Research Paper

Visualizing and assessing the 15-minute city facility configuration of city region

A study on the Beijing-Tianjin-Hebei Urban Agglomeration

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Abstract

The desire for a more liveable, highly interconnected and people-oriented city is driving a surge of interest in the '15-minute city', an intuitive, adaptable and popular vision of urban living that already takes place around the world. Elements of the 15-minute city have helped to manage urban life effectively globally by offering a way to build on positive changes to boost local economies and deliver lasting health, well-being, equity and climate benefits. As the COVID-19 pandemic continues to unfold and health concerns remain paramount, the strategy are already supporting cities towards recovery. As an important engine of global urbanization, the future development of China's cities is threatened by increasing air pollution, traffic congestion, social inequalities and other pressures. In May 2021, the Ministry of Natural Resources of China released The Standard of Spatial Planning Guidance Community Life Unity to offer technique support for future 15-minute city construction. Taking a 15-minute walking distance as the space scale, the Guidance configures various functions and facilities required for basic living of residents, ad provides a construction reference for healthy, energetic and low-carbon lifestyle, which satisfies urban residents' yearning for a better life. Furthermore, the Guidance offers a detailed spatial assessment framework of 15-minute city facilities deployment including a variety of parameters. Based on the Beijing-Tianjin-Hebei Urban Agglomeration, this paper evaluates the integrated performance of 13 cities in the Agglomeration by using the framework of the Guidance for visualizing and exploring facilities' POIs on POI-type semantic space. The compare of 15-minute community construction between different cities is rendered as a "mode map" by POI counts on various types, providing a vivid information delivery method for urban planners and POI-related urban studies and applications.

Keywords

15-minute city, community life unity, agglomeration, China, POI

1. Introduction

The rapid urbanization process has had a huge impact on the social, economic, and environmental aspects of the city. People are paying more and more attention to the pursuit of the quality of daily life[1]. After World War I, the spatial separation of urban functions, the car-oriented development, the degraded aesthetics of the landscape and the ever-growing socio-spatial divide of the modern city, emphasized the need to reconsider spatial planning practices and the role of the neighbourhood in designing sustainable cities[2]. The great evolutionary and complex nature of cities such as process, evolution, connection and variety, make urban spatial governance receive increasing attention as a means of improving city health.

This form of urban spatial governance could be traced back to the celebrated urban planner Clarence Perry, who introduced the use of the neighbourhood as a structural unit of the development of cities in the late 1920s. His concept of neighbourhood has been gradually transforming from being the spatial imprint of well-ordered urban amenities to a carrier of social data and values[3].

The newest “boost” towards achieving spatial sustainability in cities came through the emergence of the COVID-19 pandemic, pandemic, which—due to numerous challenges—prompted the need for novel and innovative mechanisms for cities to pursue their economic activities while enforcing strict health protocols[4]. The emergence of this pandemic exposed the vulnerability of cities in their current establishment and the need for a radical re-thinking, where innovative measures need to be tailored to ensure that urban residents are able to cope and continue with their basic activities, including cultural ones, to ensure that cities remain both resilient and livable in the short and long terms[5]. In the post-epidemic era, it is particularly important for the sustainable development of the community. Therefore, how to plan public space has become a crucial issue. As the ideological cognition and interest preferences of life groups become more complex and diverse, the difficulty of community construction, operation and governance has increased accordingly. With the continuous transformation of urban planning, the spatial organization model has also changed from the previous residential space organization model of "residential area-residential quarter-residential group" to a hierarchical model of "15-minute living circle-ten-minute living circle-five-minute living circle-residential neighborhood"[6].

