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Preliminary communication

Service Quality Evaluation Model of Public Living Facilities in a Community

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Abstract: Accurate evaluating the service quality of public living facilities in a community by quantitative method is significant to urban planning. However, the performances of existing methods are usually limited for service quality evaluation due to single data source or single index. To solve the above problems, we propose a service quality evaluation model of public living facilities in a community. Firstly, POI data and subjective residents' satisfaction evaluation data was pre-processed for data preparation. Then, the four evaluation indicators included in the model were established, namely, accessibility, diversity, selectivity, and satisfaction. Finally, after the completion of the calculation of the four indexes, standardized processing of the calculation results was performed, and the entropy method was used to assign different weights to the indexes, thereby achieving the quantitative evaluation of the service quality of community public living facilities. We chose the central urban area of Chengdu, China, as a case study for modeling analysis, and the case study successfully estimated the service quality and spatial difference of community living facilities. The results of this model can provide a reliable basis for future urban planning and the location of commercial facilities.

Keywords: community; public living facilities; service quality; urban computing; urbanization

1 INTRODUCTION

With rapid social and economic development, the degree of the urbanization has been obviously improved. Approximately two-thirds of the world's population will live in cities by 2050 [1]. Spatial distribution structure of human economic and social activities has entered a new stage dominated by cities [2]. Nowadays, urban residents generally pay additional attention to the quality of life. A community where people live carries most of the residents' daily lives. With the increasing demand for public living facilities in a community, the comprehensive quality of public living facilities directly reflects people's community living experience. This kind of experience will stimulate urban planning departments to strengthen the construction of facilities, which is very important to promote spatial justice [3]. High-quality facilities and service quality can attract people in the community [4]. Therefore, the service quality of public living facilities in the community should be evaluated to explore the livability and convenience of the city.

A city's main function is to provide services for residents and maintain the quality of the urban living environment. Hence, public living facilities are an important part of a city. From the perspective of residents, although urban facilities play an important role in people's daily life quality, residents cannot perceive all public living facilities, such as gas pressurization station, heating station, and other facilities. Residents' lives are usually carried out around the community, so extracting the public living facilities in the community from the urban public service facilities is necessary [5]. Community scope usually refers to the community and its surrounding radiation area. The combination of public living facilities and community forms a community neighborhood. Residents are directly aware of the service status of public living facilities. Compared with other urban areas, the impact of public living facilities within the community on residents is greater, which is closely related to the quality of life of residents. Therefore, public living facilities in the community are defined as the municipal and commercial facilities that provide daily services for residents and can be perceived within the community.

As an important part of urban life quality, the service quality of public living facilities in the community directly affects the well-being of community residents [6]. As for the influencing factors of service quality of public living facilities, accessibility and diversity are often used to describe the spatial distance and types of facilities [7]. Both are factors that residents often consider when they need facilities. Moreover, we find that selectivity is also an important factor affecting service quality when residents start to make choices [8, 9]. If certain types of living facilities in the community are less, then the waiting time of residents will increase, which will negatively affect residents' preference selection and service quality evaluation [10]. Some researchers pointed out that the consumption experience includes not only the price of receiving facility services but also the subjective satisfaction of receiving services, which is another important factor affecting service quality [11]. Therefore, we define the service quality of public living facilities in the community as the comprehensive quality of public living facilities within the community that can meet the daily needs, choices, and experiences of community residents. In the study, four indexes, namely accessibility, diversity, selectivity, and facility satisfaction score, are selected based on the demand, choice, and experience of residents to construct a service quality evaluation model of public living facilities in the community.

For better quantitative evaluation of public living facilities in a community, we proposed a service quality evaluation model based on the multi-data source and multiple indexes. This paper is further presented as follows. Section 2 analyzes the advantages and disadvantages of the existing research. Section 3 introduces the model, indexes, and the quantitative calculation of the simulation community. Section 4 implements the model with a practical case, showing that the model in this study has a certain advantage in the comprehensive study of the service quality of community living facilities. Last, Section 5 discusses and Section 6 concludes the study.

2 LITERATURE REVIEW

To study the service quality of a city's facilities, researchers mostly start from their specialty, so the analysis perspectives are different. Tourism practitioners are interested in urban culture and shopping facilities, economists are concerned about the consumption level of cities, and urban planners usually focus on describing the diversity of urban facilities [12-15]. Public living facilities in the community are a part of the city, and thus, community activities have been recognized as the basic unit of urban activities and contribute to the overall quality of life of the city [16]. Some urban research methods can also be used in community research [17]. Diversity can be used to study the level of community development [18]. The number and accessibility of living facilities and the subjective evaluation score of residents are important links to evaluate the quality of community life [19-22]. Most studies start from their specialties and choose a single index. However, the service quality of public living facilities is affected by many factors [23]. Therefore, the results of a single index analysis cannot fully interpret the service quality of facilities.

On the whole, the existing evaluation methods of the service quality of public living facilities can be divided into two categories: questionnaire- and geographic-data-based methods. The former uses a questionnaire survey as the dependent variable to collect information on urban residents' satisfaction in public living facilities. These methods establish a model combined with the preset types of facilities for exploratory or weighted regression analysis to obtain the proportion of the impact factors of facilities [24, 25]. These methods establish a model combined with the preset types of facilities for exploratory or weighted regression analysis to obtain the proportion of the impact factors of facilities. The methods reflect the overall evaluation of the residents in the living environment and aim to find the factors that affect residents' satisfaction. However, the data are subjective, and the analysis result is one-sided. By contrast, geographic-data-based methods establish a feature model by collecting real geographic data including data published by the government, POI data, and crawled website data to evaluate the service quality of urban living facilities [26-30]. The methods fully reflect the objective situation of the city. However, the subjective satisfaction of urban residents is not fully considered.

With the rapid development of computer technology, the new technology provides high-quality urban big data and a reliable data source for urban research [31, 32]. As a kind of point geospatial big data representing real geographical entities, POI data have rich content and complete categories, covering all aspects of urban facilities. In addition, POI data have been widely used in urban space research [33, 34]. Moreover, people increasingly purchase the services of living facilities through mobile phone applications, and relevant applications encourage users to evaluate their satisfaction with these living facilities. People are gradually used to using this evaluation as an important reference when selecting facilities [35]. With the advantages of considerable data and rich attribute information, the big data collection methods gradually replace the traditional questionnaire data collection method.

