Case Study Report

A Framework for incorporating Supply-Demand equity into Pedestrian and Bicycle System plans

A case of Huilongguan-Tiantongyuan District in Beijing

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Abstract

Pedestrian and Bicycle Transport System (PBTS) is an important part of urban transportation system. Efficient and reasonable urban PBTS need to conform to the current condition of supply-demand differentiation, and to achieve the fairness of public access and process, which is of great significance to the improvement of the urban master resilience management and the applicability of public space. This study proposed a PBTS planning analysis framework. In terms of research methods, the Minimum Cumulative Resistance model (MCR) is employed as the core method of the whole analysis process. In terms of data sources, the Internet Word-of-Mouth Data (IWOM) is introduced as the basis for evaluating the ability of urban public service facilities to attract pedestrian and bicycling behavior. In the end, the area of Huilongguan-Tiantongyuan District (H&T) in Changping District of Beijing is exemplified for empirical analysis. Through theoretical research, framework proposal and empirical analysis, we believe that the framework proposed in this article can reduce the supply-demand deviation in traditional PBTS planning to a certain extent, and can exert a more important influence in the future digital age.

Keywords

Supply-Demand Equity, Pedestrian and Bicycle Transport System, Huilongguan-Tiantongyuan District, Beijing

1. Introduction

The urban transportation system has achieved unprecedented development in recent years. However, it also brings many problems such as traffic congestion, environmental pollution and traffic safety (Kitthamkesorn & Chen, 2017), among the causes of which, extensive use of motor vehicles based on fossil fuel is the main reason (Adams et al., 2020). In this context, non-motorized modes of transportation dominated by pedestrian and bicycle began to draw wide attention (Lerman et al., 2014).

The planning idea of Pedestrian and Bicycle Transport System (PBTS) originated in the early 20th century and is mainly contributed to improving urban vitality, public health, travel safety and recreation equity, as well as improving the accessibility of urban public service places and facilities, and reducing the harm of urban transportation to the environment (Adams et al., 2020). Nowadays, many countries and cities in the world attach great importance to the planning and construction of PBTS, and regard them as an important component of urban transportation and even urban overall planning (Steinman et al., 2010).

Through reviewing relevant documents and academic achievements around the world, it can be found that current research on PBTS mainly focuses on the technical or conceptual design of macro layout or local blocks, the process of PBTS's route selection is more likely to dependent on the administrative classification of urban roads rather than the actual demand of citizens, so it is easy to result in mismatch between PBTS and actual function requirement (Guo & Cui, 2016), which is difficult to provide support for the supply-demand equity of urban public service system.

In view of the current situation of supply-demand differentiation in urban public space system, we propose a conceptual framework suitable for PBTS's route selection (Fig. 1). The framework aims at promoting supply-demand equity of urban public space services through PBTS. In order to clarify the guidance and methods of urban PBTS route selection, we introduced the concept of "15-Minute City" and Internet Word-of-mouth Data. "15-Minute City" is the theoretical basis of this analysis, which was first proposed by Carlos Moreno in 2016 (Moreno et al., 2021). It is an urban spatial planning and management method guided by the philosophy of Chrono-Urbanism and emphasizes the accessibility of urban public services, the target of which is to make basic services accessible to the public within a 15-minute walking or cycling distance (Bright, 2021). The explanation of "15-Minute City" on urban social function composition can provide guidance on analysis ideas for this study. Internet Word-of-Mouth (IWOM) data refers to word-of-mouth information spread in the Internet environment (Gelb & Johnson, 1995), its information carrier includes text, picture, video and score, etc. IWOM can quantify the internal differences of various Points of Internet (POI) in cities, so as to help planners more accurately grasp the public's use demand and preference for urban public service space.

