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15 分コミュニティ生活圏における施設の分布特性に関する研究
－済南市をケーススタディとして－

The distribution characteristics of facilities in 15-minute Community Life Circle：the case study of Jinan City

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This research studied Jinan City as a case study of 15min-CLCs development among second-tier cities in China and tried to identify the underdeveloped areas and underdeveloped services for future growth. There are few studies on second-tier cities with large populations and low quality of life. The main steps of this study are as follows: First, we analyzed the distribution of facilities for the daily lives of residents in the 15-minute-CLCs. Secondly, the study assessed whether each 15-min-CLC meets the daily life needs of residents. Thirdly, it discussed relevant optimization strategies for underdeveloped regions. Finally, the underdeveloped regions and insufficient facilities in Jinan City were identified.

Keywords : 15min-CLCs, Point Of Interest, optimization strategy, second-tier cities, TOD
15 分 CLC, 関心地点, 最適化戦略, 二線都市, TOD

1. Introduction

The Chinese government has advocated the transit-oriented development (TOD) concept to solve the problems of air pollution, traffic congestion, and increased commuting distance caused by rapid urban development in recent years. The TOD policy aims to solve such issues by developing public transport to build the skeleton of the urban transport system and connect different neighborhoods. However, in the current research on TOD implementation, more attention has been paid to the development of TOD stations, and few studies have discussed whether the surrounding environment of TOD is livable or workable. Improving the quality of life by improving how people meet the needs of daily life is essential for attracting new residents to TODs.

Therefore, the concept of the "15-minute Community Life Circle" (15min-CLC) has been widely recognized in China and is gradually being applied to urban planning. The concept of 15min-CLC is regarded as the basic unit to build community life in the master plan of Shanghai in 2016 [1]. In this Shanghai master plan, 15 minutes' walking distance is the public activity space that provides basic daily services for residents. At the same time, the Standard for the Planning and Design of Urban Residential Areas (GB50180-2018) that was issued by the Ministry of Housing and Urban-Rural Development of China in 2018 recommends that residential areas must meet their basic life demands within a reasonable walking distance. These new standards recommend four block community life circles based on the size of the residential areas, namely, 15-minute, 10-minute, and 5-minute [2]. The 15min-CLC is the most frequently used size among the three.

In the process of urban development, the development speeds of different communities vary, and urban expansion will also lead to the emergence of new and old communities. Therefore, the development of basic service facilities in different communities varies greatly.

Therefore, a better understanding of the distribution of basic service facilities in different communities is required to implement the concept of 15-minute-CLC.The research that

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analyzes the implementation of the 15min-CLC in Chinese cities is limited. Existing research on China's 15-min CLC is mainly concentrated in first-tier cities, such as Beijing and Shanghai, at present [3]. These first-tier cities have a very high level of urban development, and their comprehensive economic strength and transportation accessibility play a leading role nationwide. As a result, after being proposed in national standards in 2016, the concept of 15-min-CLC could be quickly adopted in first-tier cities.

However, the development practice of first-tier cities cannot be fully applied to other cities, such as second-tier cities, due to different levels of urban development and population density. Although second-tier cities have a good economic foundation and a large population, they still need to focus on improving the urban infrastructure and do not have enough capacity to quickly implement new policies. As a result, most second-tier cities have not formulated strategies to develop the 15min-CLC concept. Meanwhile, there is little research on the development of 15min-CLCs in second-tier cities.

While other second-tier cities do not have plans to apply the 15min-CLC concept, Jinan City has integrated the 15min-CLC concept with the latest master plan, putting it ahead of other cities at the same level. The analysis of the 15min-CLC implementation plan in Jinan City can provide more useful experience for other cities of the same type. Therefore, this study analyzed Jinan City as a representative city that is implementing 15min-CLC to understand the future development direction of the 15min-CLC in Chinese second-tier cities.

The purpose of this research is to identify the underdeveloped areas by analyzing the distribution characteristics of facilities in the 15-minute community life cycle areas in Jinan City and then discuss appropriate methods for effectively developing the 15min-CLCs in Chinese second-tier cities.

2. Literature review

2.1 The application of 15min-CLC in different cities

The concept of 15min-CLC has been applied in different cities in different countries recently. As the first city in China to introduce the concept of 15min-CLC, Shanghai has developed a series of strategies to implement this concept, which provides a rich experience f or other Chinese cities. With the encouragement of the Chinese central government, more and more Chinese cities are considering integrating the concept of 15min-CLC into their urban development plans. For example, Beijing, Guangzhou, Shenyang, Hefei, Jinan, etc. At the same time, many cities outside China are planning to transform urban neighborhoods into 15-minute cities. Paris has proposed implementing a 15-minute city concept in 2020. The C40 Cities Climate Change Leadership Group in 2021 discussed the 15-minute cities and summarized those residents of every neighborhood should have easy access to goods and services, particularly markets, fresh food, and healthcare [4)5)6)].

In addition, the concept of a 15-minute city has also been extended to different scales in the process of practical implementation due to the unique context of different cities. For example, Portland created a 20-minute neighborhood, with convenient, safe, and pedestrian-oriented access to the places and services people use every day: transit, shopping, quality food, schools, parks, and social activities that are near and adjacent to the housing [7)]. Melbourne advocated a 20-minute block plan, including a return trip, which means that people need a 10-minute walk from home to their destination[8)]. In addition, some researchers have proposed that people can reach their destination within 20 minutes by walking or by public transportation in a 20-minute city [9)].

2.2 The evaluation of 15min-CLC in different cities

Several previous studies have been conducted on the evaluation of the 15-min-CLC concept in various cities. For example, Wu (2021) stated that the 15min-CLC concept is one of Shanghai's important strategies for facing society with a more diverse population structure in the future. They considered incorporating people's needs into the 15-min-CLC evaluation model. They evaluated the current situation of Shanghai's 15min-CLC and carried out service area analysis to understand the shortcomings of Shanghai's 15min-CLC development through kernel density estimation. Then, they proposed some suggestions based on how to match the supply and demand [10)].

Noworól (2022) discussed the urban layout of Krakow from the perspective of a 15-minute city. They analyzed the geographical proximity of different facilities and compared them with the number of residents within different walking distances around facilities, and explained the factors affecting the number of residents within the 15min-CLCs[11)].

Li (2019) analyzed the existing situation of the distribution of service facilities in Baoding City based on POI data[13)]. They found that the public cultural facilities and elderly care facilities in Baoding were insufficient by calculating the standard rates in Baoding City. Their research also proposed optimization strategies.

Graells-Garrido (2021) analyzed the relationship between the distribution of service facilities in the 15min-CLC and human mobility by quantifying the accessibility of facilities in Barcelona's 15min-CLC. They found that facilities with

completed educational or commercial facilities are more likely to stimulate human activities[12].

The 15min-CLC concept can also be used to develop specific types of facilities. Song (2022) analyzed the spatial accessibility of health services in Guangzhou's 15-minute-CLCs. The result shows that only 39.6% of residents can get medical services within 15 minutes of travel[13].

Logan (2022) applied multiple methods to analyze the proximity of the 500 largest cities in the USA and 43 urban areas in New Zealand. Then they compared the results to find the important factors to help planners determine the scope of the community, such as geographic boundaries and amenity types [14]. Most of the 15min-CLC related studies focus on the analysis of individual cities. The types of facilities that are underdeveloped could be identified by analyzing the distribution characteristics of different facilities within 15min-CLCs, which will be useful to understand the shortcomings of 15min-CLC development and develop appropriate development strategies to overcome those shortcomings.

It is also assumed that the existing facilities can meet the daily needs of residents at 15 min-CLCs in their current situation. However, Wu (2021) stated that there are few previous studies discussing the balance between the demarcation of the 15min-CLCs and the needs based on population in the CLS (Community Life Cycle) [10]. Therefore, our research decides to develop a method to analyze the relationship between facilities and population.

In general, our study attempts to analyze the existing 15min-CLCs in Jinan City and formulate optimization strategies to overcome the deficiencies of the current situation. The structure of the research is as follows: Section 2 reviewed previous studies. Section 3 described the study area, data sources, and methods. The results were described and discussed in Section 4. Section 5 was the research conclusion.

3. Methodology

This study investigated three aspects of Jinan City's proposed 15min-CLC plan. First, we studied the distribution of facilities in each 15-min-CLC. Second, we analyzed the relationship between population and facility distribution and different walking distances. Third, divide these 15min-CLCs into several groups to find areas that need further improvement.

The following process was followed for the evaluation: First, the facilities were grouped into 6 categories as defined by the Jinan City government. Second, the number of facilities belonging to 6 groups of facilities at each 15min-CLCs was counted using POI data. Third, we calculated the ratio of the number of facilities to the population at each 15min-CLCs. Forth, the CLCs with facilities-to-population ratios below the average value was considered underdeveloped areas. Finally, the density distribution of facility categories within the 15-minute CLCs was calculated. Later optimization measures were proposed for underdeveloped CLCs. The research flow chart is shown in Figure 1.

