An Comprehensive Accessibility Evaluation Model for

Temporal An Comprehensive Accessibility Evaluation Model for Temporal Public Facilities of Urban Residential Areas Based on Internet Map

Xinxin ZHOU and LinWang YUAN and Changbin WU and Zhaoyuan YU and Chendi HU, China

Key words: accessility; public facility; urban residential areas; points of interest(POI); route planning API

SUMMARY

Public facilities of urban residential areas which assume many types of service functions are meaningful to urban residential designing and planning. Meanwhile, various public facilities capacity of residential areas changed with time ceaselessly have dynamic and micro characteristics. The development of internet map which contains web map (points of interest, POI; route planning application program interface, RP-API) provides temporal and microcosmic knowledge about residential areas. The purpose of this research is to use different time POI data and RP-API as new sources for characterizing temporal changes of comprehensive accessibility of public facilities of residential areas(CAPF-RA). We establish effective service radius principle, POI category system and design an measurement framework based on web map. In the case, a 5 km^2 residential area from Wuxi city, Jiangsu province has been selected as the case study. We calculated two years' CAPF-RA values and compare them for diverse temporal and spatial laws based on 2016, 2017 and 2018 POI data. (1) From the spatial distribution aspect, we can see that the communities with high CAPF-RA values, include: HuiJingYuan, HuaHuiXinCun, Versailles Estate; The low value include LiRen Garden 1#,LiRen Garden 2#. (2) From the temporal sequence aspect, we can find that overall CAPF-RA values of residential areas have rised consistently and developed to spatial centralization continuously. An analysis shows that this method can be used to group different urban communities' accessible public facilities capacity with dynamic and microscopic characteristics. This model method is suitable for studying the coordination and rationality between public service facilities and population scale in multi-tenses and micro-scales, which leads to significant improvements for urban designing and planning.

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1. INTRODUCTION

With the rapid development of urbanization, great changes have occurred in the urban population and living environment[1], especially in China and other countries experiencing rapid development. The allocation of various public service facilities in the city becomes complicated and microscopic. Public service facilities, such as medical treatment, education and life, have a great impact on the quality of the living environment[2]. Therefore, it is important to study the rationality of public service facilities at a micro spatial scale for sustainable urban development and design and planning purposes.

Public service facility research continues to receive attention. Most practitioners have focused on researching the allocation of public facilities in residential areas, e.g., the location of public facilities[3], indicator systems for planning service facilities[4], accessibility[5], public services equality[6], and social differentiation[7]. The traditional data source used to assess the rationality of public facilities is often statistical survey data or questionnaires provided by recruited urban planning subjects, and these data sources provide detailed information about different facility categories. The allocation of facilities in residential areas[2], public health services[5], and urban green space[8] were displayed and analyzed in geographic information systems using these data. The traditional methods used in research on facilities have obvious weaknesses, such as relying on intensive investigation, which is very costly, time-consuming and too coarse for detailed mapping and small areas. This situation is difficult to meet the requirements of high efficiency and a microcosmic scale[9].

To study the spatiotemporal continuity of geographical environments, the data acquisition method is changing from the traditional questionnaire or interview method to the use of the Internet, smart phones and other new technologies that can be used to obtain research data[10]. Researchers gradually integrate big data, which representatively contain cell-phone data, trajectory data, high-resolution night light data, into urban research and human activity. Nighttime light imagery, which is a new type of remote sensing data, has shown a strong capacity to evaluate macroscopic studies over both global and regional scales, e.g., regional economic research[11] and regional activity and war studies[12, 13]. However, these data typically concentrate on the city level or on particular kinds of public facilities. It is difficult to identify differences in community-level public facilities with these models.

Currently, many Internet mapping services, such as Google Maps (https://www.maps.google.com), Amap (https://www.amap.com), Baidu Map (https//www.baidu.map.com), are used. Internet mapping operators provide different types of map services, such as a route planning application programming interface (API) and POI. The route planning API can be performed with respect to different modes of transport, such as driving, walking, cycling and public transport[14, 15]. It has become common to use Internet map data as an important data source for regional research. At present, some scholars have applied POI data from Internet maps for the automated identification and characterization of parcels (AICP) [16], for extracting hierarchical landmarks[17], and for the hierarchical semantic cognition of urban functional zones [18, 19]. In addition, in the path planning service, relevant applications are also carried out, such as computing the fewest-turns map directions[14] and assessing the accessibility of urban service facilities[20, 21]. POI can estimate employment locations, and implement interzonal commuting patterns[22]. However, it is worth noting that the existing research on path planning services is mainly focused on the algorithm level and is less applied at the social computing level.

Based on the above description, the new multi-source Internet datasets, especial internet map data, containing microcosmic and detailed geolocation information will be pertinent to the assessment of the rationality of public facilities in urban residential land. In this paper, we analyze multi-source Internet datasets, such as POI, route planning API. To integrate these data, we propose an assessment model framework.