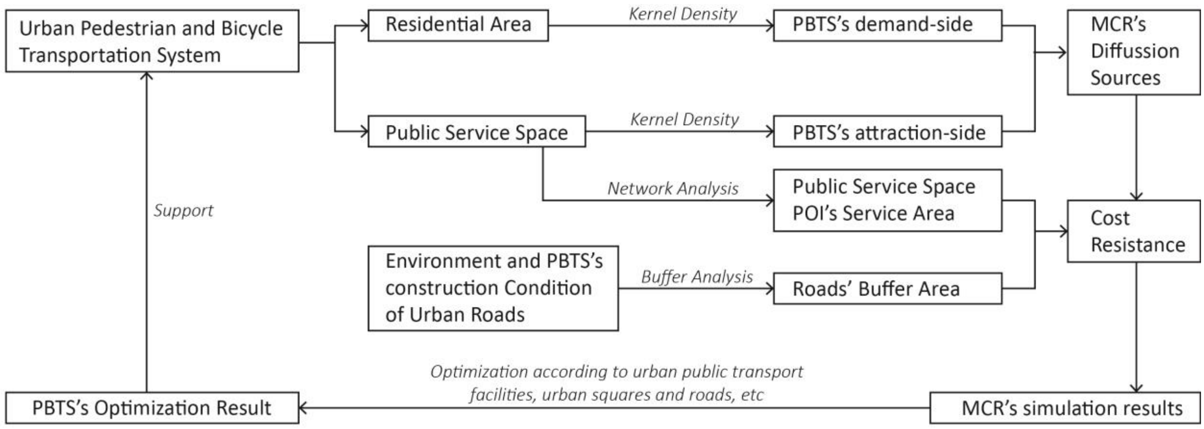

Figure 1. Conceptual framework.

2. Study area

The study area consists of five Sub-District Units of Changping District in Beijing, China (Huilongguan, Huoying, Dongxiaokou, North-Tiantongyuan and South-Tiantongyuan, H&T). H&T district is located between the north fifth ring road and the north sixth Ring Road of Beijing (Fig. 2). It is an important expansion area extending from the central urban area to the north along the central axis. The total area of H&T district is 64.5km², and the population is 851,545 in November 2020. As Asia's largest residential community, H&T district provided a large number of affordable housing and service facilities for low and middle income people and non-local people in Beijing, which also contributed to the relatively open and dynamic urban lifestyle of the district, but as the population continues to grow in recent years, the spatial distribution of supply-demand of urban public services in H&T District is unbalanced, especially the lack of PBTS that can effectively connect various service places in the city. In response, The Changping Branch of Beijing Municipal Commission of Planning and Natural Resources carried out a detailed control plan at the sub-district level for H&T district (BMCPNR, 2020). This study will take the integrated transportation planning as the core and discuss the spatial supply and demand distribution of PBTS in H&T District. Based on this, the PBTS route selection planning process will be completed to provide reference for urban master planning.

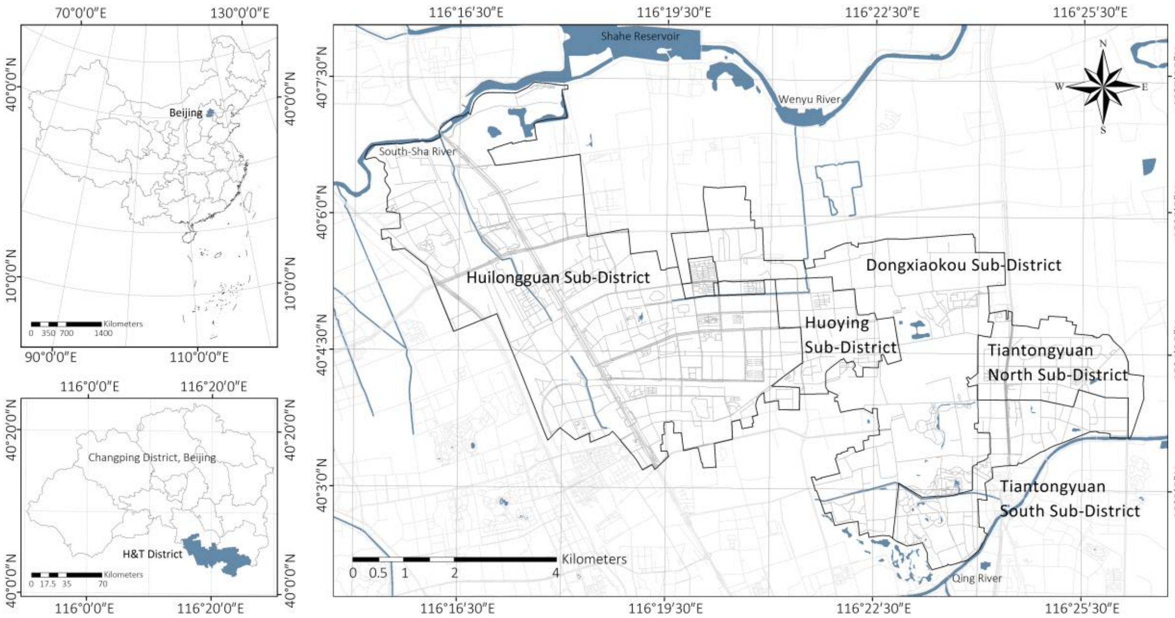

Figure 2. Location analysis of H&T district.