3.1 Study area

Jinan City is the capital of Shandong Province in China. Jinan City has 10 districts and 2 counties, with a total area of 10244.45 square kilometers. According to the 7th national population census, the permanent population of Jinan was 9.2 million by November 2020, and the average annual population growth rate was 1.27% [15]. The Jinan City government emphasized promoting the development of urban rail transit with the TOD concept, strengthening traffic congestion management, advocating low-carbon travel, and attracting people to gather around the rail stations in the "Fourteenth Five Year" Comprehensive Transportation Development Plan [16]. By March 2021, there were 3 rail transit lines in Jinan City, including Line 1, Line 2, and Line 3, with a total operating mileage of 84.1 km and 43 stations.

At the same time, the Jinan City government proposed to implement the concept of 15min-CLC in 2016, to realize the balanced development of the whole city. In 2019, Jinan City Planning Bureau issued the guideline; Jinan Planning Guidance of 15-minute Community[17].

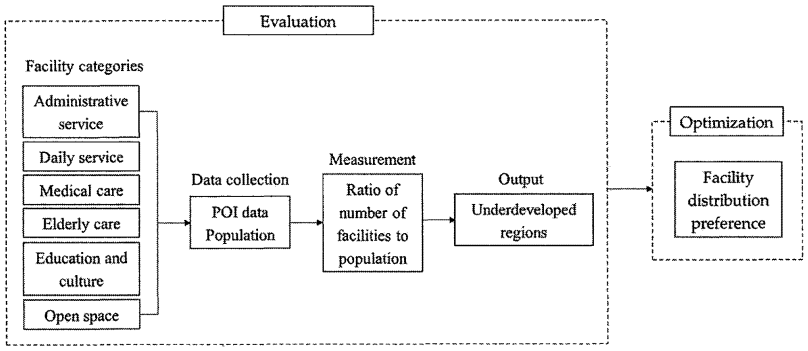

Figure 1. Research Flow Chart

Jinan City is planning to implement 15 min-CLCs in seven urban districts, namely, Lixia District, Shizhong District, Huaiyin District, Tianqiao District, Licheng District, Changqing District, and Gaoxin District. Meanwhile, this guideline defines the 15 min-CLCs from three aspects. The population of 15min-CLCs was calculated using the population density, and the population ranges from 50000 to 80000 people. The residential land area should be between 1.5 and 8 km^2. Secondly, urban blocks are the basic unit of the 15 min-CLCs. Thirdly, the scope of the 15min-CLCs was restricted to areas in which the different service facilities could be reached within 5 to 15 minutes. In addition, the guidelines recommend that 15 min-CLC should not be separated by natural factors such as large rivers, mountains, or railways and roads.

The cores of the 15min-CLCs are also defined in Jinan's guideline. First, the number of cores depends on the size of the 15min-CLC, and the buffers of cores must cover the entire 15min-CLCs within 15 minutes of walking distance. It is ensured that residents can arrive at any facilities within 15 minutes. Then, the cores can be located in the geographic center of 15min-CLCs as much as possible. The core can also be combined with public transportation nodes. There are eighty-three 15min-CLCs and 134 cores in Jinan City, defined in the Jinan City Plan as shown in Figure 2. Meanwhile, the eighty-three 15min-CLCs are numbered in Figure 2 to describe them clearly in this research.

3.2 Data collection

According to the Jinan Planning Guidance of 15-minute Community[17], different facilities are necessary to meet the basic living needs of residents within walking distance. These facilities that meet the basic needs of residents were divided into, 6 categories namely: (C1) daily service facilities, (C2) administrative service facilities, (C3) medical facilities, (C4) elderly care facilities, (C5) open space, and (C6) educational and cultural facilities as shown in Table 1.

C1 daily service facilities: Providing sufficient and diversified convenience services nearby to meet the daily needs of shopping, eating and maintenance in the life circle. Facilities include vegetable markets, housekeeping service centers, maintenance points, express service shops, small supermarkets, convenience stores, hardware stores, public toilets, renewable resources recycling stations, etc.

C2 administrative service facilities: Strengthening community autonomy, fostering the growth of social organizations, and helping residents to find jobs and start businesses. Facilities include street office management, community grassroots office, social organization incubation, employment and entrepreneurship guidance and skills training, embedded office space, etc.

C3 medical facilities: Pay attention to people's health in the whole life cycle and enrich community medical services. Facilities include community health services, health care for all age groups, tracking of chronic diseases, psychological counseling, hospice care, etc.

C4 elderly care facilities: Building a flexible, shared, and balanced elderly care system, pay attention to the physical and mental needs of the elderly. Facilities include centralized residential care for the elderly, day care services, elderly education services, catering services, etc.

C5 open spaces: Providing multi-level and multi type public activity venues and building a public activity space system in the life circle. Facilities include community public open spaces, small public spaces (street garden, cultural fitness square), etc.

C6 educational and cultural facilities: Providing diversified care and education for juveniles, increasing the allocation of public education facilities, and improving the quality of fitness and entertainment activities in the life circle. Facilities include preschool care, early childhood education training center, adult interest training, fitness etc.

Table 1. Data and sources.

Data Types		Measurements	Sources
Facility Categories	Daily service (C1)	Counting the number of POIs of food markets, maintenance shops, express delivery stations, supermarkets, banks, ATMs, convenience stores, public toilets.	Collected from Baidu Map on September 28, 2022.
	Administrative service (C2)	Counting the number of POIs of police stations, community service centers, subdistrict offices.	
	Medical care (C3)	Counting the number of POIs of hospitals, clinics.	
	Elderly care (C4)	Counting the number of POIs of elderly care facilities.	
	Education and culture (C5)	Counting the number of POIs of cultural and educational facilities, fitness services.	
	Open space (C6)	Counting the number of POIs of parks.	
Population		China population census yearbook.	Issued in 2020.

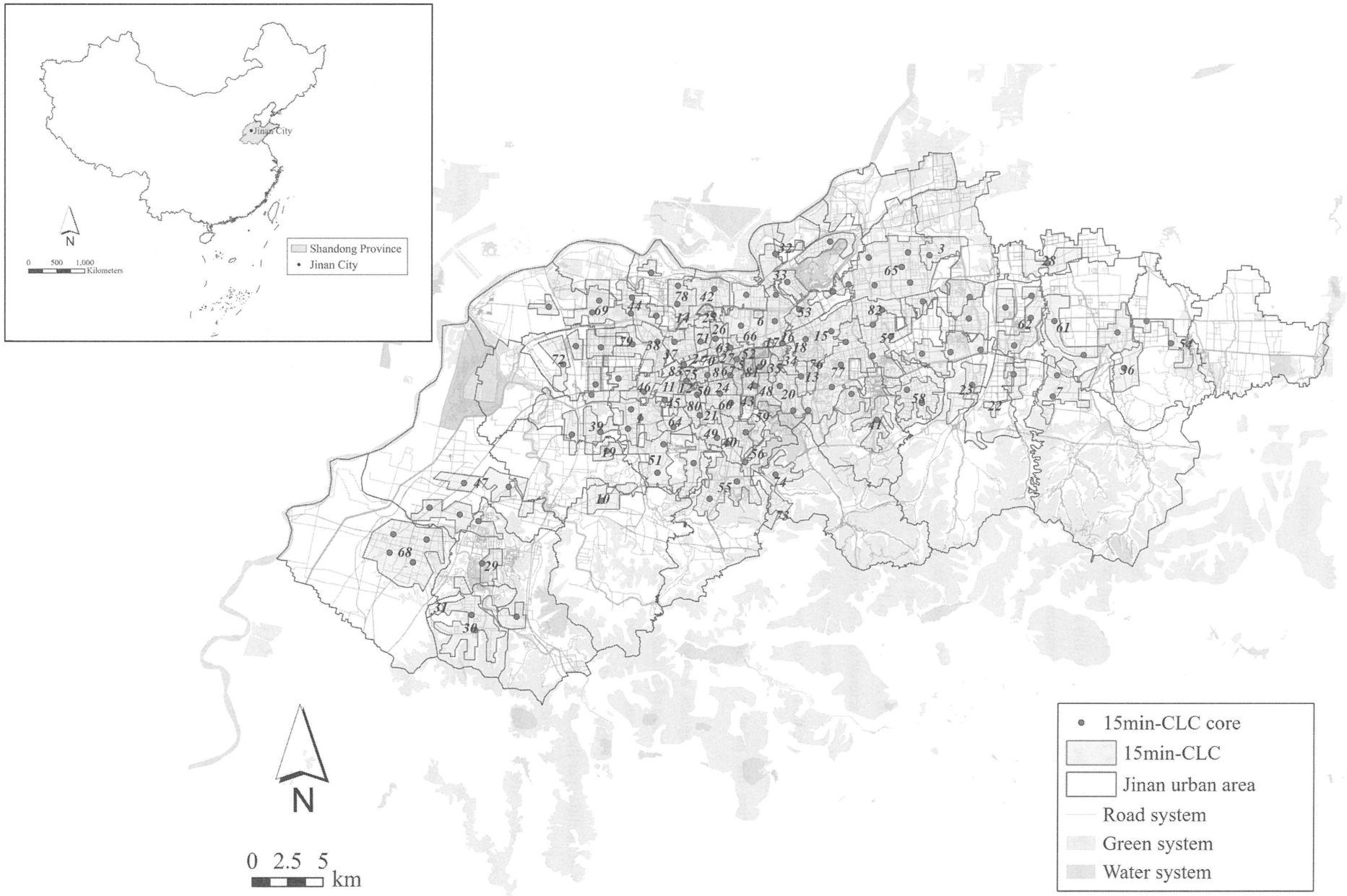

Figure 2. The eighty-three 15min-CLCs in Jinan City.