3 METHODOLOGIES

3.1 Model Framework

The service quality evaluation model of public living facilities in the community proposed in this study is based on the collected objective urban data (POI data, urban basic data) and subjective satisfaction data. These data need to be preprocessed as follows (Fig. 1):

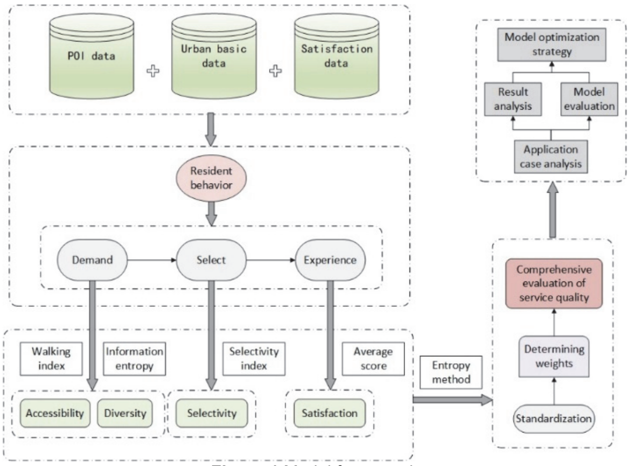


Figure 1 Model framework

Study the definition of community living facilities in China's housing policy and some journals [36, 37]. As shown in Tab. 1, the POI facilities are divided into first- and second-level facilities. First-level facilities include eight types, whereas second-level facilities include 41 types; Extract urban basic data, including built-up area, road network, river, lake and reservoir, and park data; Clean of invalid satisfaction data to clear 0 value data and other incomplete data.

Table 1 Classification of living facilities

First-level facilities	Second-level facilities
Educational and cultural facilities	Schools, training institutions, other science and education
Catering facilities	Foreign restaurants, Chinese restaurants, fast food, other catering, desserts, drinks
Sports facilities	Sports venues, other sports
Medical and health facilities	Clinic, health care, pharmacy, general hospital, specialized hospital
Entertainment facilities	KTV, bath massage, Internet bar, other entertainment
Commercial service facilities	Clothing store, supermarkets, comprehensive markets, specialty stores, building materials hardware markets, other commercial services, barber shops, telecommunication outlets, laundry stores, photo printing shops, shopping malls, specialty goods, cultural supplies
Municipal service facilities	Bus station, public toilet, government agencies, park square, scenic spots
Convenient service facilities	Logistics express, parking lot, maintenance site

Four indexes (diversity, accessibility, selectivity, and facility satisfaction) are determined by analyzing residents' behavior patterns. After the analysis results of the four indexes are normalized, the entropy method is used to determine the comprehensive evaluation of service quality. Finally, taking Chengdu as an example, this study analyzes the service quality of public living facilities in the communities in Chengdu.

3.2 Evaluation Index Design

In this section, we introduce the four indexes that constitute the service quality model of public living facilities in the community and provide the quantitative methods of four indexes. To greatly describe the index composition of the paper, Section 3.2.5 will take the simulation community in Fig. 2. As an example of calculation and demonstration Tab. 2 shows the detailed facility information of the simulation community.

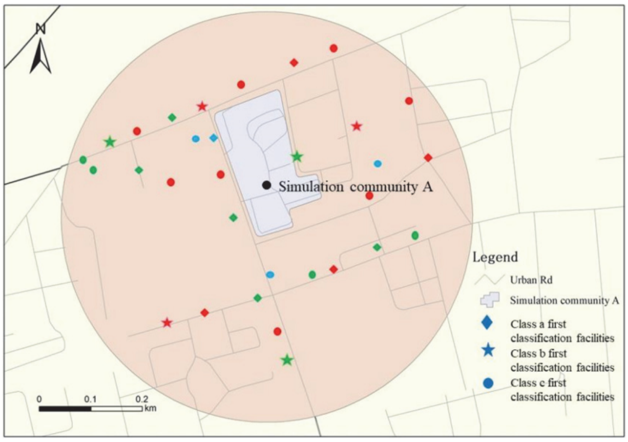


Figure 2 Simulated community

3.2.1 Accessibility

For the suitable walking distance of community residents, some researchers found that residents' willingness to choose facilities beyond a distance of 800 m is weak [38, 39]. Residents will not go to facilities that cannot be reached quickly [40]. Generally, the average walking distance of residents is approximately 400 m [41]. Therefore, the study takes 400 m as the accessible threshold of community walking distance. Some researchers have considered an ideal walking distance in the study of accessibility and take the median of average walking distance as the ideal distance [42]. Given the average distribution of various facilities in the community in China, half of the average walking distance is taken as the ideal distance in this study. For walking accessibility, some researchers have proposed the Walking Access Index (WAI) method [43] as shown in Eq. (1)

$$WAI_{SA1_i} = \sum_{j=1}^{m} N * \left(\frac{D_j^M - D_{ij}^A}{D_j^D} \right) \tag{1}$$

where $SA1$ is the Statistical Area Level 1 in Melbourne, Australia. WAI_{SA1_i} is the walking accessibility index of $SA1_i$ regions, i is the center point of $SA1$, N is the number of facilities, D_j^M is the maximum distance to destination j, D_j^D is the ideal distance to destination j, D_{ij}^A is the average walking distance from the central point i of area $SA1_i$ to destination j, and m is the type number of destination j.

This method considers not only the accessibility of facilities based on the road network but also the density of facilities, that is, land-use efficiency. However, land-use efficiency is not considered in the study, and Eq. (1) does not take into account the classification of facilities. Facilities are classified into two levels in the study, so WAI is rewritten as follows:

$$WAI_i = \frac{D^M - D_i^A}{D^D} \tag{2}$$

$$WAI_I = \sum_{i=1}^{n} WAI_i \tag{3}$$

$$WAI = \sum_{I=1}^{a} WAI_I \tag{4}$$

where I is a kind of first-level facilities, i is a kind of second-level facilities in I, WAI_i is the walking accessibility index of second-level facilities i under first-level facilities I, D^M is the maximum walking distance, D_i^A is the average walking distance to the second-level facilities i of first-level facilities I in the community, D^D is the ideal walking distance, WAI_I is the walking accessibility index of first-level facilities I in the community, n is the type number of second-level facilities in the first-level facilities I, a is the type number of first-level facilities, and WAI is the overall walking accessibility index of the community. As the WAI value increases, the overall accessibility of the community also increases.

