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A Spatial Distribution Equilibrium Evaluation of Health Service Resources at Community Grid Scale in Yichang, China

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Abstract: Whether the supplies of health services and related facilities meet the demand is a critical issue when developing healthy cities. The importance of health services and related facilities in public health promotion has been adequately proved. However, since the community population and resource data are usually available at the scale of an administrative region; it is very difficult to perform further fine-scaled spatial distribution equilibrium evaluation studies. Such kinds of activities are highly expected for precise urban planning and management. Yichang is located in Hubei province, the central part of China, along the Yangzi River. It is leading both of China's smart cities demonstration project and China's healthy cities pilot project. Yichang has defined 1271 community grids for urban management and service, where each grid consists of 200 households generally with its population distribution data routinely updated. The research set the 15-min walking distances of the residents as impedance factors, and the numbers and the types of health service resources as attractiveness factors for accessibility evaluation. The resource ratio, richness and per capita number of various health service resources that can be reached within 15 min from the community grid building is used as spatial distribution equilibrium evaluation indicators. The entropy weight method is used to assign the indicator weight value. The obtained fine-scale evaluation results were analyzed. In this way, a community grid-scale spatial distribution equilibrium evaluation of health service resources in Yichang was performed. The proposed research could be of value for rapid and precise evaluation of spatial distribution equilibrium evaluation of a variety of healthy city resources, to support healthy city planning and management.

Keywords: healthy cities; healthy urban planning; health service resource; pedestrian accessibility; spatial distribution equilibrium

1. Introduction

A healthy city has been defined as "one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and developing to their maximum potential" [1].

The concept of healthy cities was first proposed by the World Health Organization, in 1984, to encourage global government agencies, social institutions, and the public to cooperate in addressing urban health and public health-related issues. Today, the healthy city project has expanded globally and has become a promotional movement dedicated to improving health services, creating health support environments, and helping individuals adopt healthier lifestyles [1,2].

Modern urban planning originated from the urge to improve municipal sanitary and public health [3]. After municipal sanitary health and public health were developed, urban planning and public health gradually developed into separate disciplines. Due to increasing demand for better urban life quality, a healthier physical environment, and the increasingly severe impact of "urban disease", due to urban construction on public health, new interdisciplinary research between urban planning and public health has been initiated [4]. Northridge has proposed a joint urban planning and public health framework, as she believes that urban planning can improve the urban environment on multiple levels and promote public health [5]. First launched in European cities, the healthy urban planning initiative has been carried out for more than 30 years, emphasizing the importance of urban planning tools in improving the quality of life and health conditions of urban and rural residents [6]. China set up a healthy city pilot project in 1994, and after 25 years of exploration, its agenda has changed from developing hygienic cities to developing healthy cities that emphasize the construction of complete urban health systems [7]. The healthy city project of China has achieved rapid development in recent years, and the concept of a healthy city has been integrated into China's national development policies. The Chinese government also released the Healthy China 2030 Plan in 2016, setting a number of indicators for cities to conduct self-assessment. The indicators emphasize the importance of services, such as physical fitness services, health care services, and elderly-care services to public health [8]. Besides, in 2019, the Ministry of Housing and Urban-Rural Development of China proposed a pilot project of urban construction self-examination, in which, the importance of health-related services, such as urban green space, community construction, community health care services, and elderly-care services was emphasized.

Globally, many cities have constructed healthy cities and related service resources using urban planning tools. Among them, cities with mature, healthy urban planning generally have implemented health impact assessment (HIA) tools in urban construction projects [9,10]. For example, London has urged planners to use the Healthy Urban Planning Checklist on their projects to minimize the harmful impact on public health, and the Rapid Health Impact Assessment tool during the construction for supervision [11]. Such tools emphasize that communities should be built with recreational open spaces and health care facilities. Similarly, New York introduced the Active Design Guidelines [12], and encourages planners to use them in planning projects to create urban environments that encourage residents to carry out physical activities. The strategies related to health service resources mainly include community parks, bicycle lanes, and fitness spaces in office buildings. Currently, China mainly allocates relevant resources based on the Standard for Urban Residential Area Planning and Design and the Standard for Urban Public Service Facilities Planning; however, due to the different development level of each city, the above standards lack relevance and can only provide limited guidance in China. Therefore, cities with a shortage of construction funds and a scattered population often fail to meet construction standards. This is also the reason for the imbalanced levels of health service resources in urban China. It is also necessary to carry out health service resource evaluation to guide the construction of healthy cities. Although the importance of health-related service resources is widely recognized, the evaluation is still only operated as part of the overall macro-evaluation of healthy cities. Therefore, the setting of related indicators is relatively scattered and oversimplified. At present, specialized and systematic evaluation methods and indicators for health-related service resources are still scarce.

Recent research related to health service resource evaluation has mainly focused on the evaluation of the spatial layout of public service facilities, and the results have been abundant. Theoretical and empirical research on the evaluation of the spatial distribution of public service facilities can be traced

back to the 1960s, suggesting that the spatial layout of public service facilities should be optimized to ensure efficiency and fairness. This research includes Christaller's central place theory and Weber's industrial location theory [13]. In the 1970s, during the quantitative revolution, research on the public service facility layout began to combine theory with quantitative statistics. From the 1970s to the 1990s, issues, such as supply-demand balance, facility accessibility, and equality became the trend and focus of public service facility layout research [14–16]. Since the 1990s, however, the development of information technology has introduced big data and spatial analysis models into the spatial layout research of public service facilities, and it has retained a dominant position [17,18].

Many scholars believe that accessibility is an effective means to evaluate the rationality of the public service facility layout. Hansen was the first to propose the definition of accessibility, which is the potential of opportunities for interaction [19]. Since then, the researches related to accessibility have gradually received attention from urban planners and policy makers. Moreover, they have become key researches in recent years. As a result, there has been a paradigm shift in approaches to transportation planning: A shift from mobility to accessibility, and 'people's needs' has become the core of transportation planning rather than automobile [20,21]. Ingram defined accessibility as the inherent characteristic of a place concerning overcoming some form of spatially operating source of friction, including time and/or distance [22], while some believed that accessibility could also be connected with perception. Generally, measures of accessibility include both an impedance factor and an attractiveness factor [23]. Impedance factor reflects the time or cost arriving at a destination, while attractiveness factor reflects the diversity of available destinations and travel options, the route quality and also the trip experience (safety, comfort, convenience). When expressed in terms of attractiveness, the accessibility is usually based on the number and type of facilities contained within a given distance (in time or space) or in a given unit from the point of origin, with measures, including factors relevant for travellers' need and preference [24]. In some conditions, accessibility can be associated with terms, such as "within walking distance" or "walkable", and it is believed to be a measure of the quality and operational effectiveness of a community [25]. Accessibility can be optimized with multi-modal transportation and more compact, mixed-use, walkable communities, which reduces the distance between destinations [26].