The above six categories of facilities were counted by POI data. A point of interest (POI) is a specific place or location point on a map that someone might be interested in or useful for. POIs are usually defined by their geographical coordinates along with some additional attributes such as name, category, address, opening hours and contact details. This information is important because it feeds many location-based applications such as digital maps and navigation systems. Therefore, the number and location of facilities in CLCs can be known by statistics of POI data. The POI data for this study was collected from the Baidu Map (Table 1). Meanwhile, this research collects the population data of Jinan City from the 2020 China Statistical Yearbook [18].

3.3 Evaluation of facilities distribution among 15min-CLCs

Evaluating the distribution of different facilities in 15min-CLCs can be helpful to find regions that need further development. After counting the POIs of each 15min-CLC and analyzing the distribution characteristics of different categories of facilities in 15min-CLCs, the research can understand the areas where the facilities are distributed unevenly. This research attempts to show the development situation of each 15min-CLC by counting the number of facilities belongs to six categories.

Then, this research proposes a method that can directly evaluate whether the allocation of facilities in different 15 min-CLCs is balanced. In this research, we named this measurement the Facility to Population Ratio (FPR). The FPR calculates the number of facilities per thousand people at a 5min-CLC.

3.4 Evaluation of facilities distribution within 15min-CLCs

This research, after evaluating the facility distribution of 15min-CLCs in Jinan City, identified the 15min-CLCs that need further improvement by comparing them with the average value. Optimization strategies can be proposed for regions that need improvement in the distribution of facilities. Logan (2022) stated that the distance between the facility and the residence is an important measure of convenience. The distance can affect the use of facilities14). Therefore, this research attempts to figure out the suitable distance from different categories of facilities to the cores of the 15min-CLCs, which can help planners fill the gaps in the underdeveloped regions accurately. This research measured the distribution of each facility category within 2000 meters (30-minute walking distance) of 134 cores.

4. Results and discussion

4.1 Facilities distribution of 15min-CLC in Jinan City

The number of six categories of facilities in eighty-three 15min-CLCs is counted. The results are shown in Figure 3 (a),(b),(c),(d),(e) and (f).

The main distribution locations of various categories of facilities in Jinan City can be observed directly in Figure 3. Among the eighty-three 15min-CLCs, only No. 61 has a higher-than-average number of facilities in all categories. At the same time, 8% of the 15min-CLCs in Jinan City only need to develop one category of service facility, and 34% of the 15min-CLCs have fewer facilities than the average number of facilities in each category.

Figure 3 also shows regions where each category of facility is well developed. For the daily service facilities, among the eighty-three 15min-CLCs, No. 6 and No. 15 have the largest quantity. It can be seen in Figure 3(a) that the daily service facilities are mainly concentrated in the central area of Jinan City.

Area 15 has the largest number of administrative service facilities. Because it is a city center, the number of administrative service facilities in No. 15 is much higher than that in other regions.

The medical care facilities are mainly located at No. 6, 15, 57, 65, 68, and 77. Medical care facilities are widely distributed and have the largest number of facilities among all categories of facilities.

Area No. 68 has the highest number of elderly care facilities. Area No.68 is an area with open natural lands far from the high-density area of Jinan City, where most elderly care facilities are concentrated in this region.

The areas 48, 9, and 35 have the highest number of open spaces. These regions are adjacent to parks, with ample space for activities. For the educational and cultural facilities, No. 15, 57 and 77 have the largest number of facilities. This category of facility is obviously concentrated in the city center.

In general, No. 15 is the most prominent region among the eighty-three 15min-CLCs, with enough facilities from each category. The No 68 is in the new city center and has the advantage of having adequate elderly care and medical facilities.

At the same time, there are areas with small number of service facilities, such as No. 31 and No. 73. These two 15min-CLCs are located at the edge of urban areas and are easy to be ignored in the urban development. The development direction in the future can be improved according to the insufficient facility categories.