3.2.2 Diversity

Shannon first proposed information entropy and used the concept of entropy in physics for reference. In addition, Shannon used the concept of information entropy to describe the uncertainty of information sources [44]. The Shannon-Wiener index in biology was established based on the concept of information entropy and is often used to study regional biodiversity [45]. In urban research, information entropy is often used to study the diversity of the retail industry [46]. Information entropy is used to measure the diversity of community living facilities in the study. The diversity index can be expressed as follows:

$$P_i = \frac{N_i}{N_I} \tag{5}$$

$$H_I = -\sum_{i=1}^{n} P_i \log_2 P_i \tag{6}$$

$$H = \sum_{I=1}^{a} H_I \tag{7}$$

where P_i is the ratio of the number of second-level facilities i in the community to the number of first-level facilities I, N_I is the number of first-level facilities I within the community, N_i is the number of second-level facilities i of first-level facilities I within the community, H_I is the diversity index of first-level facilities I within the community, H is the diversity index of overall facilities within the community, n is the type number of second-level facilities i of first-level facilities I within the community, and a is the type number of first-level facilities within the community. $H \geq 0$, and as the H value increases, the diversity of community living facilities also increases. If the diversity of community living facilities is great, then the function of community facilities is also great. Conversely, if the H value is small, then the diversity of community living facilities is not good.

3.2.3 Selectivity

The selectivity index is defined as the number of facilities with the same function within the community that is available for residents to select when they need them. Theoretically, if facilities with the same function are plenty, then their selectivity index is great. Spatial justice is considered in the study [47]. That is, the type and quantity of facilities in all communities are equal, which are two ideal states of the index. The two ideal states of the index are described as follows:

1. The number of all second-level facilities within the community is the same, reaching the maximum selectivity of second-level facilities, which is expressed as Eq. (8).

$$K_i = \frac{N_i^{\text{all}}}{S} \tag{8}$$

where K_i is the mean value of second-level facilities i of first-level facilities I in all communities, N_i^{all} is the total number of second-level facilities i of first-level facilities I within the community in the study area, S is the total number of communities in the study area.

2. The same number of first-level facilities can indicate the same type of community public facilities. The number of all first-level facilities within the community is the same, reaching the maximum selectivity of first-level facilities, which is expressed as Eq. (9).

$$K_I = \frac{N_I^{\text{all}}}{S} \tag{9}$$

where K_I is the mean value of first-level facilities I in all communities, N_I^{all} is the total number of first-level facilities I within the community in the study area, S is the total number of communities in the study area.

In the actual calculation process, the ideal number or the actual number of a certain type of facility will be 0 in some cases. When the base is 0, the logarithm cannot be calculated. To avoid this problem, 1 is added to the ideal number and the actual number of service facilities. The selectivity index of service facilities with the actual number of 0 is still 0, and the selectivity index of other service facilities is not affected. The selectivity index is expressed as follows:

$$Q_i = \log_{K_i+1}\left(N_i+1\right) \tag{10}$$

$$\overline{Q} = \frac{\sum Q}{n} \tag{11}$$

$$Q_I = \frac{\log_{K_I+1}\left(N_I+1\right)+\overline{Q_i}}{2} \tag{12}$$

$$Q = \sum_{I=1}^{a} Q_I \tag{13}$$

where Q_i is the selectivity index of second-level facilities i of first-level facilities I in the community, N_i is the number of second-level facilities i of first-level facilities I in the community, $\overline{Q_i}$ is the average selectivity index of all second-level facilities i under first-level facilities I under first-level facilities I, Q_I is the selectivity index of first-level facilities I in the community, N_I is the number of first-level facilities I in the community, Q is the overall selectivity index of the community, a is the type number of types in first-level facilities, and n is the type number of second-level facilities of first-level facilities I. As Q increases, the overall selectivity of the community also increases.

3.2.4 Satisfaction Score

Meituan.com is a group buying website that contains considerable residents' satisfaction scores on facilities. First, this website uses inverse geocoding to assign coordinate information to the facility points containing satisfaction information. Residents' satisfaction scores on facilities belong to the corresponding community. Then, the sum of satisfaction scores of all facilities within the community is divided by the number of all facilities. Finally, the average satisfaction score of facilities is taken as the satisfaction score of the community, as shown in Eq. (14):

$$M = \frac{B}{N} \tag{14}$$

where M represents the satisfaction score of the community, B represents the sum of the satisfaction of the community, and N represents the total number of facilities in the community.

3.2.5 Quantitative Demonstration of Simulation Community

Community A in Fig. 3 is taken as an example. The community contains three types of first-level facilities (a, b, c) including 30 second-level facilities (a1, a2, a3, b1, b2, c1, c2, c3). Tab. 2 shows the details. This section will demonstrate the calculation process of each index and simulate the score of each index of community A.

(1) Calculate the walking accessibility index

When calculating walking accessibility, Eq. (2) can be used to calculate the walking accessibility index of all second-level facilities. Take class a facilities as an example:

$$a1: WAI_i = \frac{D^M - D_i^A}{D^D} = \frac{800-460}{200} = 1.7$$

$$a2: WAI_i = \frac{D^M - D_i^A}{D^D} = \frac{800-170}{200} = 3.15$$

$$a3: WAI_i = \frac{D^M - D_i^A}{D^D} = \frac{800-240}{200} = 2.8$$

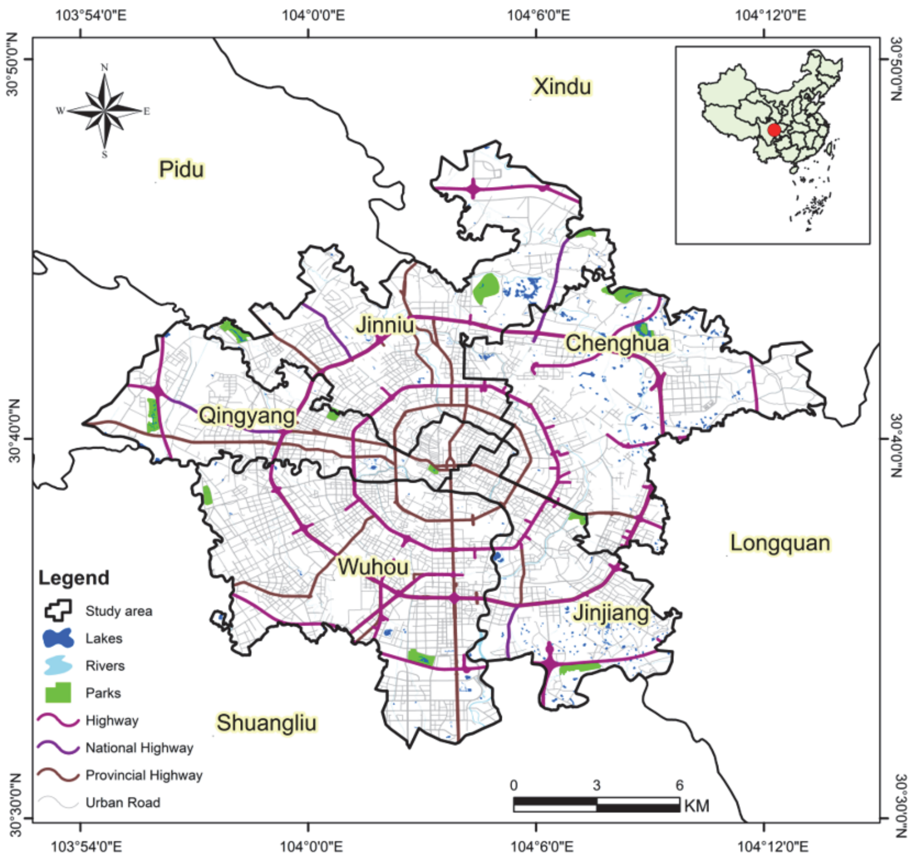


Figure 3 Study area

Table 2 Information table of facilities within community A

First-level facilities point type	Type number of second-level facilities	Second-level facilities point type	Number of second-level facilities	Average path distance from the community point / m	Average score of residents' satisfaction	Ideal number of second-level facilities	Ideal number of first-level facilities
a	3	a1	5	460	4.6	3.6	8.5
		a2	4	170	4.7	3.3	
		a3	1	240	3.9	1.6	
b	2	b1	3	320	5.0	2.5	5.8
		b2	3	200	4.3	1.7	
c	3	c1	3	400	4.4	2.9	13
		c2	8	540	3.7	5.5	
		c3	3	270	4.7	4.6	

According to Eq. (3), the walking accessibility index of facility *a* is calculated as follows:

$$a: WAI_I = \sum_{i=1}^{n} WAI_i = 1.7 + 3.15 + 2.8 = 7.65$$

After calculating the walking accessibility index of all first-level facilities, the overall walking accessibility index of community A can be calculated by Eq. (4).

(2) Calculate diversity index

The proportion of all second-level facilities in the number of corresponding first-level facilities is calculated as shown in Eq. (5). Take class *a* facilities as an example:

$$a1: P_i = \frac{N_i}{N_I} = \frac{5}{10} = \frac{1}{2}$$

$$a2: P_i = \frac{N_i}{N_I} = \frac{4}{10} = \frac{2}{5}$$

$$a3: P_i = \frac{N_i}{N_I} = \frac{1}{10}$$

The diversity index of class *a* facilities can be calculated by Eq. (6).

$$a: H_I = -\sum_{i=1}^{n} P_i \log_2 P_i$$

$$= -\left[\left(\frac{1}{2}\log_2\frac{1}{2}\right) + \left(\frac{2}{5}\log_2\frac{2}{5}\right) + \left(\frac{1}{10}\log_2\frac{1}{10}\right)\right] = 1.36$$

Using the same method, the diversity index of all first-level facilities can be calculated, and then the overall diversity index of community *A* can be calculated by Eq. (7).

(3) Calculate the selectivity index

We have simulated the ideal number of first-level facilities and the ideal number of second-level facilities. The selectivity index of all first-level facilities can be calculated by Eq. (10). Take facilities of class *a* as an example:

$$a1: Q_i = \log_{K_i+1}(N_i+1) = \log_{3.6+1}(5+1) = 1.17$$
$$a2: Q_i = \log_{K_i+1}(N_i+1) = \log_{3.3+1}(4+1) = 1.10$$
$$a3: Q_i = \log_{K_i+1}(N_i+1) = \log_{1.6+1}(1+1) = 0.73$$

To calculate the selectivity of first-level facilities in Eq. (12), Eq. (11) needs to impose a mean constraint on the selectivity of second-level facilities.

$$\overline{Q_i} = \frac{\sum_{i=1}^{n} Q_i}{n} = \frac{1.17+1.1+0.73}{3} = 1$$

Eq. (12) was used to calculate the selectivity of first-level facilities, and the selective mean value of second-level facilities was taken into account.

$$a: Q_I = \frac{\log_{K_I+1}(N_I+1)+\overline{Q_i}}{2} = \frac{\log_{8.5+1}(10+1)+1}{2} = 1.04$$

After the above calculation, the selectivity of first-level facility a in community A can be calculated. In the same way, the selectivity of the remaining facilities can be calculated. Finally, the overall selectivity of community A can be calculated by Eq. (13).

(4) Calculate satisfaction score

Using Eq. (14), we can calculate the average satisfaction of residents with the facilities in the community. As the satisfaction degree increases, the life comfort of community residents also increases.

$$a: M = \frac{B}{N} = \frac{4.6*5+4.7*4+3.9*1+5*3+4.3*3}{30} + \\ + \frac{4.4*3+3.7*8+4.7*3}{30} = 4.35$$

The simulation community in this section introduces the calculation process of indexes in detail so that readers can greatly understand the calculation process of four indexes.

3.3 Construction of the Evaluation Model

In constructing the evaluation model, assigning weights to the indexes is inevitable. The two classes of index weighting methods are subjective and objective weight methods. The former includes expert scoring and analytic hierarchy process, whereas the latter includes the entropy method [48-51]. In order to reduce the influence of human factors and social environmental factors in the weighting process, this study uses the entropy method to weight each index and calculate its comprehensive index.

In information theory, entropy is used to measure uncertainty. As the entropy value decreases, the weight increases, and vice versa [52, 53].

If n samples and m indexes exist, then x_{ij} represents the j index of the i sample $(i = 1,...,n;\ j = 1,...,m)$. Tab. 3 shows the steps of the entropy method.