Accessibility can be measured based on the time, money, and generalized cost required to reach opportunities [26]. In addition to the convenient access between two locations, the number of resources or opportunities that individuals can reach a destination can affect accessibility [21,27]. Similarly, Luo and Wang's research showed that the population at the origin point also impacts the level of accessibility; that is, in the case of equal opportunities at the destination point, the more people at the origin point, the fewer opportunities the individuals have [15]. In short, accessibility refers to the difficulty of reaching the supply node from the demand node when using a specific transport system. Its calculation is usually based on the travel cost between two nodes combined with the service capabilities of the supply node and the population of the demand node. Kwan divided accessibility into two categories: Personal and place accessibility [28]. He posited that the former reflects an individual's access to destinations and his quality of life, whereas the latter refers to the ability of a destination to be "approached". Geurs and Ritsema identified three basic perspectives on measuring accessibility [29]: (1) Infrastructure-based, often used in transport and infrastructure planning, including "level of congestion" and "travel speed"; (2) Activity-based, often seen in urban planning and geographical studies, including contour measures, potential accessibility measures and "space-time" accessibility measures; (3) Utility-based, came from economic studies, founded on the benefit people gain from spatially distributed activities.

Concerning the measure of spatial accessibility, the most published methods include provider-to-population ratio, distance to the nearest provider, the average distance to a set of providers, and gravitational models of provider influence [15,30]. The provider-to-population ratio method is also referred to as supply ratios. The larger the ratio, the better the accessibility is. It is more convenient and efficient when evaluating the regional distribution differences between public service resources [31].

The calculation results obtained by this method are intuitive and easy to understand, so it is often used as a policy analysis tool. However, since this method assumes that people only use the services of the administrative area in which they are located without considering spatial proximity, the calculation results may differ from the actual situation. The distance to the nearest provider method assumes that residents always choose the nearest public service facility. The closer the facility is, the better the accessibility is. It is mainly used for the evaluation of emergency facilities [30]. The average distance to a set of providers method is a combined measure of accessibility and availability; it sets the threshold travel time for individuals and compares the number of resources that can be reached. The higher the value, the better the accessibility is. The average distance to a set of providers method is important for the measurement of public service accessibility. It takes into account both spatial distance and resource distribution, which makes it suitable for the evaluation of non-emergency facilities. However, it does not take into account distance attenuation effects, differences in service levels of providers, and diversity of demand. Therefore, improved methods, such as the Gaussian two-step floating catchment area mode, were proposed to make up for deficiencies [30,32]. Besides, the gravitational model of the provider influence method is a combined measure of accessibility and availability. It can simulate the potential interaction between any population node and all facility nodes within a distance, while discounting the potential with increasing distance or travel impedance. The greater the potential, the better the accessibility is. The methods based on this concept include the Huff Model [33,34] and the Kernel Density Method [35]. The gravitational model of the provider influence method simulates the general behavior of residents in choosing and using public service facilities, and can more comprehensively measure the difficulty of residents in obtaining public services. It is also applicable to the evaluation of non-emergency facilities. However, the method has a certain degree of abstraction, and also, the friction coefficient that expresses the attenuation relationship between population and providers is not easy to determine. In general, the provider-to-population ratio method is suitable for measuring the accessibility of larger research units. Other methods are more advantageous for studying the accessibility of smaller research units. Also, the average distance to a set of providers method and the gravitational model of the provider influence method both involve complex models with certain operational difficulties. In practical applications, it is not that the more complex the method is, the better it is, but it is necessary to determine a suitable accessibility measurement method according to the actual needs.

Besides, environmental characteristics, such as mixed land use, street connectivity and residential density may affect the subjective experiences of travelers and their choice of travel modes, and non-motorized travel may need different analytical measures compared to motorized travel [36], which needed to be considered in accessibility evaluation. In the past few decades, many studies have attempted to measure whether and how places (and their characteristics, forms, elements) are conducive to walking. Cervero and Duncan used household activity data of San Francisco, combined with built environment factor scores with control variables (such as steep terrains), to study the links between urban environments and non-motorized travel [36]. Blecic et al. proposed a methodology and a planning and design support tool named Walkability Explorer, to evaluate the pedestrian accessibility of places that are related to people's capabilities, taking into account the quality of urban space on several attributes relevant for accessibility [37]. Due to income, age or physical condition, many people are unable to drive or use vehicles. Hence, it is important to pay close attention to the accessibility of non-motorized travel. Accessibility evaluation is often used to assist in the optimization and regulation of facility layout and to explore the relationship between the accessibility of facilities and social economic elements [38]. Recent research has mainly focused on how to promote the opportunities and efficiency of residents using public service facilities and empirical research on facility accessibility evaluation and layout optimization for the purpose of promoting resident quality of life. For example, Agbenyo et al. evaluated the accessibility of health care facilities in rural areas of Ghana and found that only a small number of residents had high-quality medical services [39]. Neutens et al. explored methods for coordinating the opening hours of public service facilities with residents' travel and

activity patterns to improve accessibility levels and optimize facility layouts [40]. Similarly, GU et al. studied methods of improving the accessibility of suburban parks by improving traffic networks so as to allow more residents to enjoy parks [41].

The concept of accessibility was not introduced to China until the 1990s. In 1999, Yu et al. presented that the accessibility of a landscape refers to the relative difficulty level from any point in the space to the landscape, and the relevant indicators are distance, time, cost, etc., and proposed to use landscape accessibility as an indicator to evaluate the service function of urban green space system to citizens [42]. Li and Lu summarized the characteristics and methods of accessibility earlier, proposed that from a micro perspective, personal travel behavior can also be influenced and constrained by various factors, including social environments, cultural environments, income levels, and psychological conditions and individual behaviors of different groups, etc. [43]. In the recent decade, accessibility researches have drawn great attention in the field of urban planning in China. Many scholars had taken Chinese cities as research objects to conduct accessibility evaluations. Song et al. utilized the new gravity P-median model to conduct an empirical study for the spatial equilibrium layout of general hospitals in Nanjing, demonstrated an approach to improve spatial equity and spatial efficiency of the facilities [44]. Cheng et al. applied the KD2SFCA method with multiple threshold times to analyze the spatial accessibility of high-level hospital in Shenzhen [45]. Shen et al. conducted the evaluation model based on the cost resistance mode, evaluated the accessibility of urban park green space in Luancheng, based on which proposed an urban park green space system planning layout plan and optimization measures [46]. Wu and Tseng identified disparities in geographic accessibility in elderly community care resource distribution of Taiwan, and proposed optimization strategies [47]. Accessibility research has kept up with information technology development. In line with the development trend of spatial big data in recent years, many map service providers have successively released their own big data plans, including Baidu Map and Gaode Map in China. Among map data, the most significant to the researchers is point-of-interest (POI) data. Urban researches supported by POI data are emerging. Steiniger et al. evaluated the POI data from OpenStreetMap (OSM) and determined that it can be used for urban accessibility evaluations [48], and later built an online platform that could evaluate a neighborhood's accessibility with POI data [49]. Peng et al. and Fang et al. utilized POI data to evaluate the pedestrian accessibility of destinations in urban areas of China [50,51]. Yue et al. developed new indices of mixed-use and neighborhood vibrancy to analyze their relationships by integrating mobile phone data and POI data [52]. As previous research on urban facility resource has been limited by traditional survey statistics, more emphasis has been placed on coarse-grained statistics at the district or city scale, which does not meet the requirements of precise planning and management of modern urban facilities. Spatial big data, such as POI provide more accurate data support, and with geographic information system (GIS) tools, researchers can integrate government and social big data to further evaluate resources accessibility from multiple dimensions. Since community population and resource data are usually only available at the scale of the administrative region, it is very difficult to perform further fine-scaled spatial distribution equilibrium evaluation studies. Such kinds of activities are highly expected for precise urban planning and management.