The proposal of "Life Circle" can be traced back to Japan, and its concept comes from Japan's "Rural Living Environment Improvement Plan", which pays more attention to transforming and reshaping communities with human scale and experience,and enhancing urban and rural vitality[7]. Based on the theory, life centers of different time scales were defined by setting circles with different radii and different population sizes according to a certain proportion, and it was used in the planning of Japan’s territories[8]. Subsequently, the concepts of "wide area living circle", "local living circle" and "settlement circle" were put forward. Among them, the concept of "settlement circle" became the prototype of the concept of "15-minute community life circle", and later this concept was accepted and gradually spread to other parts of Asia and South Korea and other countries. The concept of a 15-minute or a quarter-hour city (la ville du quart d’heure) was developed by Carlos Moreno in 2016 as an attempt to respond effectively to the climate crisis and the progressing urban sprawl[5]. It is also deemed a reflection of the goals and recommendations contained in the 2030 Agenda for Sustainable Development (Goals 3, 5, 9, 10, 11, and 13), responds to the New Urban Agenda’s call for the Right to the City[9], and also aligns with the vision of green, equitable, and productive city outlined in the New Leipzig Charter for Cities[10].

Research on the 15-minute-city in China recently mainly contains more theoretical discussions[11], such as the theory of 15-minute-city hierarchy construction, the theoretical guidance of 15-minute-city construction based on time geography or urban life circle theory[12], definition of different types of life circles and qualitative research on resource allocation of public service facilities in 15 minutes based on urban land use[13]; in terms of empirical research, it contains some 15-minute-city evaluation research based on field survey and exploration data for specific types of basic service facilities (such as shopping or sports facilities). However, a city with a high quality of life needs a basic public service system with multiple types of coverage and public service guarantees covering all age groups. Therefore, the method and technical system for evaluating and optimizing the construction of a 15-minute-city in the city still need to be further explored. In May 2021, the Ministry of Natural Resources of China released The Standard of Spatial Planning Guidance Community Life Unity to offer technique support for future 15-minute city construction. Taking a 15-minute walking distance as the space scale, the Guidance configures various functions and facilities required for basic living of residents, ad provides a construction reference for healthy, energetic and low-carbon lifestyle, which satisfies urban residents’ yearning for a better life. Furthermore, the Guidance offers a detailed spatial assessment framework of 15-minute city

facilities deployment including a variety of parameters. As the critical political and cultural center of China, the Beijing-Tianjin-Hebei Urban Agglomeration (BTH) is selected to a demonstration plot of shortening the gap between urban and rural areas and promoting coordinated development between regions. The strategy of 15-minute city is expected to create a more pleasant living environment, and to promote travel convenience for citizens. Based on the BTH, this paper evaluates the integrated performance of 13 cities in the Agglomeration by using the framework of the Guidance for visualizing and exploring facilities' POIs on POI-type semantic space. The compare of 15-minute community construction between different cities is rendered as a "mode map" by POI counts on various types, providing a vivid information delivery method for urban planners and POI-related urban studies and applications.

2. Materials and methods

2.1. Study area

The research area of this paper is the Beijing-Tianjin-Hebei Urban Agglomeration (BTH). The BTH is one of the largest and most developed urbanized region in China, with an area of about 200 thousand km^2, consisting of 13 cities: Beijing, Tianjin, Shijiazhuang, Tangshan, Baoding, Qinhuangdao, Langfang, Cangzhou, Chengde, Zhangjiakou, Hengshui, Xingtai, and Handan (Figure 1). In 2021, the population of the BTH has reached 108.25 million, and the total economic amount of the BTH was accounted for 8.4% of the whole country (Table 1). Since the 1990s, the BTH has provided significant support for the development of North China. However, regional inequality of social-economic development has been increasing simultaneously[14][15]. Specifically, Beijing and Tianjin have been enjoying at a continuously high development level despite the slow pace of development of surrounding counties, forming a poverty belt around the two major cities. The increasingly severe spatial inequality has plagued the sustainable development of the Beijing-Tianjin-Hebei urban agglomeration[16]. Nevertheless, the imbalance is expected to change. In 2014, the State Council issued the National New Urbanization Plan (2014-2020), establishing a blueprint for the development of China's city regions. With the goal of making Chinese cities more liveable and sustainable, the plan described new urbanization as "people-oriented," "green and low-carbon" and with "an optimized layout". After the release of The Guidelines on Establishing More Effective New Mechanisms for Coordinated Regional Development (issued by Central Government) in 2018, the BTH and other 6 urban agglomerations has been given the priority to cast innovation of spatial coordination and urban and rural facility layout. The equalization of public facilities has also been placed in an indispensable position in the Outline of the 14th Five-Year Plan (2021-2025), hence the need for a 15-minute city strategy will be required soon.

