

Research Article

Livability Assessment of Urban Communities considering the Preferences of Different Age Groups

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Livability is one of the major guiding principles for urban planning and policymaking, of which the definition and evaluation have become the crucial research topic. As the progress in socioeconomic development accelerates, the microscale living conditions require more urgent attention. However, few researchers have addressed the assessment of urban livability at a finer spatial scale such as the community scale. Thus, this article aims to evaluate the urban environmental quality at the community level given the residential community as the basic unit of urban living areas. We select eighteen objective indicators from five dimensions to establish an objective indicator system. Taking the preferences of different age groups into account, a comprehensive evaluation framework for the livability of communities combining both subjective perceptions and objective indicator is constructed. Then, it is applied to evaluate the livability of 1,394 residential communities in Ningbo City. There are three significant results from the study. First, different age groups have diverse preferences of demands to the livability of an urban community. The indicators they valued most concentrated in the following two dimensions: the convenience of transportation and the completeness of supporting facilities. Second, there exists significant heterogeneity in the livability of communities among districts. Third, the livability of communities shows a decreasing spatial pattern from the city center to the surroundings. These empirical results can be advantageous to urban planning departments and other relevant stakeholders.

1. Introduction

Human settlements are the basis for human survival and development. They provide places for various human activities, including residence, work, education, health, culture, and entertainment [1]. The quality of human settlements normally exerts great influence on human health and wellbeing. Over the past few decades, with the development of the economy and rapid urbanization, some issues, such as natural disasters, environmental pollution, heavy traffic, and excessive housing prices, have become increasingly prominent, which seriously affects the living quality of residents, especially in urban areas [2–5]. As a result, the urban environmental quality has received extensive

attention from the academic community, as well as the governments and the public.

To describe and measure urban environmental quality, the terms of livability and related concepts such as sustainability, quality of life, and wellbeing enjoy great popularity. As the goal of urban construction and development, livability has attracted widespread attention in the field of urban planning and urban geography. However, there is still no unified definition and connotation of livability due to its interdisciplinary and multidimensional characteristics [6–8]. An initial definition of livability is proposed by Pacione [9] and it is defined as a quality that is not an attribute inherent in the environment but is behavior-related function of the interaction between environmental

characteristics and personal characteristics. Newman [10] states that livability is the human requirement for social amenity, health, and wellbeing and it includes both individual and community wellbeing. In addition, Ruth and Franklin [11] show that livability consists of two elements: the city's environment and the population that demands goods and services. In general, these definitions emphasize the interaction between people and the environment.

Consistent with the various conceptualizations of urban livability, no consensus has been reached on the measurement of urban livability to date [12]. Numerous studies select objective indicators and construct their own evaluation framework to evaluate livability [4, 13, 14]. For example, Savageau [15] develops a comprehensive indicator system for evaluating the quality of the living environment in the metropolitan areas of the United States. The indicator system involved the following aspects: cultural atmosphere, housing, employment, crime, transportation, and education. Liu [16] examines the spatial patterns and driving factors of the urban environment from the dimensions of the physical environment, built environment, and natural hazards with a case study of Chongqing, China. Similarly, Tang et al. [17] construct a comprehensive evaluation system of living environment focusing on housing conditions, urban natural environments, social economy, and public infrastructure to analyze the trends in environmental quality changes and spatial differentiation characteristics of 35 major Chinese cities. In addition, some scholars and research institutions focus on ranking cities according to their livability [18]. The Economist Intelligence Unit (EIU) has only released its global livability ranking report annually since 2010, which contains 30 qualitative and quantitative indicators from 5 dimensions of stability, healthcare, culture, environment, education, and infrastructure [19], while Tan et al. [20] advocate the Global Livable Cities Index (GLCI) to rank the world's 64 major cities.

On the other hand, some studies pay attention to residents' satisfaction with urban livability from a subjective perspective. Assessing the degree of residential satisfaction [21] and examining its impact factors [22, 23] are the two main aspects of existing studies, while social surveys or questionnaires are common research methods. Residential satisfaction is a complex and comprehensive process, and various factors, such as residents' background and characteristics, neighborhood characteristics, housing quality, public facilities, or infrastructure, have been confirmed to have a significant influence [24–26]. Huang and Du [27] assess residential satisfaction with public housing and examined its determinants based on the Hangzhou public housing household survey. They found that the neighborhood environment, public facilities, and housing characteristics were the main factors that influenced residential satisfaction. Moreover, conducting the large-scale questionnaire surveys in 40 major cities in China, Zhan et al. explore the characteristics of satisfaction with urban livability and the effect magnitude of its determinants using the geographical detector model [12].

The findings of these studies offer a better understanding of urban livability in several ways. First, they provide

abundant knowledge of environmental quality from various aspects and different scales. Second, the existing research frameworks and methods can be extended to other related studies. Finally, these studies provide some guidance and policy suggestions for the improvement of urban environmental quality. However, several limitations still exist. Most scholars evaluate the whole city without distinguishing intraurban differences and few studies have focused on the livability at a finer spatial scale, such as residential communities, especially in China. Against the backdrop of rapid and extensive urbanization in China, "livability" is being given an increasingly higher priority by the Chinese government [28, 29]. Different from other countries, China's urban residential areas are composed of closed residential communities, which are determined by the historical development of China's urban residential mode. The residential community is a complete residential area divided by urban roads and not crossed by traffic arteries. Generally, a residential community has supporting facilities to meet the daily life needs of residents [30–33]. With urban sprawl and the emergence of urban centers and various subcenters, the disparities of the livable degree among different residential communities become increasingly prominent within each city. Furthermore, residents' material living standards are constantly improving, and their requirements for living conditions have also been raised simultaneously. It is necessary to study urban livability at the community level. On the other hand, human requirements and perceptions of living environment are highlighted in the connotation of livability. They are obviously diverse due to the different characteristics and preferences of residents. Although some researches evaluate livability from a subjective perspective, there are few studies that consider the various preferences of different groups.

Therefore, it is essential to assess the urban livability at the community level. Inspired by the theoretical framework and research methods of the abovementioned research, this paper attempts to address a crucial question: how can a comprehensive evaluation framework be established to measure the community livability considering both the objective environment factors and residents' subjective preferences? Then, the proposed evaluation framework will be applied to a specific city to obtain some empirical research results and policy implications.

The remainder of this paper is arranged as follows. Section 2 introduces the study area, the data collection, and the evaluation methods including indicator selection, indicator quantification, weight determination, and indicator integration. Section 3 describes the main findings and further discussion. Finally, the conclusions are presented in Section 4.

2. Materials and Methods

2.1. Study Area. We selected 1,394 residential communities of Ningbo, the subprovincial city in Zhejiang Province, as a case study to evaluate their livability. By 2018, Ningbo had a total area of 9,816 km², with a built-up area of 345.49 km², a permanent population of 8,202,000, an urban population of

5,979,300, and an urbanization rate of 72.9%. Situated in the middle of the southeast coast of China, Ningbo is a celebrated harbor city with a subtropical monsoon climate and four distinct seasons. The landscape in Ningbo is mostly flat with few hills, located on the alluvial plain in the Yangtze River Delta region. These advantages of climate and terrain make Ningbo one of the most livable cities in China [28, 34, 35]. In the past several decades, Ningbo has experienced rapid industrialization and urbanization processes with great urban sprawl. Simultaneously, sustained economic growth and massive populations have put tremendous pressure and challenges on living environment. Therefore, local government and residents are eager to understand and improve the urban livability, especially at community level.