In the previous studies, most of the methods are focusing on the evaluation of a certain type of facilities, and only a few scholars have explored comprehensive evaluation methods for multiple types of facilities. Tsou et al. created integrated equity indices for the analysis of the relative equity status of facility distributions, and results of an empirical case in Rende city showed the characteristics of spatial equity of urban public facilities both for disaggregated and aggregated levels [53]. Rahman and Neema proposed an integrated index for measuring the spatial equity of 6 different types of public facilities based on accessibility measurement [54]. Zhao et al. took Shenzhen city as an empirical case and estimate the density distribution and per capita of public facilities through data mining, and then, with the objective and subjective evaluation of 10 types of public facilities, eventually formatting the comprehensive evaluation of public facilities [55]. The research objects defined herein are multiple types of health service resources, including preventative facilities, therapeutic facilities, and elderly-care

facilities, which involves both private and public service resources. Therefore, it is surely not sufficient to meet demands if the method we employ can only evaluate a certain type of facilities. Thus, it is necessary for us to integrate relevant accessibility indicators of multiple resources into a system for evaluation through a comprehensive evaluation method, which is a kind of statistical analysis method to determine the overall level and order of a specific phenomenon by making a highly abstract synthesis on the quantitative manifestations. It normally includes four major steps: Evaluation purpose identification, evaluation indicator system establishment, evaluation method and model selection (including weight determination of indicators) and evaluation implementation [56,57]. The overall level of the research objects can be grasped from complex phenomena through a comprehensive evaluation. To the authors' knowledge, most of activities and phenomena can be comprehensively evaluated. At the macro level, there are evaluations for urban development [57,58] and health city construction [59]; or from specific perspectives, there are evaluations for water resources [60] and teaching performance [61]. The comprehensive evaluation method provides us with a scientific means to correctly understand phenomena and develop scientific strategies. Currently, there are only a few studies in the field about measuring the levels of multiple service resources through government big data and social open data, while integrating accessibility evaluation method and comprehensive evaluation method. Therefore, we used this concept as the starting point, and by providing the approach and results for a health service resource evaluation, it can serve as a reference for the construction of healthy cities.

Yichang joined the healthy city project in 2016 [62], and released a scheme for healthy city development in 2018. Under the achievements of China's smart cities and healthy cities construction, the research demonstrated the feasibility of conducting rapid quantitative health city evaluation research based on refined geographic information data. The fine-grained community grid data obtained in this paper allowed us to simulate the resident distribution precisely, and reflected the current demand situation. The street route data obtained through the social big data allowed us to determine the impedance factors of the accessibility evaluation, while the POI data of health service resources allowed us to determine the attractiveness factors. Based on the accessibility evaluation, we established an evaluation indicator system for the spatial equilibrium comprehensive evaluation. With the help of GIS tools and mathematical statistics tools, a comprehensive, fine-grained evaluation results of the health service resource level was demonstrated. This research aimed to show an integrated approach for precise rapid evaluation of the distribution of health service resources based on refined geographic information spatial data, which can be of significance for the current quantitative healthy cities research in China and other countries.

2. Definition of Health Service Resources

The importance of health services and related facilities in public health promotion has been repeatedly emphasized by the Tsinghua-Lancet Commission on healthy cities in China [63]. Regarding the definition of health service resources, Jiang posited that in a broad sense, "health service resources" is a general term for all resources that are conducive to better physical and mental health of people. However, in a narrow sense, it mainly refers to medical and fitness resources, represented by facilities and places that occupy certain spaces, and can, therefore, improve public health by providing an environment, services, and experience [64]. Moreover, Wang et al. and Ding et al. proposed that the community health service system should be based on the market orientation of consumer demand, and should, thus, be a combination of physical fitness, health care, and elderly care for all community residents [65,66].

The Health Resources & Service Administration (HRSA) aims to promote the health of residents and eliminate existing health inequalities in the United States by providing highly accessible and high-quality health service resources, professionally trained health care practitioners, and creative health promotion programs [67]. The HRSA focuses on a series of public health programs that can help protect and improve community health, including education, healthy lifestyle promotion, and health

and injury prevention research [68]. Smiley et al.'s research proposed that places or environmental elements in which health-related behavioral activities occur, including supermarkets, parks, and other recreational places, can be considered health-related resources [69]. Moreover, high-connectivity streets, high-accessibility living service facilities, and mixed-use lands are also closely related to health [69]. In a study by Pearce et al. on health inequalities in New Zealand neighborhoods, for example, leisure recreation, shopping, education, and medical facilities were included in the health-related community resource categories [70].

Although the definition of health service resources varies by location, the common philosophy is that the main components of health service resources are facilities that promote healthy lifestyles and maintain healthy conditions. Combined with the definition of the connotation of health service facilities in the existing research, we defined and explored the connotation of health service resources from the perspective of prior research.

Starting from the entity level of the built environment, we posited that health service resources are various material elements directly or indirectly related to human health in the urban built environment and that these resources have strong connotations. Good physical health is essential to well-being, mental health, and human self-value. Therefore, resources directly related to physiological health maintenance and promotion, as well as disease treatment, are the most important components of health service resources. As high-intensity mixed-use lands arise from the development of urban space and strong economy, health service resources for residents in the community include both public goods provided by governments and private goods provided by markets. Therefore, when measuring the health services level value, both public and private goods should be included. Out of consideration for residents of different ages and health conditions, three types of resources were evaluated in this research: Preventive, therapeutic, and elderly care (Figure 1).
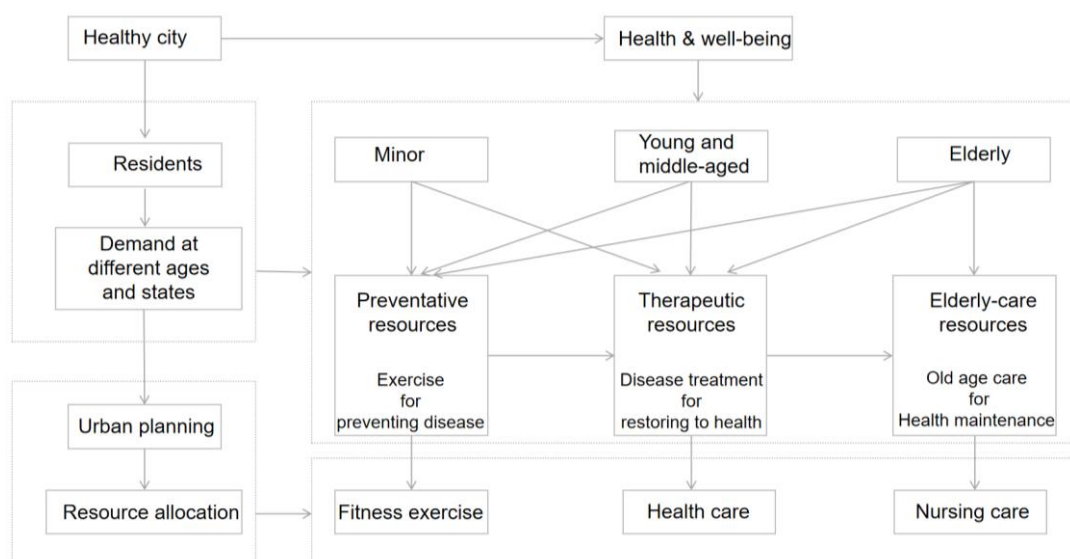

Figure 1. Health service resources. (Source: Authors).