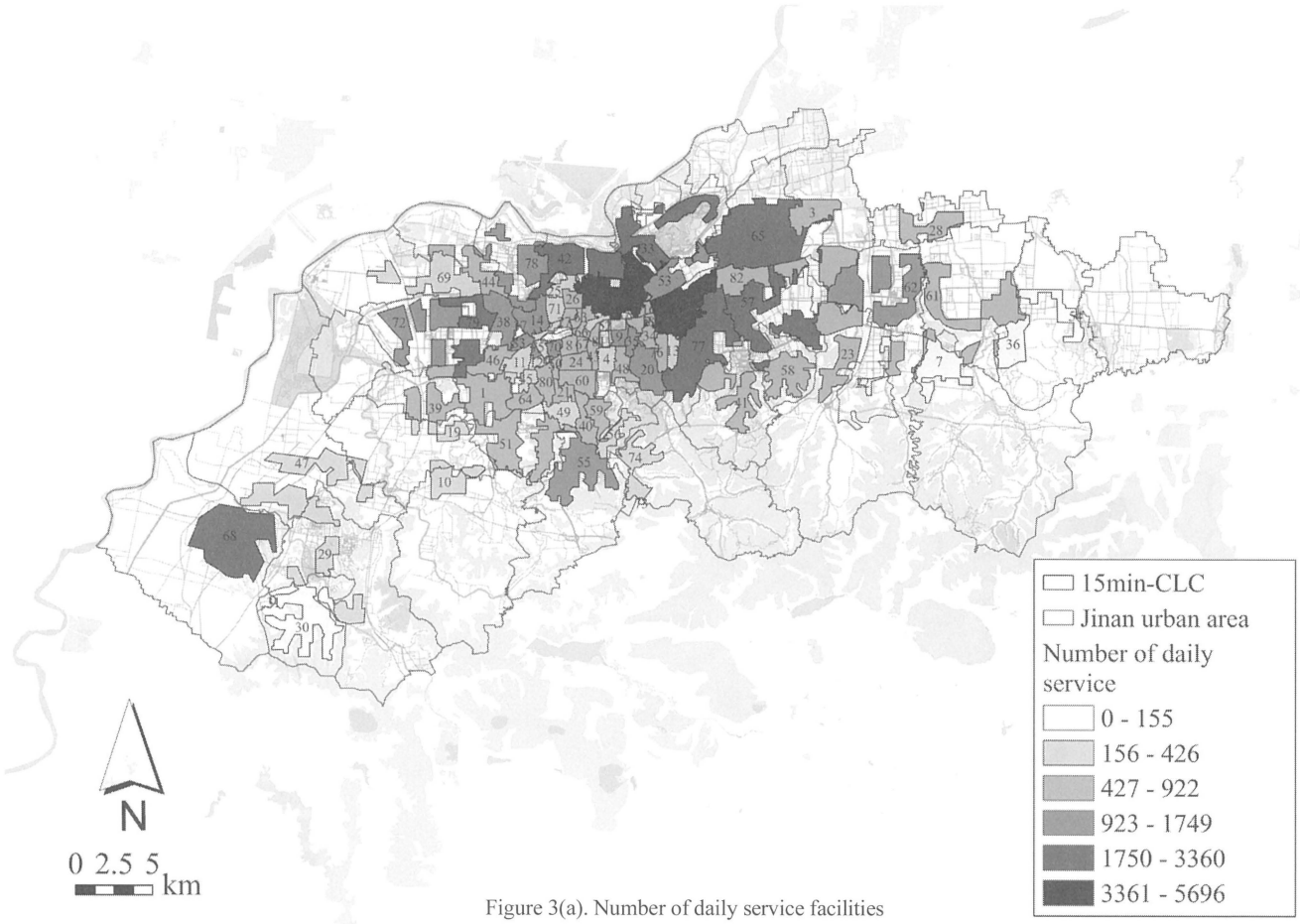

Figure 3(a). Number of daily service facilities

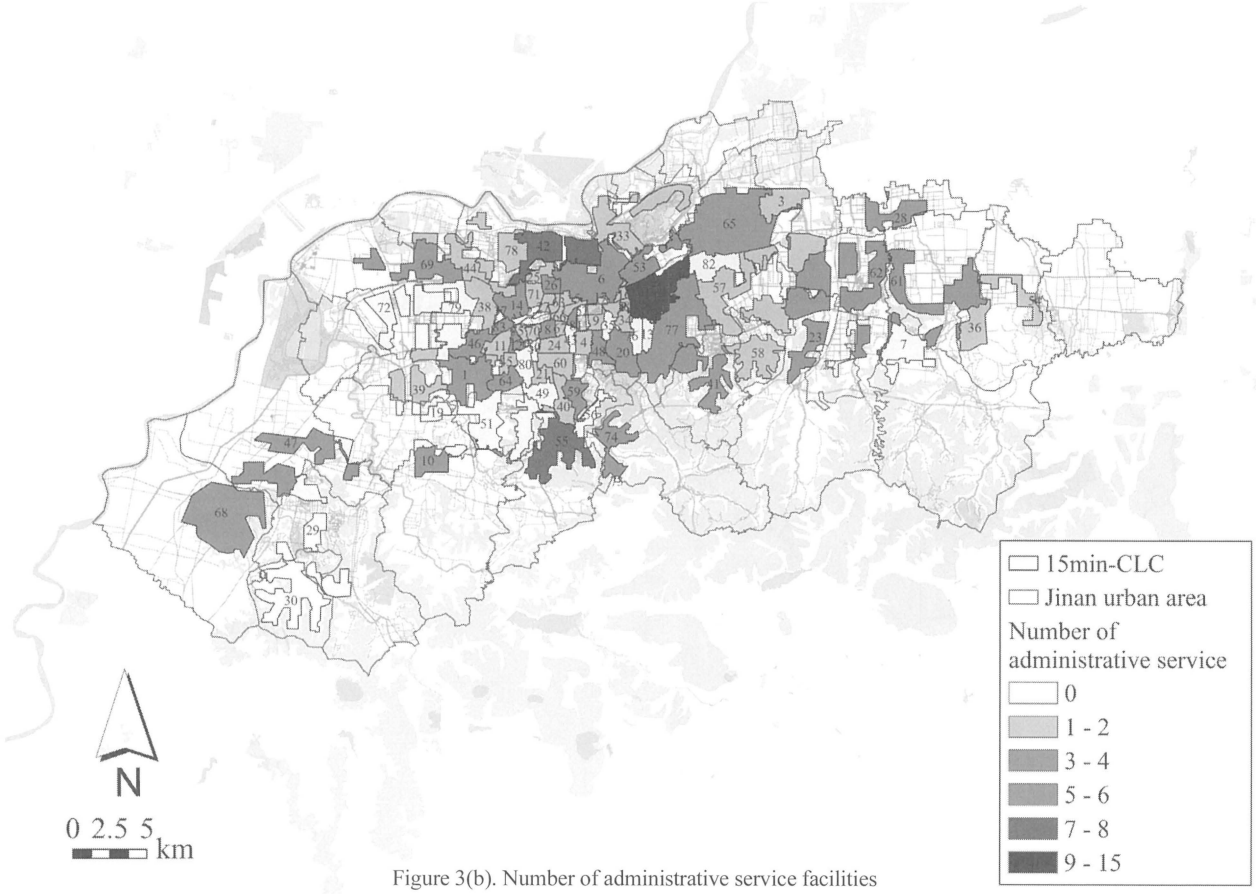

Figure 3(b). Number of administrative service facilities

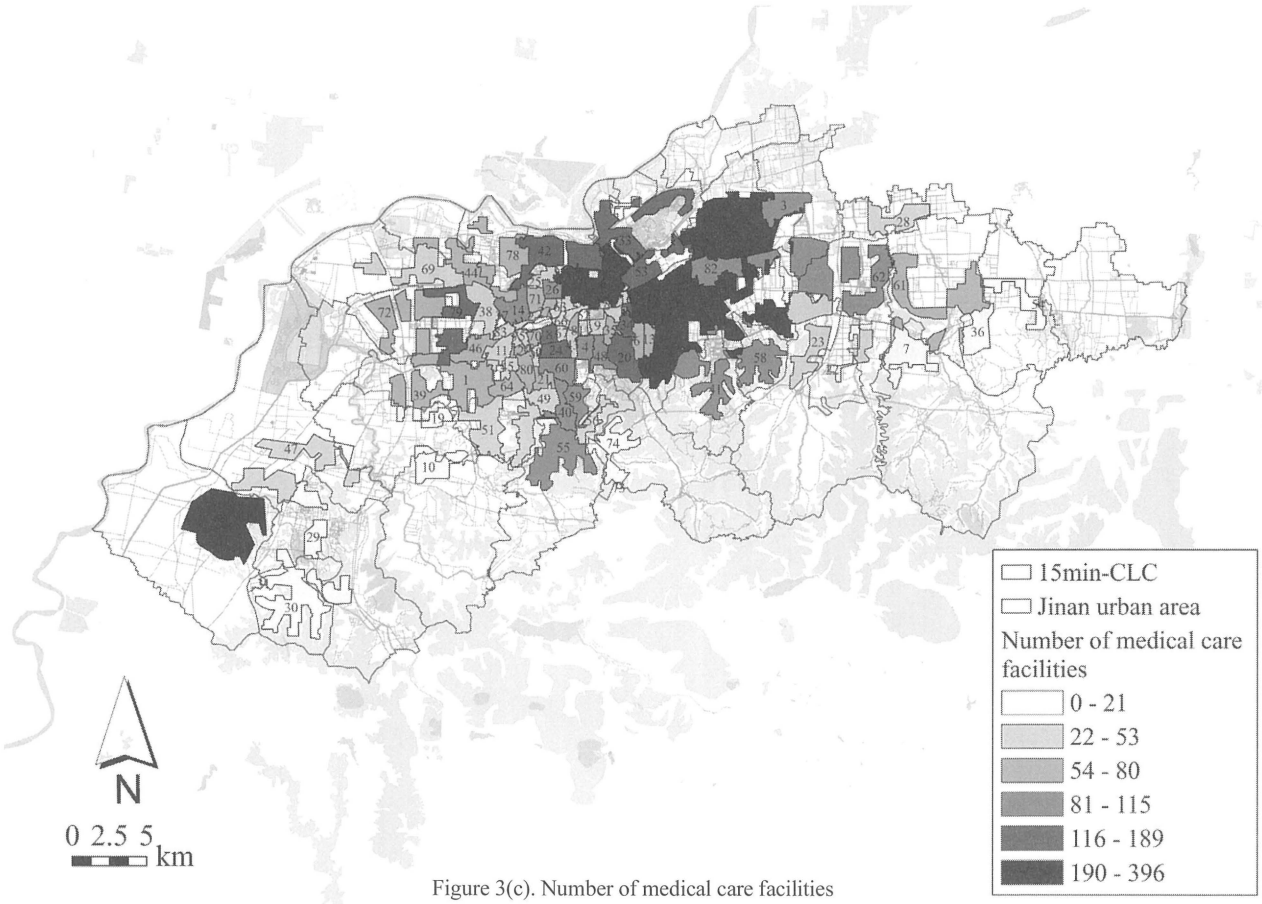

Figure 3(c). Number of medical care facilities

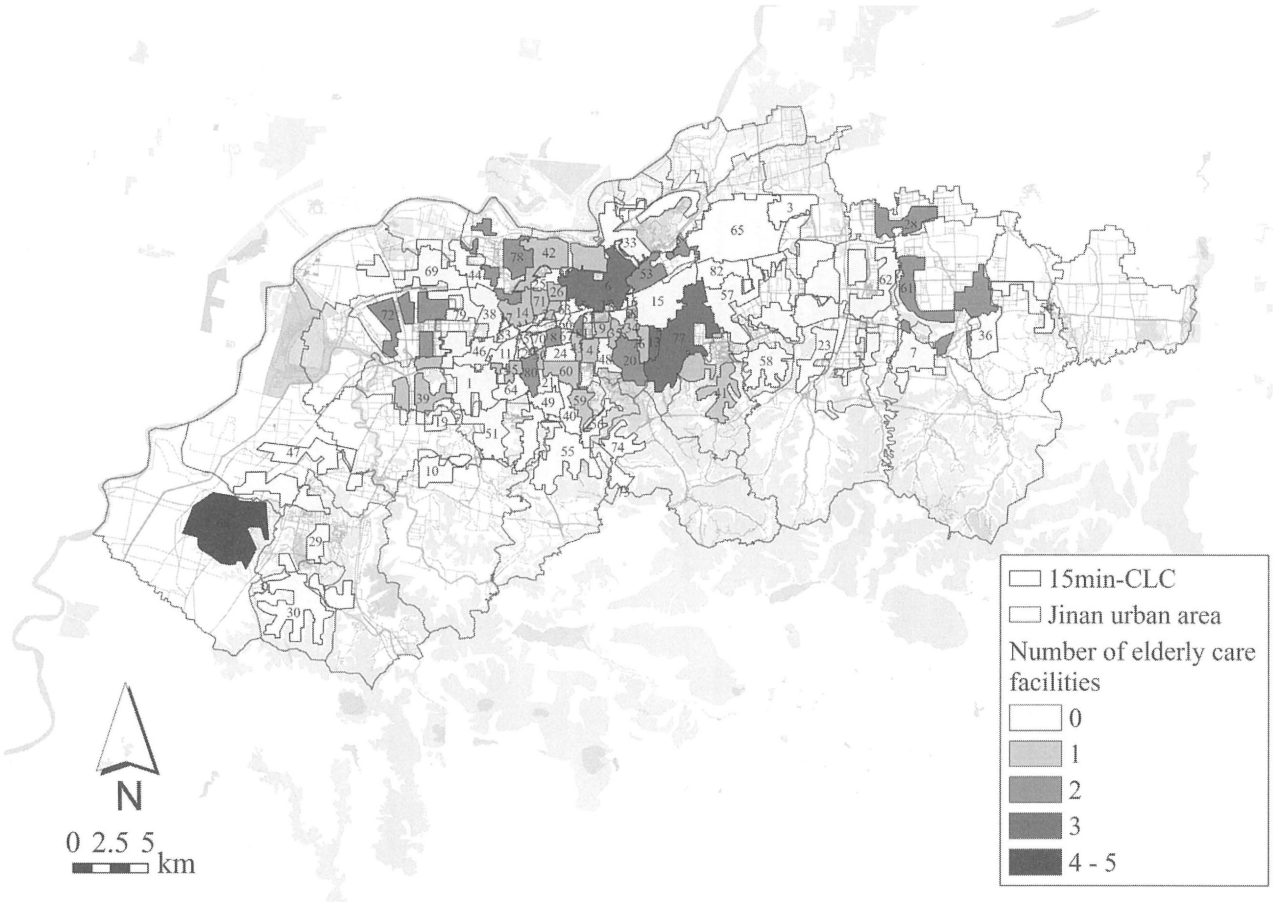

Figure 3(d). Number of elderly care facilities

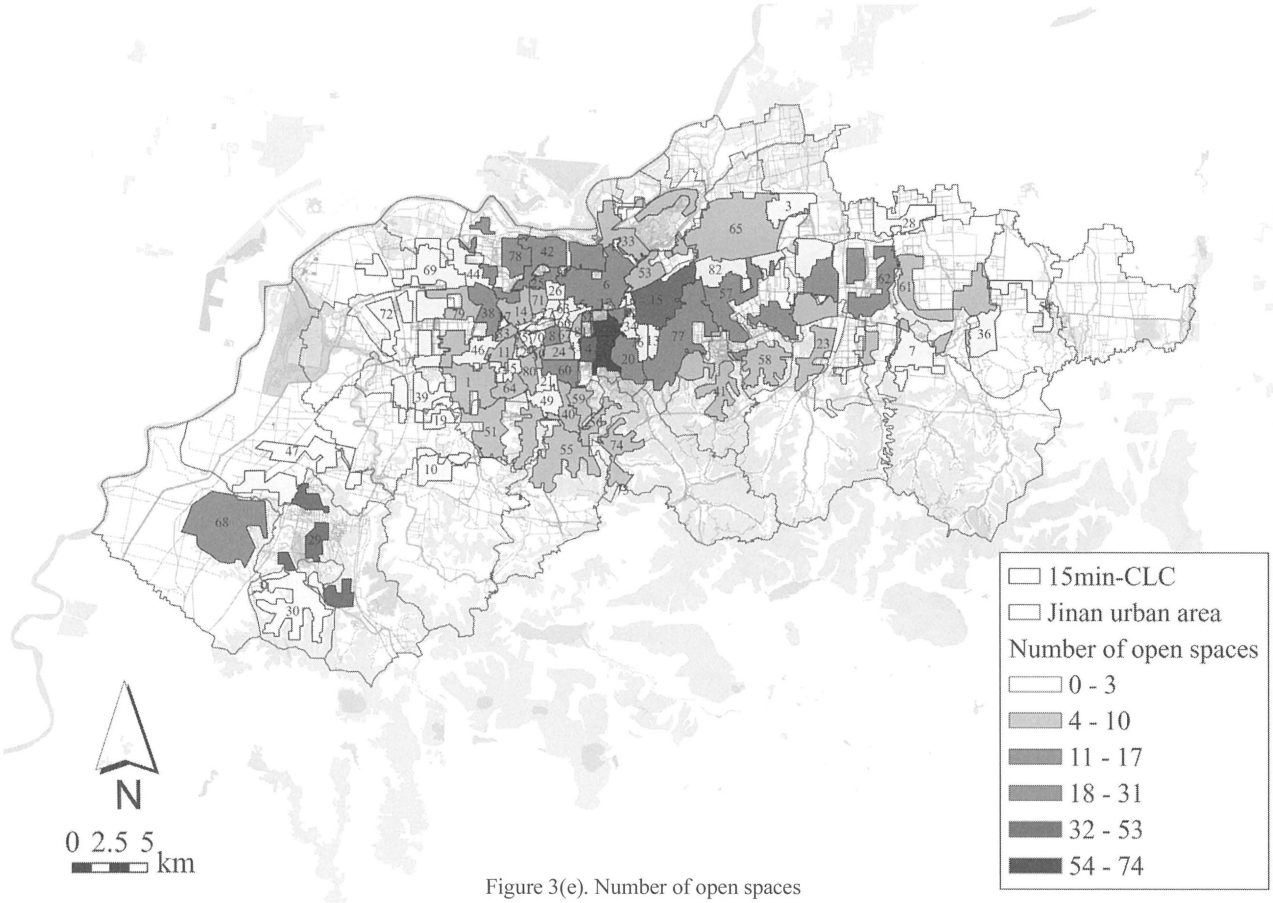

Figure 3(e). Number of open spaces

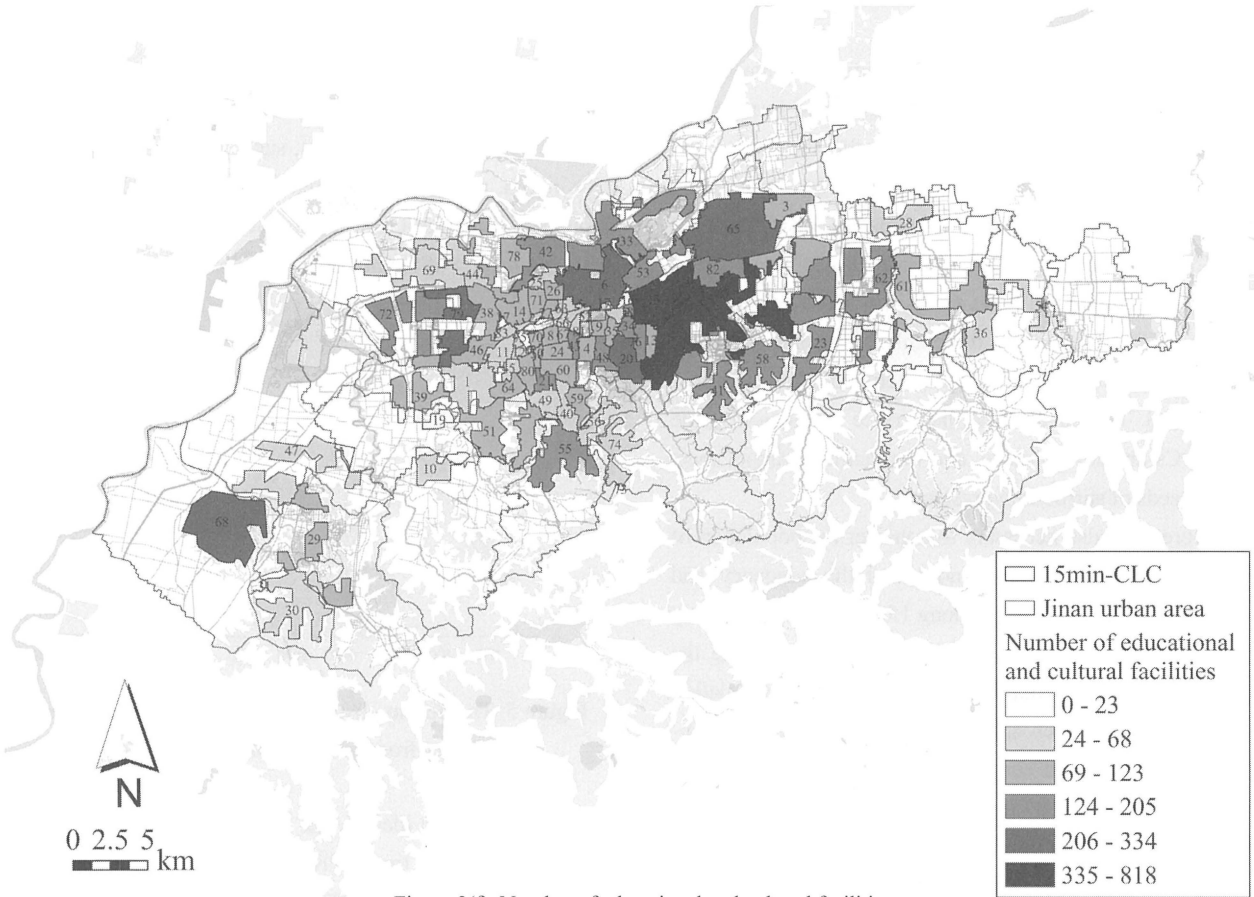

Figure 3(f). Number of educational and cultural facilities

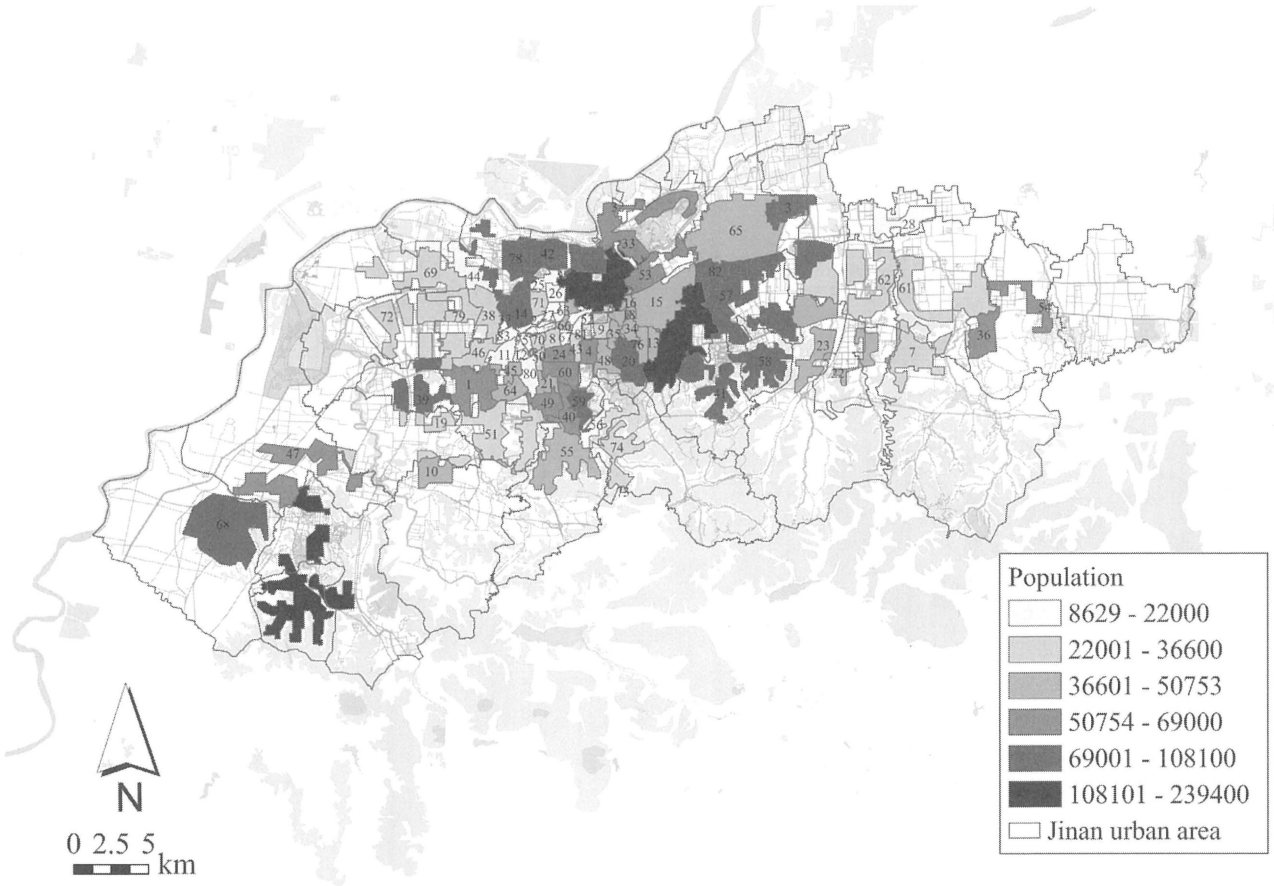

Figure 4. The population distribution of 15min-CLCs.

4.2 Evaluation of facilities distribution among 15min-CLCs

The facilities are mainly designed to serve the surrounding residents. This analysis evaluated whether the distribution and quantity of facilities meet the needs of the surrounding population. Figure 4 shows the population distribution of 15min-CLCs in Jinan City. The population distribution of Jinan is mainly concentrated in areas 6, 29, 30, and 77 (Figure 4). However, it can be found that the number of facilities in these densely populated areas is not high when comparing Figure 4 with Figure 3. This means that the service facilities in some 15min-CLCs are not adequate, and the facilities cannot meet the daily needs of surrounding residents.

Therefore, it is also necessary to consider the population of each area in the analysis to understand the adequacy and equality of resource allocation among 15min-CLCs. This study proposed a "Facility to Population Ratio" to investigate the relationship between the number of facilities and the population. The FPR values for each category of facility in each 15min-CLC are calculated and compared. The results are shown in Table 2. Those below the average value are underdeveloped regions that need further improvement. In Table 2, the gray area indicates that the FPR value is lower than the average value for all 15min-CLCs.

According to Table 2, there are insufficient facilities in densely populated 15min-CLCs, such as areas 6, 30, and 77. City needs to solve this situation in the future to fully implement its 15min-CLC development plan.