Ningbo is divided into eleven administrative districts, and six districts including Jiangdong, Jiangbei, Haishu, Zhenhai, Beilun, and Yinzhou are in the center. In this paper, 1,394 residential communities in these six districts are selected as the evaluation object. Figure 1 shows the basic geographical condition of the study area and the location of 1,394 residential communities.

2.2. Data Collection. Four types of data are adopted in this research: (1) spatial data of 1394 communities obtained from national geographic conditions census; (2) social and economic data (e.g., air quality, residential density, and green area) collected from local statistical yearbooks or relative websites; (3) other geospatial data (e.g., educational facilities, recreational facilities, and traffic stations) collected from the Ningbo Municipal Planning Bureau and relevant departments; (4) questionnaire data used to characterize different preferences for living. 600 residents from six central districts of Ningbo are randomly selected to complete the questionnaire. We finally obtain 552 valid questionnaires; therefore, the effective return ratio is 92%.

2.3. Evaluation Methods

2.3.1. Conceptual Framework. There is no consistency on which aspects should be embraced to evaluate urban livability [7, 36]. Different criteria for and measurements have been proposed at different stages of economic development [11, 37]. For example, in 1961, the World Health Organization summarized the conditions for meeting the basic living requirements of human beings and proposed the ideal status of the living environment, namely, “safety, health, convenience, and amenity” [38, 39]. Similarly, the “China livable city science evaluation standard” was officially released in 2007 to guide the construction of livability. Its main contents include six aspects: social civilization, economic prosperity, beautiful environment, loadable resources, convenient life, and public security. The evaluation criteria of livable communities can refer to livable cities appropriately, since residential communities are the basic unit of urban-dwelling districts. Starting from the actual situation of the current urban residential communities in China, this paper proposes that a livable community should meet the

following five conditions: security of residence, health of the environment, convenience of transportation, completeness of supporting facilities, and comfort of living [40–42]. Consequently, we choose objective evaluation indicators from these five dimensions and combine different groups’ subjective preferences to build a comprehensive evaluation framework for livability at the community level, as shown in Figure 2.

2.3.2. The Establishment of an Evaluation Indicator System.

In the above five dimensions, safety is the primary criterion because it is the guarantee of residence. Safety means a good security situation, convenient emergency facilities such as fire, and refuge away from all kinds of dangerous facilities. Health follows, which implies that the residence is far away from air, water, noise, and other pollutions. Convenience is another important standard, whether for work or life. Good traffic conditions can minimize the commuting costs for daily work or other activities. Community surroundings should be equipped with education, health care, commercial services, leisure, and other facilities to meet various living needs. A livable community should also be comfortable. Pleasing greenery, an open view, and being close to beautiful natural scenery will significantly increase the comfort of living [43]. We do not consider the natural environment when evaluating the livability of the community as natural suitability is homogeneous within small districts, such as inner spaces of cities or towns [26].

There are some principles to follow when constructing an evaluation indicator system. (1) The selected indicators should be as objective and complete as possible. (2) The lowest level indicators should be measurable and comparable to facilitate quantitative analysis. (3) The data required by the indicators is easily accessible [7, 38]. Based on the local characteristics of Ningbo and the availability of data, eighteen indicators are selected from five aspects: security of residence, health of the environment, convenience of transportation, completeness of supporting facilities, and comfort of living. Then, a comprehensive three-level evaluation indicator system on the livability of residential communities is established, as illustrated in Table 1 [44–46].

2.3.3. Quantification of Indicators. The third-level indicators in the evaluation system can be divided into two categories: the indicators based on statistical data (e.g., residential density, plot ratio, and air quality) and the indicators related to geospatial data (e.g., accessibility of educational facilities, accessibility of medical facilities, and accessibility of landscape). We introduce different quantification methods to quantify them. For the statistical indicators, we calculate the values according to their definition and then use a min–max normalization method to transform the indicator into a value between 0 and 100, which can eliminate the impact caused by different magnitudes and provide a basis for the subsequent integration of multiple indicators. Specifically, some data on environmental quality, such as air quality, water quality, and solid waste pollution, is obtained on the scale of the administrative district. The interpolation analysis

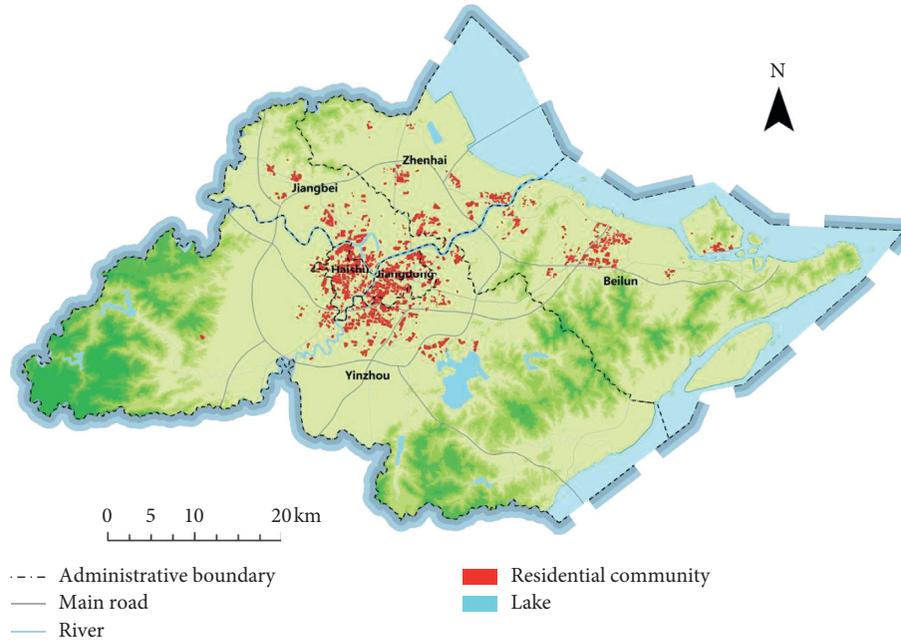


FIGURE 1: The basic geographical condition of the study area and the location of 1394 residential communities.