The preventive type mainly included parks, sports centers, fitness centers, and other recreational resources; using this type of resource, residents can boost their immunity and avoid illness [71–73]. Therapeutic resources mainly included hospitals, clinics, pharmacies, and other convalescence resources, in which residents with illnesses can restore their health through medical treatments. While the above two types of resources are the most common among all age groups, the elderly-care type mainly includes people of advanced age. As the population becomes increasingly aged, care and health services provided by elderly-care resources, including nursing homes and senior community centers, are of great significance to the health and quality of life of the elderly [74,75].

3. Materials and Methods

3.1. Community Grid Data

Community population and resource data in traditional studies are usually at the scale of the administrative regions, which may have shortcomings, such as coarse statistical granularity and insufficient accuracy. Current research is gradually developed into a block scale. Compared with the block scale, the community grid-scale data adopted in this research could simulate the community's supply-demand situation more accurately. The boundaries of the community grids are delineated by the Yichang government, and the grids are usually divided by streets and internal roads of the community. Each one of them includes dozens of adjacent buildings and is managed by a special grid administrator whose job is to ensure the security of the community, document information on buildings, households, and municipal facilities, and upload the final data to the Smart City Construction Office for storage. According to need, government departments can submit applications for data use.

This paper was supported by the Smart City Construction Office, the Big Data Management Center, and the Center for Disease Control and Prevention in Yichang. Using the grid management work of Yichang, fine-grained data at the community grid-scale were obtained; the data mainly included demographics and the longitude and latitude of residential buildings.

3.2. Health Service Resource and Road Network Data

In this research, POI data from the urban area of Yichang were obtained from the Baidu Map API (http://lbsyun.baidu.com/). A total of 3243 pieces of POI data related to the three types of health service resources were retrieved and classified. We then condensed the data into three grades, including three types of first-grade resources, six types of second-grade resources, and 15 types of third-grade resources (Table 1). The road network data in the research were obtained from the Gaode Map API (https://lbs.amap.com).

Table 1. Health service resource categories and classifications in Yichang.

| First Grade	Second Grade	Third Grade
Preventative resource	Public fitness-exercise resource	Public parks
		Public sports venues (including track and field venues, ball stadiums, swimming venues, and school sports venues open to the public)
	Private fitness-exercise resource	Private sports venues (including golf courses, ski resorts, fitness clubs, and yoga clubs)
		Resort
Therapeutic resource	Public health care resource	Public hospitals (including general and specialized hospitals)
		Community health service centers
		Public rehabilitation and prevention agencies
	Private health care resource	Private hospitals and clinics
		Private rehabilitation and prevention agencies
		Pharmacies
		Physical therapy massage parlors
Elderly-care resource	Public elderly care resource	Public nursing homes
		Home care service centers and activity rooms for the elderly
		Universities and places of education for the elderly
	Private elderly care resource	Private nursing homes

According to grid management, the built area of Yichang was further divided into 1271 grids, which were population aggregation areas with residential buildings and complete grid management data. The grids were located in the Xiling, Wujiagang, Xiaoting, and Dianjun districts (Figure 2), which contain about 791,800 residents, with a total area of approximately 218 square kilometers. The population of elderly residents is 115,500. According to the data provided, the residential buildings and residents were aggregated mainly in the Xiling and Wujiagang districts, whereas the Dianjun and
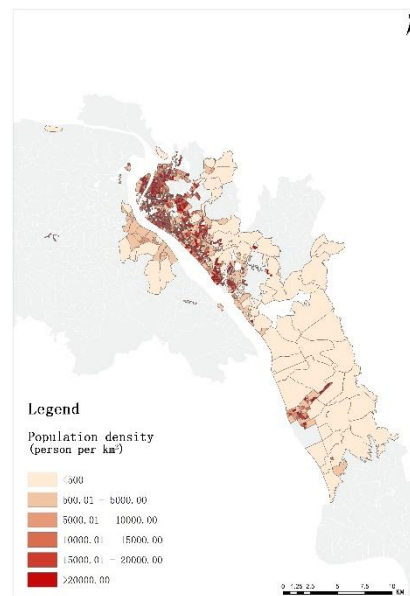
Xiaoting districts were decentralized (Figures 3 and 4). We used the 1271 grids as research objects, and the grids as the statistical units to carry out a comprehensive evaluation of health service resource levels.
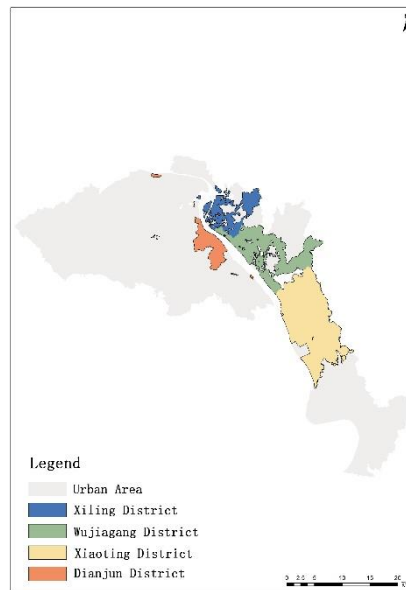
Figure 2. Research area.
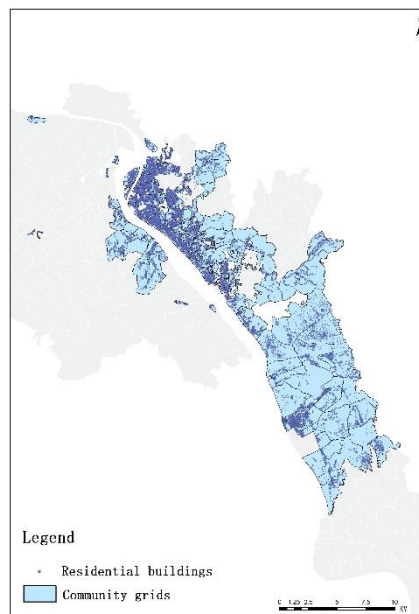
Figure 3. Grid division and distribution of residential buildings.