Through the calculation of the entropy method, the weight coefficients of accessibility, diversity, selectivity and satisfaction indicators can be determined. The weight of each indicator is multiplied by the calculation results of each indicator, and finally the service quality evaluation is realized.

4 CASE STUDY

4.1 Study area

A city's urban center forms the core of its public living facilities system. A typical urban center is characterized by developed public living facilities and a high concentration of political, economic, and cultural industries that can fully demonstrate the city's status and level of economic development. The overall layout of living facilities can well reflect the living conditions of residents after urbanization. As the capital of Sichuan Province, China, Chengdu (30°39'N, 104°03'E) is located in the central part of Sichuan metropolitan area; it is a typical city featuring basin, with a relatively complete urban function. In this study, five districts in central Chengdu--namly, Qingyang District, Jinniu District, Chenghua District, Wuhou District, and Jinjiang District, covering a total area of 465.60 km^2, including 3214 communities, the population of the central urban area of Chengdu will reach 6.2 million, were selected as the study area (Fig. 3).

Table 3 Calculation process of entropy method

Step	Equation	Remarks
1. Standardization	$X_{ij} = \frac{x_{ij} - \min\{x_{1j}, x_{2j}, ..., x_{nj}\}}{\max\{x_{1j}, x_{2j}, ..., x_{nj}\} - \min\{x_{1j}, x_{2j}, ..., x_{nj}\}}$	The aim is to homogenize the indexes, $i = 1,...,n; j = 1,...,m$
2. Calculate the proportion of i sample value under j index in the index	$p_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}$	$j = 1,...,m$
3.Calculate the entropy e of j index	$e_j = -k\sum_{i=1}^{n} p_{ij} In(p_{ij})$	$k = \frac{1}{In(n)} > 0$, $e_j \geq 0$
4. Calculating information entropy redundancy d	$d_j = 1 - e_j$	As d_j increases, the importance of the index also
5. Calculate the weight of each index w	$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$	$i = 1,...,n$
6. The comprehensive score of each sample was calculated	$s_i = \sum_{j=1}^{m} w_j X_{ij}$	$i = 1,...,n$

Table 4 Field information of some facilities

ID	Facility name	Longitude	Latitude	First-level facility attributes	Second-level facility attributes	Address
1	Pakistan Fish House	113.991176	30.601018	Catering facilities	Chinese Restaurant	Wangjinheng Street 90
2	Chengdu Youth Palace (Shuncheng Street)	104.071104	30.664422	Educational and cultural facilities	Palace of Culture	262 Shuncheng Street
3	Famous shop for shaping and dyeing	103.981018	30.702714	Commercial Service facilities	Beauty salons	No. 76, Qingchun Second Street, Qingfeng Road
4	Tianxingjian Fitness (Ronghua North Road)	104.043838	30.551731	Sports facilities	Sports venues	8th Floor, Metropolis, No. 333, Ronghua North Road

4.2 Data Description

4.2.1 Map Data and POI Data

The map data used in this study are collected from the Gaode map (http://lbs.amp.com/, accessed on 20 April 2021), including the map of the study area and the road network data.

The POI data of Chengdu City are also collected from the Gaode map, including 3214 data of community points. Community points are combined with map data to create a 400 m community range, and facility points in the community are counted through the annotation function of ArcGIS [54]. The field information of facility data includes ID, name, longitude and latitude, first-level and second-level facility attribute, and address. The community scope of adjacent communities may overlap, and the facilities in the overlapping area belong to multiple communities. If the road network distance between a facility points and its community point is greater than 800 m, then the facility will be cleaned. After data processing, 97860 facilities were obtained, and Tab. 4 shows the field information of some facilities.

4.2.2 Satisfaction Evaluation Data

Satisfaction evaluation data are obtained from meituan.com (https://jn.meituan.com/, accessed on 28 April 2021). The data are the residents' online evaluation score of the entire facility experience. Nowadays, with the development of Internet technology, researchers can use several website data [55, 56]. The statistical method of satisfaction score data is the same as the statistical method of POI data. The field information of satisfaction data includes ID, facility name, longitude and latitude, first-level and second-level facility attribute, satisfaction score (zero-five), and Address. After data processing, including repeated score data of different communities, 97860 score data were obtained. Tab. 5 shows a part of the satisfaction score data.

Table 5 Part of satisfaction score data

ID	Facility name	Score	First-level facility attributes	Second-level facility attributes	Longitude	Latitude	Address
1	Poly International Cinemas (Aux Store)	4.0	Entertainment facilities	Chinese Restaurant	104.062946	30.576248	No. 666, West Section of Jincheng Avenue, High-tech Zone
2	Botang Clinic	4.3	Medical and health facilities	Clinic	103.99801	30.668782	No. 21, Shuangxin South Road, No. 1
3	Star Factory Football Club	4.3	Sports facilities	Sports venues	103.996655	30.680349	Jinpeng Street 291
4	Caramel Hair House (Guanyin Bridge Street)	3.9	Commercial Service facilities	Beauty salons	104.10571	30.616823	No. 30 and No. 15 Guanyinqiao Street
5	Qiaotou Sichuan	4.2	Catering facilities	Chinese restaurant	104.011257	30.635074	No. 90 and No. 10, Shuangnan Section, Wuhou Avenue

4.3 Result

Through the calculation of accessibility, diversity, selectivity and satisfaction score, the calculation results of various indexes of each community point are obtained. Fig. 4a to Fig. 4d show the visualization of value distribution of four indexes, including accessibility index, diversity index, selectivity index and satisfaction index, via Kriging interpolation. Each index is divided into five levels by using the natural discontinuity method. Fig. 4a shows the distribution of community accessibility index values. Due to the development of urban road network, the accessibility is good in most of the study area. However, accessibility is poor in the eastern region of the city, which is mainly due to the fact that the road network is sparse and living facilities are few. As seen from Fig. 4b, the distribution of diversity does not show a circle structure, the phenomenon that the value of diversity decreases from the center to the periphery is not obvious. The result of diversity distribution presents a multi-center comprehensive development. Living facilities in most communities are variety and diversity. For example, the values of the diversity index in the northern region of Jinniu District are high. This finding may be explained by a great variety of public living facilities in the areas. Compared with the southern region of Jinniu District, the values of the diversity index at the outside of Wuhou District and Jinjiang District are significantly increased. This finding is mainly due to the fact that only a few kinds of public living facilities near the communities. As shown in Fig. 4c, the distribution of selectivity shows a clear circle structure, and the areas with good selectivity are mainly distributed in the central area, while the areas with weak selectivity are mainly distributed within the periphery of the study area. In the northern region of JinniuDistrct, the selectivity index is weak. This finding confirms that the number of public living facilities is small in the area while kinds of the public living facilities are abundant. Fig. 4d presents a phenomenon that the areas with high community satisfaction score are mainly distributed in the central area and the southern region, while the areas with low satisfaction score are mainly distributed in the northern and eastern regions of the study area. However, the values of the satisfaction index in the southern region of Wuhou District are high. This finding demonstrates that a large number of public living facilities with good satisfaction are distributed in the southern region of Wuhou District.

