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Heterogeneous landscapes of urban greenways in Shenzhen: Traffic impact, corridor width and land use

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ABSTRACT

Greenways are linear green spaces that are widely incorporated as policy instruments to address various urban issues. Heterogeneity is observed among the forms, functions, and activities of greenways. However, a number of studies have viewed urban greenways as homogeneous landscape features despite the increasing heterogeneity of urban greenways caused by transportation development. Taking the "three-legged stool" concept as a theoretical starting point, this article develops a conceptual framework for understanding the heterogeneous landscapes of urban greenways. The framework is then applied to empirical work in Shenzhen. This study shows that traffic impact, corridor width and land use are crucial factors in determining the heterogeneity of urban greenways and resolving the conflicts that result from the overemphasis on the transportation function of greenways. These factors also determine the primary benefits of greenways and differentiate various types of greenways. Based on field observations and empirical data, we identify four types of greenways in Shenzhen: transport greenways, forest greenways, park greenways and rural greenways. Greenways in Shenzhen have apparent heterogeneity in recreational attractiveness due to the surrounding landscape and external interference. Furthermore, the majority of Shenzhen greenways are nonmotorized transportation infrastructure with narrow corridors of street greenery. The composition and heterogeneity of greenways in Shenzhen are the result of the "one-size-fits-all" approach to greenway typologies and planning activities, which has become a challenge for multipurpose greenway planning in urban environments. Future efforts should place more emphasis on the heterogeneous landscapes of urban greenways in order to develop improvement strategies associated with specific policy goals.

1. Introduction

Greenways are linear green corridors that are planned, designed and managed for multiuse purposes (Ahern, 1995; Fábos, 1995), and they have a high degree of heterogeneity in type and name (Hellmund and Smith, 2006). The term *greenway* has been widely used in various areas to refer to diverse objects, such as ecological corridors for wildlife habitat (Von Haaren and Reich, 2006), park systems for recreational services (Gobster and Westphal, 2004), and hiking trails for outdoor exercise or natural experience (Rottle, 2006). The synergy and compatibility of multiple uses are the core characteristics of greenways (Ahern, 2002), while recreation, conservation and transportation constitute the "three-legged stool" of proposed greenway values (Erickson, 2004). However, a consensus on a precise definition of greenways likely cannot be achieved (Palardy, Boley and Gaither, 2018) because greenways evolve into various planning strategies with diverse policy goals and planning outcomes. Consequently, researchers have pointed out that the proposed benefits require further evidence-based examination (Hellmund and Smith, 2006; Rottle, 2006). In particular, many studies have attempted to analyze the social, economic and environmental impacts of greenways. However, in these studies, greenways are usually considered homogeneous urban infrastructures while the heterogeneity of greenways is rarely mentioned.

Some recent studies on urban greenways have revealed a special trend of greenway development that increases the heterogeneity of urban greenways. In a case study of greenways in Vancouver, Ngo et al. (2018, p. 716) proposed the term "new urban greenways" which is defined as "landscaped and traffic-calmed pathways with a mix of bicycle facilities and other streetscape improvements." These so-called "new urban greenways" are an adaptive strategy to integrate public rights-of-way in many cases of

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intensively developed urban environments, such as in London, Singapore and the Pearl River Delta (PRD) (Liu et al., 2019). The overstated transportation function leads to new issues. On the one hand, the traffic noise, air pollution and intensively developed environment along these transportation-led greenways could be challenges to other greenway values. On the other hand, decision-makers, planners and researchers could mistakenly consider the ecological, economic and cultural benefits of conventional greenways as policy goals of these transportation-led greenways (Liu et al., 2019). This situation raises new research questions: 1) what are the key factors that determine the heterogeneous landscapes of urban greenways? and 2) what are the implications of those factors in planning and management?

These questions are crucial to the planning and implementation of greenways in countries that have recently initiated their own greenway policies. For instance, the PRD greenways, which are recognized as the pilot greenway project in China, are characterized by the rapid implementation of over 12,500 km of greenways within seven years (Liu, 2017). Some recent studies have focused on greenways in the PRD (Liu et al., 2016; Chung et al., 2018; Liu et al., 2019) and the transfer of greenway policies in other regions of China (Zhang et al., 2020). Nevertheless, a case-specific study often leads to distinct perceptions of greenway concepts. For instance, Chen et al. (2017) and Liu et al. (2018) investigated two case studies of urban greenways in the PRD that have apparent distinctions in terms of location, users and purposes. The former case is hiking trails in a suburban scenic park, while the latter is a riverside greenway in central Guangzhou. There have also been controversies on the diversity of greenways in Shenzhen: some scholars have viewed Shenzhen greenways as homogeneous space for physical activities (Liu et al., 2016), while others have argued that many greenways overlap with the existing infrastructure and face traffic problems (Liu et al., 2019). Most of the existing studies are case-specific, and a systematic investigation on the heterogeneity of urban greenway landscape is lacking.

Therefore, this research is intended to fill this gap. Taking Erickson's concept of the "three-legged stool" of greenways as a theoretical starting point, the current paper develops a new conceptual framework for understanding the heterogeneous landscapes of urban greenways. The framework includes three key factors, namely, traffic impact, corridor width and land use, and they determine the primary benefits of greenways and differentiate types of greenways. These factors influence the features of the "new urban greenways," which are characterized by the conflicts among multiple purposes. This framework is tested in empirical work in Shenzhen, where the high-density greenway network is deeply embedded in the intensively developed urban environment.

This study is organized into six parts. Following this introduction, the second section develops a conceptual framework for understanding the heterogeneous landscapes of urban greenways. The third section introduces the background of PRD greenways and issues associated with official typologies and planning activities. The fourth section proposes an innovative methodology for the empirical investigation of greenways in Shenzhen based on data from on-site photographs, online street views, open-access planning documents and satellite imagery. The fifth section presents empirical findings in Shenzhen showing that there are obvious conflicts between the various greenway functions and the adopted one-size-fits-all planning approach. We identify four types of greenways that show the heterogeneous landscapes of urban greenways in Shenzhen City. The sixth section discusses the implication of the three key factors for greenway values and future planning strategies and presents the main theoretical and empirical contributions to international greenway research.

2. Conceptual framework

2.1. Diversity and heterogeneity of greenways

As responses to the rapid urbanization and fragmentation of landscape, greenways have arisen as planning approaches to promote social and ecological movement by establishing different forms of connection (Flink and Searns, 1993). Because of their diverse purposes, locations and surrounding landscapes, various studies have categorized different types of greenways, including urban riverside greenways, recreational greenways, ecologically significant natural corridors, scenic and historical routes, and greenway systems or networks (Little, 1990); greenways of ecologically significant corridors, recreational greenways, and greenways with historical heritage and cultural values (Fábos, 1995); and parkways, blueways, paveways, glazeways, skyways, ecoways and cycleways (Turner, 1995). Although there are many types and names of greenways, Erickson (2004) argued that recreation, conservation and transportation constitute the "three-legged stool" of greenways. Ahern (2004) suggested that the compatibility and synergy of multiple uses is one of the basic characteristics of greenway theory, especially for greenways in corridors of protected land. For instance, protected wooded riparian corridors can provide not only ecological conservation but also flood control functions and recreational uses (Ahern, 2004). Moreover, with green corridors as buffers, greenways can provide enhanced safety and attractiveness in supporting alternative transportation modes that are separated from the traffic of roadways (Shafer et al., 2000). Nevertheless, pursuing multiple benefits simultaneously sometimes results in conflicts within the functional heterogeneity of greenways. For instance, uncontrolled recreational activities may jeopardize efforts to conserve soils, vegetation, water and animal habitat (Cole, 1993). In addition, natural corridors that lack concerns of design and management could be considered potentially unsafe for women and children (Luymes and Tamminga, 1995; Asakawa et al., 2004). Erickson (2004) further argued that recreation, conservation and transportation are rarely given equal emphasis in the "three-legged stool." Enthusiasm over greenways has arisen worldwide, leading to practices in various contexts. However, an emerging issue is how to prevent greenway enthusiasm from being mere boosterism by developing evidence-based planning strategies and evaluations (Hellmund and Smith, 2006).