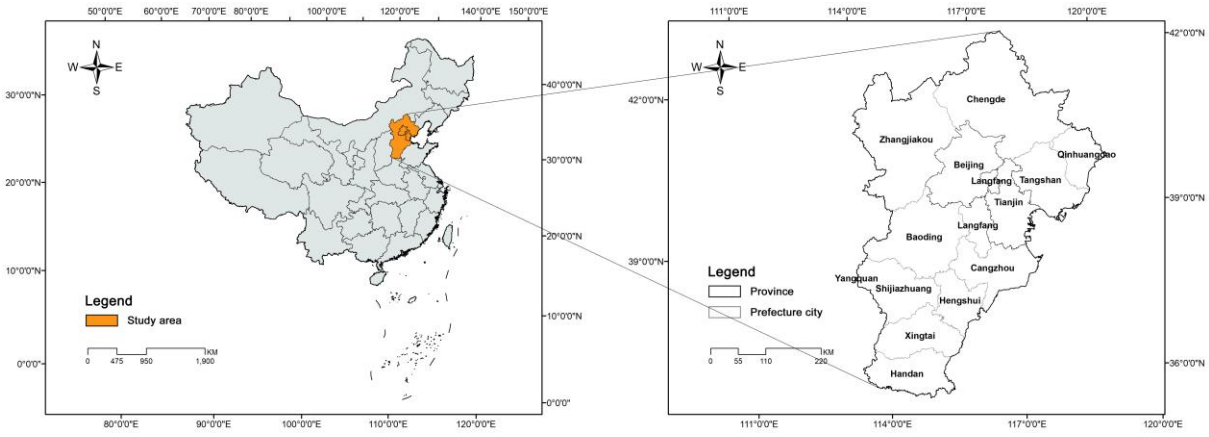

Figure 1. Study area.

City Name	Beijing	Tianjin	Shijiazhuang	Tangshan	Baoding	Qinhuangdao	Langfang
Population (10,000 people)	2188.6	1373.0	1120.5	769.7	919.5	313.4	553.8
GDP (trillion CNY)	4.03	1.57	0.65	0.82	0.37	0.64	0.36
City Name	Cangzhou	Chengde	Zhangjiakou	Hengshui	Xingtai	Handan	TOTAL
Population (10,000 people)	730.4	333.6	409.9	458.9	708.8	941.4	10824.8
GDP (trillion CNY)	0.42	0.17	0.17	0.17	0.24	0.41	10.02

Table 1. Population and GDP of 13 cities in the BTH in 2021.

2.2. Data

2.2.1. POIs data

Point of interest (POI) data provides intelligence on real-world city public facilities, such as retail stores, restaurants, parks, monuments, and other sites of convenience or tourist attractions, providing basic attribute information like name, address, spatial coordinates, and category. POIs data has become an increasingly convenient data source for territory quantitative analysis due to its availability and abundance of information[17]. The most rudimentary way of acquiring POIs data is the automatic extraction from Web sources like Google Maps, OpenStreetMap, etc. In this paper, POIs data is extracted from AutoNavi Map (a Chinese map application). All POIs data was collected within a month in 2022, and was re-edited into a database. There are finally 8 categories with more than 812.5 thousand facility points in the database (Table 2).

City Name	Beijing	Tianjin	Shijiazhuang	Tangshan	Baoding	Qinhuangdao	Langfang
Number of POIs data	132,656	109,882	89,921	65,571	96,621	29,428	53,126
City Name	Cangzhou	Chengde	Zhangjiakou	Hengshui	Xingtai	Handan	TOTAL
Number of POIs data	58,284	33,784	36,936	32,531	59,726	14,056	812,522

Table 2. Number of collected POIs data of 13 cities in the BTH.