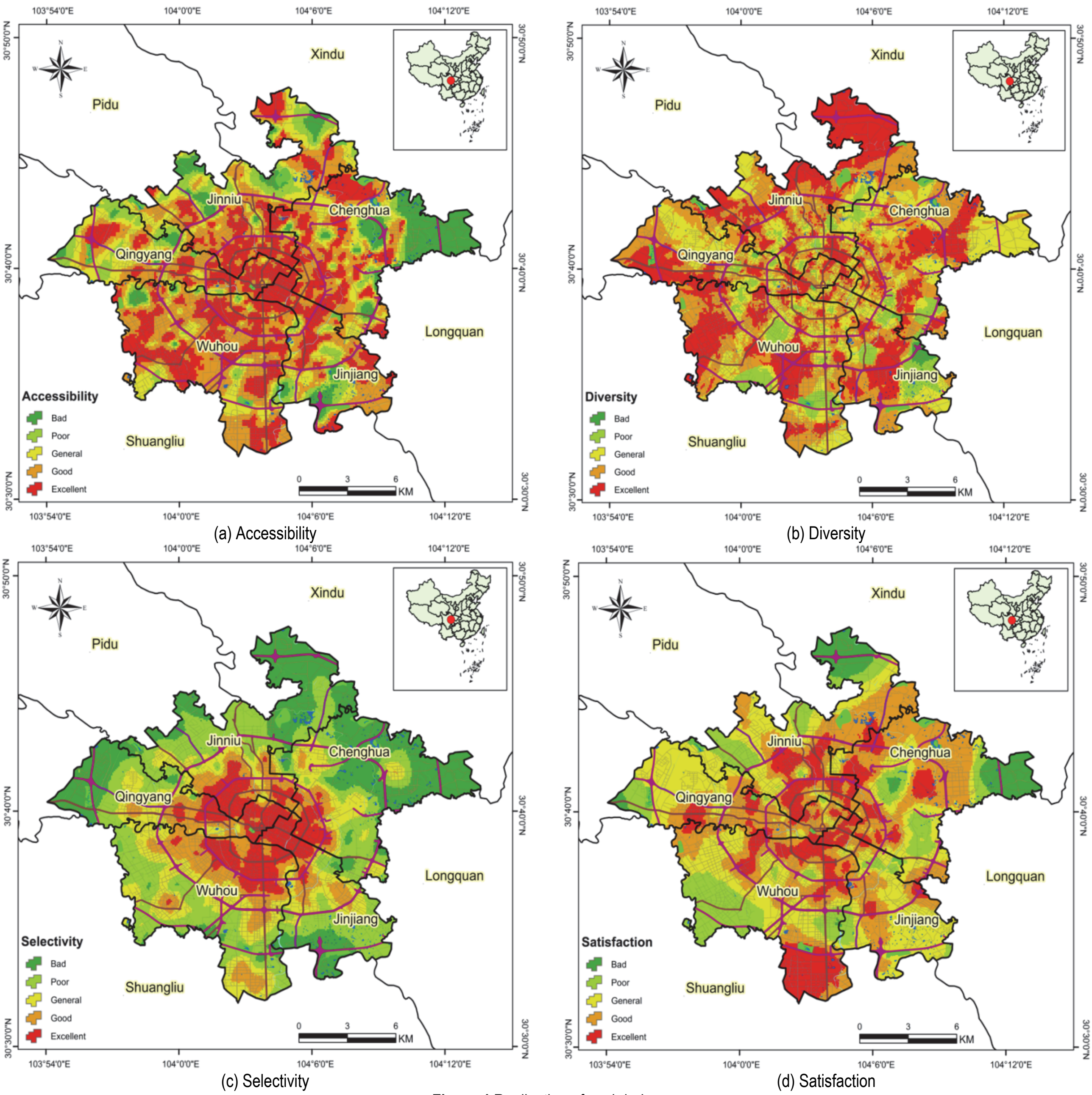


Figure 4 Realization of each index

We calculated and analyzed the four indexes by entropy method, and then confirmed the weights. First, we standardize the index, then calculate the proportion of the i sample value under the j index to the index, then calculate the entropy value e of the j index, then calculate the information entropy redundancy d, and then calculate the weight of each index w, and finally calculate the comprehensive score of each sample. Notably, a value of zero is inevitable in the process of standardization, which will negatively affect entropy calculation. Therefore, we eliminated the samples with zero values and then calculated the weights. Tab. 6 shows the final calculation results of the entropy method.

Table 6 Statistical results of weight

Summary of weight calculation results using the entropy method			
Index	**Information entropy *e***	**Information utility value *d***	**Weight coefficient *w***
Satisfaction	0.9942	0.0058	9.28%
Accessibility	0.9863	0.0137	22.07%
Diversity	0.9984	0.0016	2.59%
Selectivity	0.9590	0.0410	66.06%

Finally, the weight values calculated by the entropy method and the standardized values of the four indexes were multiplied and superimposed, and then the comprehensive service quality score of each community was calculated according to Step 6 in Tab. 3. The comprehensive service quality scores of communities were divided into five classifications using the natural discontinuity method, as shown in Tab. 7. The range of service quality evaluation scores was between 0-1.

Table 7 Service quality classification

Service quality classification					
Grade	Bad	Poor	General	Good	Excellent
Score	0.08-0.20	0.21-0.28	0.29-0.38	0.39-0.49	0.50-0.75

After the interpolation is completed, the accuracy of the interpolation result needs to be verified. Hence, we extracted the interpolation result on the test feature data set by the value extraction to point function in ArcGIS, includes 65 test feature data. Then, we calculated the average absolute error (MAE) and the root mean square error (RMSE) between the correct value and the predicted value, as shown in Tab. 8.

