China has greater relative growth in TOD parcels by 2020 than the first-class cities. Especially, at Urumchi, there would be many TOD parcels, both in its CBD and suburbs. Consequently, we predict broad implementation of TOD practices in all Chinese transit metropolises from 2015 to 2020. Eventually, the degree of TOD implementation would be destined to become a key index of evaluating the urban development policy in China.

Furthermore, the six indices for evaluating the TOD effects, ULPS, ELPS, TODPS, ExR, TODR, and TOD/Ex, are shown in Figure 5. As shown, the indicating bars: ULPS, ELPS and TODPS which use the primary Y-axis (on the left side of Figure 5) denote the total size of urban land parcels and represent the urban scale by 2020. On the other hand, the line markers: ExR, TODR, TOD/Ex which uses the secondary axis (on the right side of Figure 5) denote the degree of the urban expansion, as well as what TOD level would be up to at each transit metropolis by 2020.

As demonstrated by the ULPS, ELPS and TODPS bars in Figure 4, metropolises from Guangzhou to Chongqing are the first-class cities, which have relatively larger ULPS and ELPS values than other types of transit metropolises. For the TODPS, the first-class cities do not have the dominant value again. These situations indicate that the first-class cities would not necessarily construct more TOD communities than other types of metropolises.

As shown by ExR, TODR, TOD/Ex lines in Figure 5, we can see the urban expansion rate of each transit metropolis, the ratio of TOD parcel sizes and the ratio of TOD parcel sizes to expanded parcel sizes. It appears that the second-class and the third- class cities (the second-class cities with 5-10 million urban population: from Haerbin to Zhengzhou; the third-class cities with 1-5 million urban population: from Huizhou to Lianyungang) would have larger TODR and TOD/Ex values than those of the first-class cities. At the same time, the largest TODR values are also found in the second-class and the third-class cities, such as Kunming and Fu. This pattern tells us that the larger potential for TOD community construction would be in the second-class and the third-class Chinese cities from 2015 to 2020. Moreover, the second-class and the third-class cities of China show greater potential for TOD implementation – reflected by the large TODR and TOD/Ex as shown in Figure 5. That is, there would be a higher proportion of TOD parcels in the expanded land parcels of the second-class and the third-class cities than in the first-class cities by 2020.

In a word, TOD practices in China would necessarily become more diverse in the next five or ten years under this scenario. During the rapid urbanization process of China cities, TOD has become an important and broad trend that applies to cities beyond the first-class cities. The largest potential for TOD implementation exists among the second-class and the third-class cities in the next five years, rather than in the first-class cities as before. This pattern may arise because the first-class cities already have large metro systems which they are in the process of extending, while second- and third-class cities are building new systems which may result in a more rapid initial increase in metro system extent. As a result, there would be more TOD parcels in the second- and third-class cities than in the first-class cities, which would respond to the higher potential of TOD development. On the other hand, this result calls for a new focus on designing appropriate urban development policies for second- and third-class Chinese cities. But then again, good TOD development is not only determined by how much land space is available in a city; effective and successful TOD development requires much more than available space. Good funding, well thought out plans, careful coordination among various stakeholders, etc., are also basic requirements. Fortunately, with the ample land spaces, the second and third tier of cities could effectively carry out land development and financing to create successful TOD communities. For the first tier of cities, due to limited land space, there is also limited opportunity to cultivate viable TOD communities in the future.

4 Discussion and conclusions

This paper presented a comprehensive review of the existing literature on transit oriented development, specifically as applied to TOD in China. Our literature review demonstrates the differences in intent and practice between Western and Chinese TOD—not least of them the West's common focus on allowing denser, more compact redevelopment of automobile-dominated suburbs versus the Chinese focus on enabling suburban expansion of already dense cities. Still, the depth and breadth of Western-focused TOD literature holds important lessons for TOD planning in China as long as the context is taken into account properly, notably the importance of an active public-sector role in promoting TOD, as well as the importance of making a case for TOD with an accurate evaluation of TOD impacts.

The TOD literature has largely overlooked China until recently. Although interest has increased in recent years, there is still a void in terms of forecasting the future impacts of TOD on China's urban growth. Taking current TOD practices in China as examples, we estimated the future land development impacts of TOD strategies in all Chinese cities that are expected to have rail transit systems by 2020. We found that the second-class and the third-class cities will probably have greater potential to achieve large urban form impacts from TOD strategies than the first-class cities in China. This pattern arises out of fully built-up urban cores, as well as slowing rates of peripheral growth in the largest cities, contrasted with significant opportunities for both inner-city and suburban TOD, as well as rapid urban growth in smaller cities.