Figure 4. Population density.

3.3. Methods

To carry out a comprehensive evaluation of spatial equilibrium level of health service resources, we first need to evaluate the accessibility of health service resources. Although there are some drawbacks to using the average distance to a set of providers method, we believe that from the perspective of rapid evaluation, this method is easy-to-understand, scientific and objective, and is in line with the research goal. Therefore, the average distance to a set of providers method is adopted in the research.

Secondly, based on the comprehensive evaluation method, we have established an evaluation indicator system; the quantity ratio, the richness ratio, and the per capita number of health service resources within a 15-min walking distance of the residential buildings were taken as the basic indicators of the evaluation. Besides, the weight value of the indicators was obtained via the entropy weight method. In this way, we finally obtained the evaluation values of the health service resource level of each grid.

3.3.1. Fifteen-Minute Pedestrian Accessibility

Compared with motorized travel mode, walking is a kind of healthy lifestyles that are not constrained by economic conditions and driving abilities of individuals. In the previous pedestrian accessibility studies, residents' willingness and preference to walk were often investigated, and urban features that make the space conducive to walking were identified. However, due to that these elements were difficult to capture from available data and were less relevant to the starting point of the rapid evaluation of resource distribution in the research, residents' travel mode preferences were not considered in the following analysis.

In the previous researches related to community activities, an area reachable by a 15-min walk from home is defined as a neighborhood, and 1.6 km is considered as an average 15-min walking distance [76,77]. Colabianchi et al. found that for female adolescents, an easy walking distance was about 15-min on average, translating to 1184 m or approximately 0.75 miles; the distance of a 15 m walk varies among adolescents of different ages and genders [78]. Japan government was the first to propose the concept of a "community settlement area", which refers to an area within a radius of 1000–2000 m by a 15 m walking from a residential center, where residents can obtain their daily needs [79]. The concept then developed as a "community life circle" and was introduced to China in the early 1990s. In recent years, Beijing, Shanghai, Hangzhou, and other cities have built 15-min community life circles; that is, an area within a 15-min walk hosting the basic public services and public

activity spaces required to maintain a high quality of life. Shanghai government issued the "Shanghai 15-Minute Community Life Circle Planning Guidelines" in 2016, which defined a "community life circle" as an area within a radius of 800–1000 m by a 15-min walking from a residential area [80]. In the evaluation indicator system of Healthy China 2030 Plan, "15-min basic medical service circle" and "15-min fitness circle" are set as evaluation indicators for healthy cities, which makes the concept of a 15-min community life circle widely accepted in China.

Generally, a 15-min walking distance is considered to be an appropriate community radius, but the distance of a 15-min walk varies among people with different walking speeds. According to Zhang's walking speed research, which surveyed 1845 Chinese pedestrians between the ages of 20 to 89, the 25% upper limit value at a speed of 1.39 m/s was used as the criterion for high-low speed, and a speed of less than 1.39 m/s was considered as a regular speed; in a disease diagnosis consensus by Zhang et al. on sarcopenia in Asia, data from more than 6000 cases of the elderly walking speeds were obtained, and the 25% upper limit value of speed was 1.2 m/s [81,82]. In our research, the two upper limit values of speed were used as the walking speed standards for simulation. The preventative and therapeutic type resources were shared by residents of all ages, so a 1.39 m/s walking speed was adopted in the analysis, whereas the elderly-care type resource analysis adopted a 1.20 m/s walking speed. GIS tools were used for simulation in this research.

This research focused on the accessibility of community grids, which is also known as personal accessibility, as one of the key criteria for maintaining a healthy quality of life for residents living in the community grids. Based on the space-time prism concept and the time geographical framework used to analyze accessibility, as proposed by Miller [83], this research simulated the area and resources that residents could reach when walking from the community grids' residential buildings within a certain time constraint (15 min). The average number of the resources that each building could reach was taken into consideration in the evaluation of the community grids. After combining the average number of resources with several indicators defined in this paper, we evaluated the health service resource level of each grid.

3.3.2. Evaluation Indicators

In related research, the service capability and service radius of the resources have often been taken into consideration for better accuracy. However, in this research, due to the fact that the resources included not only public goods, but also private goods, we did not consider the influence of the service capability and service radius on the accessibility evaluation as it was difficult to obtain the relevant data and give it a unified description. The research set the 15-min walking distances of the all-aged residents and the old-aged residents as impedance factors, and the numbers and the types of resources as attractiveness factors for accessibility evaluation. In this way, a rapid quantitative evaluation was carried out. Based on the POI data collected and the entropy weight method, we obtained the level values of the three types of health service resources of each grid by calculating the third-grade indicators (i.e., the quantity ratios, the richness ratios, the per capita numbers), and then added them to obtain the values of the first-grade and second-grade indicators (Table 2).

In the table, quantity ratio refers to the ratio of the number of a resource in a grid to the total number of resources in the research area. This indicator reflected the structural and quantitative differences in the spatial distribution of the health service resources in Yichang. Richness ratio refers to the ratio of the number of resource types to the total number of the types in the research area. This indicator reflected the difference in freedom of choice in the resource type. Per capita number refers to the ratio between the number of a certain kind of resource in a grid and the population of the grid. This indicator reflected the actual reasonable degree of resource demand and supply.

Table 2. Evaluation indicators of health service resources.

First-Grade Indicators	Second-Grade Indicators	Third-Grade Indicators
A: Value of preventative type resource level	A1: Value of public fitness-exercise resource level	A11: Quantity ratio (%) A12: Richness ratio (%) A13: Per-capita number
	A2: Value of private fitness-exercise resource level	A21: Quantity ratio (%) A22: Richness ratio (%) A23: Per-capita number
B: Value of therapeutic type resource level	B1: Value of public health care resource level	B11: Quantity ratio (%) B12: Richness ratio (%) B13: Per-capita number
	B2: Value of private health care resource level	B21: Quantity ratio (%) B22: Richness ratio (%) B23: Per-capita number
C: Value of elderly care type resource level	C1: Value of public elderly care resource level	C11: Quantity ratio (%) C12: Richness ratio (%) C13: Per-capita number
	C2: Value of private elderly care resource level	C21: Quantity ratio (%) C22: Richness ratio (%) C23: Per-capita number

3.3.3. Entropy Weight Method

One necessary step in a comprehensive evaluation method is to assign different weights to indicators. The commonly used methods include the Delphi method, the analytic hierarchy process (AHP), the entropy weight method and the fuzzy cluster analysis. The Delphi method a widely used and accepted method for forecasting and aid in decision-making based on the opinions of experts [84]. The AHP method is used to construct a complex system into an orderly hierarchical structure represented by evaluation indicators based on its internal logic relations, and similarly, experts' wisdom and experience are further used to compare the importance of indicators to obtain their weights [85]. Shannon was the first to introduce the entropy principle into the information theory to evaluate the uncertainty of the discrete system [86]. The entropy weight method is based on the entropy principle and can comprehensively consider the information entropy provided by various factors to objectively estimate the relative weight of each indicator [56,84]. The fuzzy cluster analysis can be adopted to make fuzzy classification on indicators and propose the weight and order of these classifications according to the similarity between indicators in a set [56,84].