2. RELATED WORK

Urban public facilities can be directly or indirectly provided by the government for the public and are the spatial carriers for urban public services. Public property attributes are public service systems that ensure the normal operation of urban social and economic activities. The main body of urban public service facilities is not only governmental departments but also social enterprises and private departments. Urban public service facilities mainly provide residents with a variety of services, including medical, education, transportation, administrative management, communication, energy, commercial and cultural and entertainment facilities and services[4]. Therefore, the assessment of public service facilities in residential areas must synthetical and comprehensive on different types of public service facilities.

The study of the allocation of public service facilities in residential areas is being transformed from the layout of public service facilities to the spatial accessibility of public service facilities [23]. The accessibility of a public service is measured by the proximity of a resident to a public service or to a public service facility as well as by the relationship between residents and public services[24]. Furthermore, accessible public service is affected by many factors, and most define the spatial attributes of basic public service accessibility[25]. The

knowledge gaps pertain to comprehensive facilities type and more interpretable indicators, such as service area or distance.

CAPF-RA is the basis for realizing a reasonable spatial layout for public facilities as well as the equitable allocation of public service resources, and this method is conducive for achieving the goal of "equality of basic public services". This paper defines the basic concept of CAPF-RA, i.e., the sum of the public facility resources that residential areas can obtain within a specified spatiotemporal range. Therefore, it is necessary to define the spatiotemporal scope and design using the obtained public facilities resource method. Due to the different impacts various public facility resources have on residents, the public facility resources must be classified and weighted. The specific CAPF-RA calculation method is described in detail in Section 2.3.

3. STUDY AREA AND DATA

This paper selected a 5 km^2 area of the urban built-up land in Hudai Town, Binhu New District in Wuxi as the experimental area (Figure 1). Wuxi is a typical city in the Yangtze River Delta region of China. It ranked 18th among the top 100 cities in China, with 10,511.8 billion GDP and 6,553,300 residents in 2017. Binhu District is dominated by secondary and tertiary industries, among which the township of Hudai has a tax sale of 20.107 billion. The experimental area is located in Wuxi Hudai Industrial Park, where the population is dense and the industry mainly relies on electronics, light and textiles. The experimental area used to research the carrying capacity pressure of the service facilities contained 14 communities. This paper collected 3 years Amap POI dataset(2016, 2017, 2018) and requested route planning API of Internet maps for travel cost calculating. The basic geographic data referred to the remote sensing image with a resolution of 2 m × 2 meter, which was obtained from Tianditu (www.tianditu.com). Details about data volume, data descriptions and data applications shown as follows.

(1) The route planning API is an Internet map service that requests an open API to obtain a corresponding planned path.

(2) POI is an important expression of an Internet map service. Generally, POI data contains information such as name, address, latitude and longitude, and category; thus, POI data are dynamic, massive and realistic. POI is important in geographic information services, and the amount of data from Internet map operators is large.

(3) Basic geographic data are used to reflect the present situation.

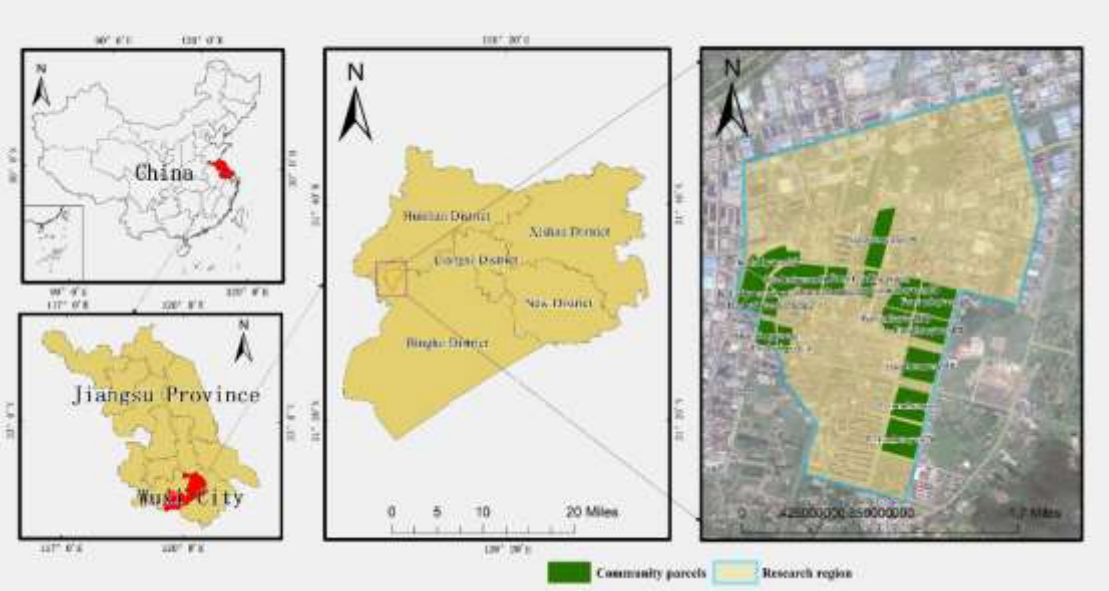

Figure 1. The research area of Hudai Town

4. METHODOLOGY

4.1 Measurement framework for CAPF-RA

The architecture of the method of the support model of CAPF-RA is shown in Figure 2. The specific implementation process is as follows:

Step 1: Basic data preparation. The community polygon is extracted from the basic geographic data to form a basic research unit plot. A POI crawler program is written to crawl all POI data in the Lake District area. The data attributes include latitude and longitude, category, and address, and all invalid data are cleaned.