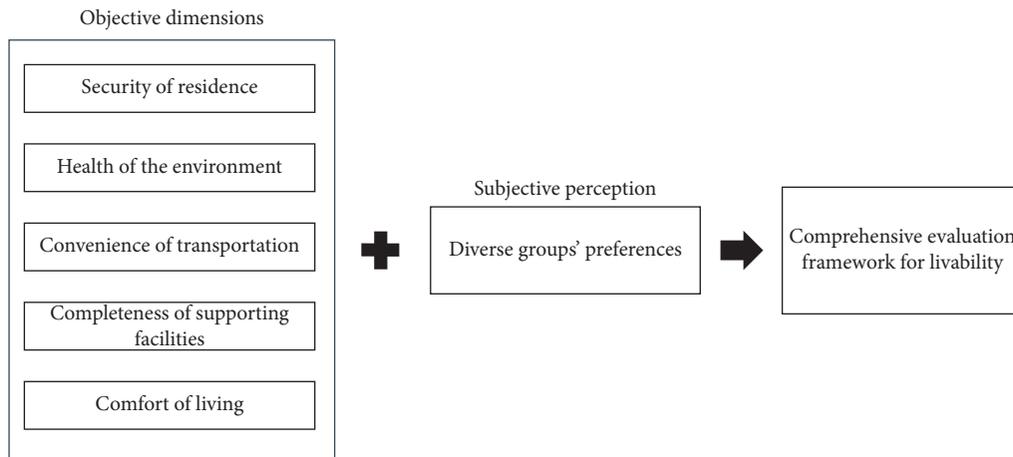


FIGURE 2: A comprehensive evaluation framework for livability at the community level.

is employed to obtain the value of each community on these indicators [16, 26]. Residential density is measured by the ratio of the households' number to the area of a community. Per capita green areas and per household parking also use a similar method of calculating the ratio. The normalization formula is as follows:

$$X_i^* = 100 \times \frac{(X_i - X_{\min})}{(X_{\max} - X_{\min})}, \quad (1)$$

where X_i^* is the normalized value for indicator X of community i , X_i is its initial value, X_{\min} is the minimum of indicator X , and X_{\max} is the maximum.

As for the indicators related to geospatial data, the geographic field model is applied to measure the accessibility of each type of geospatial factor (e.g., educational facilities) to each community, instead of traditional distance-based

measurements. The geospatial data used in the model calculation should include location information and attribute information. The basic principle of the geographic field model is described in the following. A spatial object, such as point, line, and polygon, has external influence on other adjacent objects. This external influence can be abstracted as a geographic field with a limited boundary. The degree of influence of the object on other objects, namely, the intensity of the geographic field, gradually decays from the origin to the surroundings. The intensity of a geographic field can be quantified by a function of distance, and there are some continuous function forms to measure these attenuation trends, such as a linear function, logarithmic function, and exponential function. The selection of function forms depends on the actual situation [47]. The original intensity is the highest value when the distance is zero, representing the

TABLE 1: The evaluation indicator system on the livability of residential communities in Ningbo.

First-level indicators	Second-level indicators	Third-level indicators
Livability of the residential community	(A) Security of residence	(A1) Accessibility of fire-fighting equipment (A2) Accessibility of emergency shelter (B1) Air quality
	(B) Health of the environment	(B2) Water quality (B3) Solid waste pollution (B4) Noise pollution
	(C) Convenience of transportation	(C1) Accessibility of public transportation (C2) Accessibility of private transportation (D1) Accessibility of educational facilities (D2) Accessibility of medical facilities
	(D) Completeness of supporting facilities	(D3) Accessibility of commercial service facilities (D4) Accessibility of recreational facilities (D5) Accessibility of other supporting facilities (E1) Residential density (E2) Per capita green areas (E3) Per household parking (E4) Plot ratio (E5) Accessibility of landscape
	(E) Comfort of living	

external influence ability of the object. The influence range is the maximum distance when the intensity of field becomes zero. Both the original intensity and the influence range are determined by the object's inherent attributes, including size, grade, type, and functionality [32]. In this paper, we adopt a linear distance-decay function due to its understandability [48–50]. The linear intensity function with a limited boundary is expressed as follows:

$$F(x) = T * (1 - r(x)),$$

$$r(x) = \begin{cases} \frac{d(x)}{R}, & d(x) < R, \\ 0, & d(x) \geq R, \end{cases} \quad (2)$$

where $F(x)$ is the field intensity at location x , T is the original field intensity and the function score of the object, $d(x)$ is the distance from x to the object, R is the influence range of the object, and $r(x)$ is the relative distance measure given by dividing $d(x)$ by R . F and R must be predetermined when computing the intensities of geographic fields. The computational progress of these parameters is described in the following, taking the educational facilities as an example.

Educational facilities are divided into three categories: kindergarten, primary school, and secondary school. Assume there are two kindergartens (K_1 ; K_2), a primary school (P_1) and a secondary school (S_1) around a community (C_1) (i.e., within a search radius of 5 km), as shown in Figure 3. The original field intensity T is calculated first according to their attribute value (e.g., size, grade, type, and functionality) by method of elements classification. Subsequently, we determine the value of R based on a similar approach. For example, secondary schools are divided into provincial key secondary schools, municipal key secondary schools, and general secondary schools. Referring to the local service radius planning standards for urban public facilities, the influence ranges R of provincial key secondary schools,

municipal key secondary schools, and general secondary schools are set to 2,000 m, 1,500 m, and 1,000 m, respectively. The R values of other facilities are similarly obtained. Then, the path distance d from C_1 to each school is obtained separately using ArcGIS. The calculated d of K_1 , K_2 , and P_1 is less than its corresponding R , which shows that C_1 is within the influence range of K_1 , K_2 , and P_1 , without S_1 . The relative distance r is calculated from the ratio of d and R . Then, we obtain the effect score F of each school on C_1 according to formula (2). Finally, the total influence degree of educational facilities on C_1 is determined by integrating the F values of K_1 , K_2 , and P_1 and normalized into $[0, 100]$. The other indicators based on geospatial data are also measured with the same process. The geographic field model comprehensively considers the distance between the object and the community, the influence capability, and influence range of the object itself, which can obtain more realistic and reasonable quantification results. The quantification result of eighteen third-level indicators on the 1,394 communities is an $18 * 1,394$ matrix, which is the basis for posterior indicator integration.

2.3.4. Weight Determination. The weights of indicators in this study are determined by residents' subjective perception. Our questionnaire consists of two parts. The first part is to inquiry the residents' personal information, including gender, age, education level, and family size, while the second part lists 18 third-level indicators in the evaluation system from five dimensions. Respondents are asked to evaluate the importance of indicators when measuring the livability of a community. Each indicator needs to be scored according to its importance, with a ten-point scoring system. The results of the questionnaires can fully reflect the differences in preferences of residents. In order to explore the regularity of differences, this research divided residents into three groups according to age. Since we require respondents to be at least 18 years old, the three groups are 18–30, 31–55,

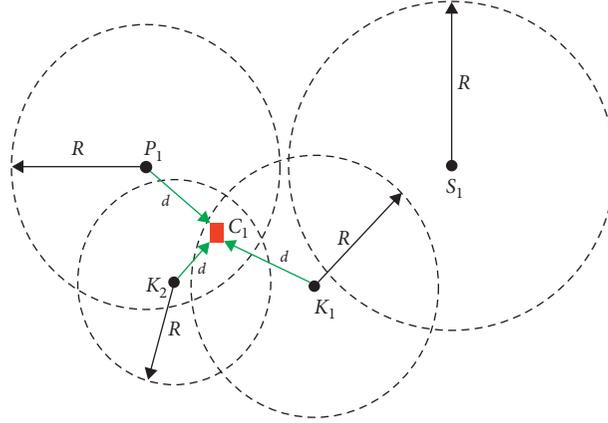


FIGURE 3: The combined effect of the educational facilities on a community.