3. Materials and Methods

3.1. PBTS's demand-side and attraction-side data

According to the description of PBTS route selection and analysis process in conceptual framework, we collected the data through professional software and website (Fig 3). The relevant information and obtained sources are shown in Table 1. The data used in this study included PBTS demand-side and Attraction-side data. PBTS' demand-side refers to the starting point of citizens' pedestrian and bicycle trips, and the location where crowd activities are concentrated. We use POI kernel density of urban residential areas, NPP-ViIRS night lighting DN value of urban built-up areas and Baidu API value as the basis for screening PBTS 'demand-side (Li & Wen, 2021). PBTS' attraction-side refers to all kinds of urban public service Spaces or places that attract citizens. We use Dianping Internet (http://www.dianping.com/) as the basis for selecting the attractive end of PBTS. This website is one of the earliest and most influential review websites among Chinese social media websites, years of data's accumulation make it highly used and representative (Zhao, 2020), and the review data for services, places and other functions can provide comprehensive internet word-of-mouth information.

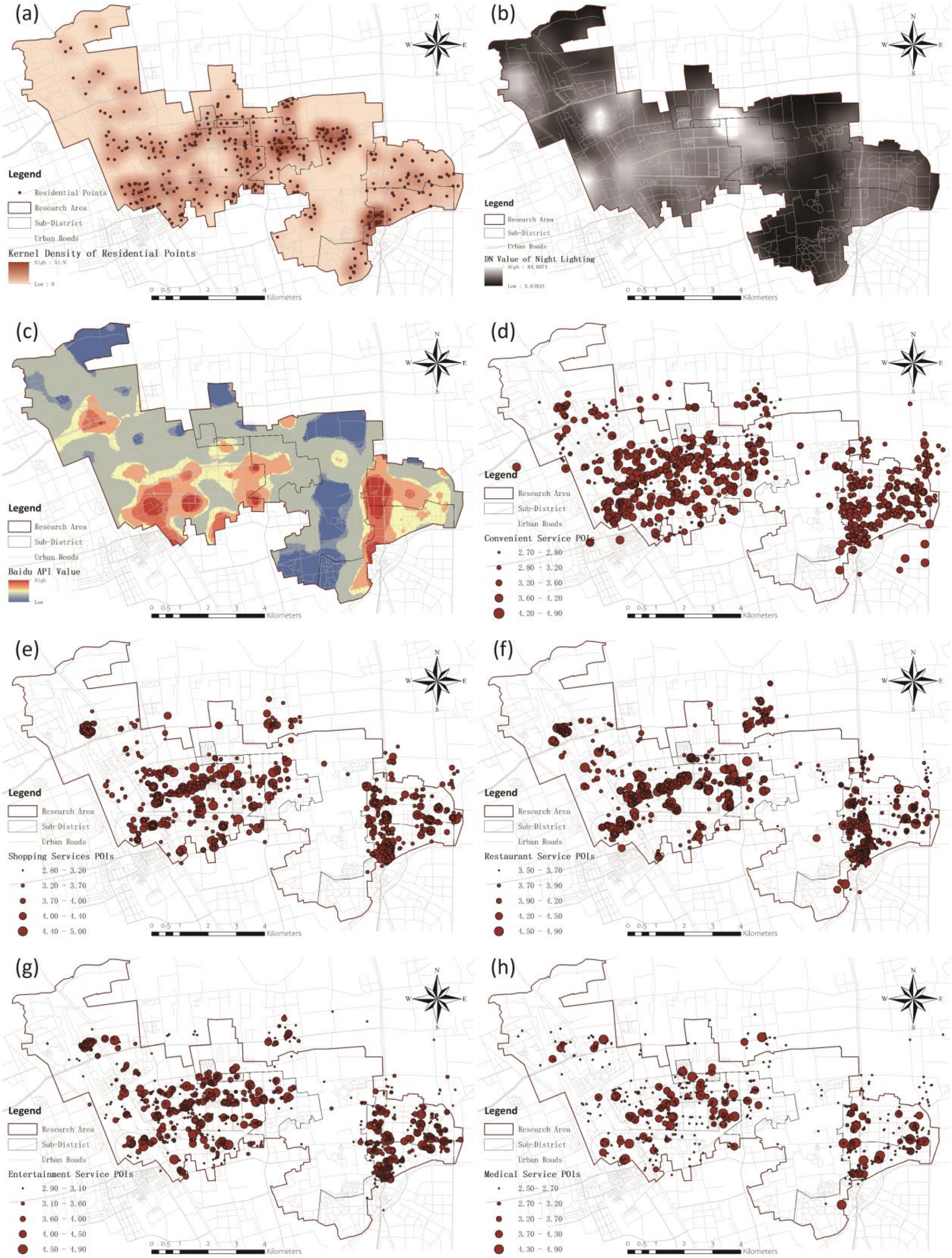

Figure 3. Location of PBTS's demand-side and attraction-side data in H&T District (a. Residential points and its kernel density; b. DN value of night lighting; c. Baidu API value; d. General service POIs and its IWOM data; e. Shopping Services POIs and its IWOM data; f. Catering Service POIs and its IWOM data; g. Entertaining Service POIs and its IWOM data; h. Medical Service POIs and its IWOM data).

Table 1: Information of PBTS's demand-side and attraction-side data

Type	Name and time	Description	Source
PBTS's Demand-side data	Residential Area (January, 2021)	Location of the entrance to the residential area in H&T district	BigeMAP GIS Office software downloader
	DN Value of Night Lighting (January, 2021)	Night light data	https://eogdata.mines.edu/products/vnl/
	Baidu API Value (August 17, January, 2021)	The vitality difference of public travel in urban space	http://lbsyun.baidu.com/
