Research Paper

The construction of the dynamic index system of livable cities based on big data

--taking the construction of livable cities in Zuhai as an example

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Abstract

The traditional evaluation method of livable cities is based on statistical indicators. In the era of big data, the construction of smart cities needs to achieve a high-dimensional breakthrough with the help of "Internet +". Based on the big data such as cell phones, cabs and network information, together with the basic urban information data such as urban land use and planning management, this study focuses on the calculation method of dynamic livability index based on urban spatial big data to provide a new perspective and method for livability evaluation. The method of constructing dynamic livability index system based on big data and its practical application are also elaborated with the example of livable city construction in Zhuhai, which provides support for refined urban governance and intelligent management in Zhuhai.

Keywords

Big Data, Livable index, Index system, Zuhai

1. Introduction

Today, as the economic situation in cities continues to improve, the overall quality of the environment is declining and the threat to natural systems is increasing, and urban habitat is under great pressure. On the other hand, people are more and more concerned about the quality of living environment, and creating a good living environment is both a social ideal and a basic need of people's life. Therefore, the study of livable city construction has important theoretical significance and practical value. Since promoting the construction of ecological civilization is proposed, various measures have been taken from the central to the local level to improve the ecological environment, and each city has also adopted various projects to improve the quality of human living environment and make the construction of livable cities an important part of the construction of ecological civilization.

For a long time, extensive research has been conducted at home and abroad on the urban evaluation index system of livability. Internationally, in 1974, David Smith advocated the importance of livability in his book Livability and Urban Planning, and proposed three indicators for evaluating the livability of cities: first, public health and pollution problems; second, comfort and living environment; and third, historical architecture and natural environment [1]. In 1995, Knox evaluated six categories of influencing factors in people's living and living environment: aesthetics, accessibility and circulation, noise, neighborhood, safety, and annoying things [2].In 1998, Gideon E.D. Omuta, regarding the quality of community life in Benin, the capital of Nigeria, proposed housing, education, employment, negative events, public facilities and services, economic and social The economic and social factors include the socio-economic development of the city. The economic and social factors include the level of socio-economic development, the size and structure of the population, and the development of health care, education and health [3]. In 2004, a think tank of British economists selected five categories of urban livability evaluation indicators, including social stability, health, culture and environment, education quality, and infrastructure, and more than 40 factors [4], which is more complete and detailed than the previous research system. In 2014, the "Best City to Live in" index developed by the American Association of Middle Aged Persons included seven aspects: housing, health, environment, proximity to work, transportation, job opportunities, and social participation [5].

In 1999, Ning Yue-min selected three categories of living conditions, ecological environment quality, and infrastructure and public services, and 19 evaluation indexes such as per capita living area and greenery coverage, which were subdivided into these three categories to quantitatively evaluate Shanghai [6]. In 2004, Zhou Zhitian analyzed and measured the livability level of 50 major cities in China in detail by selecting 18 specific indicators from 6 aspects, such as economic development potential index and ecological environment index [7]. In 2006, the Chinese Society for Urban Science published the Scientific Evaluation Criteria for Livable Cities, which specified six items such as social civilization and economic affluence as the first-level indicators in the livable city index system, and was the first national evaluation criterion for livable cities in China [8]. However, this standard is only used as a guiding scientific evaluation standard, not a mandatory administrative technical standard. In the same year, the Ministry of Construction promulgated the reference index system of China Habitat Award, including 14 quantitative indicators and 25 qualitative indicators [9]. In the same year, Zhang Wenzhong studied and evaluated the safety and health of the city from the perspective of residents' life and living environment in his book "Research Report on Livable Cities in China (Beijing)" [10]. In 2008, Li Jiafei took six indicators such as humanistic environment and safety environment as livability evaluation indicators and evaluated Dalian city [11]. in 2009, Dong Xiaofeng selected five categories of indicators such as safety and happiness as the evaluation indicators of urban livability based on a large amount of statistical data [12].

2. Problems of the traditional livable city evaluation index system

Although the existing livable city evaluation index system has comprehensively and systematically constructed the framework of international livable city index system, which provides good support for the construction of livable cities.