The evaluation results have important implications for practical TOD strategies, and could be applied to many aspects of the urban policy establishment. First, when carrying out urban master planning, TOD parcel sizes could be used as an important index to evaluate an area's potential for sustainable development. Second, the TOD parcel size ratio could be used as a key control indicator of land use planning during the urban zoning planning, allowing planners to zone for TOD in the areas most suitable for TOD. Recently, zoning plans (also called regulatory plans) in many Chinese cities have been required to consider TOD. However, current evaluation of TOD lacks the aid of evaluation indices such as those employed in the U.S., which makes the monitoring of TOD progresses in Chinese cities a difficult task. Our analysis shows that the TOD parcel size ratio offers one effective evaluation index. Third, although there is increasing focus in the literature on TOD across China in recent years, most of that focus has been on the larger cities. Based upon our study, it appears that the second- and third-class cities have the greatest potential for TOD implementation. Effective TOD promotion in smaller cities calls for a different set of policy solutions from TOD promotion in the largest cities, reflecting the context of less mature transit systems and simultaneous explosive suburban growth and inner-city redevelopment. As such, establishing TOD supporting policies focused on these mid-size cities is important, e.g., requiring TOD around large metro stations, adding metro lines to and across developing areas and encouraging relocations of population and jobs to areas near metro stations in the second- and third-class cities of China.

This research took currently planned rail transit lines as given, but future research on the subject could focus on optimal transit alignments and planning to support TOD implementation for the second-class and the third-class cities of China. Additionally, future research could also jointly consider TOD focused land use and transit planning with an eye to impacts: building on the method laid out in this paper to develop strategies for not only achieving regionally significant levels of TOD implementation, but also realizing desired travel behavior results from it. Such an integration of TOD focused land development policy (as studied here) with TOD focused transit planning could form the basis of an iterative TOD planning practice allowing transit systems and new communities to grow into each other in moderate sized Chinese cities (and elsewhere), rather than requiring either one to fit itself to the other. Such a planning practice would be highly valuable anywhere transit development and rapid urban growth meet.

Acknowledgments

This research has been supported in part by Humanity and Social Science Youth foundation of the Ministry of Education of China (under Grant No. 12YJCZH237) and National Natural Science Foundation of China (under Grant No. 51208445).

References

Aljoufie, M., Zuidgeest, M., Brussel, M., van Vliet, J., & van Maarseveen, M. (2013). A cellular automata-based land use and transport interaction model applied to Jeddah, Saudi Arabia. *Landscape and Urban Planning, 112,* 89–99.

Arrington, G. B., & Cervero, R. (2008, January). Effects of TOD on housing, parking, and travel. Presented at the annual meeting of the Transportation Research Board of the National Academies, Washington, DC.

Atkinson-Palombo, C., & Marshall, W. (2013). *Quantifying transit-oriented development's potential contribution to federal policy objectives on transportation-housing-energy interactions.* Center for Transportation and Livable Systems (CTLS). Mansfield, CT: University of Connecticut, Department of Geography.

Browne, D., & Ryan, L. (2011). Comparative analysis of evaluation techniques for transport policies. *Environmental Impact Assessment Review, 31*(3), 226–233.

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

Cervero, R. (1995). *TCRP research results digest 4: Transit ridership initiative.* Washington, DC: Transportation Research Board.

Cervero, R. (2002). Built environments and mode choice: Toward a normative framework. *Transportation Research Part D: Transport and Environment, 7*(4), 265–284.

Cervero, R. (2003). *Ridership impacts of transit-focused development in California.* Berkeley, CA: University of California, Institute of Urban and Regional Development.

Cervero, R. (2008). *Effects of TOD on housing, parking, and travel.* Washington, DC: Transportation Research Board, the Federal Transit Administration in cooperation with the Transit Development Corporation.

Cervero, R., & Dai, D. (2014). BRT TOD: Leveraging transit-oriented development with bus rapid transit investments. *Transport Policy, 36,* 127–138.

Cervero, R., & Day, J. (2008). Suburbanization and transit-oriented development in China. *Transport Policy, 15*(5), 315–323.

Chen, X. (2010). Prospect of the transit-oriented development in China. *Management Research and Practice, 2*(1), 83–93.

Curtis, C., & Scheurer, J. (2017). Performance measures for public transport accessibility: Learning from international practice. *Journal of Transport and Land Use, 10*(1), 1–26.

De Vos, J., Van Acker, V., & Witlox, F. (2014). The influence of attitudes on transit-oriented development: An explorative analysis. *Transport Policy, 35,* 326–329.

Dou, Y., Luo, X., Dong, L., Wu, C., Liang, H., & Ren, J. (2016). An empirical study on transit-oriented low-carbon urban land use planning: Exploratory spatial data analysis (ESDA) on Shanghai, China. *Habitat International, 53,* 379–389.