4.3 Evaluation of facilities distribution within 15min-CLCs

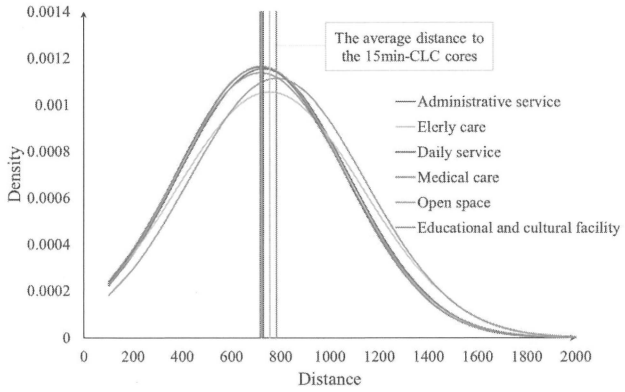

Figure 5. The density distribution of facilities at different distances from the cores of 15min-CLCs.

This research can identify the future development direction of each 15min-CLC from FPR calculations. While improving the 15-minute-CLCs, it is critical to maximize the utilization of

Table 2. Results of FPR in eighty-three 15min-CLCs.

NO.	C1	C2	C3	C4	C5	C6
1	3.2468	0.0566	1.1703	0.0000	0.1321	1.2647
2	8.7584	0.0000	2.5334	0.0000	0.0000	2.5334
3	8.4085	0.0867	3.7275	0.0000	0.1300	3.8575
4	4.4380	0.0662	3.1795	0.0331	1.5235	3.1463
5	5.5559	0.0654	3.0067	0.0000	0.0654	2.8106
6	4.6961	0.0271	1.3650	0.0136	0.1175	1.4147
7	5.5712	0.0000	2.0259	0.0000	0.5065	11.6488
8	7.4257	0.1046	4.3230	0.0697	0.5578	2.8936
9	11.9261	0.0438	1.8415	0.0438	3.2446	4.4284
10	21.1645	2.9532	10.3362	0.0000	1.4766	17.2269
11	14.6954	0.0948	5.0249	0.0000	0.5689	6.0678
12	32.9400	1.3176	25.0344	0.0000	0.3294	16.1406
13	4.0113	0.0000	1.7803	0.0676	0.0451	2.0507
14	3.7950	0.0477	1.1814	0.0119	0.0597	1.4321
15	29.5021	0.3719	9.8175	0.0000	1.0660	20.2796
16	6.4104	0.0661	1.8504	0.0000	0.0661	1.3217
17	5.7862	0.4451	0.4451	0.0000	0.0000	0.8902
18	6.1287	0.0494	2.2736	0.0000	1.5322	2.0264
19	10.2655	0.0000	5.4179	0.0000	0.8555	5.7031
20	6.7145	0.0809	3.0579	0.0324	0.4368	5.4040
21	5.6548	0.0394	1.2807	0.0000	0.0394	3.5072
22	10.7135	0.0000	10.7135	0.0000	0.0000	6.6959
23	24.5378	0.5577	8.7369	0.0000	0.7436	25.2814
24	3.9130	0.0145	1.9565	0.0000	0.1304	1.4928
25	9.1450	0.1115	4.6840	0.0000	2.2305	4.4610
26	25.7453	0.4999	11.3729	0.1250	0.2500	12.9976
27	15.5584	0.1341	5.0296	0.0671	0.0000	5.8344
28	25.3674	0.5854	8.7810	0.3903	0.0000	11.7080
29	5.3875	0.0000	0.4754	0.0000	4.1991	5.5459
30	1.7542	0.0000	0.5093	0.0000	0.0566	2.3767
31	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
32	10.2533	0.0000	0.0000	0.0000	0.0000	1.8642
33	29.3652	0.0559	7.5510	0.0000	0.2237	10.3477
34	5.3894	0.0395	2.4282	0.0197	0.0592	3.1784
35	10.0693	0.0000	1.5922	0.0224	1.6595	2.7584
36	2.4765	0.1126	0.5628	0.0000	0.0000	5.2907
37	50.3694	0.0000	5.0369	0.0000	0.0000	15.1108