and >55, named youth group, middle-aged group, and elderly group [24]. Then, the results of the questionnaire are counted based on these three age groups, and all S_{ij} are obtained, which represents the score of the j -th indicator in the i -th dimension in a certain group. Ultimately, the weights of the three-level indicators are calculated by formula (3), and the weights of the second-level indicators are gained by formulas (4) and (5):

$$W_{ij} = \frac{S_{ij}}{\sum_{j=1}^n S_{ij}}, \quad (3)$$

$$\text{SAVR}_i = \frac{\sum_{j=1}^n S_{ij}}{n}, \quad (4)$$

$$W_i = \frac{\text{SAVR}_i}{\sum_{i=1}^5 \text{SAVR}_i}, \quad (5)$$

where S_{ij} is the score of the j -th indicator in the i -th dimension, W_{ij} is the weight of the j -th indicator in the i -th dimension, n is the number of indicators in the i -th dimension, SAVR_i is the average score of the indicators of the i -th dimension, and W_i is the weight of i -th second-level indicator.

2.3.5. Indicator Integration. The general linear weighting method is embraced to integrate the indicators of all levels. The second-level indicators are calculated by formula (6) and the result is a $5 * 1,394$ matrix. Similarly, the first-level indicator, namely, livability index of each community, is obtained by formula (7):

$$S_i = \sum_{j=1}^n S_{ij} * W_{ij}, \quad (6)$$

$$L = \sum_{i=1}^5 S_i * W_i, \quad (7)$$

where S_i is the score of i -th second-level indicator, S_{ij} is the score of the j -th indicator in the i -th dimension, W_{ij} is the weight of the j -th indicator in the i -th dimension, L is the

livability index, and W_i is the weight of i -th second-level indicator.

3. Results and Discussion

3.1. Characteristics of Subjective Perception for Community Livability. The demographic characteristics of the respondents in 552 valid questionnaires should be illustrated. There are slightly more men (53.1%) than women (46.9%). Based on the age division method in this article, the youth group (18–30), middle-aged group (31–55), and elderly group (>55) account for 34.5%, 38.2%, and 27.3%, respectively. As for education level, the respondents with undergraduate degree or above are in the majority (58.9%). Additionally, 38.9% of respondents have a three-person family, while the proportions of two-person family, four-person family, and five-person family are 25.6%, 21.8%, and 13.7%.

The questionnaire results are classified according to the above three age groups, and we get the preferences of each group when measuring the livability of the urban community. The average value of the importance scores of the eighteen third-level indicators is calculated separately. Figure 4 shows the five most important indicators for each group. The youth group believes that the five most important conditions for a livable community are accessibility of public transportation (8.542), accessibility of commercial service facilities (8.065), accessibility of private transportation (7.852), accessibility of educational facilities (7.521), and being away from noise pollution (6.938), as displayed in Figure 4(a). For the middle-aged group, accessibility of educational facilities (8.346), accessibility of private transportation (7.964), accessibility of commercial service facilities (7.529), accessibility of public transportation (7.065), and per household parking (6.514) are the top five indicators (Figure 4(b)), while the elderly group considers that accessibility of public transportation (8.627), accessibility of medical facilities (8.221), air quality (7.735), accessibility of commercial service facilities (7.256), and accessibility of recreational facilities (6.795) are more significant (Figure 4(c)). It is found that these indicators are concentrated in the two dimensions: convenience of transportation and completeness of supporting facilities. Specifically, the

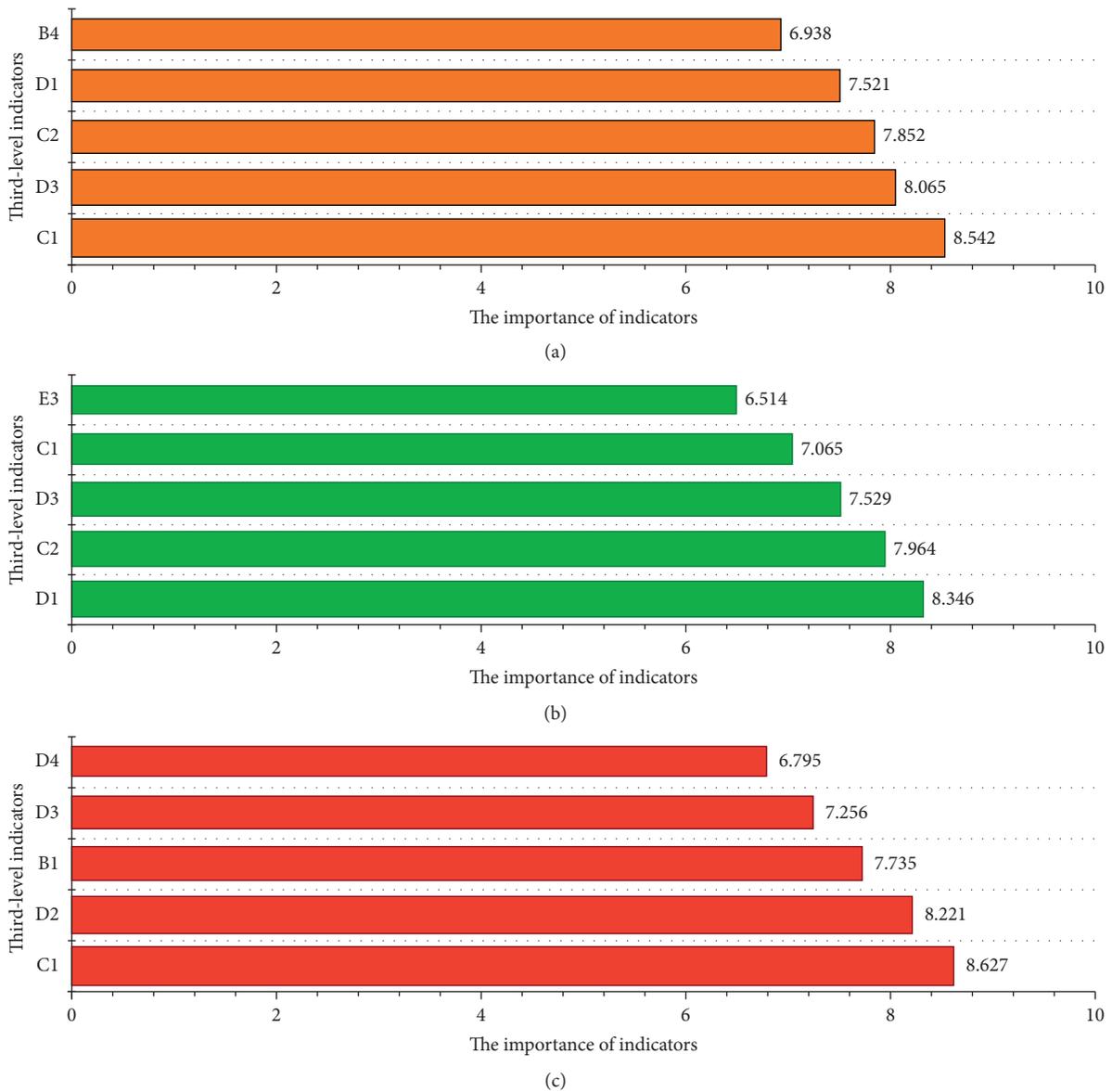


FIGURE 4: The five most important indicators measuring the livability of the urban community. (a) The preferences of the youth group. (b) The preferences of the middle-aged group. (c) The preferences of the elderly group.

youth group and the elderly group pay more attention to public transport accessibility, while the middle-aged group believes that private transport accessibility is more important. As for supporting facilities, the youth group emphasizes commercial service facilities, the middle-aged group focuses on educational and commercial facilities, and the elderly group prefers medical and recreational facilities.