Doulet, J.-F., & Delpirou, A. (2017). Taking advantage of a historic opportunity? A critical review of the literature on TOD in China. *Journal of Transport and Land Use, 10*(1), 1–17.

Eboli, L., & Mazzulla, G. (2011). A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view. *Transport Policy, 18*(1), 172–181.

Feudo, F. L. (2014). How to build an alternative to sprawl and auto-centric development model through a TOD scenario for the North-Pas-de-Calais region? Lessons from an integrated transportation-land use modelling. *Transportation Research Procedia, 4,*154–177.

Geurs, K. T., & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography, 12*(2), 127–140.

Gmbh, G. D. G. f. I. Z. G. (2015). Draft MRV Blueprint for Urban Passenger Transport NAMAs Illustrated by the Chinese Transit Metropolis Programme, Urda Eichhorst (Wuppertal Institute) and Daniel Bongardt (GIZ).

Guthrie, A., & Fan, Y. (2013). Streetcars and recovery: An analysis of post-Katrina building permits around New Orleans streetcar lines. *Journal of Planning Education and Research, 33*(4), 381–394.

Guthrie, A., & Fan, Y. (2016). Developers' perspectives on transit-oriented development. *Transport Policy, 51,* 103–114.

Handayeni, K. D. M. E. (2014). TOD best practice: Lesson learned for GHG mitigation on transportation sector in Surabaya City, Indonesia. *Procedia—Social and Behavioral Sciences, 135,* 152–158.

Hatzopoulou, M., & Miller, E. J. (2009). Transport policy evaluation in metropolitan areas: The role of modeling in decision-making. *Transportation Research Part A: Policy and Practice, 43*(4), 323–338.

Heeres, N., Tillema, T., & Arts, J. (2012). Integration in Dutch planning of motorways: From "line" towards "area-oriented" approaches. *Transport Policy, 24,* 148–158.

Huang, X., Cao, X., Cao, X., & Yin, J. (2016). How does the propensity of living near rail transit moderate the influence of rail transit on transit trip frequency in Xi'an? *Journal of Transport Geography, 54,* 194–204.

Idris, A. O., Nurul Habib, K. M., & Shalaby, A. (2015). An investigation on the performances of mode shift models in transit ridership forecasting. *Transportation Research Part A: Policy and Practice, 78,* 551–565.

Jeihani, M., Zhang, L., Ardeshiri, A., Amiri, A., Baghaei, B., Nasri, A., & Zamir, K. R. (2013). *Development of a framework for transit-oriented development (TOD).* Baltimore, MD: U.S., Maryland State Highway Administration Office of Policy and Research.

Jiang, Y., Zegras, P. C., & Mehndiratta, S. (2012). Walk the line: Station context, corridor type and bus rapid transit walk access in Jinan, China. *Journal of Transport Geography, 20*(1), 1–14.

Ku, C.-A. (2016). Incorporating spatial regression model into cellular automata for simulating land use change. *Applied Geography, 69,* 1–9.

Lagarias, A. (2012). Urban sprawl simulation linking macro-scale processes to micro-dynamics through cellular automata, an application in Thessaloniki, Greece. *Applied Geography, 34,* 146–160.

Li, G., Luan, X., Yang, J., & Lin, X. (2013). Value capture beyond municipalities: Transit-oriented development and inter-city passenger rail investment in China's Pearl River Delta. *Journal of Transport Geography, 33,* 268–277.

Li, Y., Guo, H. L., Li, H., Xu, G. H., Wang, Z. R., & Kong, C. W. (2010). Transit-oriented land planning model considering sustainability of mass rail transit. *Journal of Urban Planning and Development-ASCE 136*(3), 243–248.

Liu, X., & Long, Y. (2016). Automated identification and characterization of parcels with OpenStreetMap and points of interest. *Environment and Planning B: Planning and Design 43*(2)*,* 341–360.

Long, Y., & Wu, K. (2017). Simulating block-level urban expansion for national wide cities. *Sustainability, 9*(6), 879.

Loo, B. P. Y., & du Verle, F. (2016). Transit-oriented development in future cities: Towards a two-level sustainable mobility strategy. *International Journal of Urban Sciences, 21,* 54–67.

Macharis, C., & Bernardini, A. (2015). Reviewing the use of multi-criteria decision analysis for the evaluation of transport projects: Time for a multi-actor approach. *Transport Policy, 37,* 177–186.

Mishra, S., Welch, T. F., Torrens, P. M., Fu, C., Zhu, H., & Knaap, E. (2014). A tool for measuring and visualizing connectivity of transit stop, route and transfer center in a multimodal transportation network. *Public Transport, 7*(1), 77–99.

MOHURD. (2013). *Chinese City Construction Statistics Yearbook 2012.* Beijing: Ministry of Housing and Urban-rural Development of the People's Republic of China, China Planning Press. In Chinese.