38	11.9571	0.0408	1.8772	0.0000	0.8570	3.3055
39	5.5166	0.0634	2.2193	0.0317	0.0634	2.7583
40	3.5275	0.0355	1.4535	0.0000	0.0709	1.2054
41	12.0337	0.1399	4.2911	0.0466	0.2799	7.3695
42	9.3400	0.1184	2.3979	0.0148	0.2368	2.8124
43	9.1715	0.0000	1.7033	0.0328	0.0983	5.9615
44	38.8778	0.2234	13.4061	0.0000	0.4469	8.9374
45	2.5780	0.0286	1.1458	0.0286	0.0000	1.3177
46	10.5366	0.1653	3.3056	0.0000	0.0000	3.3056
47	10.2717	0.3804	3.8043	0.0000	0.3804	4.8188
48	6.5179	0.0850	2.6355	0.0000	2.0687	4.4208
49	2.2184	0.0000	0.8836	0.0000	0.0376	0.7332
50	6.9355	0.0000	1.9934	0.0415	0.2492	3.0732
51	6.4477	0.0000	2.3133	0.0000	0.2461	4.6266
52	9.9883	0.0000	2.6219	0.0000	1.7480	5.2439
53	9.4443	0.0798	3.3787	0.0532	0.1596	4.8951
54	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
55	47.3303	0.7926	13.0215	0.0000	1.1323	23.2122
56	11.7618	0.0000	4.9007	0.0000	0.9801	8.0045
57	27.3593	0.0259	6.4314	0.0000	0.5705	14.0298
58	19.3437	0.1115	5.6303	0.0000	0.4460	9.5325
59	4.0802	0.0580	1.7790	0.0193	0.1740	1.7790
60	3.7099	0.0345	1.6048	0.0173	0.3624	1.8636
61	20.7350	0.3681	9.0792	0.2454	0.6135	9.8154
62	21.5464	0.3380	7.1821	0.0000	1.2674	13.6883
63	9.8182	0.0909	2.2727	0.0000	0.2727	4.4545
64	4.2389	0.0731	1.6322	0.0000	0.0974	1.7784
65	17.2509	0.1842	6.9372	0.0000	0.2149	10.0375
66	5.7984	0.0641	1.5377	0.0000	0.0961	1.3134
67	8.8636	0.0909	2.2727	0.0000	0.2273	3.6364
68	36.6805	0.1493	11.7457	0.2488	0.8461	12.0941
69	13.6825	0.6928	4.3299	0.0000	0.1732	5.8887
70	8.9854	0.0344	2.0312	0.0000	0.0344	2.9263
71	4.3485	0.0313	2.2837	0.0313	0.1564	2.4402
72	21.5324	0.0000	5.6043	0.1475	0.2212	11.2087
73	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
74	27.9884	1.3994	8.8630	0.0000	1.8659	23.7901
75	5.0672	0.1408	2.3928	0.0000	0.0704	1.0557
76	5.5117	0.0000	1.8617	0.0245	0.0245	4.3359
77	7.6840	0.0274	2.3675	0.0205	0.1368	3.7975
78	13.0879	0.0338	2.0291	0.0676	0.4396	3.2466
79	34.0072	0.0000	11.6861	0.0000	0.4328	14.7158
80	21.8394	0.0000	7.1604	0.2387	0.7160	12.1728
81	6.5018	0.1489	2.9779	0.0993	0.1985	2.0349
82	2.7511	0.0000	0.8409	0.0000	0.0208	2.0556
83	10.0742	0.2399	3.1182	0.0000	0.2399	2.9383
Mean	**12.2179**	**0.1749**	**4.1338**	**0.0278**	**0.4973**	**6.0678**