Greenway suitability analysis is a traditional tool for greenway alignment planning, which helps to assess land suitability, greenway potential, and adjacent use conflicts (Miller et al., 1998; Qian et al., 2018; Xiang, 1996). However, greenway suitability analysis usually have high requirements for the diversity and sufficiency of data, so they are not always incorporated into greenway planning practices, especially for projects that are under a tight schedule (Liu et al., 2019). Moreover, the heterogeneity of greenways and their diverse influences on greenway uses are rarely studied from the perspective of policy outcomes and public perception. A growing body of literature has focused on the impacts of greenways, such as property values (Noh, 2019), crime (Harris et al., 2018), and physical activity (Liu et al., 2016; Auchincloss et al., 2019). Nevertheless, previous studies have paid little attention to the heterogeneous landscapes of greenways and have often treated greenways as homogeneous infrastructure.

In addition, limited research has focused on new types of greenways. In recent years, transportation-led greenways have been widely adopted as adaptive strategies in the urban environment. For instance, in London, a greenway is "a safe, quiet route through a park, a green space or a street with light traffic" (Transport for London, 2014). In Boston, the ongoing greenway project "Emerald Network" aims at "a high-quality, non-motorized transportation network suitable for people of all ages and abilities" (LivableStreets Alliance, 2018). These greenways incorporate public rights-of-way into greenway resources so that land acquisition can be avoided in establishing a greenway network (Liu et al., 2019). More research is needed to understand how these new transportation-led greenways contribute to the heterogeneous landscapes of greenway networks.

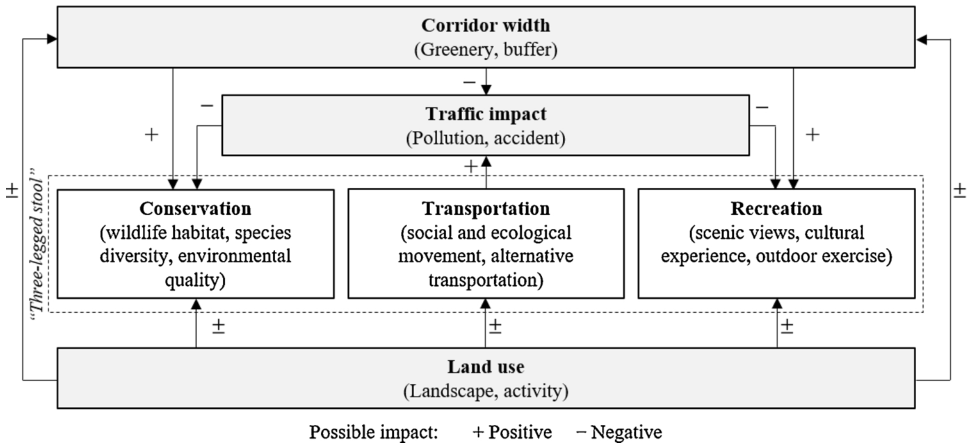


Fig. 1. Conceptual framework of basic factors for greenway values.

2.2. Land use, traffic impact, and corridor width

Greenways have primarily been investigated in three fields: land suitability assessment (Xiang, 1996; Miller et al., 1998; Conine et al., 2004; Qian et al., 2018), use preference and perception in the human dimension (Gobster, 1995; Asakawa et al., 2004; Gobster and Westphal, 2004; Pettengill et al., 2013; Keith and Boley, 2019) and ecological integrity at the regional scale (McGuckin and Brown, 1995; Sinclair et al., 2005). Among all the related elements, land use, corridor width, and traffic impact are the core factors for greenway values (see Fig. 1). First, the land use type, particularly the landscape type, is the core feature in land suitability assessments for greenway alignment planning. Moreover, the primary threat to greenway values is associated with landscape fragmentation and increasing human activities, which are usually the result of intensive urban development. Therefore, land use control becomes crucial in preventing further damage to existing green corridors. Second, traffic impact has become a serious issue for both conservation and recreation, because trespassing vehicles not only threaten the safety of wildlife but also increase air pollution, noise and traffic accidents among nonmotorized travelers. Third, corridor width is essential in greenway planning to decrease the traffic impact, because a wider green corridor and buffering space can reduce the external impacts of vehicle traffic and the related effects. In addition, corridor width can also improve the scenic and recreational values of green spaces.

2.2.1. Land use

In early greenway research, including studies of environmental corridors and ecological greenways, land resource management was considered one of the primary objectives of greenway planning (Zube, 1995). In particular, investigations on environmental corridors in Wisconsin and Georgia provide crucial evidence that support the hypothesis on the co-occurrence of natural and cultural resources in corridor areas (Ahern, 2002). Thus, Ahern (2002) argued that greenways are an efficient approach to protecting land resources. However, instead of being a general tool for various scenarios, greenways, especially those for ecological purposes, still have many requirements for environment conditions (e.g., slope, landscape type, and vegetation cover). Therefore, land suitability is a critical factor in developing alignment planning (Miller et al., 1998; Xiang, 1996). In the existing studies, land suitability is usually assessed based on many factors of the landscape, such as the vegetation types and forms, land use and development, landscape types, and ownership (Xiang, 1996; Miller et al., 1998; Conine et al., 2004; Qian et al., 2018). Among others, identifying land use functions is one of the key concerns in greenway suitability assessment (Miller et al., 1998; Qian et al., 2018). It is not only closely correlated with land cover (Feng and Flewelling, 2004) but also determines the human activities along greenways. For instance, the compactness and mixture of land use is crucial to promoting nonmotorized travel and physical activities (Rodríguez et al., 2009; Stevenson et al., 2016; Liu et al., 2018).

In China, the greenway planning have been strongly influenced by the development and management of land resources. China has adopted a dual urban-rural land system in which rural land resources are collectively owned and urban land resources are state owned. The central government controls land quotas that are distributed to local governments. Therefore, local governments prefer to develop greenways without consuming their land quotas, especially in areas where land resources are already intensively developed and the ability to acquire land quotas is limited (Chung et al., 2018; Liu et al., 2019). Ultimately, a few types of land resources that have public rights-of-way accommodate most greenways (see Table 1). Moreover, the type of land use not only demonstrates the dominant landscape context and primary social activities but also shows the jurisdictions of spaces. For instance, transportation land is managed by the department of transportation and subdistrict offices; forest land is managed by the department of forest

Table 1
Primary types of land use associated with greenways in China.
Source: Ministry of Housing and Urban–Rural Development, 2018

Type of land use	Code of land use	Description
Transport land	S1	Transport land is space for urban roads, transportation facilities, etc., which excludes internal roads and parking lots inside residential land and industrial land.
Green buffer land	G2	Green buffer land is green space for purposes of public health, separation and safety protection.
Park land	G1	Park land is green space that is open to the public, with recreation as the primary function, as well as other purposes, including ecological services, beautification, and disaster prevention.
Forest land	E13	Forest land is space where trees, bamboo, and shrubs grow and where mangroves grow along the coast.
Rural land for service purposes	E15	Rural land for service purposes is space for agricultural facilities, ridges, ponds, rural roads, etc., which excludes farmland, shrubland, woodland and grassland.

and offices of scenic parks; and rural space is managed by collective villages. Since greenways are subcontracted to various local departments (Liu et al., 2019), the method of developing and managing greenways could be influenced by the institutional traditions of the departments.

2.2.2. Traffic impact

Traffic impact is one of the major factors that determines the integrity of the natural environment and the availability of recreational resources (Tomczyk et al., 2017). The conflicts between high-speed traffic and wildlife migration routes can result in dangerous accidents (Bueno et al., 1995). In terms of recreation, heavy motorized traffic can bring air pollution, noise, and disturbance, which can decrease people's desire to walk and cycle (Chataway et al., 2014). Therefore, off-road paths are more attractive to cyclists than street facilities (Hankey et al., 2012). From the Radburn system in the 1920s (Forysth, 2018) to the East Coast Greenway that was initiated in the 1990s to the recent Emerald Network project (LivableStreets Alliance, 2018), planning efforts to increase off-road travel have a long history. In the Emerald Network, urban greenways are categorized as *park path*, *off-road path*, *neighborways*, and *greenway connectors*, and *greenway connectors* are strictly limited to a distance of less than one mile (LivableStreets Alliance, 2018). Meanwhile, *park path*, *off-road path*, and *neighborways* require off-road space and low traffic volume (LivableStreets Alliance, 2018).