However, with the advent of the era of big data, the construction of smart cities needs to achieve a high-dimensional breakthrough with the help of "Internet +". The existing livable city evaluation index system assesses the whole city, and does not describe the variability of livability indicators over time. The assessment of livability basically treats the city as a static point, and the assessment indicators are often "one number for the whole city, one number for the whole year", which does not go deep into the city and makes it difficult to propose targeted improvement measures.

(1) Residents in cities are the most direct perceivers of the good or bad of urban construction, and the purpose of urban construction is to make the residents' life comfortable. Therefore, whether a city is livable or not is mainly reflected in the residents' satisfaction with the city, and there are not many literature about the residents' satisfaction with the livability of the city, and few studies start from the livelihood indicators that citizens are concerned about.

(2) The existing livability index systems and city rankings are numerous, but they are mostly evaluated in terms of cities as a whole. The existing livability indicator systems do not study the livability of cities in detail, especially the internal differences, and do not describe the variability of the livability indicators over time. The livability assessment basically treats the city as a static point, and the assessment

indicators are often "one number for the whole city, one number for the whole year", without going deeper into the city, making it difficult to propose improvement measures in a targeted manner.

(3) Traditional livability evaluation methods are based on statistical indicators, but in the era of big data, smart city construction needs to achieve a high-dimensional breakthrough with the help of "Internet+". In terms of livability evaluation methods, most of the existing index systems are based on data reported by departments and questionnaires from research groups. Very few of the data are calculated by the basic information of the city. With the popularity of big data such as cell phones, cabs and network information, together with the data of urban basic information such as urban land use and planning management, we can provide new perspectives and methods for livability evaluation through modeling and calculation.

3. Problems of the traditional livable city evaluation index system

Based on the above analysis of the problems of the traditional livable city evaluation index system, this paper attempts to elaborate the preliminary idea of constructing a dynamic index system of livable city based on big data through the example of the construction of livable city in Zhuhai. Zhuhai is one of the first 90 pilot smart cities by the Ministry of Housing and Construction, and has formulated documents such as "Zhuhai Smart City Construction Master Plan (2013-2020)", "Zhuhai Smart City Construction Recent Action Plan (2013-2015)" and "Smart Zhuhai 2015 Action Plan".

3.1. Current Development of Zhuhai City

Zhuhai is one of the four special economic zones initially established in China, located in the southwestern coast of the Pearl River Delta, northeast of Shenzhen and Hong Kong across the sea, south and Macao land connected, northwest and directly west adjacent to Jiangmen City, north and Zhongshan City, 140km from Guangzhou, is both the main outlet to the sea in the West River basin, but also an important port of China's external links. Zhuhai has a land area of 1,701km^2 and a sea area of 6,135km^2. At the end of 2009, the city had a resident population of 1,491,200, of which 1,026,500 were registered, making it the smallest city in Guangdong Province among the 21 prefecture-level cities in terms of population size and land area. According to the data of the seventh census, the resident population of Zhuhai was 2,439,850,000(deadline is 00:00 on November 1, 2020).

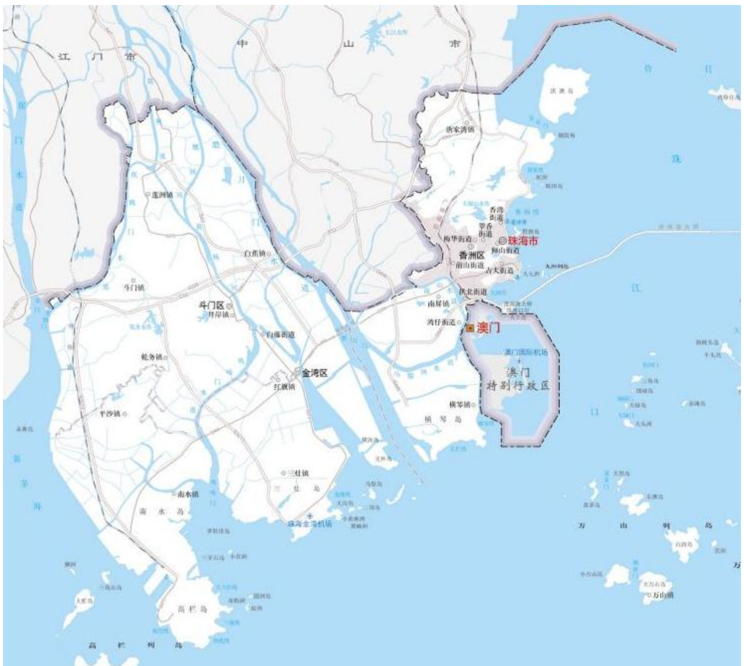


Figure 1. Zhuhai City Administrative Map. Source: Internet.