C1: Number of daily service facilities per thousand people; **C2**: Number of administrative facilities per thousand people; **C3**: Number of medical care facilities per thousand people; **C4**: Number of elderly care facilities per thousand people; **C5**: Number of Open spaces per thousand people; **C6**: Number of educational and cultural facilities per thousand people.

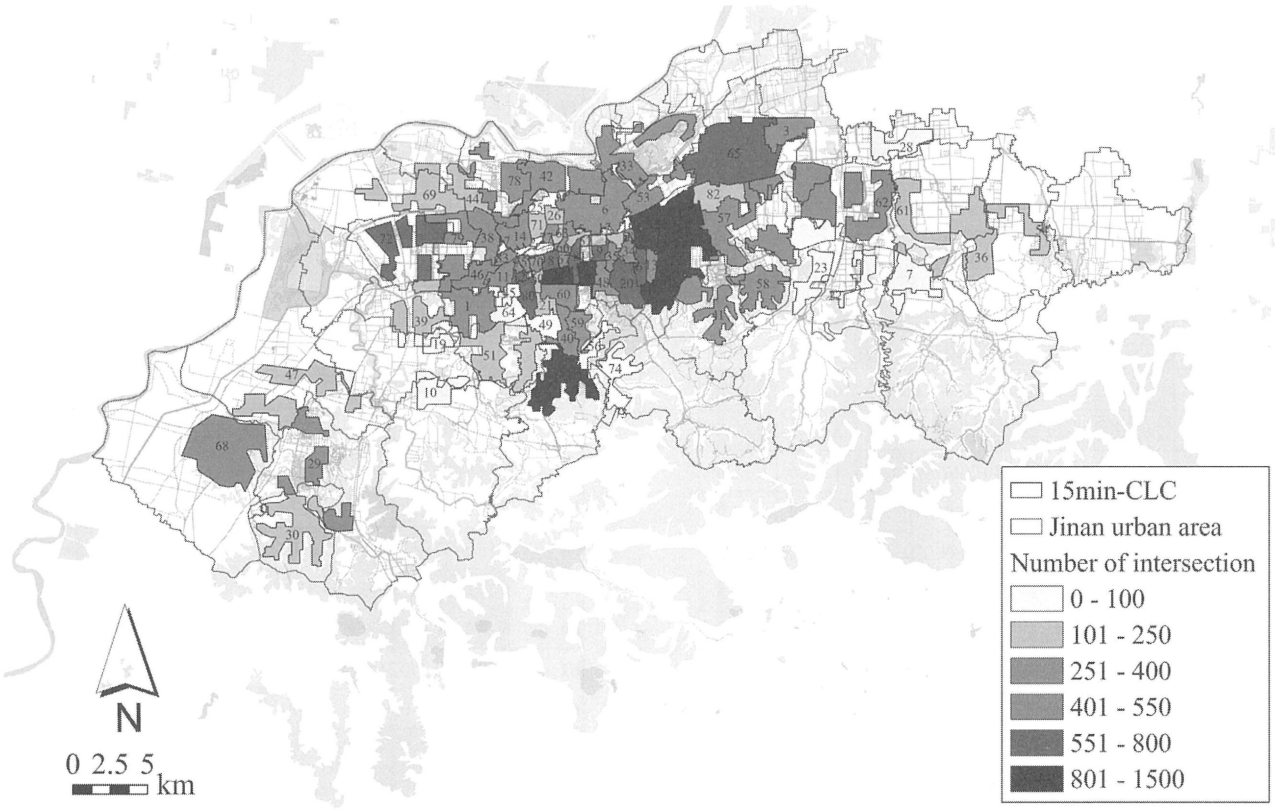

Figure 6. The intersection distribution of 15min-CLCs.

facilities. The distance between the facilities and the core of the 15min-CLCs can affect their utilization. Therefore, this research attempted to understand the optimal distance between various facilities and the cores of 15min-CLCs by analyzing the distribution pattern of different categories of facilities in the 15min-CLCs. The density distribution of the six categories of facilities at different distances is calculated as shown in Figure 5.

According to the results, the facilities in Jinan City are mainly distributed between 600 and 800 meters from the cores of 15min-CLCs. This analysis, combined with the FPR, shows the categories of facilities that are insufficient in 15min-CLCs.

Area 6 is a community with a high population density in the central area of Jinan City. The huge population also brings a high demand for facilities. From the FPR calculation, the FPR value for different facilities is lower than the average value for the whole city. Therefore, improving facilities within the range of 600m to 800m is necessary to meet the daily needs of surrounding residents. At the same time, since there is almost no vacant land in the central urban area, various public facilities can be concentrated in urban facility complexes.

Li (2019) analyzed the allocation of urban community life circles in Baoding City by calculating the standard rates of public service facilities in each district. The communities with more types of facilities were considered better-developed 15 min-CLCs [3]. We counted the number of facilities in Jinan City to find the underdeveloped regions. Meanwhile, determining whether the number of facilities is enough to meet residents' daily needs is important. Therefore, we proposed calculating the ratio between the number of facilities and residents in different 15 min-CLCs to help achieve equal development in different regions

Wu (2021) calculated the service coverage of different types of facilities [10]. They also assigned weights to the different types of facilities since the service coverage of different types of facilities has different demand levels. Then, they obtained a value to measure the comprehensive service convenience in the region. Although this total value can help people compare the convenience of different 15min-CLCs quickly, it cannot find the types of facilities that are lacking. Therefore, we attempt to measure each category of facility separately. However, Wu (2021) proposed that different facilities should be given a weight since different types of facilities have different coverage areas. This provides a useful hint for future research.

Noworól (2022) focused on facilities and analyzed population density at various walking distances to examine the relationship between population distribution and facilities [11]. But we focused on residential areas and analyzed the density of facilities within different walking distances. Since the smallest unit of population statistics in Chinese cities is the subdistrict,