In the PRD, the provincial department has issued a series of documents to set limitations on greenway connectors, which are greenways that use transportation infrastructure and lack sufficient green buffers between motorized roads (Department of Housing and Urban–Rural Development of Guangdong Province, 2014, p. 443). According to the official guidelines, a greenway connector should be no longer than 3 km and the total length of the greenway connectors should be less than 10 % of the length of all regional greenways (Department of Housing and Urban–Rural Development of Guangdong Province, 2014, p. 444). Between 2010 and 2012, the provincial department organized nine supervisory groups to guarantee that greenway connectors were correctly adopted in the local planning initiatives for *provincial greenways,*while *procincial greenways*, *municipal greenways* and *community greenways*in the PRD belong to one greenway typology proposed by the provincial government (see Table 2). However, the proportion of greenway connectors in *municipalgreenways* and *community greenways* has been overlooked.

2.2.3. Corridor width

According to Little (1990), greenways are networks of green corridors of various widths. From the perspective of promoting greenway benefits, only greenways with sufficient corridor width can protect ecological integration with the necessary barriers (Forman and Godron, 1986; Thorne, 1990). The recommended corridor width varies according to the location, landscape and targeted species but ranges from 9 m to 1609 m (Bueno et al., 1995). Corridor width is also a key indicator of recreational resources, because it determines the level of openness, greenness and wildlife habitat. For example, openness contributes to both recreational attractiveness (Zhang et al., 2013) and psychological health (Velarde et al., 2007).

In China, a series of documents have included corridor width as the key planning content. According to the master plan and official guidelines for the PRD greenways, corridor width is a primary factor that differentiates the types of greenways (Department of Housing and Urban–Rural Development of Guangdong Province, 2010; Guangdong Provincial Government, 2010). According to the greenway typology proposed by the provincial government, namely, *ecological greenways*, *countryside greenways* and *urban greenways*(see Table 2) should have corridors that are wider than 200 m, 100 m and 20 m, respectively (Department of Housing and Urban–Rural Development of Guangdong Province, 2014, p. 410). The classification of corridor width was developed based on the research of Zhu et al. (2005), which systematically reviewed various effects of ecological corridors with different widths. They concluded that ecological corridors with a width less than 12 m can hardly increase the diversity of birds while corridors wider than 60 m can support the migration of small mammals. As the handbook of greenway planning, particularly for local actors that lacked experience in greenway planning, the official guidelines played a crucial role in the PRD greenways. Moreover, the planning outcomes could be considered as results of how local actors perceived greenway knowledge and what means they selected to implement the regional discourse. In addition to the outline plan and design guidelines, the provincial government issued a document about the *Greenway Control Area* to highlight the corridor width, which has been the key feature in planning provincial greenways (Department of Housing and Urban–Rural Development of Guangdong Province, 2011). However, the *Greenway Control Area* received little attention in the implementation and management of the PRD greenways (Liu et al., 2019) because its role in ecological protection and development control was replaced by another policy concept, namely, "*Ecological Control Line*" (Ma, 2019).

In the official guidelines issued by the central government, greenways should have a minimum corridor width as a means "*to achieve better ecological and landscape environment and to perform the basic functions of greenways*" (Ministry of Housing and Urban–Rural Development, 2016, p. 14). More specifically, the *ecological greenways*, *countryside greenways* and *urban greenways* (see Table 2) should have corridors on each side that are wider than 20 m, 15 m and 8 m, respectively (Ministry of Housing and Urban–Rural Development, 2016, p. 14).

3. PRD greenways as a pilot project in China

Since 2010, a large greenway movement has been observed in China. According to our investigation of news reports and government documents, the implementation of greenways by cities has grown rapidly from 11 cities in 2010 to 163 in 2016. With over 12,500 km of greenways being implemented within six years under a "top-down" institutional structure, the PRD greenways have been recognized as a pilot project for their exploratory efforts in rapid greenway development (Liu, 2017). Many cities in other regions in China, such as Maanshan, are currently considering greenways as a special strategy to express the "environmental turn" in entrepreneurial governance as well as a practical tool to improve liveability and support active transport (Zhang et al., 2020).

In the PRD, the definition of greenways was proposed in reference to the research of Flink and Searns (1993): "*a nonpolluting commuter route, a horse or bicycle trail, a means to promote stream-water quality or to preserve wildlife habitat, a method to buffer land uses such as residential development or agriculture activity, or a way to safeguard a viewshed or the historic character of an area*" (Department of Housing and Urban–Rural Development of Guangdong Province, 2014, p. 4). The PRD greenways were further categorized into two different typologies, which were later adopted by the Ministry of Housing and Urban–Rural Development in 2016 (see Table 2).

The first typology, which contains *provincial greenways* (*regional greenways*), *municipal greenways* and *community greenways*, was developed based on the institutional structure of provincial, municipal and district/county governments. The second typology, which contains *urban greenways*, *countryside greenways*, and *ecological greenways*, was developed based on the locations and related functions of greenways. For instance, *urban greenways* are located in developed urban areas, which highlights their functions of improving living conditions and increasing accessibility to spaces for outdoor exercises. Meanwhile, *countryside greenways* are located on the fringes of urban areas and *ecological greenways* are located in rural villages (Department of Housing and Urban–Rural Development of Guangdong Province, 2014, p. 318). Although the second typology highlights the differences among

Table 2
Greenway types according to the official documents of the Guangdong Province government and the central government.
Source: Department of Housing and Urban–Rural Development of Guangdong Province, 2010; Ministry of Housing and Urban-Rural Development, 2016.

	Key criteria	Classification
Guangdong greenway guidelines	Scale	- Provincial greenways (regional greenways)- Municipal greenways - Community greenways
	Location and function	- Urban greenways- Countryside greenways - Ecological greenways
National greenway guidelines	Scale	- Regional greenways- Municipal (county) greenways - Community greenways
	Location and function	- Urban greenways - Contryside greenways

diverse greenway conditions, it has been adopted only for *provincial greenways* according to both the planning documents and statistics. Our investigation of the existing planning documents shows that the majority of the PRD greenways are *municipalgreenways* and *community greenways* in urban areas, though detailed information on their form and function is still lacking.

However, the rapid development of greenways in the PRD has led to considerable debate on greenway planning and implementation, especially issues associated with the “one-size-fits-all” approach (Zhao et al., 2019; Liu, 2020). The “one-size-fits-all” approach of greenway planning has been criticized as formalism in two ways. On the one hand, it refers to the use of bicycling infrastructure as an oversimplified greenway form to achieve multiple policy goals. These infrastructure-like greenways are adapted to the fragmented natural landscape and costly land acquisition. But they primarily serve as strategies to accomplish the connectivity of greenway networks (Liu et al., 2018). On the other hand, oversimplification still occurs, even from the perspective of bicycling infrastructure. A painted surface or colorful bricks become the primary change to existing routes (see Fig. 2). However, bicycle-friendly designs, such as surface design, bicycle lane protection in shared traffic and bicycle-pedestrian segregation, are usually overlooked (Liu et al., 2019).

4. Methods and data collection

To elaborate on our arguments, we developed an approach to a city-scale investigation of the Shenzhen greenways. First, after collecting the official greenway documents (e.g., official greenway plan, see Fig. 3) from the municipal and district governments, we drew a map of the Shenzhen greenways in a GIS database that contains the geographic information of the greenways as well as satellite images and regulatory plans. However, because of the lack of consistency among the agencies, dates, and standards in the greenway documents, the map included many mistakes and gaps.