3.2 Background of livable city construction in Zhuhai

Zhuhai attaches great importance to the construction of ecological civilization, always adheres to the development path of economic development and ecological protection, and has put forward the development requirements of environmental livability comparable to those of advanced countries in Europe and the United States under the new situation, and strives to build a model city of beautiful China. In terms of overall strategy, Zhuhai has issued policies and programs such as the Decision on Implementing the New Urbanization Strategy and Building an International Livable City and the Work Plan for Reforming the Ecological Civilization System in Zhuhai. The plan is to build Zhuhai into an international livable city in three steps, basically approaching an international livable city by 2020, and basically building an international livable city in 5-10 years.

At the same time, Zhuhai attaches importance to the application of big data and smart city construction, and Zhuhai is one of the first 90 pilot smart cities of the Ministry of Housing and Construction. It has also formulated documents such as "Zhuhai Smart City Construction Master Plan (2013-2020)", "Zhuhai Smart City Construction Recent Action Plan (2013-2015)" and "Smart Zhuhai 2015 Action Plan", which focus smart city construction on transportation, industrial development, city management, social services, cultural heritage and talent convergence. By creating a wisdom service center, deepening the theme of wisdom applications, building wisdom service channels, consolidating information infrastructure and other tasks and work, as well as intelligent transportation construction project, geographic information platform construction and other ten key projects to achieve wisdom management, wisdom services, so as to achieve the goal of building a beautiful and livable city. In the construction of smart city, the acquisition and application of big data occupies an important position. The construction of smart city platform helps to obtain and integrate a large amount of urban static data and spatial data of urban operation status such as traffic travel, population distribution, urban microclimate and urban environment. It provides data support for urban planning and management with high spatial and temporal resolution, helps to realize the refinement and dynamization of urban planning and management, and provides the basis for decision making for the construction of an international livable city. At the same time, the construction of livable Zhuhai and the implementation of the relevant livability index also enriches the application field and depth of Zhuhai's big data, and adds an important component to the construction content of the smart city.

3.3 The "Zhuhai City Index System for Building an International Livable City" has been compiled

In November 2014, the Zhuhai Housing and Urban-Rural Development Bureau organized the preparation of the "Zhuhai International Livable City Indicator System", a comprehensive and systematic study of the livable city construction target system conducted by the Ecological City Planning and Construction Center of the China Urban Science Research Association (hereinafter referred to as "CUSR"). The CUSR proposed the structure of the index system with the overall objectives of "ecological safety and sustainability, compact and pleasant space, green and smooth travel, quality and shared services, social peace and harmony, low carbon and innovative economy, and international diversity of humanities", covering all elements of environmental, economic and social development. At the same time, through a scientific index system research process, a set of index system including 7 major objectives, 35 implementation paths and 70 specific indicators was formed to comprehensively and systematically guide and evaluate the progress and level of the construction of a livable Zhuhai.

Data on 70 indicators in seven major areas were collected through a series of channels, of which 49 of the 70 indicators were obtained through official statistics and analysis, including official statistics, including Guangdong Province and Zhuhai Statistical Yearbook, Zhuhai Statistical Information Network, as well as statistics and various indicator system data available from various departments and district governments in Zhuhai. Public satisfaction rate of urban environmental protection, satisfaction rate of urban landscape control, average commuting time, satisfaction rate of governmental environment, happiness index of residents, satisfaction rate of barrier-free facilities, and satisfaction rate of tourists are 7 indicators that need to be obtained through relevant questionnaire surveys. The following 14 indexes need to be analyzed and calculated using big data, CAD, GIS spatial analysis, etc.: forest coverage, proportion of ecological protection land to national land area, naturalization rate of water bodies' shorelines, proportion of areas close to nature within a 10-minute walk, average block length, coverage rate of sidewalk boulevards, coverage rate of park green space service radius, development rate around TOD model, road network density, density of slow traffic line network, coverage rate of 300-meter service radius of bus stops, connection rate of self-confidence car rental points at bus stops, coverage rate of 10-minute public cultural and sports service circle, coverage rate of emergency disposal radius of emergency evacuation sites.