Step 2: The three important criteria for building CAPF-RA are the category system of public facilities, the service radius, and the weighting system.

Step 3: The CAPF-RA accessible public service facility acquisition, using the navigation path planning API, obtains the number of reachable service facilities in a residential area, and through Equation (2), the CAPF-RA value of each community can be calculated.

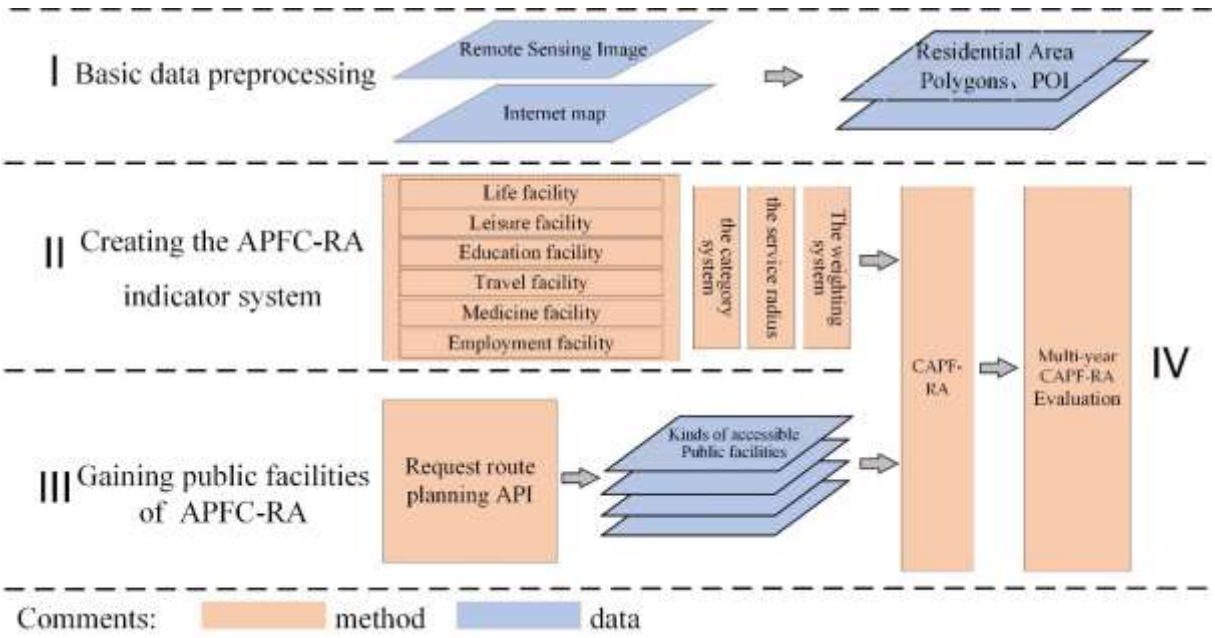

Figure 2. Overall assessment roadmap

The basic object of the study is the community residential area. The CAPF-RA value of the i community residential area can be indicated by $V_{CAPF-RA}(i)$, and the calculation is represented in Equation (1). The basic meaning of $V_{CAPF-RA}(i)$ is the comprehesive accessibility of public service facilities in residential areas.

$$V_{CAPF-RA}(i) = f_i(WQ) = \sum_{k=0}^{r} w_{ki} * q_{ki} \qquad k \in [1, r] \qquad (1)$$

In Equation (1), r indicates that the number of service facilities is r, w_{ki} indicates the weighting factor of the k-type service facility in the residential area of community i, and q_{ki}indicates the number of the k-type of facilities in the residential area of community i.

By combining the residential areas of multiple communities, the reasonable value of the public service facilities in residential areas can be obtained for the entire study area, which includes m community residential areas, as shown in Equation (2).

$$V_{CAPF-RA} = \sum_{i=1}^{m} V_{CAPF-RA}(i) \qquad i \in [1, m] \qquad (2)$$

The weighting system is the basis of the weighting coefficient that implements the weighting and calculates the result value of CAPF-RA. It is necessary to establish a weighting system for different public service facilities: w_{ki}. There are many methods for establishing w_{ki}, including the entropy weighting method, TOPSIS, AHP, Delphi and entropy method. The weight value is calculated by entropy method of each type of facilities as follows: {life = 0.12, education =0.17, medicine =0.18, travel =0.20, leisure =0.16, employment =0.17}.