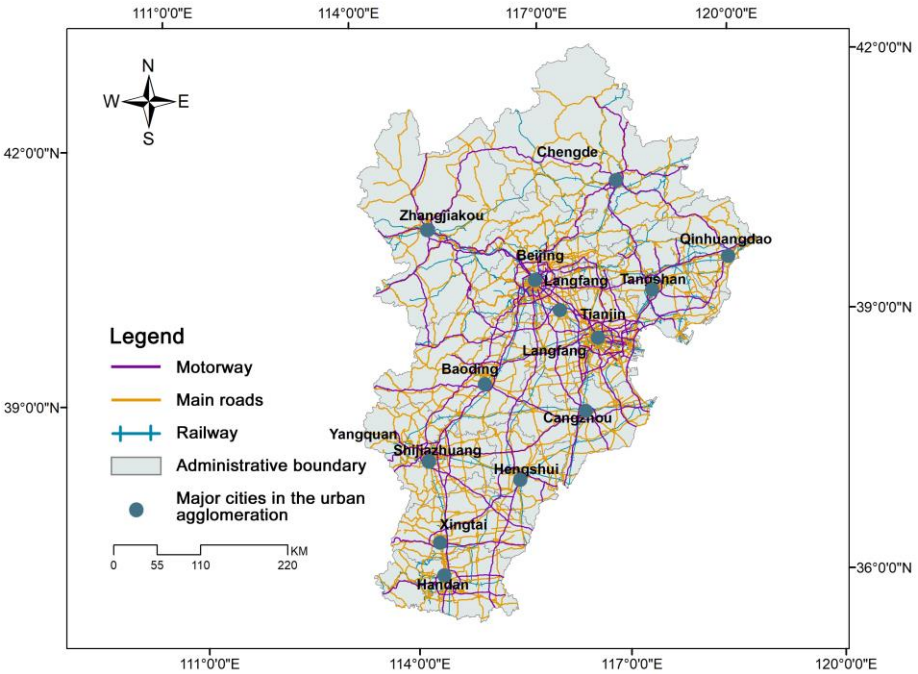

Figure 2. Urban road network data of the BTH.

2.2.2. Urban road network data

The urban road network data is also acquired from AutoNavi Map, including highways, arterial roads, city branches, and trails. Through topology inspection and tailoring, the road network database is obtained (Figure 2).

2.2.3. City boundary data

The city boundary data of Beijing, Tianjin and Hebei Province is from the National Science & Technology Infrastructure of China, National Earth System Science Data Sharing Infrastructure (http://www.geodata.cn)[18].

2.2.4. Land-use data

The land-use dataset for 2020 of the BTH is provided by Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (http://www.resdc.cn). The dataset based on Landsat 8 remote sensing images generated by visual interpretation were applied in the national land resources survey[19], as well as in hydrological and ecological research[20]. The BTH land-use dataset have a spatial resolution of 30 m × 30m and is classified as croplands (CPL), woodlands (WDL), grasslands (GSL), waters (WRT), urban and built-up lands (UBL), and unused lands (UUL); a total of 6 first-level types and 25 secondary types were discerned (Figure 3)[21].