The Delphi method and the AHP method do not require objective sample data to determine indicators' weights. Instead, both methods rely on subjective opinions of experts. The entropy weight method determines weight based on information characteristics of sample data, and it is more objective than the Delphi method and the AHP method. However, this method is limited by data availability and the lack of horizontal comparison between indicators in practical applications. The fuzzy clustering analysis method is suitable for the classification of the importance of fuzzy indicators, especially when there are multiple indicators at the same level. The disadvantage of the method is that it can only give the weights of the indicator classifications, but not the weight of a single indicator. Therefore, when a complete data sample is available for mathematical processing, the entropy method is a better choice. Due to that the entropy weight method overcomes the randomness that cannot be avoided by the subjective weighting method, while weakening the bad effect from abnormal values and presents more accurate and reasonable evaluation results; hence, the entropy weight method is adopted for analysis.

In this research, the entropy weight method was achieved through the following steps:

Step 1: First, construct a matrix comprising 18 third-grade indicators and data from 1271 grids from each indicator. In order to eliminate the errors caused by different units or different numerical ranges of the data, the original matrix data were standardized as follows:

$$Y_{ij} = \frac{X_{ij} - X_{j\min}}{X_{j\max} - X_{j\min}}, \tag{1}$$

where the standardized value of the data in each indicator is Y_{ij}, X_{ij} is the original data, $X_{j\min}$ is the minimum value in the column j, and $X_{j\max}$ is the maximum value in the column j.

Step 2: Calculate the information entropy of each indicator as follows:

$$E_j = -\ln (n)^{-1} \sum_{i=1}^{n} p_{ij} \ln p_{ij}, \tag{2}$$

where E_j is the information entropy of the indicator in the column j; $n = 1271$, which is the number of the grid of data in each set of indicators; and $p_{ij} = Y_{ij} / \sum_{i=1}^{n} Y_{ij}$. Moreover, if $p_{ij} = 0$, it was defined as $\lim_{p_{ij} \to 0} p_{ij} \ln p_{ij} = 0$.

Step 3: Calculate the weight of each indicator through information entropy as follows:

$$W_j = \frac{1 - E_j}{m - \sum E_j}, \tag{3}$$

where W_j is the weight of the indicator in the column j, and m = 18, which is the number of indicators.

Step 4: Finally, calculate the value of the 18 indicators as follows:

$$F_{ij} = \sum Y_{ij} W_j, \tag{4}$$

where F_{ij} is the evaluation value of the indicator, Y_{ij} is the standardized matrix data, and W_j is the weight of the indicator in column j.

The entropy weight method was used to obtain the third-grade indicator weights, and the third-grade indicator values of each type were then accumulated to obtain the second-grade indicator values. Subsequently, the second-grade indicator values were accumulated to obtain the first-grade indicator values, and finally, we obtained the level values of the health service resources of each grid by accumulating the first-grade indicator values. The specific calculation steps are shown in Figure 5.
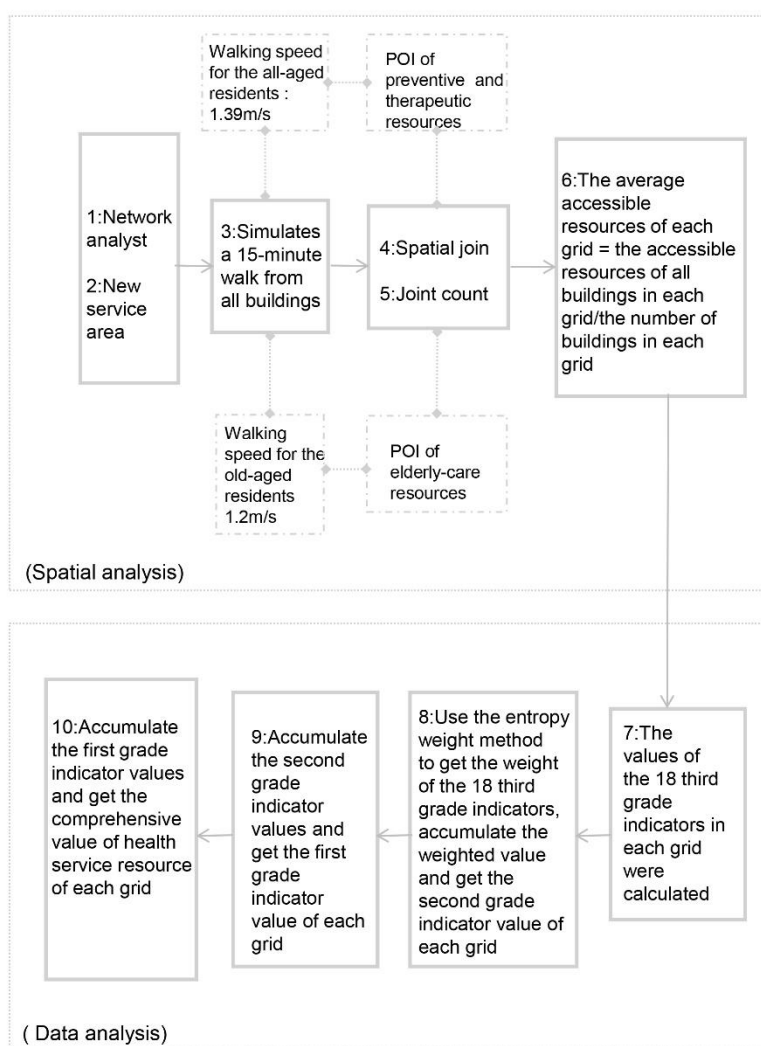
Figure 5. Evaluation process (Source: Authors).

4. Results and Discussion

4.1. Comprehensive Evaluation

4.1.1. Weight Calculation Results

First, the weight values of 18 third-grade indicators were obtained by using the entropy method (Table 3). In order to reveal the differences in the weight of the indicators at each grade, we converted the weight of the indicators by calculating the ratio of the weight value of each indicator to the sum of the weight value of its corresponding grade and type (Table 4).

Table 3. Calculation results of third-grade indicator weight.

Resource Type	Third-Grade Indicator Weight
Public fitness-exercise	Quantity ratio (0.025), Richness ratio (0.008), Per-capita number (0.106)
Private fitness-exercise	Quantity ratio (0.024), Richness ratio (0.006), Per-capita number (0.103)
Public health care	Quantity ratio (0.016), Richness ratio (0.005), Per-capita number (0.101)

Table 3. *Cont.*

Resource Type	Third-Grade Indicator Weight
Private health care	Quantity ratio (0.017), Richness ratio (0.002), Per-capita number (0.092)
Public elderly care	Quantity ratio (0.056), Richness ratio (0.035), Per-capita number (0.110)
Private elderly care	Quantity ratio (0.088), Richness ratio (0.069), Per-capita number (0.138)

Table 4. Calculation results of health service resource evaluation indicator weights.