Second, between November 2015 and January 2016, we investigated all greenways in Shenzhen to verify the integrated map. Through the field investigation, we identified 1,935.87 km of greenways (Fig. 4), and mismatches between the identified length and the official figure of 2,377 km which occurred for two reasons: 1) some greenways had not been implemented or had been implemented at other locations and 2) we calculated greenways that had been implemented on both sides of a street as one greenway while the official data calculated some of these greenways twice.

Third, during the field investigation, we recorded the spatial features of greenway space by taking photographs with geographic information for each photo. The primary focuses of each photo were the landscape surrounding the greenways and the features designed for greenway use, such as physical separation for nonmotorized travel, street greenery and signs.

Fourth, according to the geographic locations of the photos, we attached them to the greenway network in the GIS database (Fig. 5). For greenways that lacked on-site photos, we chose an internet street view (i.e., Baidu Map and Tencent Map) as a complementary source of data. Ultimately, we recorded and collected 3,623 photos of Shenzhen greenways, of which 2,785 photos were taken on-site and 838 pictures were taken from internet street views.

Fifth, we further identified the relation between the greenways and motorized roads, the corridor width and the type of land use (Fig. 6). Through observations of the photos, we identified the relation between greenways and motorized roads and categorized them as “off-road trails,” “buffered bike paths,” “shared bike paths,” “buffered bike lanes,” “bike lanes,” and “mixed-used roads” (Fig. 7). The category shows different levels of traffic stress according to the classifications developed by the U.S. Department of Transport (2019), National Association of City Transportation Officials (2012), and California Department of Transportation (2017). By measuring the green space in satellite images, we recorded the corridor widths of the greenways, which were later categorized as “less than 3 m,” “3 – 12 m,” “12 – 30 m,” “30 – 60 m,” “60 – 100 m,” and “over 100 m.” Using regulatory planning documents, we identified the land use types where greenways were implemented, such as *transport land*, *forest land* and *green buffer land*. We established a database listing the important greenway information, including the greenway type in the official documents, location, length, type of land use, corridor width, and traffic impact of 708 segments of greenways in total (see sample data in Table 3).

5. Empirical work in Shenzhen City

5.1. Existing issues in the official typology and planning

Shenzhen greenways are a product of the three-year political

Fig. 2. Bikeway-like greenways lacking bicycle-friendly design.
(Source: photos by the first author; location: left photo in Machong, Dongguan, and right photo in Tianhe, Guangzhou).

Table 3
Data sample (Jingtian, Futian District).

No.	Type	Location	Length	Code of Land use	Corridor width	Traffic Impact
1	Provincial greenway	Xin'an Street	4.44 km	G2	3 – 12 m	Buffered bike paths
2	Community greenway	Xin'an Street	0.48 km	S1	3 – 12 m	Buffered bike paths
3	Community greenway	Xin'an Street	1.16 km	S1	3 – 12 m	Shared bike paths
…	…	…	…	…	…	…

campaign in the PRD, and most of them were developed between 2010 and 2012. Therefore, the Shenzhen municipal government followed the greenway typologies that were issued by the provincial department. The policy goals for *provincial greenways*, *municipal greenways* and *community greenways* were 300 km, 500 km and 1,200 km, respectively (Shenzhen Municipal People's Government, 2010). Proposed by the provincial department, the *provincial greenways* consist of two spine routes that cross the city from east to west and are not located close to intensively built-up areas. Local planning departments and agencies were responsible for the planning of the *municipalgreenways* and *community greenways*.

Although the deadline for the three-year greenway scheme was the end of 2012, detailed plans for *community greenways* were still absent in the special plan for Shenzhen greenways in 2011 (Fig. 3). However, this absence did not slow the progress of the greenway scheme. At the end of 2012, the anticipated greenway length had been accomplished, with 346 km of *provincial greenways* and 1,864 km of *municipal greenways/community greenways* in total (Zhang and Wen, 2013).

The policy effects of the official typologies on greenways are a primary challenge in studying the campaign-style greenway development in the PRD. For this 2,377-kilometer greenway network (see Table 4), the official typologies provides little information about the surrounding landscape, the primary functions and the anticipated social activities. *Urban greenways*, *countryside greenways* and *ecological greenways*, as one official typology, are adopted only as *provincial greenways* and accounted for 14.43 % of the total greenways in 2015 (Urban Management Bureau of Shenzhen Municipality, 2015). As the majority of the greenway network, *municipal greenways* and *community greenways* show only structural roles in the network, with *municipal greenways* providing the framework of the greenway network at the municipal scale and *community greenways* filling in the framework as the main body of the network. In the 189 km of greenways that were developed by Dapeng District, the Urban Management Bureau, or the Water Resource Bureau, *municipal greenways* and *community greenways* are mixed together (Urban Management Bureau of Shenzhen Municipality, 2015), which further decreases the implications of the typology. In addition, because most of the greenways in Wutong Mountain National Forest Park are trails with steps, they are too steep for ordinary cycling activities; thus, the local department added "hiking trails" as a new category.

5.2. Disparity and diversity in greenway settings

According to our empirical investigation (Table 5), significant diversity and disparities occur in the settings of greenways; nevertheless, the majority of the greenway network is categorized into two general types in official documents. From the perspective of corridor width, greenways show apparent differences in the surrounding landscape: 43.48 % of greenways have a corridor width of less than 3 m, and 33.15% of greenways have a corridor width of over 100 m. Therefore, although some greenways are surrounded by urban forests and greenery, some narrow-corridor greenways lack sufficient greenery to support recreational activity, not to mention provide ecological benefits.

From the perspective of traffic impacts, off-road trails, buffered bike paths, shared bike paths, and mixed-use roads are all common forms of greenways. On the one hand, some greenways are separated from motorized roads and therefore have quieter and safer conditions for

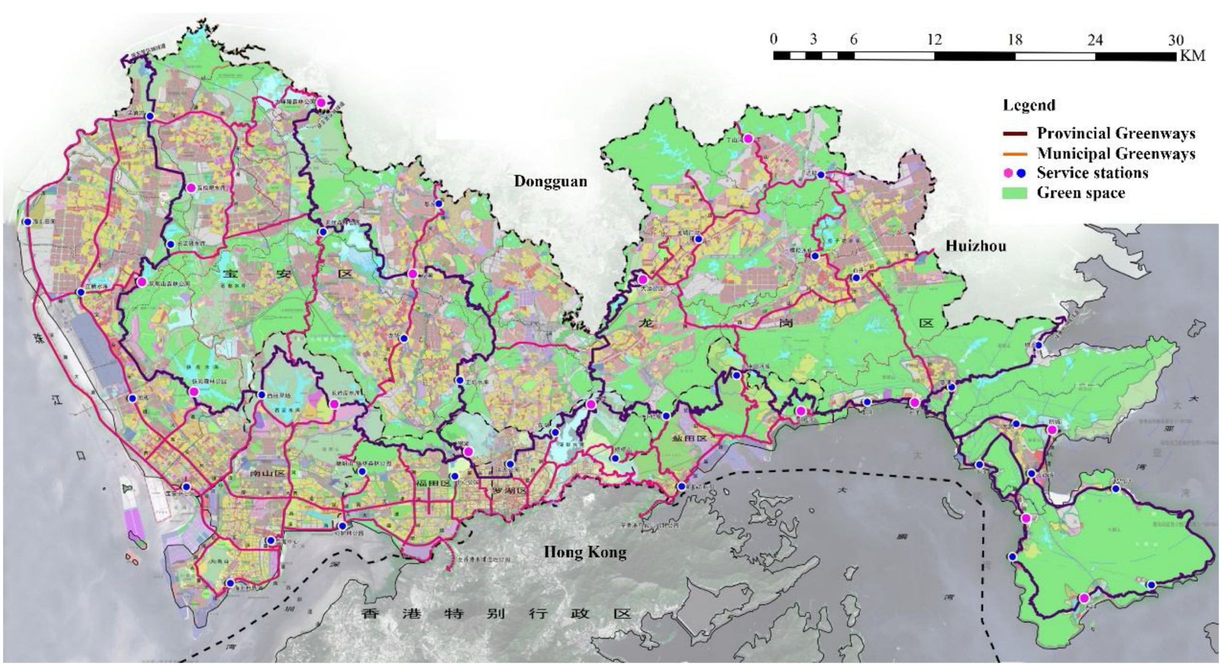


Fig. 3. Greenway map based on official planning documents in 2011.
(Source: Urban Planning, Land and Resources Commission of Shenzhen Municipality, 2011)