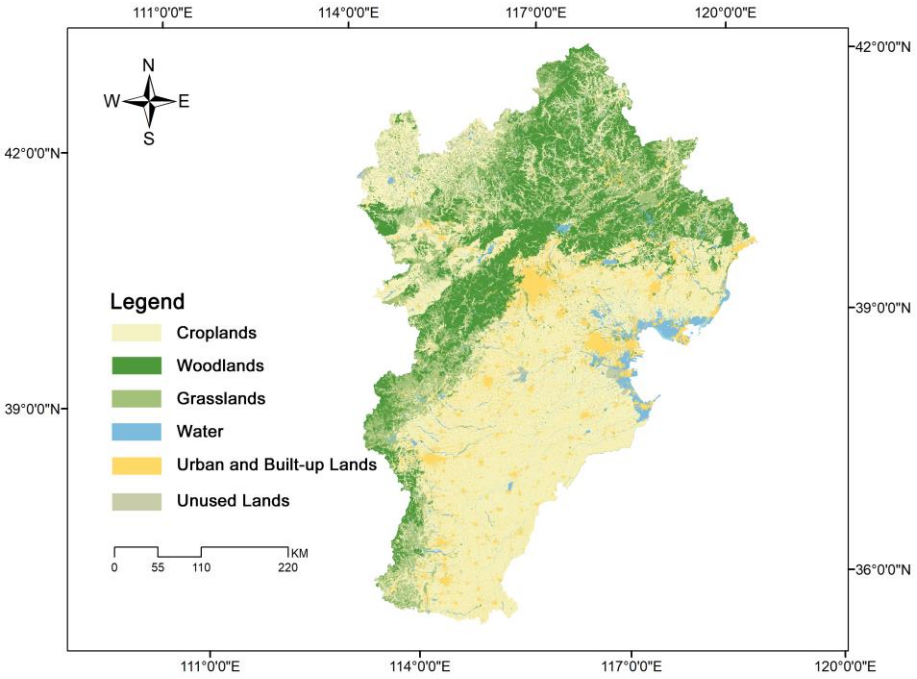

Figure 3. Land use of the BTH in 2020.

2.3. Methods

This paper uses multiple types of POI data and road network data as basic data, combined with land-use data, to calculate the coverage rate of the 15-minute city, and then evaluates the performance between 13 cities to acquire the measurement of 15-minute city of the BTH region. According to the The Standard of Spatial Planning Guidance Community Life Unity, the taxonomy of urban & rural public service facility is based on 3 categories and 8 sub-categories (Table 3), which makes it difficult to assess the performance efficiently. Hence, a simplified taxonomy, with 7 categories and 14 types of facility, is proposed in this paper to conduct the evaluation (Table 4). The new taxonomy consider the integrity and succinctness.

Category	Sub-category	Scale	Facility Name	Service Radius
Community Services	Health Management	15-minute	Health Service Centre	1000m

		15-minute	Clinic	1000m
	Retirement Services	15-minute	Retirement Home	——
		15-minute	Nursing Home for the Aged	——
		5/10-minute	Day-care Centre for the Aged	300m
	Life-long Education	15-minute	Middle School	1000m
		15-minute	Primary School	500m
		5/10-minute	Kindergarten	300m
	Cultural Activities	15-minute	Cultural Activity Centre	
		5/10-minute	Cultural Activity Station	
	Physical Fitness	15-minute	Multi-Purpose Sports Stadium	1000m
		15-minute	Multi-Purpose Sports Gym	500m
		5/10-minute	Multi-Purpose Sports Site	300m
		5/10-minute	Outdoor Sports Site	300m
	Commercial Services	15-minute	Shopping Mall	500m
		15-minute	Wet Market or Fresh Food Supermarket	500m
		15-minute	Dining Facility	——
		15-minute	Bank (including ATM)	——
		15-minute	Telecom Office	——
		15-minute	Post Office	1000m
		5/10-minute	Commercial Facility	300m
	Administrative Services	15-minute	Community Service Centre	——
		15-minute	Community Sub-district Office	——
		15-minute	Office of Justice	——
		5/10-minute	Community Service Station	——
	Other Services	5/10-minute	Renewable Resources Recovery Spot	——
		5/10-minute	Household Waste Collection Station	400m~1000m
		5/10-minute	Public Lavatory	——
Vocational Counsel Services		15-minute	Community Employment Service Centre	——
Mobility Services		15-minute	Public Transport Stop	500m

Table 3. Suggestions on the allocation of basic public service facilities in community life circle.