3.2. Descriptive Analysis of Community Livability Based on the Preferences of Different Age Groups. The weights of three-level indicators and second-level indicators are demonstrated in Tables 2 and 3. After obtaining the scores of objective indicators and the indicator weights considering the preferences of different age groups, we calculate the value of the second-level indicators and livability index under each

group's preferences. In order to further analyze the difference of these indicators' values among areas, this paper counts the average value of the indicators according to the administrative district to which each community belongs. Figure 5 shows the statistical results under the preferences of each group. Specifically, based on the preferences of youth group, the average livability index of Jiangdong (72.28), Haishu (68.93), and Jiangbei (64.03) is significantly higher than the other three administrative districts. Among them, Zhenhai has the lowest livability index (53.82). For the average value of second-level indicators, there is no significant disparity in the two dimensions among districts: health of the environment and comfort of living. Instead, the average values of security of residence, convenience of transportation, and completeness of supporting facilities have obvious variations in different districts. Jiangdong has a relatively higher value

TABLE 2: The weights of three-level indicators considering the preferences of different age groups.

Third-level indicators	Youth group	Middle-aged group	Elderly group
(A1) Accessibility of fire-fighting equipment	0.5822	0.6028	0.6222
(A2) Accessibility of emergency shelter	0.4178	0.3972	0.3778
(B1) Air quality	0.2542	0.2739	0.2814
(B2) Water quality	0.2246	0.2558	0.2621
(B3) Solid waste pollution	0.2132	0.2249	0.2229
(B4) Noise pollution	0.308	0.2454	0.2336
(C1) Accessibility of public transportation	0.5829	0.4635	0.5734
(C2) Accessibility of private transportation	0.4171	0.5365	0.4266
(D1) Accessibility of educational facilities	0.2213	0.2934	0.1997
(D2) Accessibility of medical facilities	0.1822	0.2169	0.2828
(D3) Accessibility of commercial service facilities	0.3272	0.2557	0.2346
(D4) Accessibility of recreational facilities	0.1932	0.1814	0.2312
(D5) Accessibility of other supporting facilities	0.0761	0.0526	0.0517
(E1) Residential density	0.2236	0.1833	0.2004
(E2) Per capita green areas	0.2132	0.2218	0.2226
(E3) Per household parking	0.2024	0.2361	0.1641
(E4) Plot ratio	0.2086	0.1723	0.1964
(E5) Accessibility of landscape	0.1522	0.1865	0.2165

TABLE 3: The weights of second-level indicators considering the preferences of different age groups.

Second-level indicators	Youth group	Middle-aged group	Elderly group
(A) Security of residence	0.1418	0.1368	0.1547
(B) Health of the environment	0.1581	0.1529	0.1716
(C) Convenience of transportation	0.2612	0.2659	0.2369
(D) Completeness of supporting facilities	0.2534	0.2734	0.2414
(E) Comfort of living	0.1855	0.171	0.1954

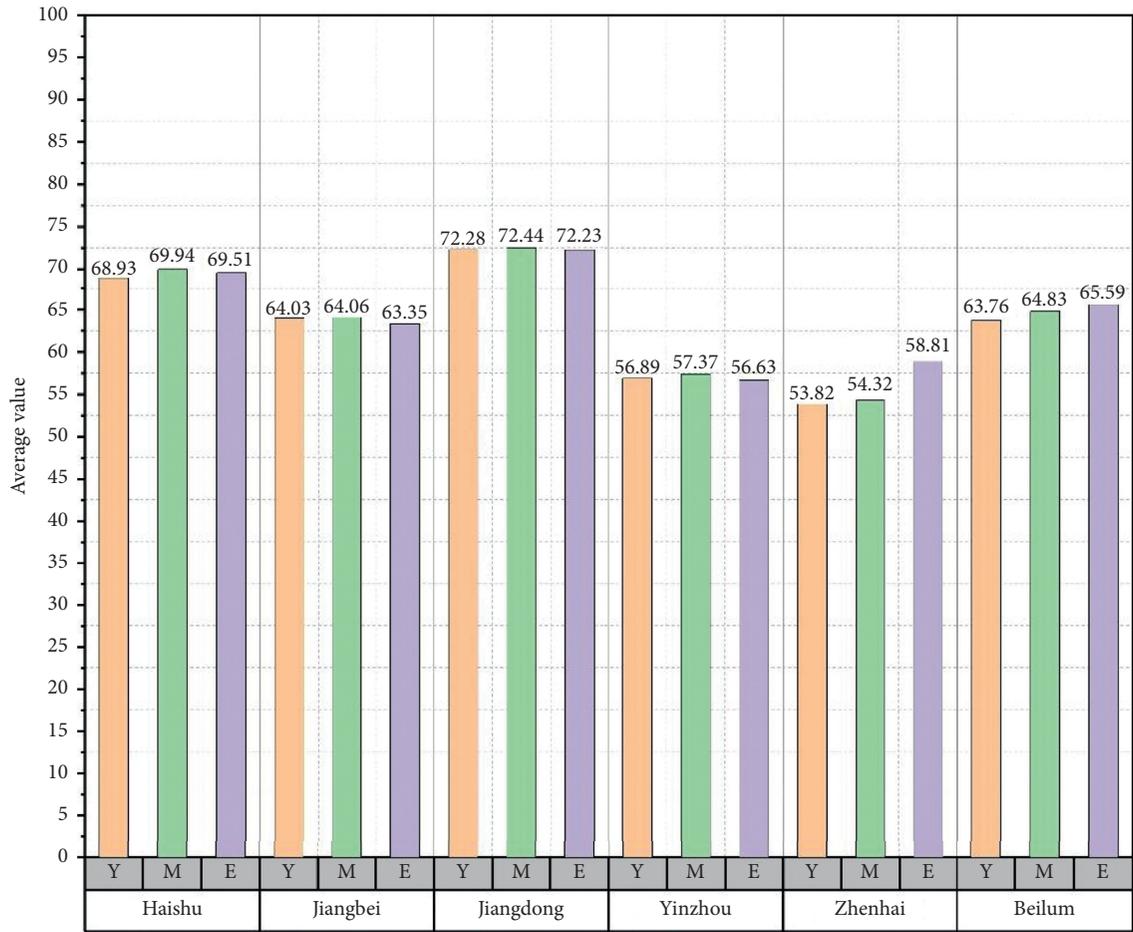
in these three indicators, while Yinzhou and Zhenhai have lower values and need more government attention to improve existing deficiencies. Based on the preferences of middle-aged group, the top three administrative districts in the livability index are Jiangdong (72.44), Haishu (69.94), and Beilun (64.83), and the last one is still Zhenhai (53.32). The variation rule of the second-level indicators is like the characteristics under the preferences of youth group. Moreover, based on the preferences of elderly group, the overall livability is better in Jiangdong (72.23), Beilun (65.59), and Haishu (69.51). And the worst district is Yinzhou (56.63), which is different from the results of the above two age groups. As for the five second-level indicators, except for completeness of supporting facilities, there are no particularly obvious differences of the remaining four dimensions' average value among six administrative districts.