First-Grade Indicator Weight	Second-Grade Indicator Weight	Third Grade-Indicator Weight
Preventative-type resources (0.271)	Public fitness-exercise (0.512)	Quantity ratio (0.179), Richness ratio (0.059), Per-capita number (0.762)
	Private fitness-exercise (0.488)	Quantity ratio (0.180), Richness ratio (0.046), Per-capita number (0.774)
Therapeutic-type resources (0.232)	Public health care (0.523)	Quantity ratio (0.129), Richness ratio (0.044), Per-capita number (0.827)
	Private health care (0.477)	Quantity ratio (0.150), Richness ratio (0.022), Per-capita number (0.827)
Elderly care-type resources (0.496)	Public elderly care (0.407)	Quantity ratio (0.280), Richness ratio (0.175), Per-capita number (0.546)
	Private elderly care (0.593)	Quantity ratio (0.298), Richness ratio (0.233), Per-capita number (0.468)

4.1.2. Evaluation Results

According to the first-grade indicator values of the preventive resources, the therapeutic resources, and the elderly care resources that were accumulated, we obtained the total value of health service resources in each community grid (Tables 5 and 6 and Figure 6). The total value of health service resources mostly fell in the range of 0.0000–0.2000. Due to the small recorded population in some grids, and the high weight value of their per-capita number indicators, these grids had a significantly higher value for health service resources.

Table 5. Evaluation results of health service resources (partial).

Grid ID	Comprehensive Value of Health Service Resources	Value of Preventative Resources	Value of Therapeutic Resources	Value of Elderly Care Resources
1	0.023697	0.013890	0.009807	0.000000
2	0.041664	0.024228	0.017436	0.000000
3	0.061833	0.021031	0.014066	0.026736
4	0.061027	0.011336	0.010208	0.039483
5	0.109773	0.021483	0.012254	0.076035
6	0.073652	0.019147	0.014701	0.039803
7	0.175674	0.020267	0.010910	0.144497
8	0.023697	0.013890	0.009807	0.000000

Table 6. Basic information on grids A, B, and C and their 15-min resource availability.

Grid	Population	Elderly Population	Type and Number of Preventive Resources	Type and Number of Therapeutic Resources	Type and Number of Elderly Care Resources
A	16	3	Public sports venues (2) Public parks (4) Private sports venues (24)	Public hospitals (5) Private hospitals and clinics (14) Pharmacies (21) Community health service centers (1) Physical therapy and massage parlors (16) Public rehabilitation and prevention agencies (2)	Private nursing homes (1) Homecare and elderly activity centers (1)

Table 6. *Cont.*

Grid	Population	Elderly Population	Type and Number of Preventive Resources	Type and Number of Therapeutic Resources	Type and Number of Elderly Care Resources
B	1134	50	Private sports venue (5)	Private hospitals and clinics (11) Pharmacies (8) Community health service centers (3) Physical therapy massage parlors (3) Public hospitals (2)	Public nursing homes (1) Private nursing homes (1)
C	492	192	-	Public hospitals (1) Pharmacies (1)	Homecare and elderly activity centers (3)

(**a**)   (**b**)
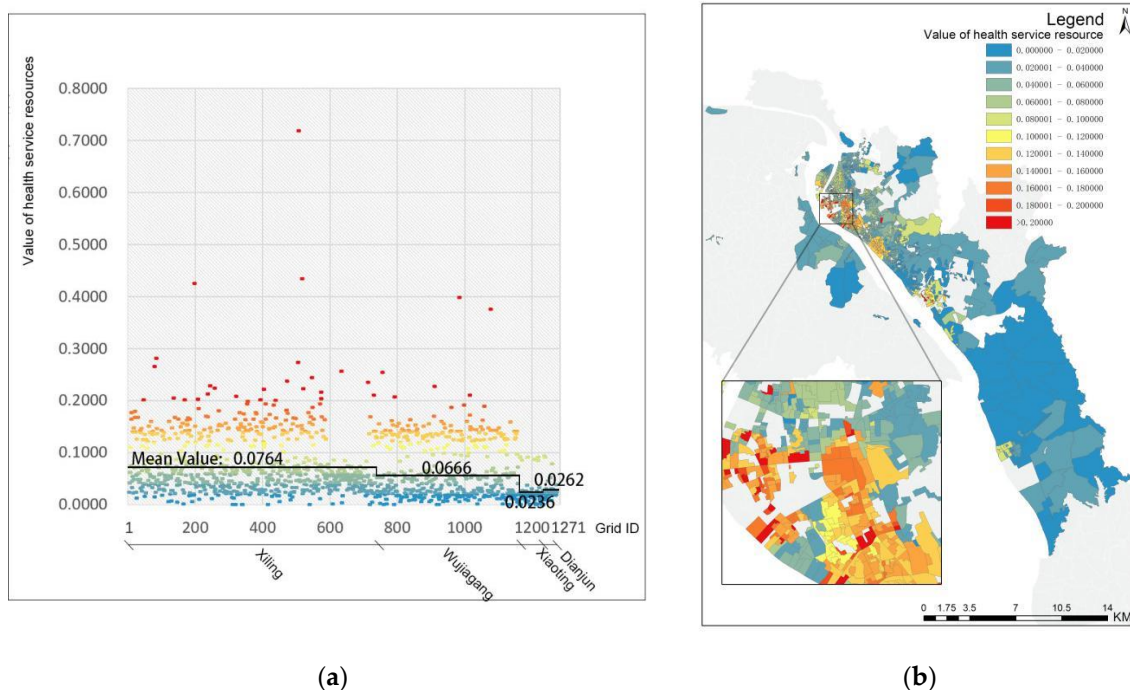
Figure 6. The evaluation result of health service resources. (**a**) Value range; (**b**) Spatial distribution.

Community grid health service resource values were significantly different (Figure 6). The mean value for the Xiling district was the highest (0.0764); that of the Wujiagang district was the second highest (0.0666), and those of the Xiaoting and Dianjun districts were below the middle level; the mean values were 0.0236 and 0.0262, respectively. The difference in evaluation results reflected the uneven distribution of health service resources in Yichang. Although the Xiling district and Wujiagang district, which were located in the central area of the city, had a higher population density, the health service resources abundant in quantity and variety within 15-min of walking allowed the residents to enjoy the most superior health services in Yichang. Meanwhile, residents in Xiaoting district and Dianjun district were unable to enjoy the same level of health service resources, due to lack of resources. The results of the evaluation urged the government to take necessary measures to improve health services.

4.2. Evaluation Results of the Three Types of Resources

Preventative resource values were more similar (Figure 7). Except for a small number of grids with small populations that exhibited higher values, the values of most grids were in the range of 0.0000–0.0300. The Xiling district, with a mean value of 0.0184, had higher-value grids, meaning that residents in Xiling district could enjoy more high-level preventive health services than residents in other areas. The Wujiagang and Dianjun districts had a small number of grid values at medium to high levels, with mean values of 0.0143 and 0.0154, respectively. The preventive-type resources of the

Xiaoting district were at the lowest level (0.0083). The poor condition of preventive health services in Xiaoting district needed to be taken seriously by the policymakers, and necessary means should be taken for resources supplement and services improvement.