Category	Facility Name	Scale/Service Radius	Types involved
Medical Facility	Health Service Centre	1000m	general hospitals, community hospitals, specialized hospitals, outpatient departments, clinics, centers for disease prevention, emergency centers, etc
Retirement Services Facility	Retirement & Nursing Home	15-minute	nursing home, chronic disease hospital, rehabilitation hospital, etc
Educational Facility	Middle School	1000m	——
	Primary School	500m	——
	Kindergarten	300m	——
Cultural Facility	Cultural Activity Facility	15-minute	KTV, Internet cafe, game hall, picking park, fishing park, cultural venues (library, museum, art gallery, exhibition hall, botanical garden, etc.), playground, chess and card room, nightclub, scenic spots, disco hall, etc
Physical Facility	Multi-Purpose Sports Place	15-minute	city square, park square, park, water sports center, ski resort, fitness center, campground, various sports venues, equestrian club, rugby field, football field, basketball court, badminton court, skating rink, Taekwondo arena, etc

Domestic Facility	Shopping Mall	500m	large stores (furniture, building materials, home appliances, stationery), specialty stores, small commodity markets, wet markets and fresh markets, etc
	Dining Facility	15-minute	——
	Bank (including ATM)	15-minute	——
	Telecom Office	15-minute	——
	Post Office	1000m	——
	Community Commercial Facility	300m	convenience stores, supermarkets, beauty salons, laundromats, digital electronics maintenance centers, bath centers, pack & stack, etc
Mobility Facility	Public Transport Stop	500m	subway station, bus station

Table 4. Allocation of basic public service facilities of 15-minute city in this paper.

The network service area analysis method is used in this paper, which based on the road network and combined with certain impedance conditions (such as traffic mode, time or distance) to calculate the reachable coverage area, that is, the network service area. The network limitation of the network service area analysis method in this paper is the pedestrian road network, and the impedance condition is related to the scale/service radius in Table 4, and then combined with the land-use data, to calculate the coverage rate of each facility with urban & rural built-up area. The result reflects the mixed accessibility of multiple types of public service facilities in the 15-minute city. The higher the value, the better the comprehensive service convenience of multiple types of public service facilities in the 15-minute city in the area.

3. Visualizing and assessing the 15-minute city facility configuration of 13 cities

The result of the public service facility 15-minute city coverage rate is illustrated in Figure 4. A heat map is used to visualize to performance of 14 categories of facility of 13 cities (Figure 4).

Urban built-up area

	BJ	TJ	SJZ	TS	BD	QHD	LF	CZ	CD	ZJK	HS	XT	HD
DF	0.65	0.43	0.74	0.20	0.62	0.56	0.51	0.49	0.28	0.32	0.84	0.66	0.37
SM	0.14	0.07	0.12	0.05	0.06	0.02	0.10	0.06	0.05	0.06	0.03	0.04	0.02
CCF	0.27	0.16	0.27	0.14	0.21	0.12	0.27	0.24	0.14	0.14	0.25	0.20	0.15
CAF	0.61	0.33	0.64	0.22	0.46	0.41	0.40	0.38	0.20	0.23	0.57	0.47	0.20
HSC	0.48	0.25	0.57	0.21	0.44	0.36	0.39	0.37	0.20	0.22	0.59	0.46	0.24
PO	0.13	0.10	0.14	0.05	0.10	0.09	0.09	0.10	0.08	0.07	0.10	0.11	0.03
TO	0.21	0.20	0.49	0.17	0.36	0.28	0.30	0.28	0.16	0.18	0.47	0.34	0.11
Bk	0.47	0.27	0.50	0.19	0.38	0.35	0.31	0.34	0.17	0.20	0.51	0.38	0.17
R&NH	0.47	0.25	0.56	0.21	0.44	0.38	0.37	0.38	0.17	0.21	0.57	0.45	0.18
MS	0.12	0.09	0.17	0.06	0.11	0.09	0.09	0.12	0.06	0.07	0.17	0.18	0.37
PS	0.06	0.04	0.08	0.03	0.05	0.03	0.06	0.07	0.04	0.04	0.07	0.09	0.02
Kn	0.06	0.05	0.08	0.03	0.05	0.03	0.10	0.08	0.06	0.06	0.09	0.07	0.03
PTS	0.28	0.23	0.38	0.16	0.26	0.22	0.27	0.25	0.16	0.17	0.35	0.21	0.21
MPSP	0.36	0.14	0.30	0.08	0.11	0.05	0.13	0.16	0.07	0.08	0.05	0.09	0.05