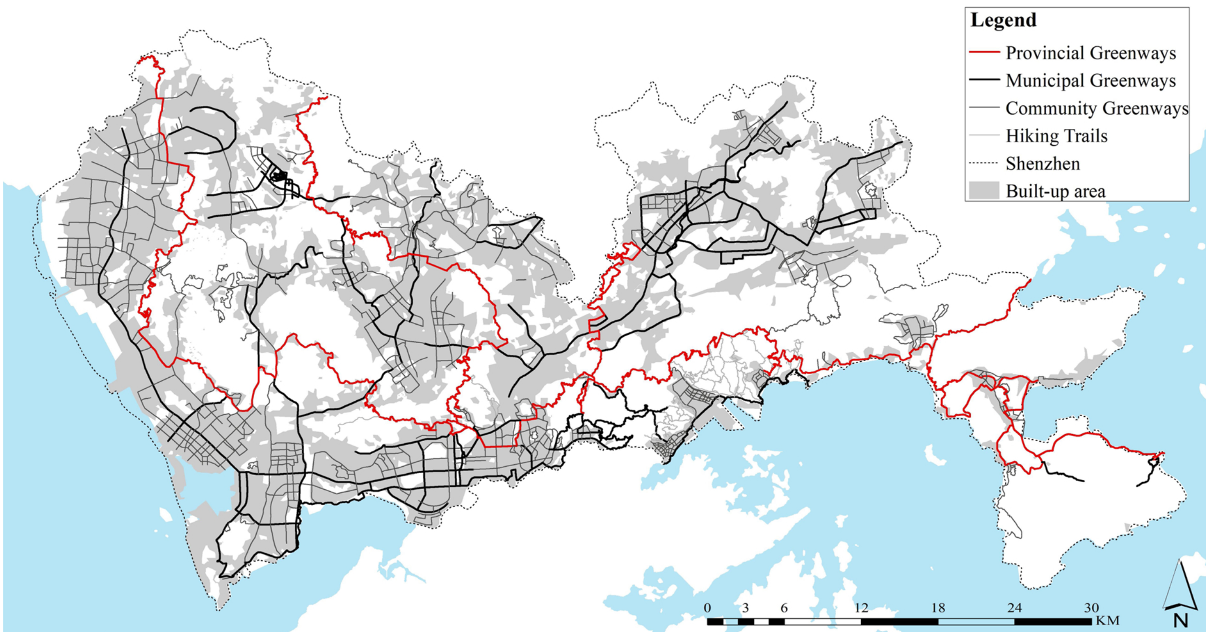


Fig. 4. Adjusted Shenzhen greenway map with the official typology.
(Source: Urban Planning, Land and Resources Commission of Shenzhen Municipality, 2011; Urban Management Bureau of Shenzhen Municipality, 2014)

recreational uses. On the other hand, many greenways still have a high dependency on the transport infrastructure and are threatened to different degrees by noise, air pollution and unsafe uses.

From the perspective of land use, five types of land use are associated with greenways in Shenzhen: *park land*, *green buffer land*, *rural land for service purposes*, *forest land* and *transport land. Transport land*, in which 71.65 % of the Shenzhen greenways are developed, is the primary type of land use for Shenzhen greenways. The high proportion of *transport land* results in a close relation with motorized road systems because 82.05 % of the greenways are in transport corridors, including greenways in the *transport land* and the *green buffer land*. Because 43.48 % of the greenways have green corridors less than 3 m wide, the supporting landscape is insufficient for vegetation buffering, which can lead to exposure to traffic pollution.

Land use influences greenway spaces in many ways, including changes in the corridor width and traffic impact (Tables 6 and 7). As the primary supporting land use, *transport land* is characterized by a high proportion of narrow green corridors and a close relationship with the urban pedestrian systems that are part of the transport network. Of greenways in *transport land*, 82.10 % have a green corridor that is less than 12 m wide and 87.72 % are on sidewalks. Compared with greenways along transport corridors, *forest land* in general has a better supporting landscape, with 89.87 % of these greenways having a green corridor that is wider than 100 m. However, because of their remote location and lack of investment in infrastructure, 32.89 % of these greenways are still mixed-use roads. Greenways that are in *green buffer*

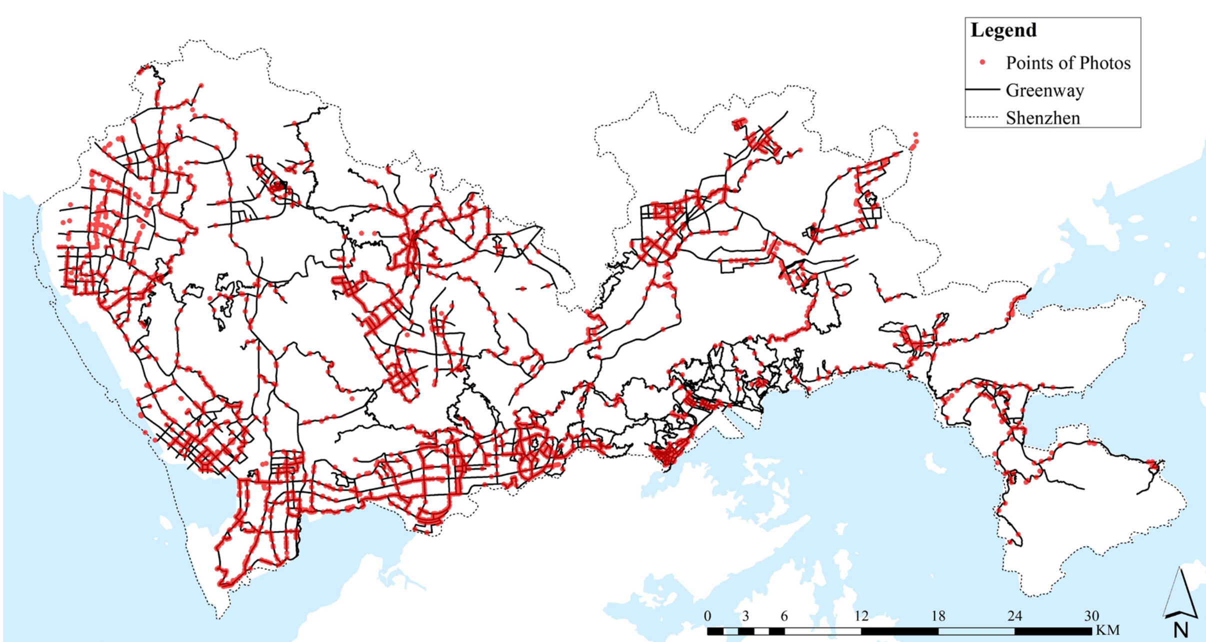


Fig. 5. Shenzhen greenways and points of photos.