3.4 Problems of the existing Zhuhai livable city index system

The "Zhuhai International Livable City Index System" has been compiled to comprehensively and systematically construct the framework of Zhuhai's international livable city index system, giving the indexes for building an international livable city in seven aspects, including humanistic international diversity, compact and pleasant space, ecological safety and sustainability, green and smooth travel, quality and shared services, low-carbon and robust economy, as well as peace and harmony of values, to provide good support for the construction of a livable city. The index system provides a good support for the construction of livable cities. Although the index system provides a good basis for this study and a framework for livability assessment, the index system assesses the livability of Zhuhai as a whole city and does not describe the variability of livability indicators over time. It is difficult to propose improvement measures in a targeted manner.

4. Construction of Ten Livable Zhuhai Livelihood Indicators Based on Big Data - An Example of Livable City Construction in Zhuhai

4.1. The idea of constructing the indicator system

“The Indicator System for Building an Internationally Livable City in Zhuhai” gives indicators for building an internationally livable city in seven aspects: humanistic international diversity, compact and pleasant space, ecological safety and sustainability, green and smooth travel, quality and shared services, low-carbon and robust economy, and peace and harmony of values. This study takes the index system compiled by the Urban Science Council as the basis and framework of the study, and combines the characteristics of big data to evaluate the existing indexes from several aspects, so as to lay the foundation for the selection and establishment of the indexes in this study. In view of the shortcomings of the existing indicator system, which is "one number for the whole city and one number for the whole year", the ten livelihood indicators of livable Zhuhai based on big data are reconstructed, and the following three aspects are considered in the selection and construction of the indicator system: (1) feasibility: to identify the indicators that can be calculated by applying big data or pan-big data, and to give data sources and ideas for calculation of indicators. (2) Necessity: Identify the indicators that can improve the quality or reduce the difficulty of acquisition after applying big data decomposition and calculation; (3) Operability: Identify the indicators that can be calculated at this stage and on the basis of existing data information.

4.2. Indicator System Components

This study combines citizens' concerns and the functions of urban space management of the planning department, focusing on four aspects: ecology, space, travel, and services to construct ten livelihood indicators. Considering the typicality of the indicators and data availability, 2-3 representative indicators were selected for each category. Some of these ten indicators directly correspond to one indicator of the City Science Council, some are translated from the indicators of the City Science Council, and some are composed of multiple sub-indicators. Indicator scores were converted to 0-100 based on the results of big data calculations after standardization.

No.	Category	Index Name	Index introduction
1	Ecology	Pleasant natural environment	Public satisfaction rate of urban environmental protection, PM2.5 monitoring concentration (annual average PM2.5 concentration), water quality monitoring data of water functional areas (water quality compliance rate of water functional areas).
2		Green space accessebility	Convenience of areas close to nature (proportion of areas within a 10-minute walk of nature), convenience of parks and green spaces (coverage rate of 500-meter service radius of parks and green spaces), coverage rate of pedestrian boulevards, density of slow mobility traffic network, naturalization rate of water bodies' shorelines.
3	Space	Convenient neighborhood activities	Neighborhood size (average block length), land use mix
4		Reasonable function layout	Radius of daily living circle of occupants
5		Comfortable commuting distance	Commuting distance (average commuting time)
6	Mobility	Smooth mobility	Road network density, real-time vehicle speed (average speed of public transportation during weekday peak hours)
7		Convenient use of public transportation	Public transportation as a percentage of motor vehicle travel, convenience of using bus stops (300-meter service radius coverage of bus stops), connection rate of bicycle rental points at bus stops
8	Service	Easy access to compulsory education	Convenience of primary and secondary schools (12-year free education coverage rate)
9		Convenient medical service	Convenience of access to health care (number of practicing physicians per 1,000 population, number of general practitioners per 10,000 population)
10		Satisfactory housing prices	Housing prices (housing price to income ratio)