Rural built-up area

	BJ	TJ	SJZ	TS	BD	QHD	LF	CZ	CD	ZJK	HS	XT	HD
DF	0.44	0.33	0.61	0.14	0.39	0.23	0.37	0.38	0.20	0.21	0.33	0.51	0.18
SM	0.02	0.02	0.01	0.01	0.04	0.10	0.01	0.01	0.01	0.01	0.07	0.12	0.00
CCF	0.13	0.14	0.12	0.10	0.08	0.04	0.15	0.10	0.07	0.06	0.04	0.09	0.05
CAF	0.41	0.22	0.24	0.10	0.14	0.08	0.19	0.14	0.09	0.10	0.09	0.18	0.04
HSC	0.27	0.21	0.34	0.18	0.22	0.13	0.26	0.23	0.13	0.13	0.21	0.35	0.13
PO	0.26	0.05	0.07	0.05	0.05	0.04	0.05	0.06	0.06	0.07	0.06	0.07	0.02
TO	0.10	0.14	0.30	0.10	0.16	0.11	0.18	0.12	0.10	0.09	0.15	0.21	0.08
Bk	0.16	0.17	0.20	0.11	0.13	0.09	0.12	0.12	0.09	0.08	0.12	0.17	0.04
R&NH	0.19	0.17	0.27	0.11	0.17	0.09	0.17	0.15	0.05	0.07	0.13	0.20	0.03
MS	0.05	0.05	0.07	0.04	0.04	0.04	0.04	0.06	0.04	0.03	0.04	0.06	0.18
PS	0.03	0.05	0.09	0.05	0.06	0.03	0.06	0.07	0.06	0.04	0.09	0.17	0.02
Kn	0.03	0.03	0.03	0.03	0.02	0.01	0.04	0.03	0.01	0.01	0.01	0.03	0.01
PTS	0.26	0.20	0.14	0.07	0.07	0.03	0.14	0.07	0.08	0.07	0.08	0.07	0.05
MPSP	0.13	0.05	0.04	0.02	0.05	0.10	0.03	0.02	0.01	0.02	0.08	0.13	0.01

Figure 4. Public service facility 15-minute city coverage heat map of 13 cities in the BTH ***(Note: city name abbreviation:"BJ" refers to "Beijing"; "TJ" refers to "Tianjin"; "SJZ" refers to "Shijiazhuang"; "TS" refers to "Tangshan"; "BD" refers to "Baoding"; "QHD" refers to "Qinhuangdao"; "LF" refers to "Langfang"; "CZ" refers to "Cangzhou"; "CD" refers to "Chengde"; "ZJK" refers to "Zhangjiakou"; "HS" refers to "Hengshui"; "XT" refers to "Xingtai"; "HD" refers to "Handan"; facility abbreviation: "DF" refers to "Dining Facility"; "SM" refers to "Shopping Mall"; "CCF" refers to "Community Commercial Facility"; "CAF" refers to "Cultural Activity Facility"; "HSC" refers to "Health Service Centre"; "PO" refers to "Post Office"; "TO" refers to "Telecom Office"; "Bk" refers to "Bank (including ATM)"; "R&NH" refers to "Retirement & Nursing Home"; "MS" refers to "Middle School"; "PS" refers to "Primary School"; "Kn" refers to "Kindergarten"; "PTS" refers to "Public Transport Stop"; "MPSP" refers to "Multi-Purpose Sports Place"）.***