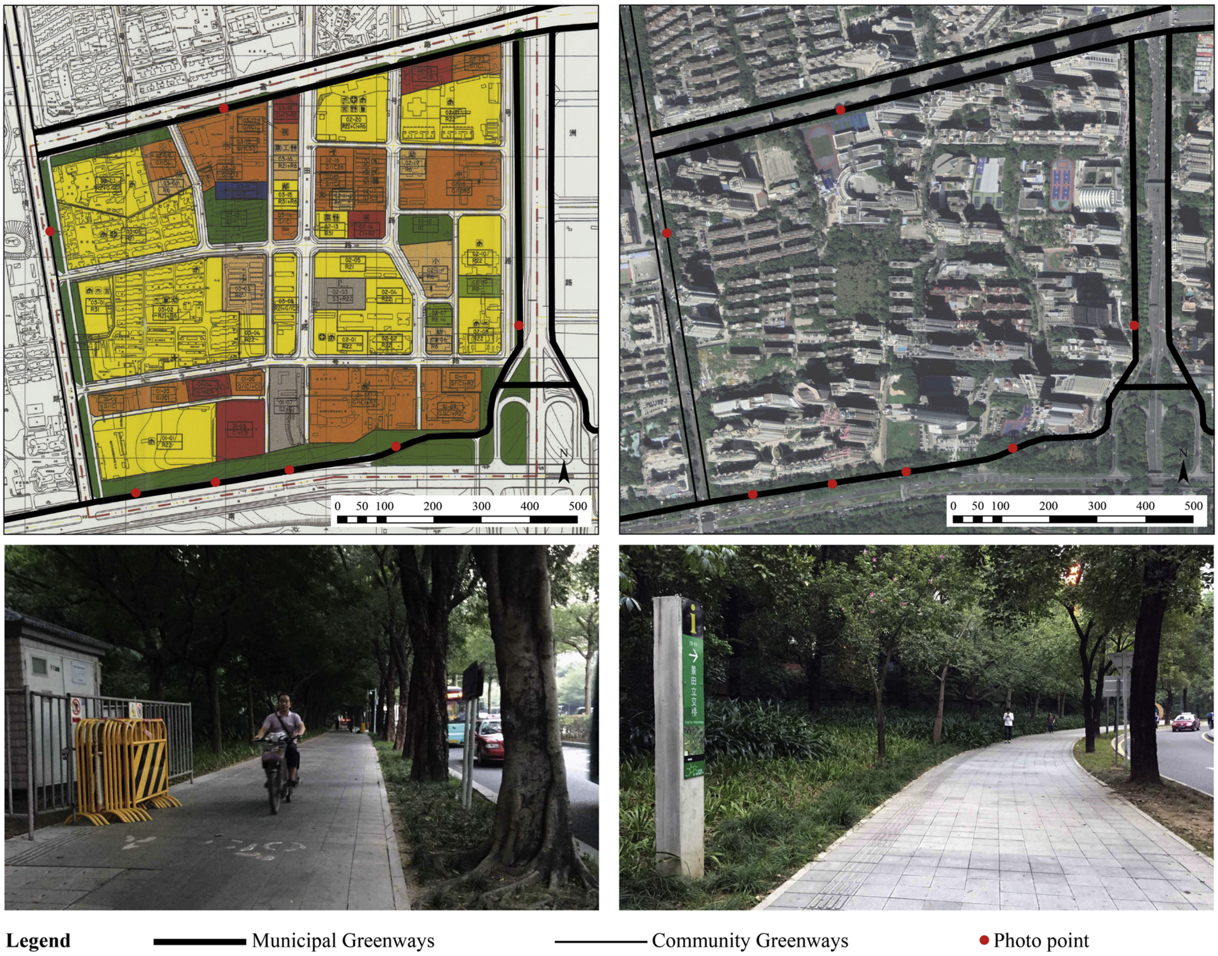


Fig. 6. Examples of regulatory plans, satellites, and on-site photos of greenways.
(Source: www.szpl.gov.cn; Location: Jingtian, Futian District)

Table 4
Official statistics of Shenzhen greenways.
Source: Urban Management Bureau of Shenzhen Municipality, 2015

	Length (kilometers)	Percentage
Regional greenways	342	15%
Urban greenways	673	28%
Community greenways	1,031	43%
Urban/community greenways	189	8%
Hiking trails	142	6%
Total	2,377	100%

land and *park land* usually have better green space resources, with 84.55 % and 88.82 % having green corridors that are wider than 100 m, respectively. Furthermore, they also have a better nonmotorized environment for recreational activities, with 84.88 % and 89.92 % being off-road trails, respectively. Greenways in *rural land* are the connection between the built-up environment and the natural environment. Therefore, they have wider green corridors (85.66 % of them are wider than 100 m) but also face potential traffic impacts due to the high proportion of mixed-use roads (41.81 %).

The high proportion of *transport land* is a common issue for greenways in China, and *transport land* currently accounts for 71.65 % of the total greenways in Shenzhen. Influenced by land use, 1,055.71 km of greenways (54.53 % of the total) are shared bike paths, which are not only exposed to traffic pollution but also result in potential conflicts between pedestrians and cyclists. Moreover, 841.67 km of greenways have a green corridor less than 3 m wide and 1,178.35 km of greenways (60.87 % of the total) have a green corridor less than 12 m wide. Over half of Shenzhen greenways (1,045.09 km of 1,935.87 km) are on-sidewalk greenways with corridors less than 12 m, while 143.58 km of greenways that have wide corridors are mixed-use roads that face safety issues (Fig. 8).

5.3. Heterogeneous landscapes within observed new typology

According to the different surrounding landscapes in Shenzhen, we further identified four types of greenways: transport greenways, forest greenways, park greenways, and rural greenways (Table 8). As the majority of greenways in Shenzhen, transport greenways are bikeways in *transport land*, and they have narrow green corridors of street greenery that are commonly influenced by motorized traffic. Forest greenways are hiking trails and a few informal mixed-use roads in *forest land*, where the wide green corridor exists due to the natural environment. Park greenways are off-road recreational trails in *park land* and *buffer land*. They have green open spaces that are planned and designed. Rural greenways are recreational trails in *rural land for service purposes,* which is in fact rare in Shenzhen and isolated by expanding urban built-up areas. Surrounded by croplands and the countryside environment, certain paths were formerly used in agricultural production and are now open to the public.

From the perspective of the “three-legged stool” greenway values, transport greenways, forest greenways, park greenways, and rural greenways show disparities in achieving recreational and transportation benefits. Forest greenways, park greenways, and rural greenways serve as recreational resources in different ways: forest greenways

Table 5
Summary of land use, green corridors and transport impacts of Shenzhen greenways (km).

	Provincial greenways		Municipal greenways		Community greenways		Hiking trails		Total	
Corridor width										
0–3 m	33.18	10.21%	247.88	44.47%	557.80	58.82%	2.81	2.68 %	841.67	43.48 %
3–12 m	30.31	9.32%	123.96	22.24%	182.41	19.23%	–	0.00 %	336.68	17.39%
12–30 m	1.84	0.57%	17.52	3.14%	41.79	4.41%	–	0.00 %	61.15	3.16 %
30–60 m	10.21	3.14%	20.89	3.75%	7.61	0.80%	–	0.00 %	38.71	2.00 %
60–100 m	5.75	1.77%	4.44	0.80%	5.68	0.60%	–	0.00 %	15.87	0.82 %
Over 100 m	243.79	74.99%	142.76	25.61%	153.02	16.14%	102.22	97.32%	641.79	33.15%
Traffic impact										
Off-road trails	114.47	35.21%	98.97	17.75%	65.65	6.92 %	67.78	64.54%	346.87	17.92%
Buffered bike paths	12.19	3.75 %	95.47	17.13%	102.56	10.82%	–	0.00 %	210.22	10.86%
Shared bike paths	119.88	36.88%	329.72	59.15%	606.11	63.92%	–	0.00 %	1,055.71	54.53 %
Buffered bike lanes	11.00	3.38 %	23.52	4.22%	90.04	9.49 %	–	0.00 %	124.56	6.43 %
Bike lanes	3.66	1.13%	3.24	0.58 %	20.82	2.20 %	–	0.00 %	27.72	1.43 %
Mixed-use roads	63.88	19.65%	6.53	1.17 %	63.13	6.66 %	37.25	35.46%	170.79	8.82 %
Land use										
Transport land (S1)	132.40	40.73%	452.44	81.16%	802.25	84.60%	–	0.00 %	1,387.09	71.65 %
Forest land (E13)	172.89	53.18%	33.14	5.95%	74.75	7.88%	105.03	100.00 %	385.81	19.93%
Green buffer land (G2)	8.13	2.50 %	38.00	6.82%	6.50	0.69%	–	0.00 %	52.63	2.72%
Park land (G1)	7.22	2.22 %	27.73	4.97 %	37.17	3.92%	–	0.00 %	72.12	3.73%
Rural land for service purposes (E15)	4.44	1.37 %	6.14	1.10 %	27.64	2.91%	–	0.00 %	38.22	1.97 %
Total	325.08	100.00 %	557.45	100.00 %	948.31	100.00 %	105.03	100.00 %	1,935.87	100.00 %

provide access to the natural environment and long-distance routes for physical exercise for occasional users; rural greenways provide countryside experience and sightseeing for tourists who are urban residents; and park greenways have advantages in proximity to people's daily activity spaces and in their capacity to serve groups that have difficulty accessing remote areas, such as elderly people, disabled people and children.