The important criteria of CAPF-RA are as follows: the category system of public facilities, the service radius. The category system of public facilities is a classification system for various basic service facilities. The service radius is a spatiotemporal standard for determining the accessible basic service facilities.

4.2 POI category system

It is needful to construct the public service facility indicator system in the residential areas. The category system of 6 public service facilities in residential areas will be constructed based on the four concepts of basic human living requirements proposed by the World Health Organization. First, the system should be selected according to the principle of ensuring basic living conditions and combining this information with the living environment of the city[26]. This paper refers to a total of 339 indicators in the evaluation index systems of 9 livable cities at home and abroad; these indicators comprehensively consider the attributes of residential life services in residential areas from six aspects, including daily life services, cultural and educational services, sports and leisure services, transportation services, medical facilities services, and corporate services. Life service mainly contains sife service, shopping service, catering service, accommodation service, financial insurance service, public utilities, business residence; Education service mainly contains science and culture service; Leisure service mainly contains park, sports and leisure services; Travel service mainly contains parking lot, repair public service facility, transportation facilities service and road auxiliary facilities; Medicine service mainly contains medical public service facility; Employment service mainly contains enterprise.

4.3 Effective service radius principle

Second, it is necessary to establish an acceptable service radius threshold for different types of public service facilities. According to previous research, the service radius R of a service facility refers to the geographical coverage area of the demand points in the region. The service value function F(s) is the key to studying the service radius of a service facility, and F(s) is shown in Equation (3) and Figure 3. The basic characteristics are satisfied between F(s) and R: (1) The service principle with service facility distance R enjoys complete and stable service value, and R is the stable value distance; (2) As the distance increases, F(s) gradually decreases. (3) When the value to distance S is 0, S is the maximum impact distance of the service facility; as the value of R increases, the strength of the service capacity of the service facility increases; and (4) As the parameter α decreases, the faster the service value is reduced. (5) Different types of service facilities have great differences in service capabilities [27], and their R values are different. (6) As the number of service facilities in the same type becomes greater, the greater the value of the service will be[28]. (7) The same service facilities will have different service capabilities but at different sizes. For example, the population service capacity

of large supermarkets is far greater than that of small convenience stores. (8) The R with different travel methods is also different.

$$F(s) = \left[\frac{\text{S-s}}{S-R}\right]^{n} \quad (3)$$

where R is the stable value distance, S is the maximum impact distance of the service facility, and the as the decrement parameter n increases, the faster the service value will be reduced.

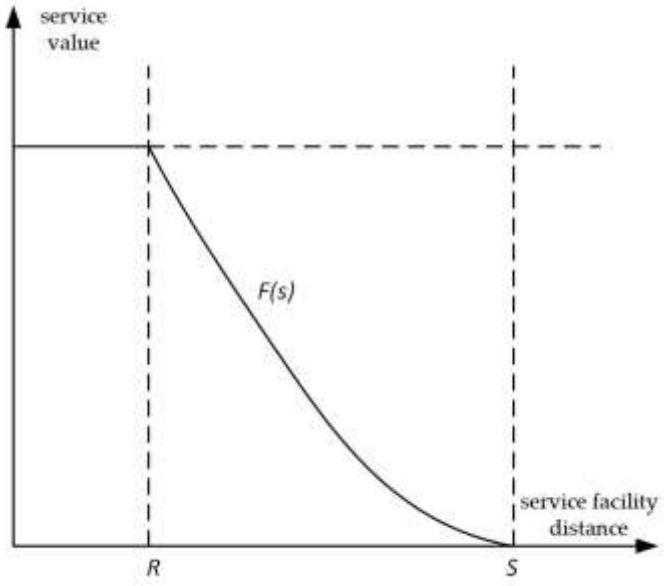

Figure 3. Schematic diagram of the service value function.

The identified ways of travel include walking, public transportation, self-driving, cycling and combinations of these methods[20]. There are many factors that influence the choice of travel mode, including economic conditions, travel distance, and travel urgency. Walking is the most basic and most common mode of travel for human beings[29]. The principle that is usually followed is as follows: People will choose to walk if a destination can be easily reached by walking. Therefore, to quantitatively judge the service radius of the service facility, the walking mode is used for measurement purposes. Determining the R of different types of service facilities is the basis for the follow-up study in this paper. To determine the walking time of the service radius, the time of life, education, leisure, travel and medicine was determined to be 30 minutes. It is believed that employment causes a specific type of commute between work and home, and this commuting distance can be large and differs from that of other trips; thus, the time was selected as 60 minutes.