Table 8 Accuracy verification results

Project	Mean deviation	MAE	RMSE
Service quality	0.0005	0.0150	0.0007

After accuracy verification, the average deviation of service quality is less than 0.01, and the average absolute value error and root mean square error are both less than 0.1, which proves that the Kriging interpolation method is effective to visualize the calculated community service quality results. The final result of community service quality visualization is shown in Fig. 5.

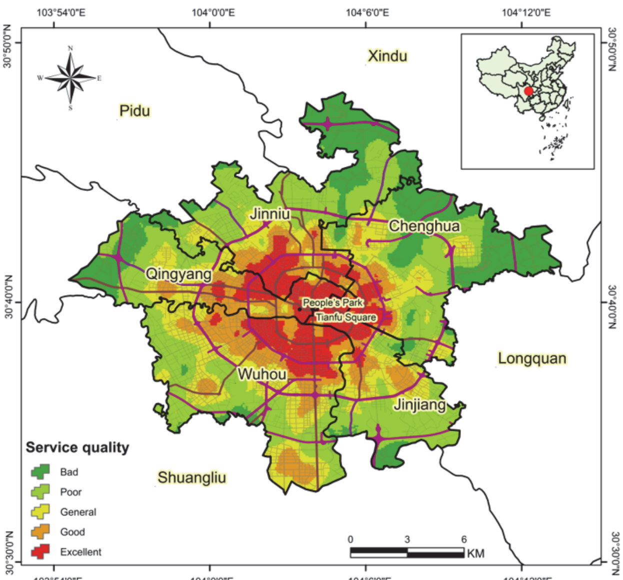
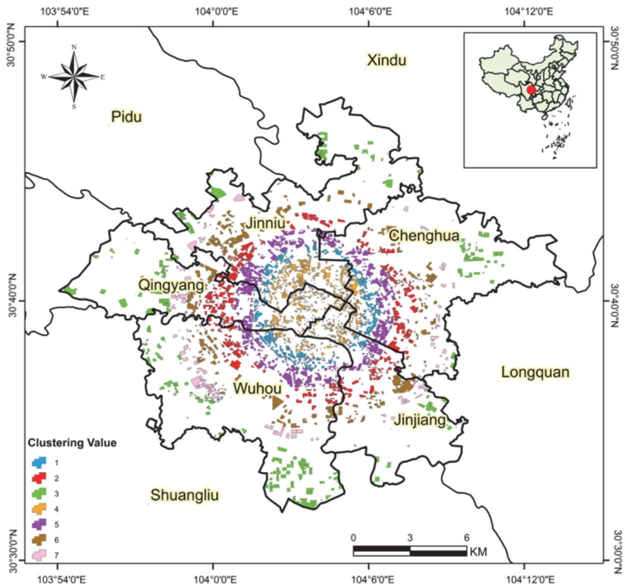
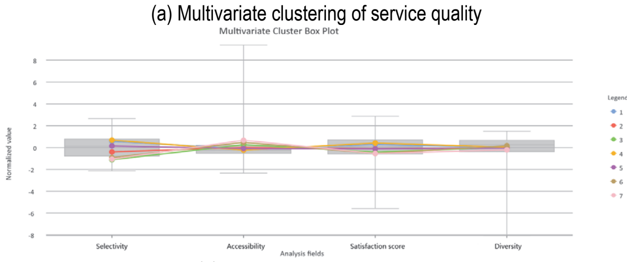


Figure 5 Comprehensive service quality evaluation

As shown in Fig. 5, communities with high service quality values are mainly distributed within the inner regions of the city, while communities with low service quality values are distributed in the periphery of the study area. Most of the communities with the excellent service quality are distributed in the central areas near the Tianfu Square and People's Park, where the road network is dense and the public living facilities are rich. Communities with good service quality are mostly distributed in the peripheral area of the central area, where the road network is relatively dense and the facilities are relatively rich. Then, communities with general service quality are most distributed in the sub peripheral areas of the central area. Last, communities with poor or bad service quality are distributed in the area except for the central area, showing a circular feature. The road network in the area is sparse, and the living facilities are less. It is undeniable that there are some problems in the communities with bad or poor service quality. For example, the public living facilities and municipal infrastructures are insufficient. Municipal departments need to discuss and demonstrate how to improve the public living environment of these communities. As Chengdu is still in the process of urbanization, a large number of municipal works is ongoing. In fact, in 2022, the Chengdu Municipal Government put forward a requirement that continuously improves the quality of public service facilities and enhances the connotation of community quality.



(a) Multivariate clustering of service quality



(b) Multivariate cluster box plot

Figure 6 Multivariate clustering

In order to further analyze the impact of the four indexes on community public service quality, we made a multivariate clustering analysis on the comprehensive service quality of public living facilities, as shown in Fig. 6a. Fig. 6a shows that the results obtained by the multivariate clustering analysis are divided into 7 categories, and the central area is mainly category 4. Other categories are circularly distributed around the center. It can be concluded that the quality of community service in the center of the study areas is the best, and the quality of community service in other regions is also at a high level.

With the continuous advancement of urbanization, the quality of community service in urban fringe areas is also improved. Many communities are newly built, some living facilities are not rich. We should pay long-term attention to these communities and believe that their performance will be improved in the future. According to Multivariate Cluster Box Plot of Fig. 6b, it can be seen that the areas with better community service quality have higher selectivity and satisfaction score. Higher selectivity and satisfaction score concentrate on category 4, which illustrates that service quality is good. Category 3 has poor selectivity and satisfaction value, and its service quality is also low. The impact degree of diversity and accessibility is relatively small.