Table 1. 10 Livable Zhuhai Livelihood Indicators Based on Big Data

4.3 Research data resource

The big data in this study includes not only the "big data" that the industry has generally agreed on, such as cell phone signaling, webpage crawling, location information of Baidu and Tencent, swipe card records, social networking site records, public transportation swipe card and traffic monitoring data. It also includes data with 5V characteristics - Volume, Velocity, Variety, Value, Veracity, and all data are analyzed and processed without the shortcut of random analysis method (sampling). However, the scale of data is not able to be called massive, urban basic information data related to urban planning and spatial management. We call it pan-big data, which mainly includes data on the status of urban land use, the scale and distribution of infrastructure and public services, and urban environmental monitoring.

4.4 Calculating index method

(1) Indicator standardization method

The comprehensive livability index multi-indicator evaluation method is to combine the information of multiple indicators describing different aspects of the evaluation object and obtain a comprehensive indicator, so as to make an overall judgment on the evaluation object and make horizontal or vertical comparison. In the multi-indicator evaluation system, due to the different nature of each evaluation index, it usually has different levels and orders of magnitude. When the level of each indicator differs greatly, if the analysis is carried out directly with the original indicator values, it will highlight the role of the indicators with higher values in the comprehensive analysis and relatively weaken the role of the indicators with lower value levels. Therefore, in order to ensure the reliability of the results, the raw indicator data need to be standardized.

Normalization of data is the scaling of data so that it falls into a small, specific interval. This is done in order to allow comparison and weighting of metrics of different units or magnitudes. Common methods are: Min-max normalization, log function conversion, atan function conversion, zero-mena normalization, and fuzzy quantization methods. The most typical ones are 0-1 normalization and Z normalization.

1) 0-1 normalization

Also known as outlier normalization, is a linear transformation of the original data so that the results fall into the [0,1] interval, the conversion function is as follows: $x^* = \frac{x - min}{max - min}$

One drawback of this method is that when new data are added, it may lead to changes in max and min, which need to be redefined.

2) zero-mean normalization

Also called standard deviation normalization, the processed data conform to the standard normal distribution, i.e., the mean is 0 and the standard deviation is 1. It is also the most commonly used standardization method in SPSS, and its transformation function is $x^* = \frac{x - \mu}{\sigma}$

(μ is the mean of all sample data and σ is the standard deviation of all sample data.)

Based on the comparison of the two methods and the need to compare the indicators horizontally and vertically in this study, the 0-1 normalization method was chosen for the calculation so that the standard values of each indicator were in the range of [0-1].

(2) Determination of indicator weights

The weight of an indicator refers to the relative importance of the indicator in the overall evaluation. When calculating the Zhuhai Comprehensive Dynamic Livability Index, each weight factor is given the same equivalent value.

(3) Multi-factor spatial superposition of indicators

When the basic spatial unit is determined and the same basic spatial unit is used for each index, the value of each individual index is available for each basic spatial unit and can be calculated directly according to the determined weights; when different basic spatial units are used for different individual indexes, the spatial overlay and spatial analysis functions are needed to extract multi-attribute information for each plot.

Through these two methods, all the index values of each basic spatial cell are obtained, and then standardization is used to determine the standard values of each individual index on the street and grid spatial cells, and finally the calculation is performed according to the determined weights. The standard values of all indicators under the same cell are summed and divided by the number of indicators, and then multiplied by 100 to arrive at the two spaces in the street and grid.

5. Index system result

5.1 Calculation result

According to Figure 2, it can be seen that the livability degree of each administrative center of Zhuhai is higher than that of the suburbs, and the livability degree of the marginal areas of the city is lower. On the whole, the livability index of people's livelihood in the central city of Xiangzhou is higher, while the livability index of people's livelihood in some areas of Doumen and Jinwan is lower, while in the two districts of Doumen and Jinwan, the livability index of the district and town center locations is relatively higher, which may be related to the fact that these areas have certain infrastructure and urban construction, and also have good natural conditions and ecological environment.