4.4 Gaining accessible public facilities of the CAPF-RA

Calculating the service area is one of the key links of accessible facilities. The traditional method is mainly based on the GIS analysis of origin-destination (OD) matrices, which need

large amounts of fundamental geographical data[30]. The concentric circle method, Thiessen polygon method and path planning method can be used, as shown in (a), (b) and (c) of Figure 4. Among them, the concentric circle service radius distance D is the radius of the circle, as shown in Figure 4 (a). The service area drawn by the Thiessen polygon method is mutually exclusive—a facility serves only one residential area, as shown in Figure 4 (b). The methods shown in Figure 4 (a),(b) are ideal models that ignore the actual geospatial and overlapping service areas. The path planning method can evaluate actual geospatial space and service area overlap, as shown in Figure 4(c); thus, this method can be used to provide various routes for walking, driving and cycling. Therefore, the method based on Internet map path planning is a new and accurate method[21].

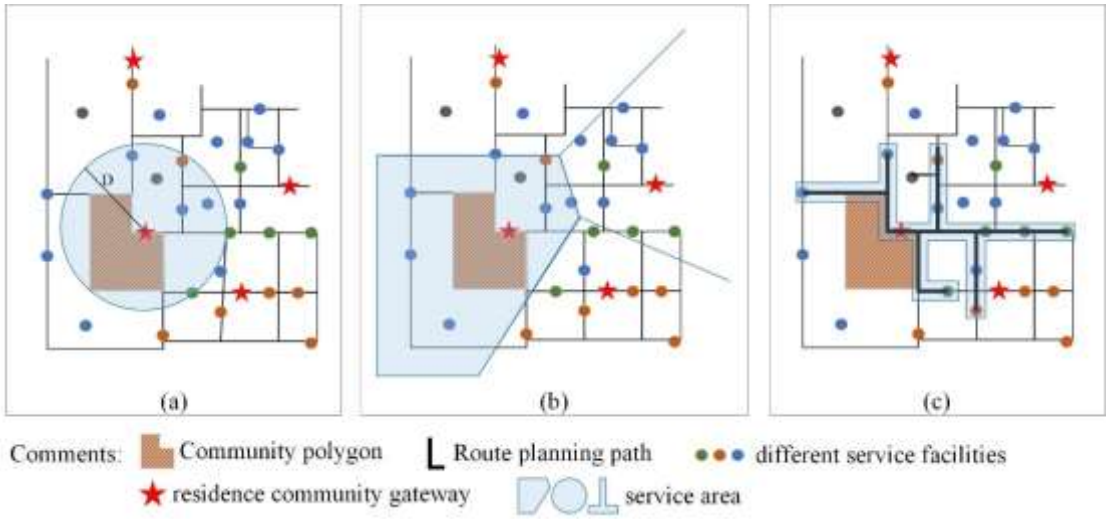

Figure 4. Schematic diagram of the methods used to calculate the accessible public service facilities

To gain the accessible residential public service facility trough route planning API from Amap, this paper uses Python3.6 and ArcGIS ArcPy10.2 to write a parsing program for layer data parsing. The specific steps are as follows:

(1) Data input: respectively input the POI community layer and the POI public facility layers, which are multi-layered, where the community layers are used as the starting list and the POI public facility layers are used as the ending list.

(2) Service radius input: enter the service radius identification list as the criteria for judging the threshold of reachable service facilities.

(3) Traversing the points of community and public service facilities to verify its travel time: Clarify the start points and end points request Amap path planning API for dynamic planning of walking distance time. By splicing the HTTP, request the URL to receive the data (JSON or XML format) returned by the HTTP request, then parse the data, e.g.,:http://restAPI.amap.com/v3/direction/walking?origin=116.45925,39.910031&destination =116.587922,40.081577&output=xml&key=<the key of users>.

(4) Dictionary output: Output the number of different types of public service facilities in each district. The specific implementation process is the following pseudo code.

5. RESULTS

According to the calculation formula of CAPF-RA and the experimental data, 3 years' CAPF-RA values of each residential areas are measured. The difference in the comprehensive CAPF-RA values of each residential areas is remarkable large, what's more, the temporal change tendency of CAPF-RA values is concordant, as shown in Figure 5. The specific performances are as follows: (1) CAPF-RA value of each residential areas keep sustainable growth; (2)The annual growth rate remains fairly consistent. (3) The CAPF-RA values of Li Ren Hua Yuan 1# and 2# are less than average value. (4) The CAPF-RA values of Hua hui Yuan, Hua hui Yuan 2#, Hua hui Yuan 3#, Hua hui xin cun, and Huijing Yuan are more than average value.