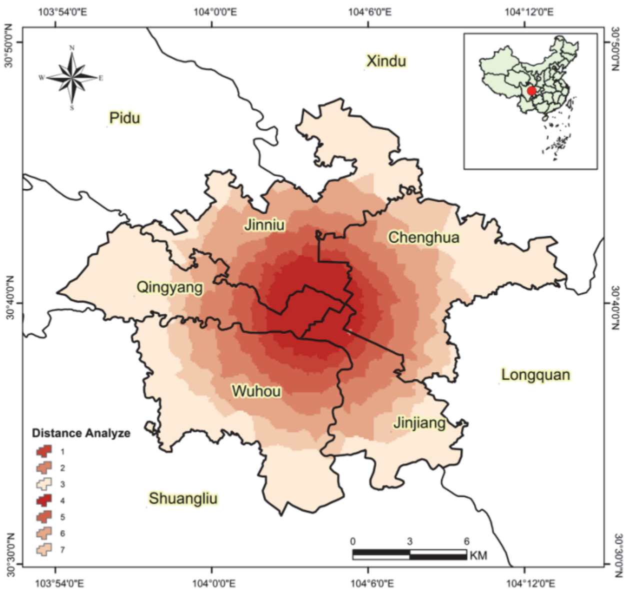


Figure 7 Distance distribution of service quality

Finally, we analyse the distance distribution of the study area according to the clustering results, and the result of distance distribution is shown in Fig. 7. The spatial distribution pattern of the study area is circular distribution. Most of communities with good service quality and perfect service facilities are distribute in area 4. Service facilities in other communities are also in the stage of development and improvement. We should pay long-term attention to such communities and believe that their performance will improve in the future.

5 DISCUSSIONS

During urbanization, community construction is very important. The service quality of public living facilities in the community is related to residents' sense of happiness. With the rapid development of the overall economy, residents are generally concerned about the quality of life. A city with efficient and convenient public living facilities can not only attract people to settle down and promote the development of business enterprises but also effectively reduce the cost of living. Therefore, as a part of urban research, measuring the service quality of public living facilities in a community can help residents understand the overall situation of their living community. Thus, urban planning and development departments must understand the current situation of urban infrastructure and greatly plan and construct in the future.

At present, most researches focus on the resident survey data to collect the residents' scores on the convenience and overall sense of urban living facilities. The methods have certain effectiveness, but the manual acquisition of survey data requiring considerable workload is low efficiency. Some researchers construct the model to achieve the evaluation of the city based on the real data of the city, but ignore the residents' subjective feelings. The performances of existing researches are usually limited for service quality evaluation due to single data source or single index. Therefore, considering multiple data sources, we proposed the service quality evaluation model of public living facilities in a community in the study. The proposed model, including accessibility, diversity, and selectivity indexes, is constructed based on the objective and subjective data. We chose the central urban area of Chengdu, China, as a case study for modelling analysis, and the case study successfully estimated the service quality and spatial difference of community living facilities. In short, experiment results demonstrate that our model is effective.

In the future, the proposed model could be further improved. For example, consumer price could be considered. We have constructed a consumption experience index (Appendix A). The composition of the index includes the average consumption price of second-level facilities i and the sum of the consumption price of second-level facilities i and the average satisfaction score of second-level facilities i and the total satisfaction score of second-level facilities i in the community. However, we did not obtain enough per consumption price of facilities and only obtained the satisfaction score data. In the future, we will consider the consumption experience index to further improve the model when we obtain the price data.

6 CONCLUSIONS

The service quality evaluation model of public living facilities in a community is proposed in this paper, and the validity and reliability of the model are verified through case analysis. The indexes of the model comprehensively consider the objectivity of facilities and the subjective expression of residents. The proposed model realizes the comprehensive quantitative evaluation of the service quality of community living facilities. In the information age, additional big data of cities will be produced in the future, which means that the model method proposed in this study will play a more powerful role in the future. We propose a concept of selectivity index for the first time and quantify the "choice preference" in residents' behavior. Furthermore, this index can reflect spatial justice to some extent. By enriching the connotation of the selectivity index, this index can be taken as the direction of future research.

Geographic information system (GIS) has been widely used in spatial data and spatial analyses, such as urban functional area division, facility optimal location, land use classification, and spatial structure analysis of occupation and residence. Considering the strong advantages and applicability of GIS technology in database construction and analysis modeling, efficiency and quality of the research have been greatly improved. Based on GIS technology, this study constructs the evaluation model.

Although the evaluation model realizes the quantitative evaluation of community facilities, the model can still be improved. For example, we did not consider the impact of population distribution which is a very important factor. In a densely populated community and a relatively sparsely populated community, residents' perception of facilities must be different. In the next work, we plan to include population factors into the model. This model is not only suitable for communities but is also applicable to the evaluation and difference comparison of facilities and service quality among cities. The analysis results can quantitatively find the degree of improvement and deficiencies of urban communities and provide a reliable basis for municipal departments to conduct planning and commercial settlement site selection.

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Appendix A: Construction of Consumption Experience Index

Most researchers focus on the satisfaction of urban facilities and adopt the questionnaire survey method. They collect the satisfaction score of residents on living facilities and then conduct correlation analysis according to the collected survey data which are used to explore the relationship between satisfaction and residential areas. However, existing research does not consider the consumption cost. Generally speaking, the service cost of community residents receiving peripheral facilities services is highly sensitive, which is the key factor affecting residents' decision whether to accept services. Satisfaction is a subjective evaluation after receiving services. Consumption cost and satisfaction together constitute the complete process of the consumption experience. The Equation is as follows:

$$\overline{B_i} = \frac{B_i + 1}{N_i + 1}, \overline{E_i} = \frac{E_i}{N_i}, \overline{B}_i^{\text{all}} = \frac{\sum B_i^{\text{all}} + 1}{N_i^{\text{all}} + 1},$$

$$M_i = \frac{\overline{B}_i^{\text{all}}}{\overline{B_i}} * \overline{E_i}, M_I = \sum_i^n \frac{\sum M_i}{N_i}, M = \sum M_I .$$

where $\overline{B_i}$ is the average consumption price of second-level facilities i in a community, B_i is the sum of the consumption prices of second-level facilities i in a community, N_i is the number of second-level facilities i in the community, $\overline{E_i}$ is the average satisfaction score of second-level facilities i in the community, E_i is the total satisfaction score of second-level facilities i in the community, $\overline{B}_i^{\text{all}}$ is the average consumption of second-level facilities i within the city, $\sum B_i^{\text{all}}$ is the total consumption price of second-level facilities i in the city, N_i^{all} is the number of second-level facilities i in the city, M_i is the consumption experience index of second-level facilities i, B_i represents the actual consumption of a second-level facility i, E_i represents the score of a second-level facility i, M_I represents the consumption experience index of first-level facilities I within the community, and M represents the total consumption experience index within the community.

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