3.3. Spatial Pattern of Community Livability Based on the Preferences of Different Age Groups. The communities are classified into five levels by the method of natural breaks according to their livability index. Natural breaks is a commonly used classification method that identifies the classification interval based on the inheritance properties of the dataset. Then, a similar value can be combined appropriately, and the difference among various categories can be maximized. The results of the classification are demonstrated in Table 4. It is shown that the proportion of

communities with livability at the second level is the largest, regardless of groups' preferences. If the first-level and second-level communities are defined as more livable communities, then under the preferences of the elderly group, the more livable communities account for the largest proportion (50.26%), followed by the preferences of the middle-aged group (44.15%) and the youth group (40.93%).

We use different colors to label the previous grading results on the map, respectively, as shown in Figures 6(a)–6(c). It can be observed that although the proportion of communities in each level varies with the diverse age groups' preferences, the spatial distribution of communities with different livability level has roughly the same pattern. The change of livability grade presents an obvious circular structure, and the livability declines from the city center to the surroundings. That is, despite groups' preferences, the communities located in the central district (e.g., Haishu, Jiangbei, and Jiangdong) are generally more livable, while those farther away from the center have relatively low livability.

3.4. Discussion. An ideal livable community should meet the requirements of all residences. It is necessary to consider the preferences of different groups when evaluating the livability of the community. Some meaningful findings in this study deserve further discussion. Firstly, the results of the questionnaire indicate that all groups attach great importance to



(a)

FIGURE 5: Continued.