Shishan Street Office, Gongbei Street Office, Meihua Street Office, Cuihua Street Office and Jida Street Office have relatively high livability indicators for people's livelihoods in general, because these streets have a high mix of land use, suitable neighborhood size, and good infrastructure such as transportation and services, and residents have a relatively short commuting distance regardless of the small radius of the living circle. The Livability Index of Lianzhou Town, Nanshui Town, Pingsha Town, Qianwu Town and Doumen Town is relatively low, firstly, because of the unsuitable neighborhood scale and low land use mix; secondly, because the transportation facilities, education facilities and medical facilities are not well developed and unevenly distributed, resulting in a relatively large living circle radius and a relatively long commuting distance for residents.

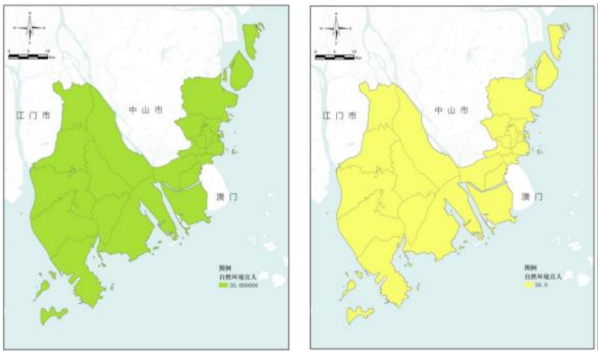


Figure 2. Well natural environment. Source: Author.

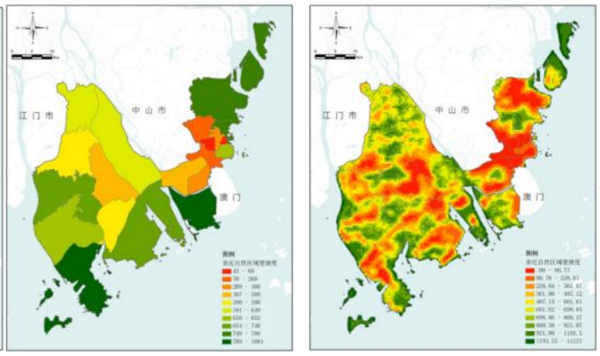


Figure 3. Accessable green space. Source: Author.

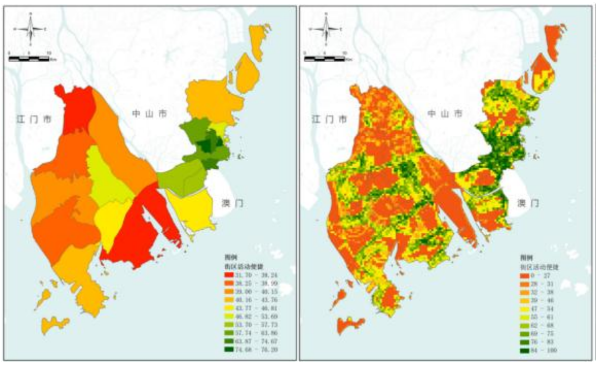


Figure 4. Convenient life in neighbourhood.

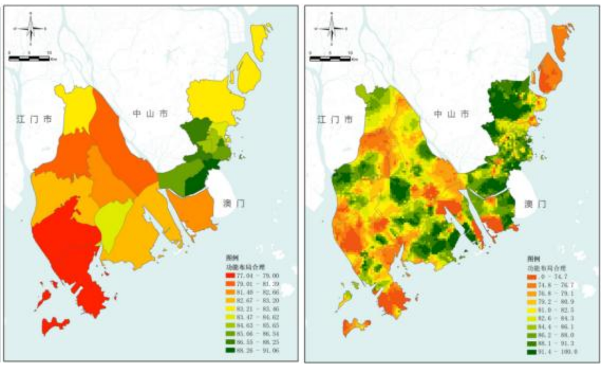


Figure 5. Reasonable land function layout. Source: Author.

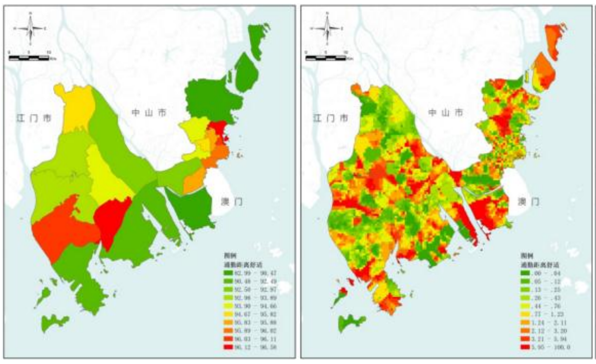


Figure 6. Comfortable commuting distance.