In contrast, transport greenways, the most common form of greenways in Shenzhen, have intensive daily transportation usage. Transport greenways are characterized by the narrow green corridor of street greenery and high traffic impact from both motorized vehicles and large volumes of nonmotorized travelers. In fact, the overstated transportation values are the greatest challenge to the recreational values as well as conservational values. Thus, the "three-legged stool" is uneven due to the emphasis on transportation values and the unrealized recreational and conservational functions.

6. Discussion and conclusion

The synergy and compatibility of multiple greenway functions represent the basis for greenway policy enthusiasm worldwide, especially in cities that attempt to use greenways as a new planning strategy to address local development issues. However, many studies suggest that policy-makers and practitioners should be more careful in developing policy goals and adapting greenway planning to local contexts. More specifically, although recreation, conservation and transportation constitute the "three-legged stool" of greenway values, they are rarely achieved evenly in practice (Erickson, 2004). These values not only determine different requirements in assessing land suitability (Miller et al., 1998) but could also result in potential conflicts if multiple purposes are set simultaneously (Cole, 1993; Liu et al., 2019b; Lynch, 2019a). Moreover, the heterogeneity of greenway functions and forms become a new issue in the transformation of greenways. As an adaption to the context of over-constrained urban areas, urban greenways are shifting from conservation to recreation (Lindsey, 2003; Erickson, 2004) and recently from recreation to transportation (Liu et al., 2019; Lynch, 2019a,b). However, although greenway practices have spread throughout the world, Lynch (2019a, p.131) argued that "*no studies conducted within the past ten years examine the on-the-ground results of corridor projects, such as greenways*," and the planning effects on enhancing habitat connectivity should be tested. Furthermore, few studies have focused on the heterogeneity of the landscape as a planning outcome of greenways, particularly for greenways that are developed as a new planning strategy at a regional scale.

This research contributes to the issues associated with greenways in two ways. First, it proposes a new conceptual framework and an innovative approach to examine how to employ land use, corridor width and traffic impact as critical factors to investigate the heterogeneous landscapes of greenways. The framework and the approach are applied in a case study of Shenzhen greenways. Although Shenzhen greenways were developed under the same guiding policy and time schedule as other greenways in the PRD, they have a large network crossing the city and are embedded into various urban development conditions. Thus, Shenzhen serves as a good example to elaborate on the heterogeneous landscapes and determining factors of urban greenways.

Second, this research illustrates the heterogeneous landscapes of

Table 6
Green corridors and land use of Shenzhen greenways.

	Transport land (*S1*)		*Forest land* (*E13*)		*Green buffer land* (*G2*)		*Green park land* (*G1*)		*Rural land for service purposes* (*E15*)	
0–3 m	815.25	58.78%	18.40	4.77%		0.00 %	4.61	6.39 %	3.41	8.93 %
3–12 m	323.51	23.32%	8.72	2.26%	4.45	8.45%		0.00 %		0.00 %
12–30 m	46.47	3.35 %	11.23	2.91%		0.00 %	3.45	4.79 %		0.00 %
30–60 m	38.00	2.74 %	0.71	0.19 %		0.00 %		0.00 %		0.00 %
60–100 m	10.12	0.73 %		0.00 %	3.68	7.00 %		0.00 %	2.07	5.41%
> 100 m	153.74	11.08%	346.75	89.87 %	44.50	84.55 %	64.06	88.82 %	32.74	85.66 %
Total	1,387.09	100.00 %	385.81	100.00 %	52.63	100.00 %	72.12	100.00 %	38.22	100.00 %

Table 7
Transport impact and land use of Shenzhen greenways.

	Transport land (S1)		*Forest land (E13)*		*Green buffer land (G2)*		*Green park land (G1)*		*Rural land for service purposes (E15)*	
Off-road trails	4.69	0.34%	218.52	56.64%	44.67	84.88 %	64.85	89.92 %	14.14	36.99%
Buffered bike paths	190.18	13.71%	15.58	4.04%	4.45	8.45%	–	0.00 %	–	0.00 %
Shared bike paths	1026.59	74.01%	22.93	5.94%	1.66	3.15%	1.13	1.57%	3.41	8.93%
Buffered bike lanes	21.15	1.52%	1.88	0.49%	–	0.00 %	–	0.00 %	4.69	12.27%
Bike lanes	119.95	8.65%	–	0.00 %	–	0.00 %	4.61	6.39 %	–	0.00 %
Mixed-use roads	24.53	1.77%	126.90	32.89 %	1.85	3.52 %	1.53	2.12 %	15.98	41.81 %
Total	1,387.09	100.00 %	385.81	100.00 %	52.63	100.00 %	72.12	100.00 %	38.22	100.00 %

emerging transportation-led greenways. The empirical findings show that the majority of greenways (71.65 % of the total) are nonmotorized paths on sidewalks or on shared roads along narrow corridors that consist of street greenery. Although these transportation-led greenways, or “new urban greenways” (Ngo et al., 2018), have been recognized as strategies for alternative transportation, they are actually unanticipated results of the rapid construction of greenways; thereby preventing these greenways from meeting the criteria of traditional greenways (Fábos, 1995; Little, 1990) and the policy goals of PRD greenways (Guangdong Provincial Government, 2010). The prevalence of transportation-led greenways in Shenzhen could be attributed to many contextual factors, including the tight schedule, limited budget and fragmented landscape (Liu et al., 2019). Among other factors, an oversimplified understanding of the greenway concept and the one-size-fits-all approach are two key reasons that have led to the challenges associated with greenways.

This research further identifies three gaps in the existing literature on greenways. First, there is a gap between land suitability assessment and greenway alignment planning. Most existing studies on land suitability assessment focus on identifying greenway resources with scenic and ecological value (Xiang, 1996; Miller et al., 1998; Conine et al., 2004; Qian et al., 2018). However, a new challenge is how to adapt the ecology-oriented land suitability assessment to emerging transportation-led greenways. With resource analysis and user preference investigation, the land suitability assessment could prevent transportation-led greenways from being oversimplified into transportation infrastructure. Greater effort should be made to understand the requirements of greenway alignment planning in urban areas. For instance, the results of two studies on the land suitability for greenway alignment planning in the Wuchang district of Wuhan (Teng et al., 2011; Qian et al., 2018) show apparent differences from the actual plans, which is primarily because land acquisition and land resources of public rights-of-way are overlooked. Therefore, land use, corridor width and traffic impact should be highlighted in land suitability assessment for greenways, particularly for greenways planned for recreational and transportation purposes.

Second, a gap is observed between the planning guidelines and policy outcomes. The case study of Shenzhen greenways shows that planning guidelines attempted to follow the definition and typology of greenways in previous studies (Fábos, 1995). However, the planning guidelines yielded little influence on greenway practices and was replaced by a one-size-fits-all approach because of a lack of in-depth understanding of the local context, issues associated with development and the requirements of land suitability. In fact, according to our interviews with local stakeholders in various departments, the planning guidelines served as an important policy tool in delivering necessary knowledge to those who had little experience in developing and managing greenways. However, inherent conflicts occurred in the discourses regarding the guidelines and planning practices. Although the official guidelines follows the greenway literature that highlights the ecological and environmental benefits, the practice focuses on the establishment of connected greenway networks. Thus, further research and practice should pay more attention to the potential conflict between policies and practice.