PBTS's attraction-side data	Public Service POIs and its IWOM data (January 12, 2021 to January 20, 2021)	Location of urban public service space and the satisfaction of public user	http://www.dianping.com/

3.2. MCR simulation

The Minimum Cumulative Resistance model (MCR) was proposed by Knappen, a Dutch ecologist (Knaapen et al., 1992), which was first applied to the study of species diffusion, and has been widely applied to biodiversity protection and landscape pattern analysis (Ray & Burgman, 2006; Adriaensen et al., 2003). In recent years, many scholars have combined MCR model with urban greenway or heritage corridor analysis (Feng, 2019), which demonstrated the feasibility of applying MCR model in urban transportation fields. On this basis, the MCR model is employed as the method of this study, the urban pedestrian and bicycle traffic experience is regarded as a spatial dynamic process. In the analysis process, and the urban built environment is considered as a resistance factor affecting the process of PBTS's route selection. The Analysis process is expanded by GIS10.5 Spatial Analysis toolkit and Table. 2, the calculation formula is as follows:

$$MCR = \int min \sum_{j=n}^{i=m} (Dij \times Ri)$$

Where: $\int$ represents the positive relationship between the accumulated resistance and the process of pedestrian and bicycling; *Dij* is the distance from a starting point *j* to a destination *i*; *Ri* is the resistance of the built environment of the city where *i* is located to the process of pedestrian and bicycling.

Table 2: Information of MCR resistance index

Index	Reference	Resistance classification	Resistance value	Weight
POIs Service Area (m)	Sisson, 2020; NLRSC, 2020; Guo & Cui, 2016	x⩽500	1	0.19 (the first level of IWOM score)
		500⩽x⩽1200	3	0.12 (the second level of IWOM score)
		1200⩽x⩽1800	5	0.08 (the third level of IWOM score)
		1800⩽x⩽3000	7	0.05 (the last level of IWOM score)
		X⩾3000	9	

Landscape quality of urban road	Liang, 2019; Zhou, 2016	Highest quality	1	0.27
		Relatively high quality	3	
		Middle quality	5	
		Relatively low quality	7	
		Lowest quality	9	
PBTS construction condition of urban road	BMCPNR, 2020	Most suitable	1	0.29
		Relatively suitable	3	
		Middle suitable	5	
		Relatively unsuitable	7	
		Most unsuitable	9	