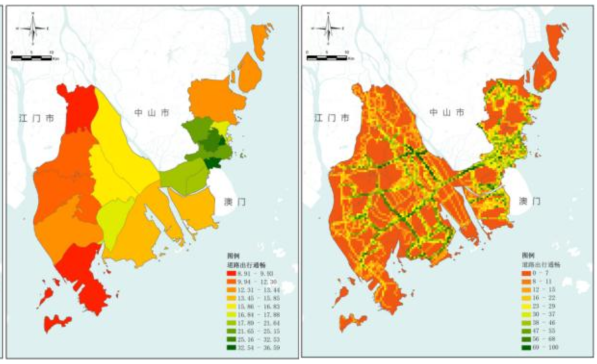
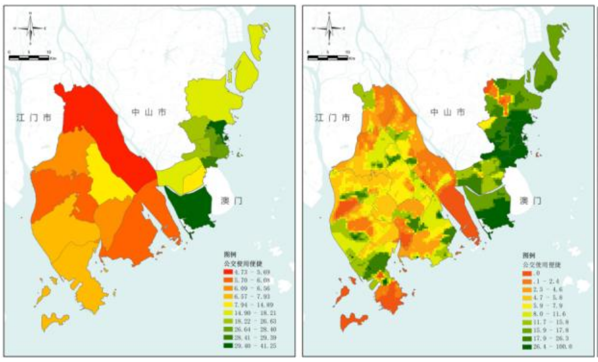


Figure 7. Smooth mobility. Source: Author.



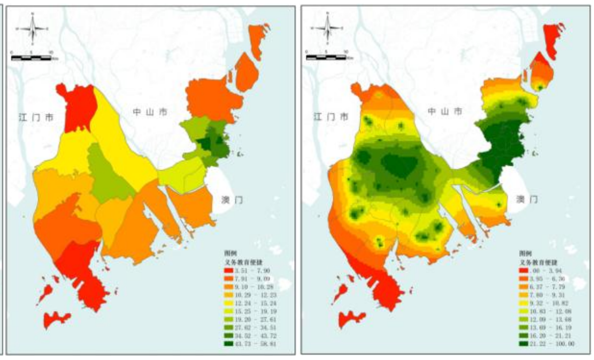
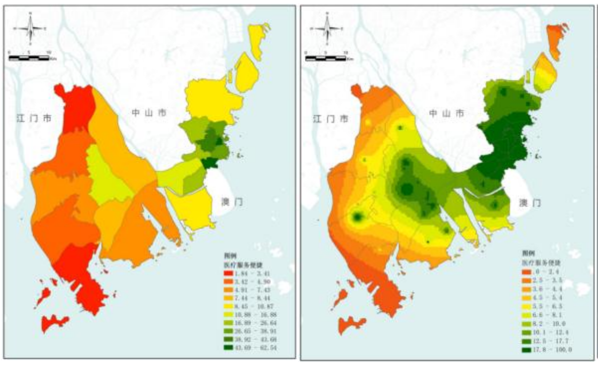


Figure 8. Convenient public transportation.

Figure 9. Convenient compulsory education. Source: Author.