Mu, R., & de Jong, M. (2016). A network governance approach to transit-oriented development: Integrating urban transport and land use policies in Urumqi, China. *Transport Policy, 52,* 55–63.

Mu, R., & de Jong, M. (2012). Establishing the conditions for effective transit-oriented development in China: The case of Dalian. *Journal of Transport Geography, 24,* 234–249.

Mu, R., Heuvelh, T, Groenewegen, E. F., & de Jong, M. (2013). Transit-oriented development in China: How can it be planned in complex urban systems? Working paper of Delft University of Technology, Delft, Netherlands.

NDRC (National Development and Reform Commission). (2016). *Three-year action plan for major projects in transportation infrastructure construction.* Beijing, China: NDRC of China. In Chinese.

Nelson, D., & Niles, J. (1999). Essentials for transit-oriented development planning: Analysis of non-work activity patterns and a method for predicting success. *Proceedings of the Seventh TRB Conference on the Application of Transportation Planning Methods,* Boston, Massachusetts. Retrieved from http://docs.trb.org/00939750.pdf

Noland, R. B., & DiPetrillo, S. (2015). Transit-oriented development and the frequency of modal use. *Journal of Transport and Land Use, 8*(2), 21–44.

Noland, R. B., Ozbay, K., DiPetrillo, S., & Iyer, S. (2014). *Measuring benefits of transit-oriented development.* San Jose, CA: Mineta National Transit Research Cosortium, Mineta Transportation Institute, College of Business, San Jose State University.

Pan, H. X., Shen, Q., & Liu, C. (2011). Transit-oriented development at the urban periphery insights from a case study in Shanghai, China. *Transportation Research Record, 2245,* 95¬–102.

Puget Sound Regional Council. (2015). Transit-Supportive Densities and Land Uses. PSRC VISION 2040 M. Hubner. Seattle, WA: Puget Sound Regional Council.

Reconnecting America. (2010). Inventory of TOD programs: A national review of state, regional and local programs that fund transit-oriented development plans and projects. Retrieved from http://reconnectingamerica.org/assets/Uploads/2010 _inventory_of_tod_programs.pdf

Straatemeier, T. (2009). *Transit-oriented development in the United States—What can the Dutch learn?* Washington, DC: The German Marshall Fund of The United States.

Taeihagh, A., Bañares-Alcántara, R., & Millican, C. (2009). Development of a novel framework for the design of transport policies to achieve environmental targets. *Computers & Chemical Engineering, 33*(10), 1531–1545.

TCRP. (2002). Transit-oriented development and joint development in the United States: A literature review. G. Chisholm, Washington, DC: Federal Transit Administration, Transportation Research Board.

Thomas, A. (2014). Collaboration and learning: The means to sustainable transportation in China. Berkeley, CA: University of California.

Thomas, A., & Deakin, E. (2008). Land-use challenges to implementing transit-oriented development in China case study of Jinan, Shandong Province. *Transportation Research Record, 2077,* 80–86.

Tian, G., Ma, B., Xu, X., Liu, X., Xu, X., Liu, X., Xiao, L., & Kong. L. (2016). Simulation of urban expansion and encroachment using cellular automata and multi-agent system model—A case study of Tianjin metropolitan region, China. *Ecological Indicators, 70,* 439–450.

Venhoeven, T. (2014). *Transit-oriented development in China and the Netherlands. The multi-annual program Towards 2050: Developing a Sino-Dutch approach for sustainable urbanization.* Beijing: Towards2050.

Wei, Y. D. (2005). Planning Chinese cities: The limits of transitional institutions. *Urban Geography,* *26*(3), 200–221.

Wei, Y. D., & Li., W. (2002). Reforms, globalization, and urban growth in China: The case of Hangzhou. *Eurasian Geography and Economics, 43*(6), 459–475.

Xu, T., & Zhang, M. (2016). Tailoring empirical research on transit access premiums for planning applications. *Transport Policy, 51,* 49–60.

Yang, J., Chen, J., Le, X., & Zhang, Q. (2016a). Density-oriented versus development-oriented transit investment: Decoding metro station location selection in Shenzhen. *Transport Policy, 51*: 93–102.

Yang, J., Quan, J., Yan, B., & He, C. (2016b). Urban rail investment and transit-oriented development in Beijing: Can it reach a higher potential? *Transportation Research Part A: Policy and Practice, 89,* 140–150.

Zhang, M., Meng, X., Wang, L., & Xu, T. (2014). Transit development shaping urbanization: Evidence from the housing market in Beijing. *Habitat International, 44,* 545–554.

Zhang, M., & Wang, L. (2013). The impacts of mass transit on land development in China: The case of Beijing. *Research in Transportation Economics, 40*(1), 124–133.