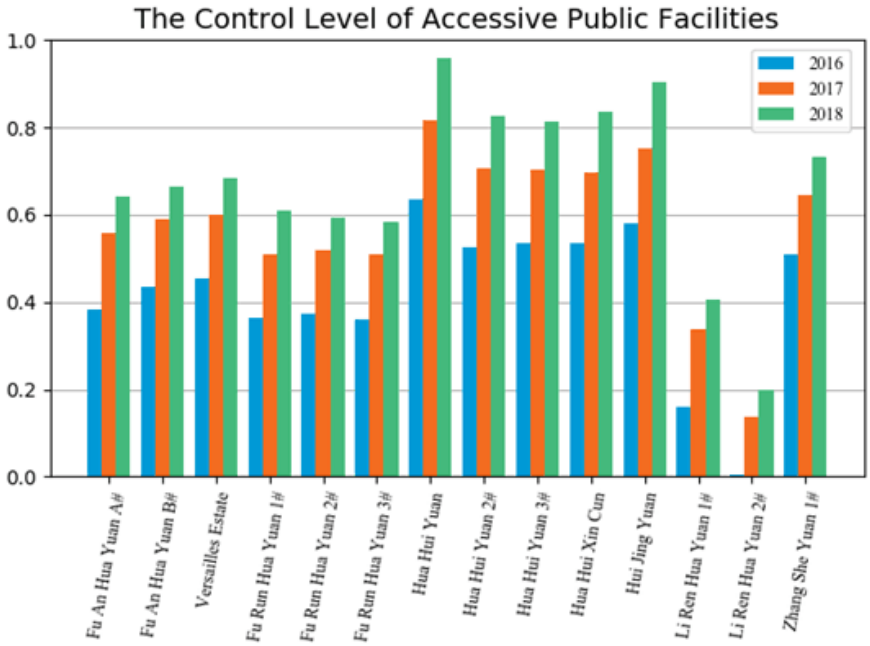

Figure5. CAPF-RA values histogram of 14 communities

The accessibile quantity of 6 types of public facilities of different residential areas is shown in Figure 6. For the life service, leisure services, education services, transportation services, medicine services, employment services, calculate the level of public service facilities of various facilities in each residential area. The different categories of different communities can reach different levels of public service facilities. The overall performance is that life service facilities and employment service facilities are at the forefront, while educational facilities, leisure facilities, transportation services and medicine services are less. While the experimental area is located in Wuxi Hudai Industrial Park, various enterprises are distributed among them.

What's more, educational facilities and leisure facilities, such as primary schools, middle schools, and gymnasiums, are large in scale, wide in service spatial region, so those are less distributed in experimental area.

Through geographical lens, the spatial-temporal distribution of CAPF-RA values is shown in Figure 7. In the Figure 7, the dark color regions indicates that the scores is at a high value convergence. The deeper the polgons' color, the more obvious the phenomenon of high value convergence. The tint color regions indicates that the scores is at a low value convergence. It is discovered visually that the CAPF-RA values present high spatial autocorrelation. Spatial autocorrelation refers to the potential interdependence of observational data between variables in the same distribution. Moran's I is a measure of the degree of spatial correlation. Moran's I >0 represents the spatial positive correlation. The larger of Moran's value, the more obvious the spatial correlation. Based on the spatial correlation analysis of the service resource supply level within the experimental area, it is found that the Moran's score of 3 years respectively are 0.54, 0.57, 0.62. This result illustrates that the CAPF-RA valuse rise to centralization continuously. It can be concluded that the overall service resource supply level in the northwest area of the experimental area is relatively high, and the infrastructure in the southeast area is generally not perfect.

6. DISCUSSION

This paper studies mutil-years comprehensive acessibility of public service facilities in urban residential areas spatial-temporal variance through internet map data. The conclusions are as follows: (1) internet map provides new verification data for the micro-scale public service facility synthetical accessibility research, which has practical value for the implementation evaluation of urban detailed planning and design. (2)Through research, it is found that the overall service resource supply level in the experimental area is higher on the northwest side and lower on the southeast side, and the high and low level cells show a strong agglomeration phenomenon in space. And the distribution of the five major types of services also shows obvious spatial agglomeration. This conclusion can help the government understand the regional dominance. (3)The comprehensive acessibility of public service facilities emerge consistent growth, which declare that the increasing invest in infrastructure of experimental area stimulates service facilities to develop. This research has made great progress in the application of internet map data to comprehensive accessibility measurement, but it is still limited by the incompleteness of data acquisition, and there are some shortcomings. The following points are worth further improvement and improvement: (1) The experimental area is small, and the latter can select a representive metropolitan as complete research area. (2) The number and scale of public service facilities are two important indicators for measuring the supply of public service facilities. Due to the lack of scale data of POI, this study has certain

limitations. Access to data on the scale of each service facility through the means of open data on the Internet is also worthy of further study.

In the context of the new era, geographers should move from the study of the pattern of factors and the pattern of static patterns led by the old thinking to the study of the system pattern and dynamic pattern under the guidance of new thinking, that is, to explore the geographical pattern of time and space flow, revealing geography. Process to explore new geographic mechanisms.