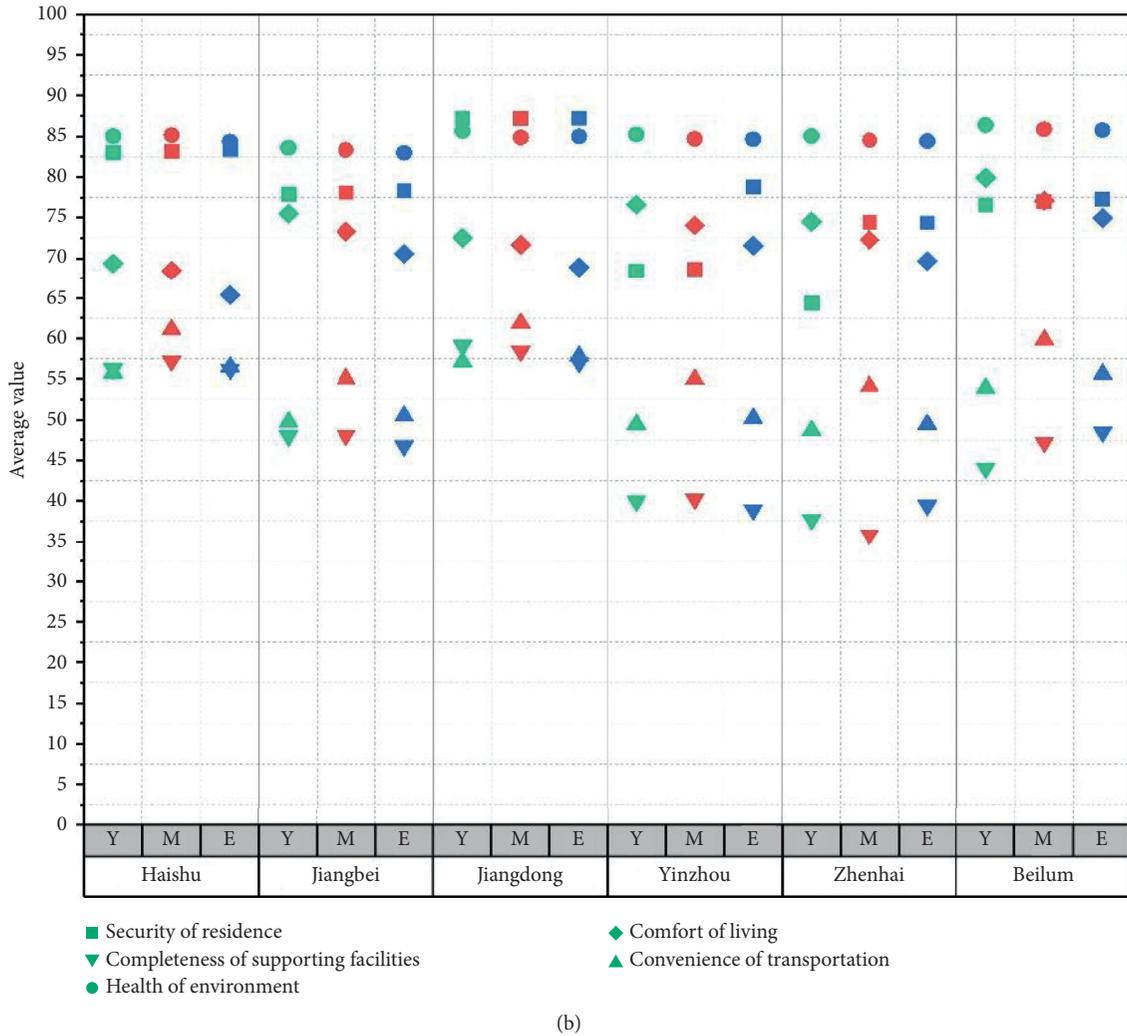


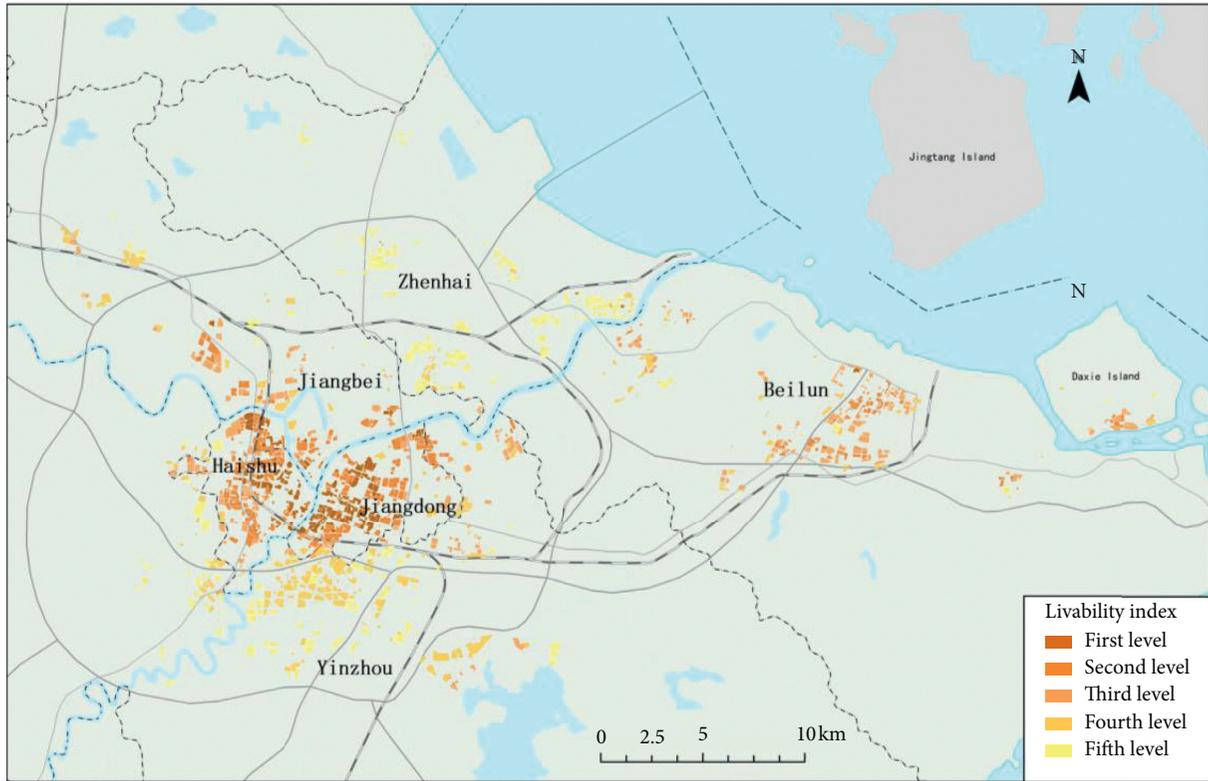
FIGURE 5: Average value of indicators for each administrative district considering the preferences of different age groups. *Y* represents the youth group, *M* represents the middle-aged group, and *E* represents the elderly group. (a) The average value of livability index. (b) The average value of second-level indicators.

TABLE 4: The classification statistics of the livability index considering the preferences of different age groups.

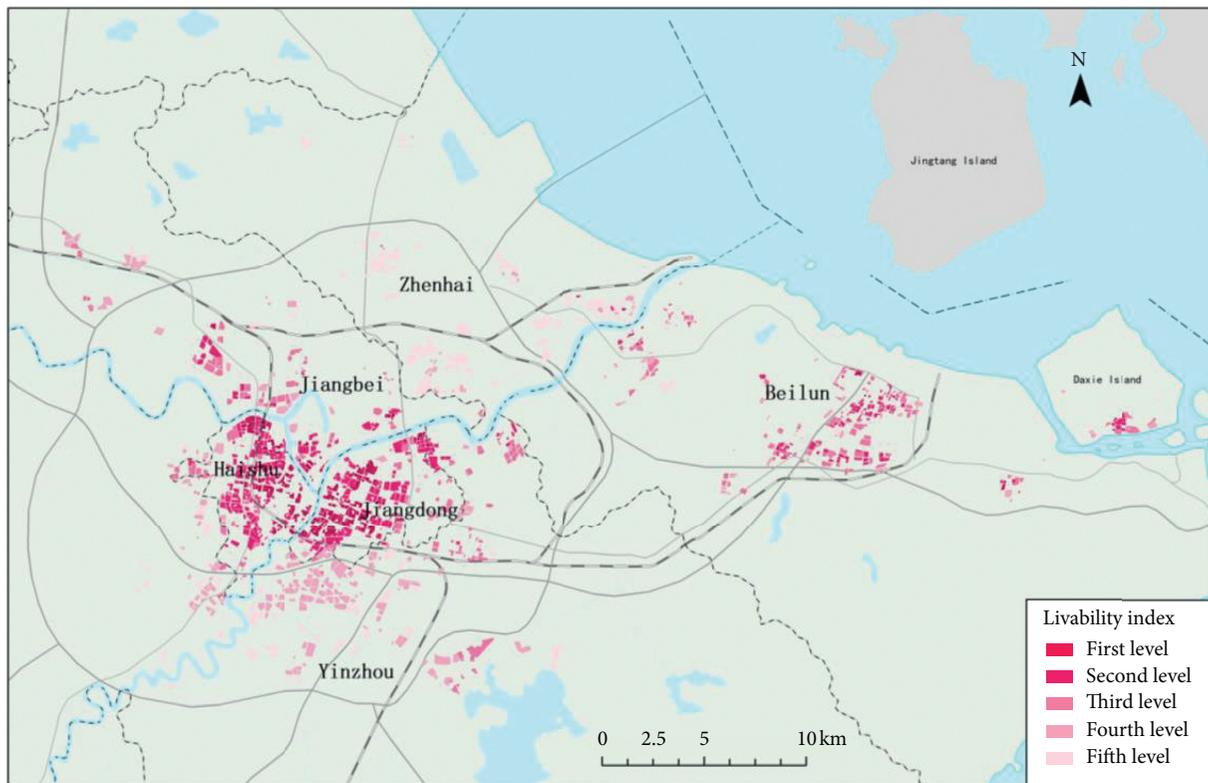
Grade	The preferences of the youth group		The preferences of the middle-aged group		The preferences of the elderly group	
	Livability index	Proportion (%)	Livability index	Proportion (%)	Livability index	Proportion (%)
First level	69.35–78.25	15.97	69.89–78.99	16.17	68.76–78.53	19.47
Second level	64.21–69.34	24.96	64.30–69.88	27.98	62.86–68.75	30.79
Third level	58.19–64.20	20.70	57.78–64.29	19.36	56.12–62.85	16.88
Fourth level	50.83–58.18	19.68	50.13–57.77	19.68	48.83–56.11	18.76
Fifth level	36.12–50.82	18.69	34.02–50.12	16.81	35.56–48.82	14.10

the convenience of transportation and completeness of supporting facilities. This finding is consistent with the actual situation since these two aspects are strongly involved in residents' daily lives [12, 51]. The daily commute time depends largely on the location of the residential community and its surrounding traffic conditions. Among supporting facilities, commercial service and educational and medical facilities are preferred by residents. Due to the uneven

distribution of educational resources and school district division systems, many urban families in China, especially those with minor children, focus on the accessibility to high-quality schools when selecting a satisfying community [52]. Secondly, under any kind of group' preferences, there is a great heterogeneity for the livability of communities in different administrative districts. The same difference also appears in some second-level indicators (e.g., convenience of