4. Results

4.1. Selection of diffusion sources of PBTS

In terms of attraction side, the Kernel density analysis was carried out for POI data from Dianping website which include five categories (urban general, shopping, catering, entertaining and medical service). On this basis, the density results are summated with the same weight, which will be used as the basis for the process of PBTS attraction-side's selection. Finally, we select 20 coordinate points (Fig. 4), which including shopping mall, large community service center, etc. In terms of demand side, the Kernel density analysis results of residential areas in H&T District, urban night lighting DN value and Baidu API value are firstly processed by fuzzy normalization in GIS 10.5, and then summated with the same weight, so as to get the spatial analysis results of raster format about PBTS demand-side. On this basis, 20 PBTS demand-side points were selected (Fig. 4), which including bus stops, city squares, etc.

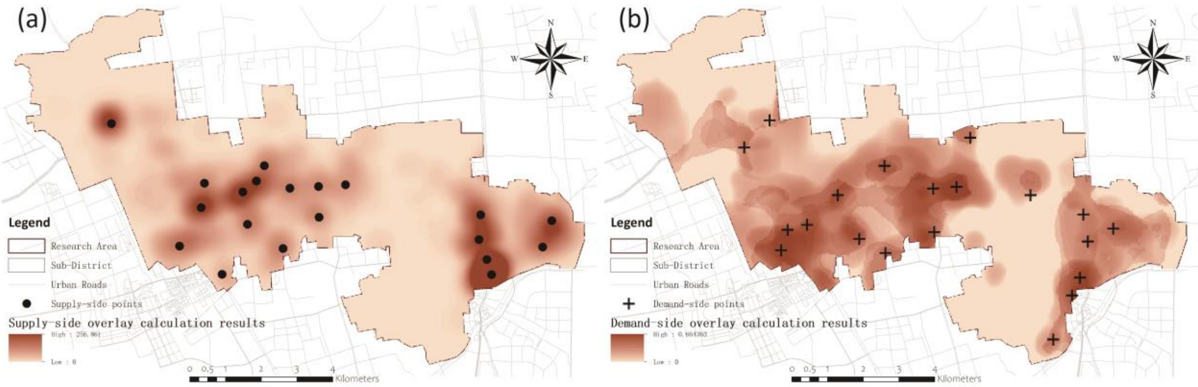

Figure 4. Selection results of PBTS's attraction-side (a) and demand-side (b).

4.2. Evaluation of spatial suitability of PBTS

The content of spatial suitability analysis of PBTS in H&T district includes three categories, the service area of urban public service POIs, the landscape quality and the PBTS construction conditions of urban roads. According to the description of resistance classification and resistance value in Table 2, we calculated a total of 7 types of data and summed them with the corresponding weight (Fig. 5).