7. Appendix A

Table 1. Table of 3 years calculation results for each type of POI in the experimental area

the name of residential	life			education			leisure			travel			medicine			employment		
areas	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Fu An Hua Yuan A#	1187	1337	1290	21	29	30	29	33	44	51	55	57	40	35	40	1327	1604	1508
Fu An Hua Yuan B#	1216	1370	1314	22	29	29	28	32	42	55	54	60	43	38	43	1348	1621	1528
Versailles Estate	1254	1399	1357	20	26	26	29	32	42	67	75	81	43	37	43	1351	1621	1529
Fu Run Hua Yuan 1#	1089	1225	1170	20	26	27	29	32	44	52	52	59	39	35	41	1339	1612	1521
Fu Run Hua Yuan 2#	1190	1345	1289	20	26	26	26	30	40	51	51	57	41	36	41	1324	1601	1506
Fu Run Hua Yuan 3#	1177	1329	1273	20	26	26	26	30	40	51	51	57	40	35	40	1319	1596	1501
Hua Hui Yuan	1319	1482	1441	23	32	34	40	39	48	92	112	125	45	39	49	1403	1704	1608
Hua Hui Yuan 2#	1195	1354	1311	21	31	33	36	36	45	80	96	103	40	33	42	1436	1736	1642
Hua Hui Yuan 3#	1278	1436	1392	21	30	31	33	35	45	80	93	100	44	36	44	1406	1696	1603
Hua Hui Xin Cun	1249	1409	1367	21	30	33	36	35	45	79	93	99	43	36	46	1375	1664	1572
Hui Jing Yuan	1295	1462	1424	22	31	34	38	36	45	87	104	117	44	39	49	1367	1660	1569
Li Ren Hua Yuan 1#	925	1059	1008	18	24	26	24	27	35	30	38	39	30	29	34	1248	1510	1411
Li Ren Hua Yuan 2#	744	852	803	16	19	22	23	25	33	20	25	26	24	23	26	1120	1337	1249
Zhang She Yuan 1#	1257	1407	1362	25	30	29	30	33	44	66	68	80	44	39	44	1365	1641	1554

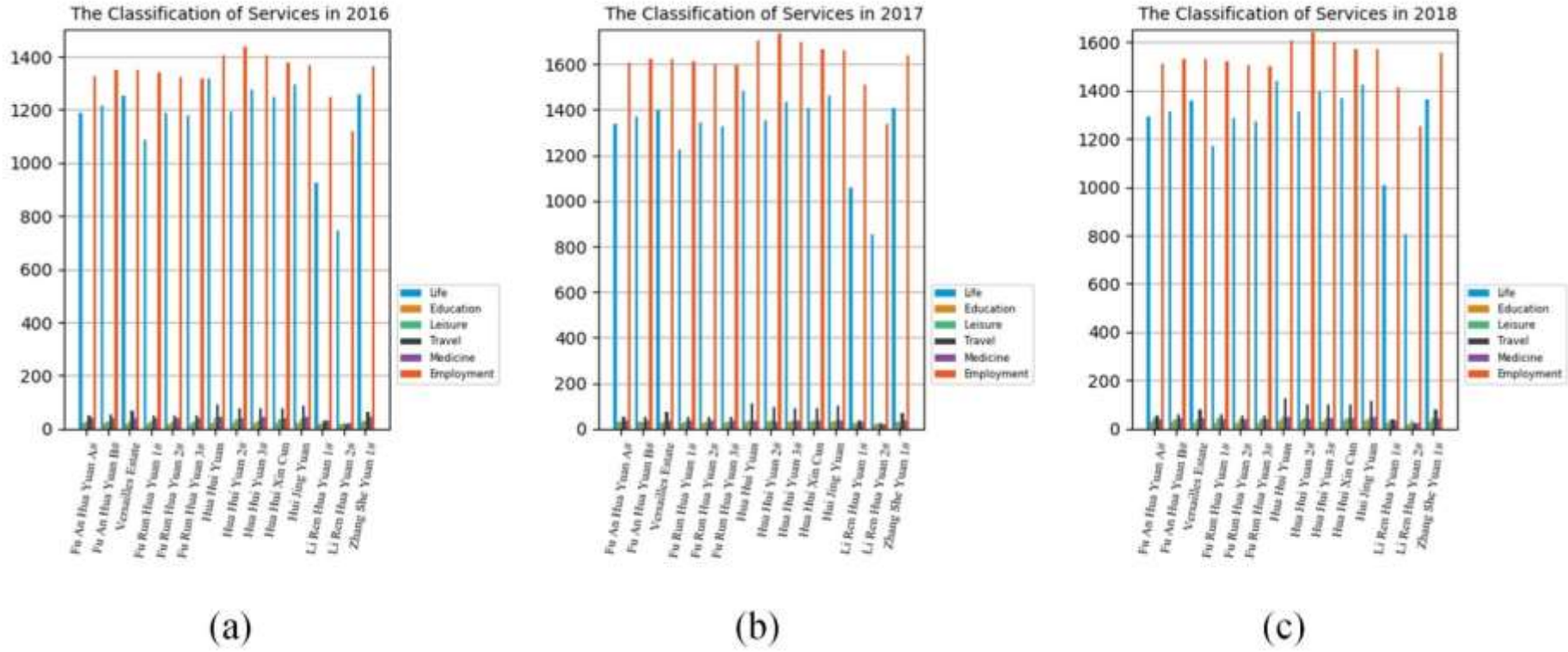

Figure 6. Histograms of the result distributions.