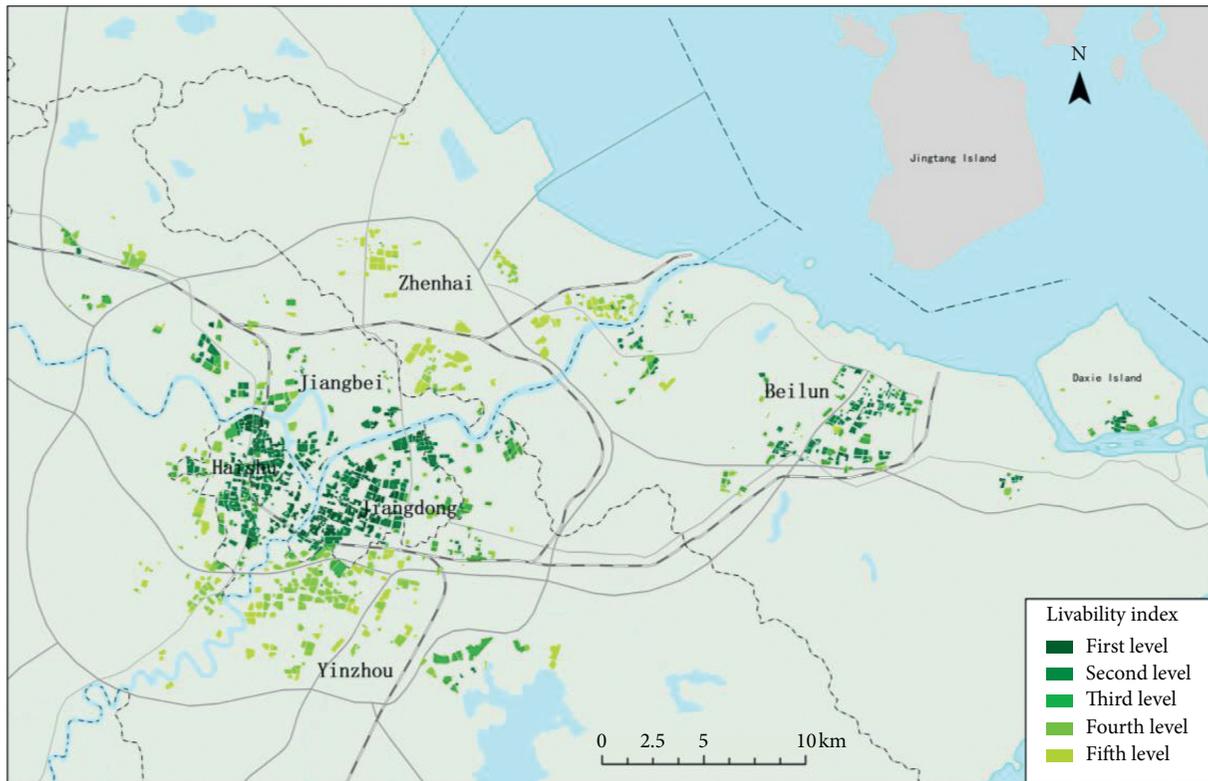


(a)



(b)

FIGURE 6: Continued.



(c)

FIGURE 6: The spatial distribution of communities with different livability levels. (a) The preferences of the youth group. (b) The preferences of the middle-aged group. (c) The preferences of the elderly group.

transportation and completeness of supporting facilities). These results help to provide indicative policy suggestions to improve overall livability. In addition, despite groups' preferences, communities at different livability levels have approximately the same spatial pattern (i.e., circular structure). This pattern is basically consistent with the distribution of urban housing prices [32]. The possible explanation is that the community in the urban center has convenient transportation conditions and complete supporting facilities. The weight of these two dimensions is also high based on the actual residents' preferences. Combining higher scores of objective indicators and larger weights of subjective perception, communities located in the central area have a higher livability index.

Findings in this paper have several significant policy implications. Primarily, the government should focus on more microscales, such as the community scale when considering the urban livability. Constructing the livable communities and achieving a coordinated development of the economy and people's livelihood are the foundation of building a livable city. Then, the individual needs of residents and the preferences of different groups should be valued. In the process of planning and constructing a livable community, it is essential to combine objective environmental elements with the subjective feelings of the residents, which could be more conducive to the realization of people-oriented livability. Residents can also benefit from

participation as they could choose ideal communities based on their actual requirements and preferences. Moreover, the government should pay more attention to the significant heterogeneity of different administrative districts in the overall livability and some secondary dimensions. The strengths and weaknesses of each community are identified and some targeted measures could be taken to make up for the defective communities or districts. Specifically, it is necessary to continue to increase investment in infrastructure and public facilities, not only to increase the quantity but also to strengthen the quality of construction [38, 53, 54]. The spatial differences should be highly appreciated when planning and laying out some important facilities. We recommend that high-quality public resources should be shifted towards resource-scarce areas to promote spatial justice and social equity. The improvement of some auxiliary facilities in numbers and functionality can effectively promote residents' living quality in noncentral areas. For example, the government should create rational plans to improve transportation conditions and various public resources (e.g., education, medicine, and commercial services) in Yinzhou and Zhenhai to enhance their livability.

Several limitations of this study should be mentioned and the future research will focus on the following topics. First, when measuring the preferences of residents, this article divides the groups based only on the age of respondents. In the follow-up research, other demographic

characteristics will be employed for classification, in order to understand the different living needs more comprehensively. Second, due to restrictions in the availability of data, intercity comparison or the evolution of livability for a certain city is not considered. Future research should explore more analysis patterns for urban livability with the purpose of providing a reference for regional planning and development.

4. Conclusions

Microscopic livability evaluation is an important research direction in the field of urban livability. In this paper, we attempt to evaluate the quality of living environment at the community level. Based on the geospatial data and relevant statistical data, we select eighteen indicators from five dimensions to establish an objective indicator system. Considering the diverse groups' preferences, a comprehensive evaluation framework for the livability of communities combining subjective perceptions and objective indicator system is constructed. Then, this framework is applied to 1,394 residential communities in Ningbo, to obtain some significant findings. This study has some contributions to the existing research area.

First, this paper focuses on the finer scale of environmental quality and selects the residential community as the object to evaluate and analyze its livability, which is in accordance with the inevitable tendency of the living environment from macro to micro. Second, we proposed an integrated evaluation framework which takes both the objective environment factors and residents' subjective preferences into account. This methodological framework has good scalability and operability, which not only enriches the theoretical connotation of the urban livability field but also has great practical application value. In the case of available data, the comprehensive evaluation framework can be applied to more cities such as Ningbo. As for the indicator quantification, objective geospatial data and statistical data are involved, and different methods are adopted. Specifically, we introduce the geographic field model to quantify the indicators based on geospatial data. This quantitative method considers the distance between the community and the facilities and the influence ability of facilities themselves determined by their inherent attributes (e.g., size, grade, type, and functionality). Compared with conventional methods (e.g., typically distance-based measures), the geographic field model can obtain more persuasive and realistic results, which can be introduced to other indicator quantifications. Furthermore, applying the framework to evaluate the residential communities in Ningbo, some meaningful results are acquired. (1) Different age groups have diverse preferences of demands for the livability of an urban community. The indicators they valued most concentrated in the two dimensions: the convenience of transportation and the completeness of supporting facilities. (2) Under the preferences of each age group, there exists significant heterogeneity in the overall livability and the performance of some secondary indicators of the communities among districts. (3) Despite groups' preference, communities at

different livability levels have approximately the same spatial pattern (i.e., circular structure). These empirical results can provide insight for relevant policy formulation and residence choice.

Data Availability

The data cannot be shared at this time as the data also forms part of an ongoing study.

Conflicts of Interest

The authors declare no conflicts of interest.

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