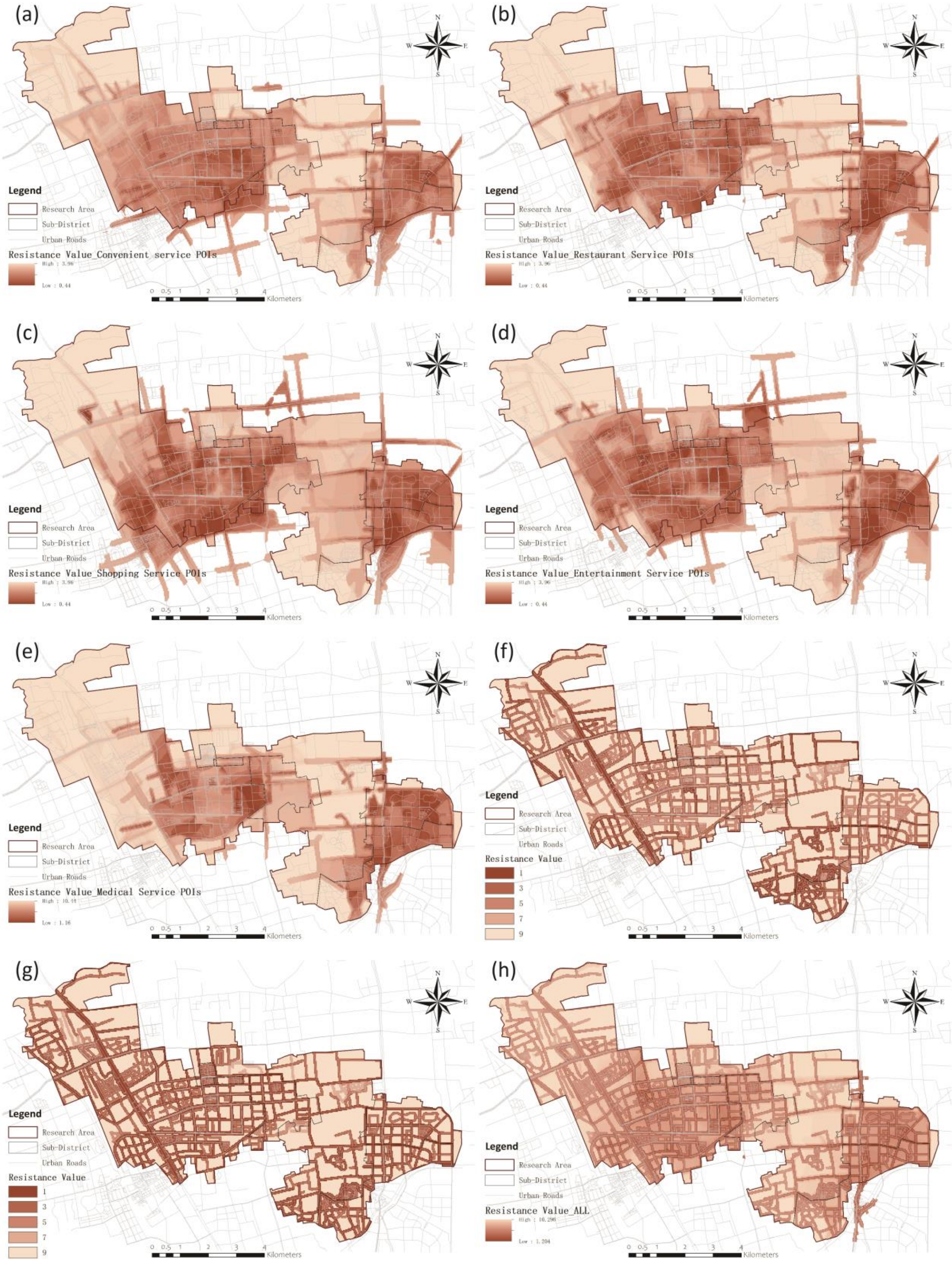

Figure 5. Result of calculation about resistance value (a. Service area of General service POIs; b. Service area of catering servces POIs; c. Service area of shopping services POIs; d. Service area of entertaining service POIs; e. Service area of medical service POIs; f. Landscape quality evaluation of H&T district roads; g. PBTS's construction of H&T district roads; h. Calculation result of all resistance value).

4.3. MCR diffusion simulation and Optimization

Through the Cost Connectivity module in ArcGIS 10.5, we carried out the MCR diffusion simulation in H&T district. During the simulation, 20 PBTS demand-side points and 20 PBTS attraction-side points were treated together as the starting points, the spatial suitability result of PBTS is regarded as an environmental restriction element. Finally, we get a set of PBTS lowest-cost paths (Fig. 6). It can be found that the most suitable routes for pedestrian and bicycle activities in H&T district are not always along with the arterial roads, branch roads or streets, but the combination of these under the influence of the urban environment.

In order to improve the rationality and constructiveness of the results of PBTS's route selection in H&T district, we optimized the MCR simulation results to build a more systematic and coherent PBTS route network (Figure 7). In this process, we combined the newly planned or under construction large-scale linear green infrastructure in Beijing and Changping District (such as Beijing Central Axis North Extension, Shahe Wetland Park, etc.), and sorted out the relationship between H&T district and surrounding urban environment after investigation.