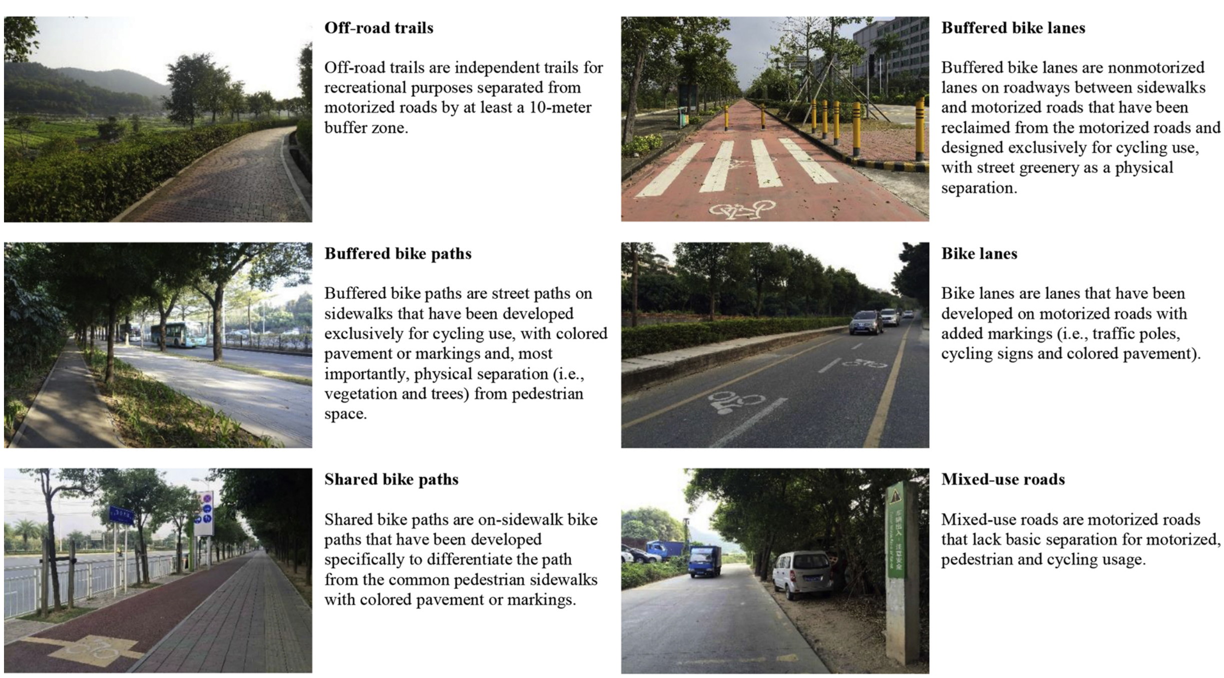


Fig. 7. Six types of greenway spaces from the perspective of traffic impact.

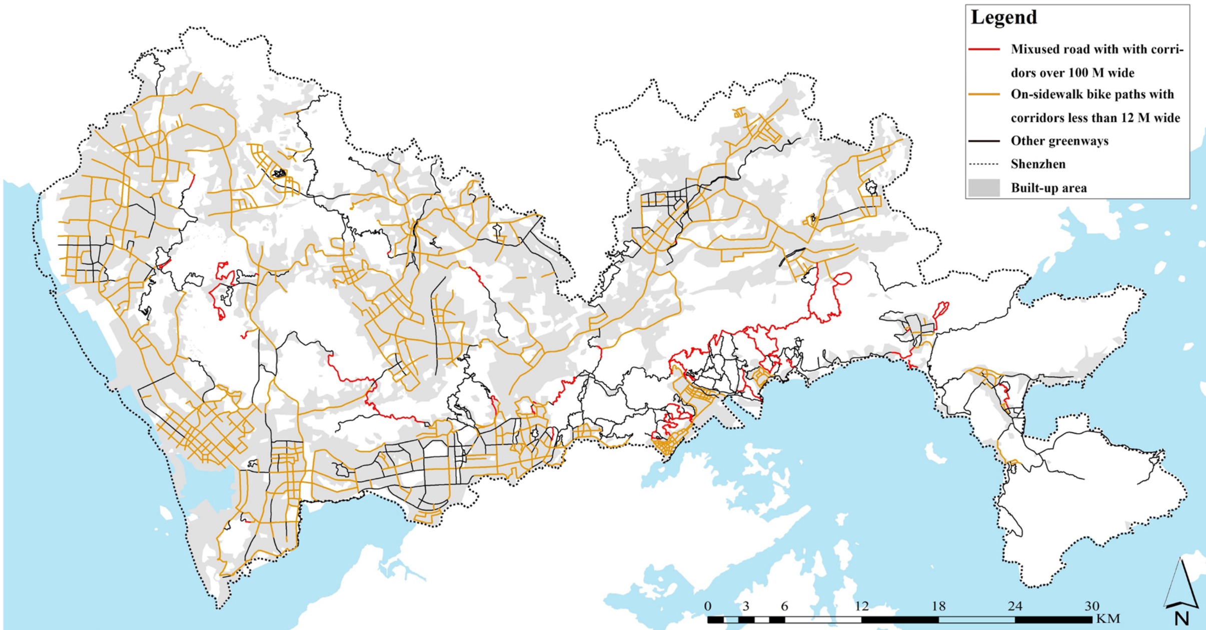
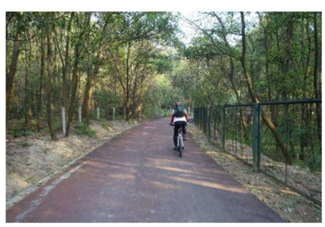
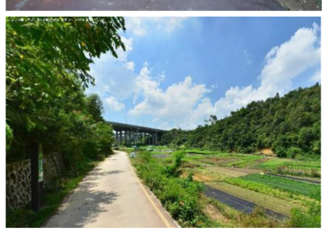


Fig. 8. Cross-comparison between corridor width and traffic impact of Shenzhen greenways.

Table 8
Four types of greenway observed in Shenzhen.

Forest greenways: - Wide green corridor; - Low traffic impact; - Forest land; - Natural landscape; - Tourism and long-distance exercise.	
Rural greenways: - Wide green corridor; - Low traffic impact; - Rural land for service purposes; - Countryside landscape; - Tourism and long-distance exercise.	
Park greenways: - Wide green corridor; - Low traffic impact; - Park land and green buffer land; - Surrounded by designed landscape; - Everyday recreational activities.	
Transport greenways: - Narrow green corridor; - High traffic impact; - Transport land; - Street greenery; - Everyday nonmotorized travel.	

Third, there is a gap between the heterogeneous landscapes of greenways and their multiple benefits. The empirical findings in Shenzhen show that heterogeneity exists in the various conditions of green spaces and disturbances from motorized traffic. Future research should specify these differences among greenways and their economic, social or environmental benefits. Rather than being considered as homogenous infrastructure, greenways should be viewed as heterogeneous landscapes. Recent studies have begun to recognize the different effects of diverging types of greenways. Harris et al. (2018) argued that not all parks and greenways could have equal impacts on property values because both the contextual differences and spatial disparities could be determining factors. In addition, Frank et al. (2019) and Auchincloss et al. (2019) found that greenways had different effects on promoting physical activities. However, little empirical research has been conducted to investigate these effects.

By identifying land use as a key factor, this research emphasizes the importance of land acquisition and land use control in greenway planning and management. Although greenways show advantages in utilizing public rights-of-way and providing alternative transportation, land acquisition and land use control are essential in creating green corridors and protecting greenway resources. The four types of greenways identified in this research suggest that land use is an important factor that determines the quality, functions and social activities of greenways, especially for greenways on transportation land. It should be noted that the types of land use found in Shenzhen should not exclude other potential land resources. In fact, the opportunities to combine greenways and diverse land uses will bring new insights to land suitability assessments for greenway planning, especially for greenways in over-constrained urban areas and fragmented natural landscapes.

CRediT authorship contribution statement

Zheng Liu: Conceptualization, Methodology, Writing - original draft, Visualization, Investigation, Data curation, Formal analysis, Writing - review & editing. **Yanliu Lin:** Conceptualization, Writing - original draft, Writing - review & editing, Supervision. **Bruno De Meulder:** Writing - review & editing, Supervision. **Shifu Wang:** Supervision.

Declaration of Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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