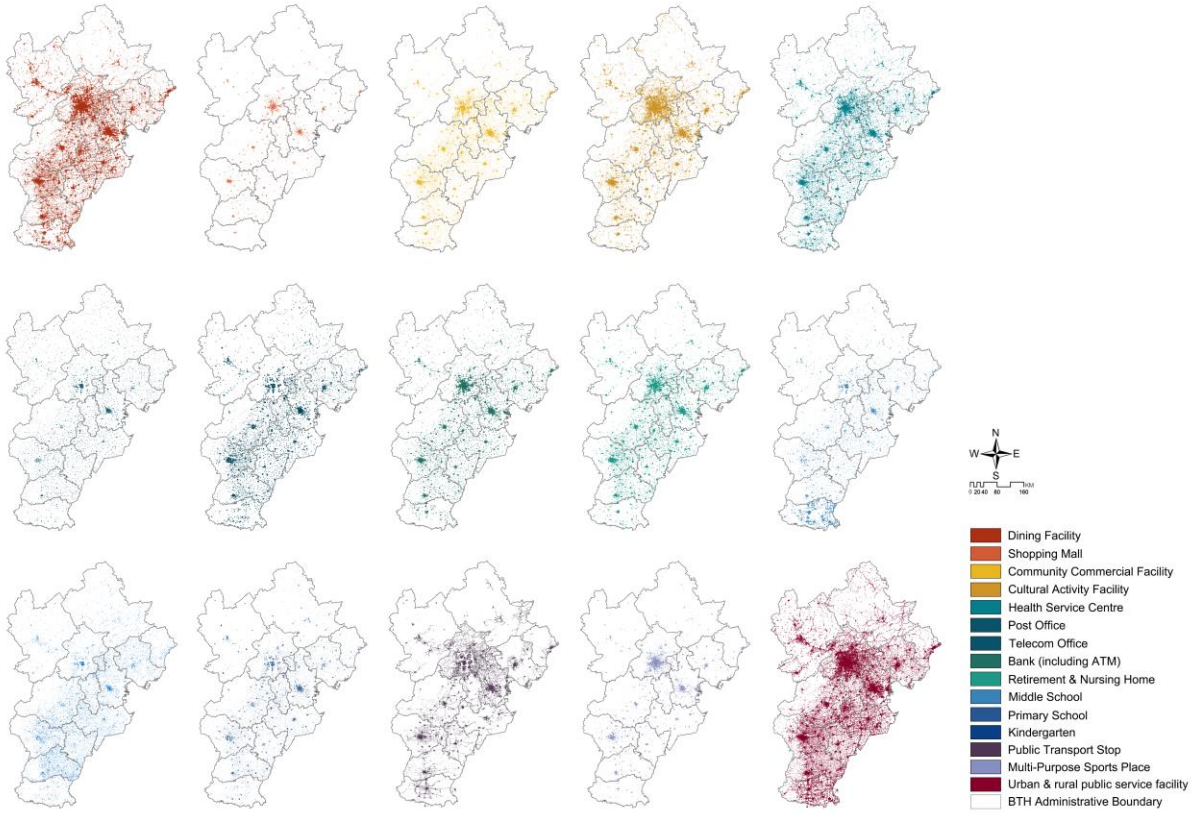

Figure 5. Public service facility 15-minute city coverage spatial distribution of 13 cities in the BTH.

The results reflect a significant difference between the 15-minute city coverage of the 14 public service facilities (Figure 5). The specific performance is that there is a remarkable gap between cities with different levels, and the 15-minute coverage of the same type of facilities in the same city in urban and rural areas is quite different, reflecting 1) The problem of uneven distribution of urban and rural public service facilities within the BTH region remains prominent; 2) There will be long periods of time before the 15-minute city construction in completed, and the speed of construction is directly related to the level of the city.

4. Discussion

The study area of this paper focuses on the BTH urban agglomeration, providing a quick method to evaluate and visualize the 15-minute city coverage of public service facilities in different cities, but there are still many aspects to be further studied.

First, the taxonomy of land-use data needs to be further refined. The current results are based on urban and rural built-up areas, so the spatial performance of various facilities is relatively poor. If the spatial data of residential land in each city can be obtained, then the results would theoretically be considerably higher.

Secondly, from the perspective of data, the POIs data used in this paper is acquired from an open source data application, which is already a relatively mature volunteer geographic information service though, the data still has a certain degree of subjectivity, and there will still be a big discrepancy with the reality, which is probably one of the main reasons for the overall poor results.

Finally, the classification of public service facilities used in this paper filters out some types of facilities that have little to do with basic community life. However, with the continuous improvement of urban life quality, the needs of subgroups should also be considered in future study.

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