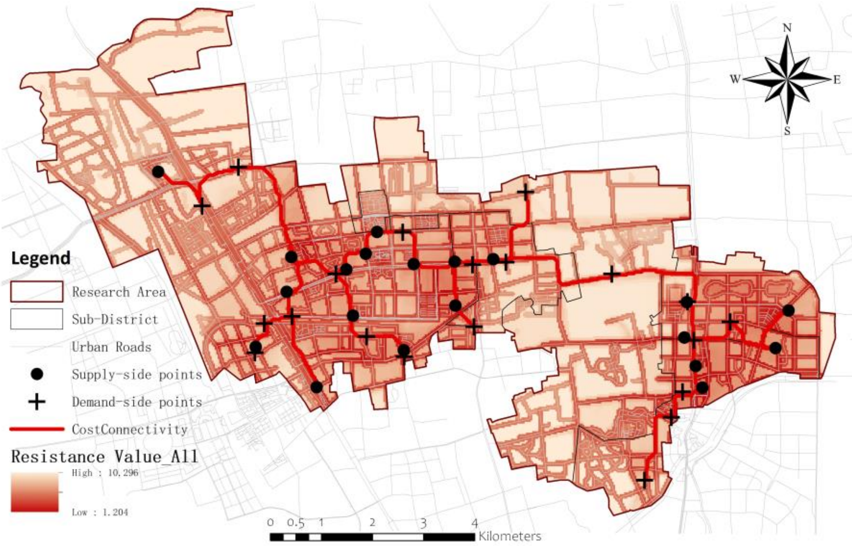

Figure 6. MCR diffusion simulation of PBTS's routes in H&T district

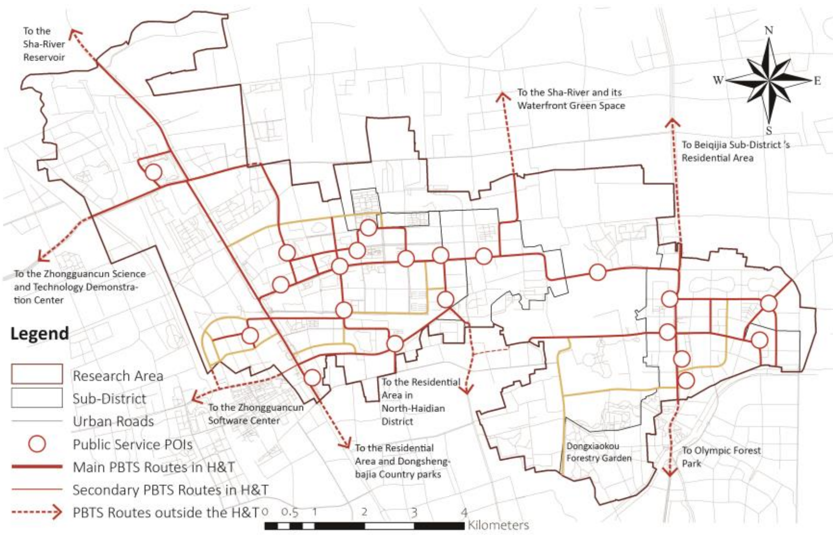

Figure 7. Optimization result of PBTS's routes in H&T district

5. Broader impact

The emergence of IWOM data provides a way for planners and decision makers to identify the satisfaction of urban public service space, so that they can grasp the public's demand for urban public service places more comprehensively (Liu et al., 2020). With the support of massive spatio-temporal big data, identifying the suitability distribution of urban PBTS construction through spatial analysis has important practical guiding significance for improving the fit degree of urban PBTS network and urban public demand. The COVID-19 pandemic has taught us that efficient and coordinated urban transport, especially pedestrian and bicycling transport, has a critical impact on resilient management and sustainable development of cities (Li & Yang, 2020). With many cities around the world step into the planning & management stages of Smart Growth and Inventory regeneration (Downs, 2005; Wu et al., 2020), How to build an appropriate PBTS network is still the focus of us, and how to carry out PBTS planning with a more balanced supply and demand distribution needs more attention.

This paper discusses the method and process of urban PBTS route selection, at the same time, an empirical analysis was carried out based on the case of H&T district, trying to find the logic that can improve supply-demand equity in PBTS planning. The intelligent development of cities in the future will prompt us to produce new urban spatial cognition and planning ideas at a faster speed (Kandt, 2021). As the explorers of urban public space planning theory and practitioners of practice, we need to continue to pay attention to the actual use needs of urban public, select appropriate data information and analysis methods according to the patterns and regulations of public activities, and finally improve the matching of PBTS's supply-demand equity.

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