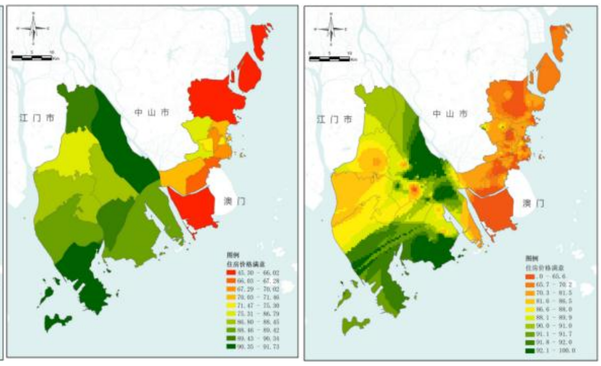
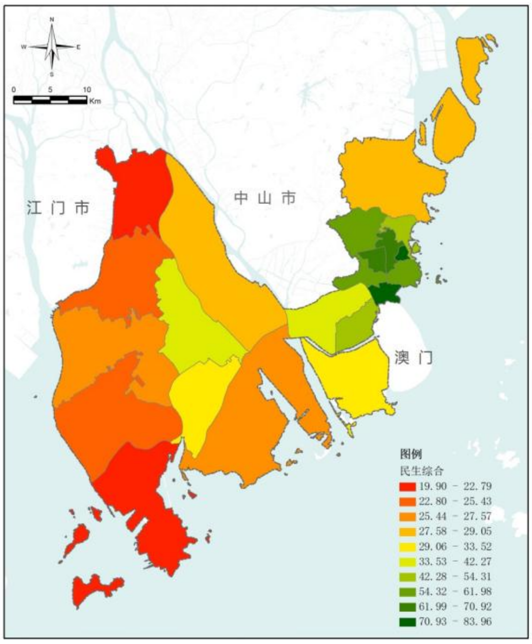


Figure 10. Convenient medical services.

Figure 11. Satisfing housing price. Source: Author.



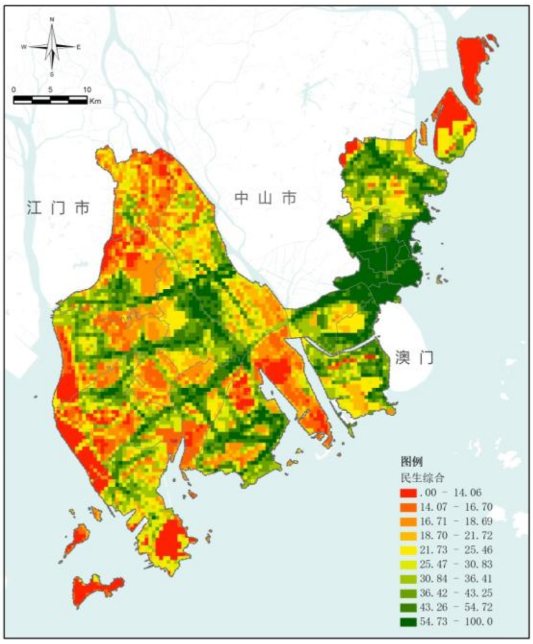


Figure 12. Comprehensive Livability Index (Street). Figure 13. Comprehensive Livability Index (Mesh) Source: Author.

5.2 Application of Index

Developing a decision support platform for individual citizens - Livability Map, such a platform can be developed and personalized based on a mobile app. For example, Mr. Pang's livability map, Mr. Pang's main concern is mainly the convenience of medical treatment for the elderly, the proximity of children to school, the unobstructed drive to work, and the ability to go to the natural environment with his family at ordinary times, for leisure and relaxation. These indicators were combined, and the results are shown in

Figure 15. For Mr. Pang, the eastern coastal area of Zhuhai is the most livable, the central central area is more livable, and most of the western area is not livable.

Figure 14. The platform of APP. Source: Author.

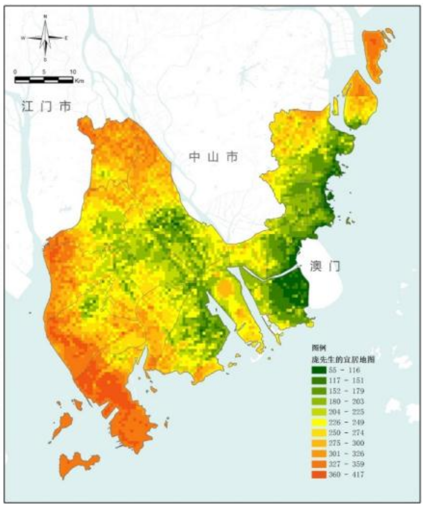


Figure 15. Mr.Peng's livability map.

6. Conclusion

By exploring a personalized platform that regularly publishes dynamic livability indicators of Zhuhai to the public, this study regularly publishes individual indicators related to people's livelihoods and the comprehensive livability index of Zhuhai to the public, providing support for the refined urban governance and intelligent management of Zhuhai. The innovation point is the combination of urban big data and livable city index system construction, which is a positive exploration of livable city construction but has yet to be tested in practice.

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