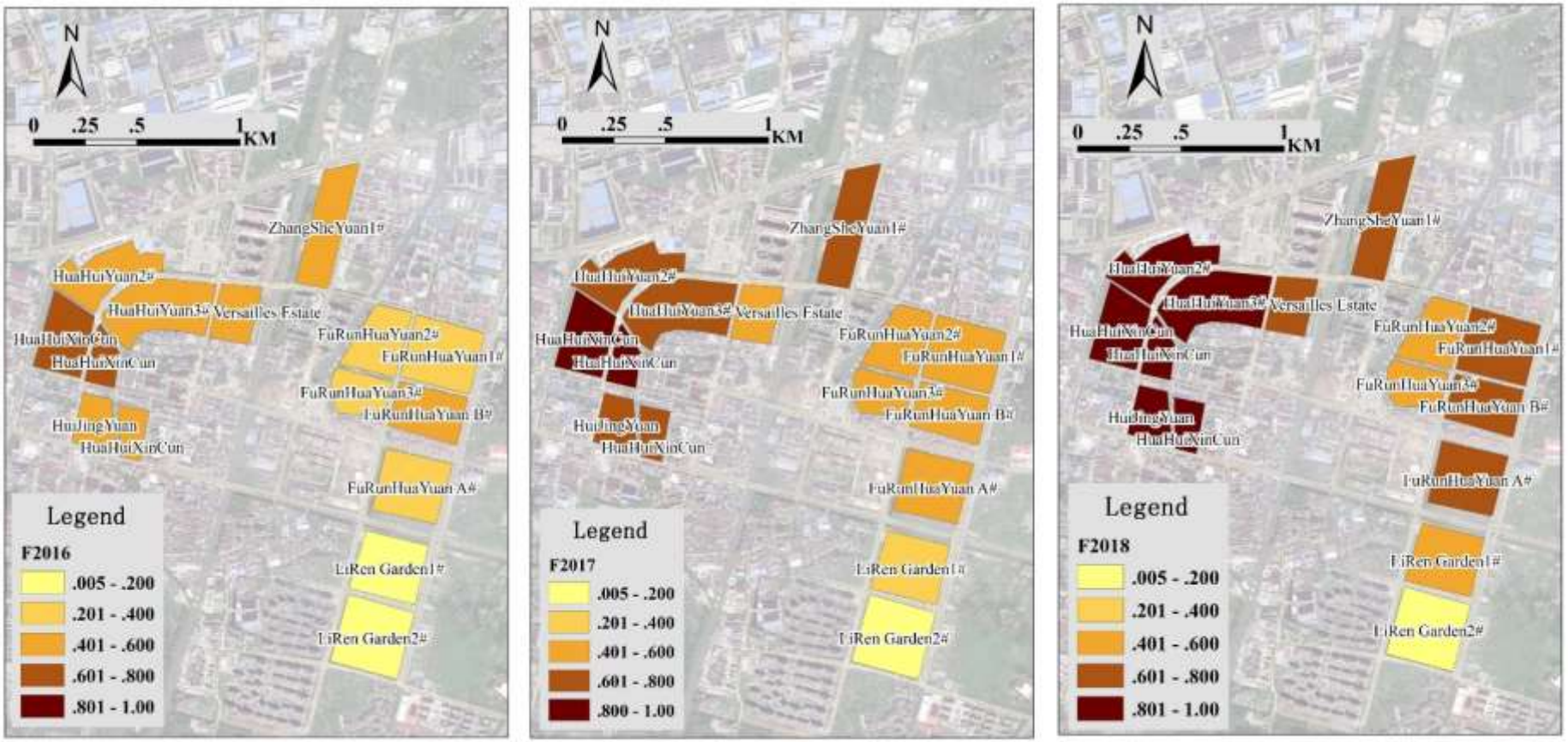

Figure 7. 3 years spatial distribution of CAPF-RA map results

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BIOGRAPHICAL NOTES

Xinxin Zhou is currently a PhD candidate in geographical information systems at the Nanjing Normal University. His research interests primarily involve novel methods for the modeling and predicting of human mobility patterns among intercity, learning smart strategies for urban transportation, and traffic flow prediction from fine-grained GPS and sensor network data. He uses R and Python every day for his work, where he finds R superb for data manipulation/visualization and Python an ideal environment for machine learning tasks. He is also interested in applying data science for the social work and international development work. When not behind the computer screen, he is an avid traveler, fisher. Previously, he had worked a long time at the department of TDC(Technology Development Center) of Nanjing Guotu Inc., an award-winning firm that specializes in geospatial technology integration and land planning in China. He obtained his master's degrees from Nanjing Normal University in GIS too.