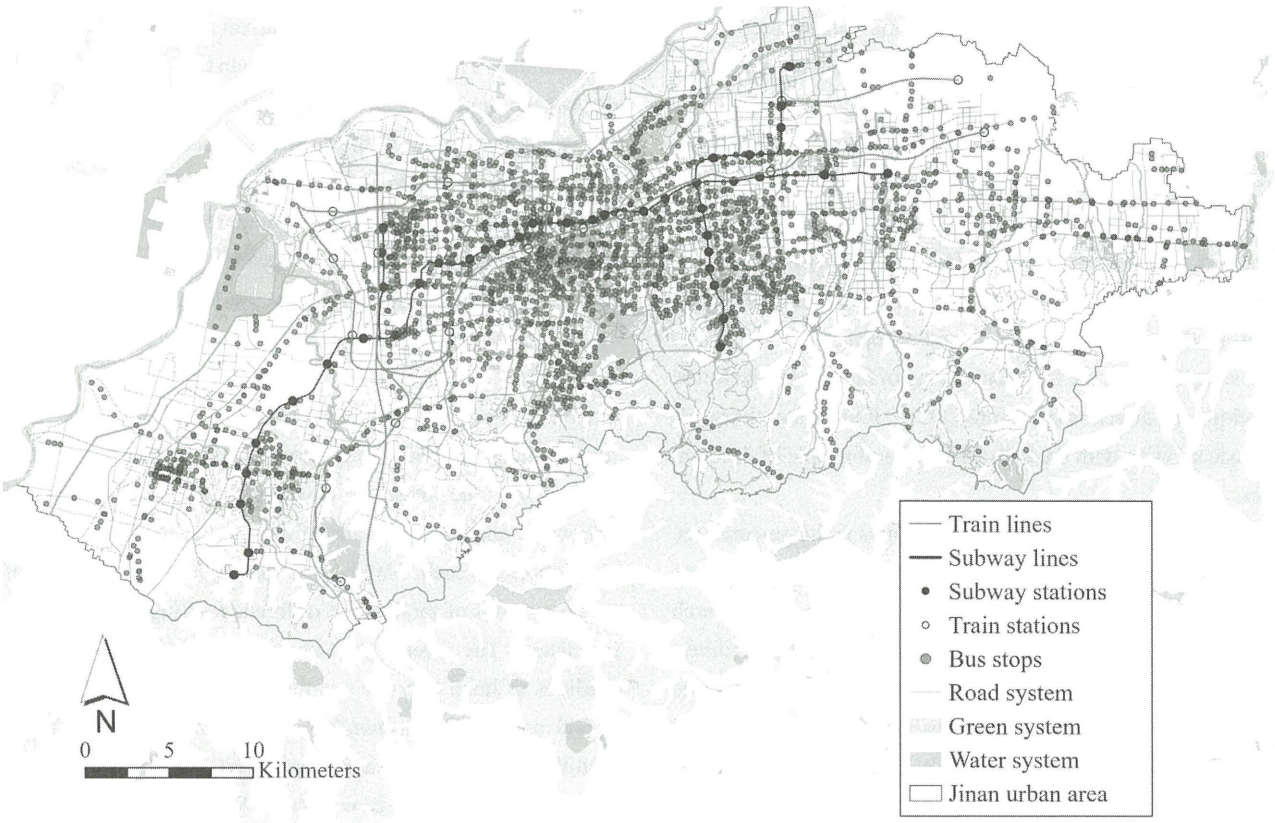

Figure 7. Public transport system in Jinan City

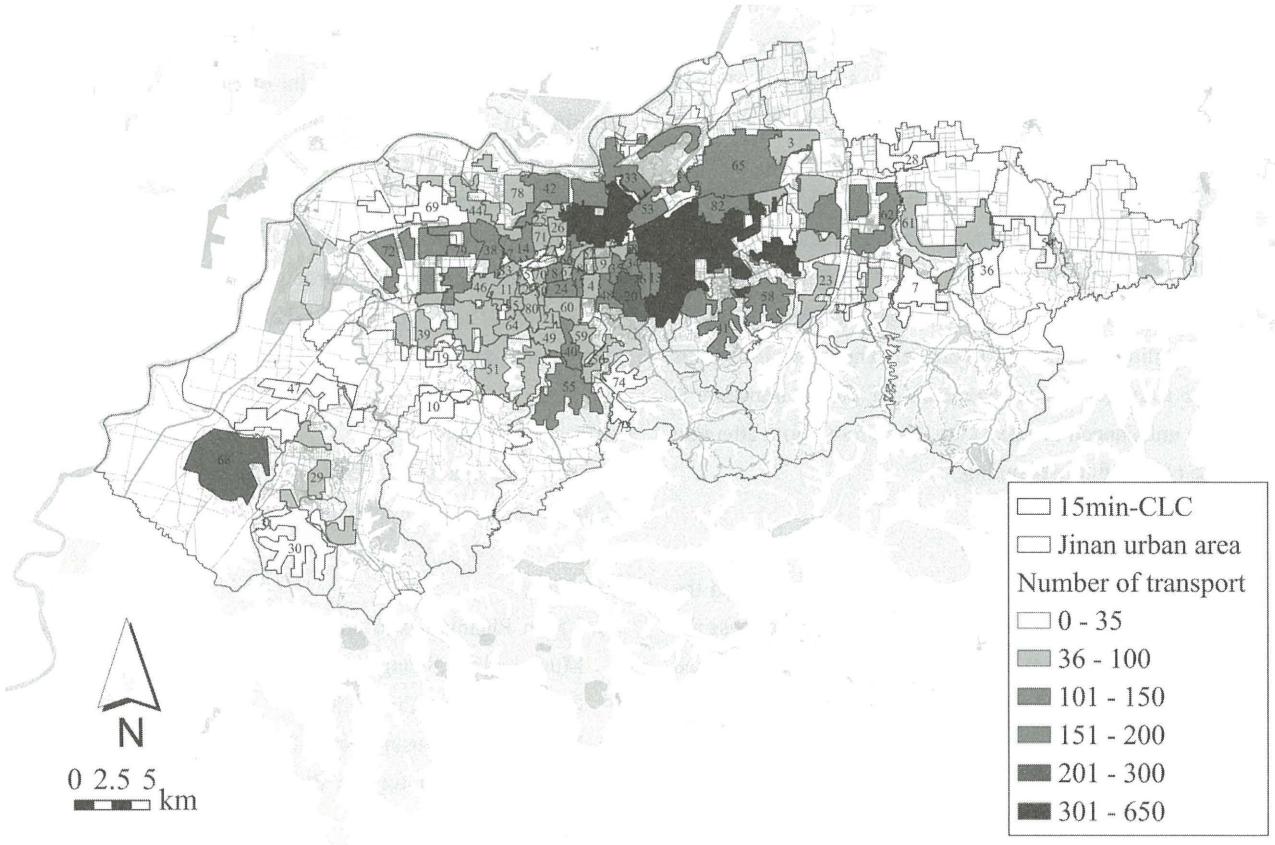

Figure 8. Public transport distribution of 15min-CLCs.

which is larger than a residential area, the method used in our research is more suitable for cities where accurate population data cannot be obtained on a small scale.

Our calculation shows the facilities in Jinan City were distributed 600 to 800 meters from the core of the 15min-CLCs. Compact developments can be considered for new facilities in locations with less developable land. Li (2019) proposed the concept of shared facilities, and these shared facilities will be built in adjacent areas to reduce land occupation [3]. Wu (2021) also suggested that the function sharing of facilities is the future development direction of 15min-CLC [10]. It integrates the needs of basic services with the daily life habits of people of different ages.

In addition, the six categories of facilities in this research are defined based on the guidelines set by Jinan City. In addition to the facility categories given in the Jinan City Plan, this research included the accessibility of residents to various facilities, which can help improve the use of facilities. We evaluated accessibility in the community by analyzing the number of road intersections within the 15min-CLCs. This research counts the number of intersections in each 15min-CLC in Figure 6 and calculates the average number of intersections per square kilometer. The average number of intersections is 161 intersections per square kilometer in 15min-CLCs of Jinan City. Among the eighty-three 15min-CLCs, the accessibility faculties in areas 31, 37, 54, and 73 are lower than the average value. The guidelines of Jinan City also advocate combining 15min-CLCs with public transport, to improve the daily travel of residents and ease access to basic facilities (Figure 7). The results of public transport stations in each 15min-CLC are shown in Figure 8. It can be found that public transport facilities are mainly concentrated in central area of the Jinan City, such as areas 6, 15, 57, and 77. Jinan City has an average of 35 public transport facilities per square kilometer. There are 48 regions below the average. The development of public transport is extremely unbalanced in Jinan City. Therefore, more attention should be paid to future planning.

5. Conclusion

In recent years, the Chinese government has advocated the concept of transit-oriented development (TOD) to address the problems of air pollution, traffic congestion, and increased commuting distance caused by rapid urbanization, a well as to connect different communities. However, several research studies on TOD implementation have discussed whether the surrounding environment of TODs is good for living and working. The concept of the "15-minute community life circle" (15min-CLC) has been promoted in many Chinese cities and is gradually being applied to urban planning improve communities. This research studied Jinan City as an example to discuss the development of 15min-CLCs in second-tier cities and attempted to identify the underdeveloped regions for future development. The main steps are as follows: First, we analyzed the distribution of facilities that are important for the daily lives of residents in the 15min-CLCs. Secondly, it assesses whether each 15 min-CLC meets the daily needs of residents. Third, optimization strategies for underdeveloped regions are proposed.

In this research, we counted six categories of service facilities closely related to residents' daily lives in the 15min-CLC. Then the research determined the underdeveloped regions by analyzing the ratio of the number of facilities to the population in each 15min-CLC. Later, the distribution of different types of facilities at different walking distances was calculated. The results of this research indicated that the facilities in Jinan City are mainly distributed within the range of 600 meters to 800 meters from the community cores, and the facilities for elderly care are closer to the core of the residential area. Therefore, combined with the FPR results, the distribution of facilities from the core can provide suitable optimization strategies for the insufficient facilities in each 15min-CLC.

Factors that can describe the accessibility condition of facilities need to be studied using road intersections, and transport facilities to improve the usefulness of this research. In addition, we will sort the results of FPR by combing more information, such as accessibility or population, to have a deeper understanding of the 15min-CLCs. Meanwhile, the method developed in this research can be applied to other cities and different ranges of community sizes. Application of the optimal walking distance as proposed by Logan (2022) [14] and application of this method in other cities could improve the method in future research.

Acknowledgements

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