(**a**)   (**b**)
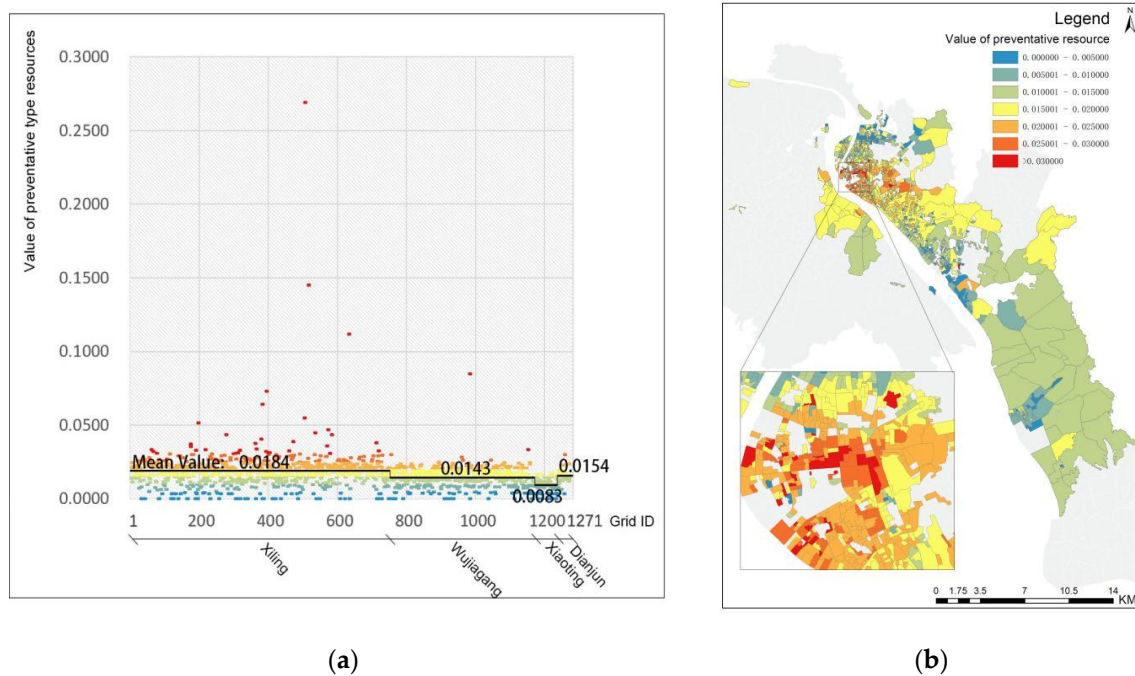
Figure 7. Evaluation result of preventative resources. (**a**) Value range; (**b**) Spatial distribution.

Therapeutic resource values were also more similar (Figure 8). Except for a small number of grids with small populations that exhibited higher values, most of the grid values were in the range of 0.0000–0.3000. The Xiling district had more high-value grids than the others and had the highest mean value of 0.0132, meaning that residents in Xiling district had the most advantageous access to therapeutic resources; the Wujiagang and Dianjun districts both had a small number of high-value grids; they had the mean values of 0.0116 and 0.0109, respectively. Moreover, the therapeutic resources of the Xiaoting district were at the lowest level, with a mean value of 0.0061. The results showed that the therapeutic resources available to residents living in Xiaoting district were very limited, and the policy makers needed to pay more attention and have a further investigation for making the optimization plans.

Among the three types of resources, the elderly care resource values were the most different (Figure 9). Except for a small number of grids with a small number of populations that had higher values, most of the grids in blue were in an extremely lacking state, so the values were zeroes. The remaining grid values were mostly in the range of 0.0200–0.1500. The Xilin district had the highest mean value (0.0450); the Wujiagang district had the second-highest value (0.0407), and the grids of the Xiaoting and Dianjun districts were lacked in elderly care resources, so had mean values of 0.0092 and 0.0000, respectively. The evaluation results of the elderly care resources among the districts were quite different. Except for the residents of Xiling district and Wujiagang district, who can enjoy better elderly care service resources, there were almost no service facilities available for the elderly in Xiaoting district and Dianjun district. The serious imbalance issue needed to be taken care of as soon as possible.
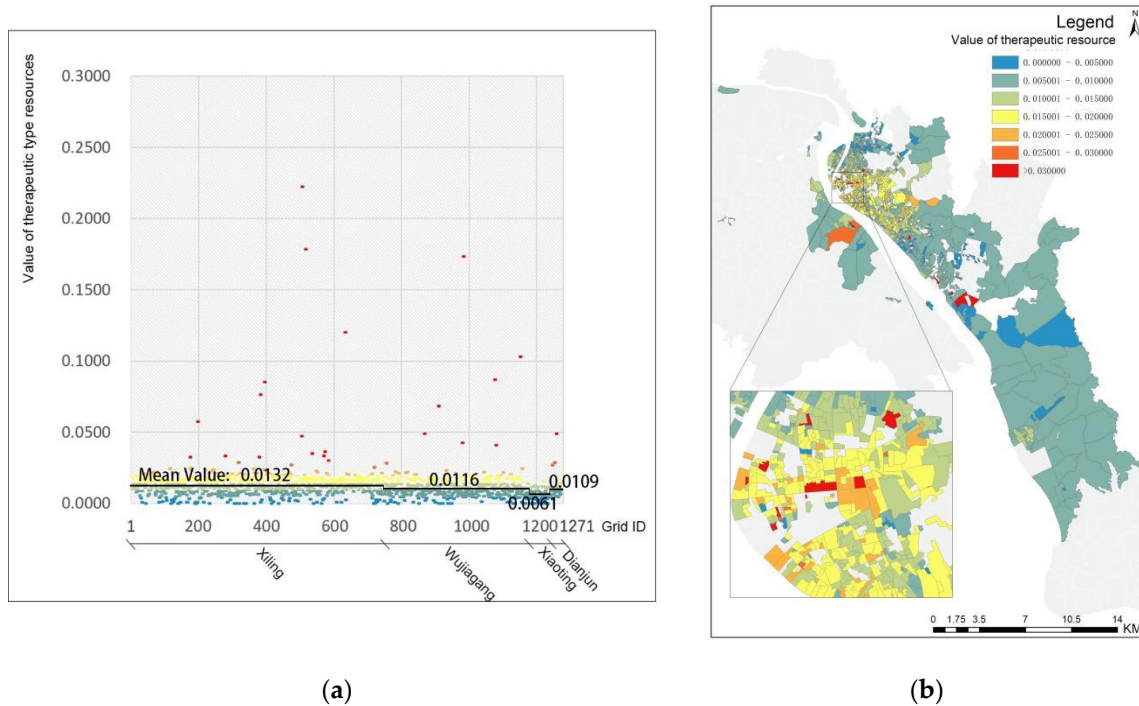
(**a**) (**b**)

Figure 8. The evaluation result of therapeutic resources. (**a**) Value range; (**b**) Spatial distribution.
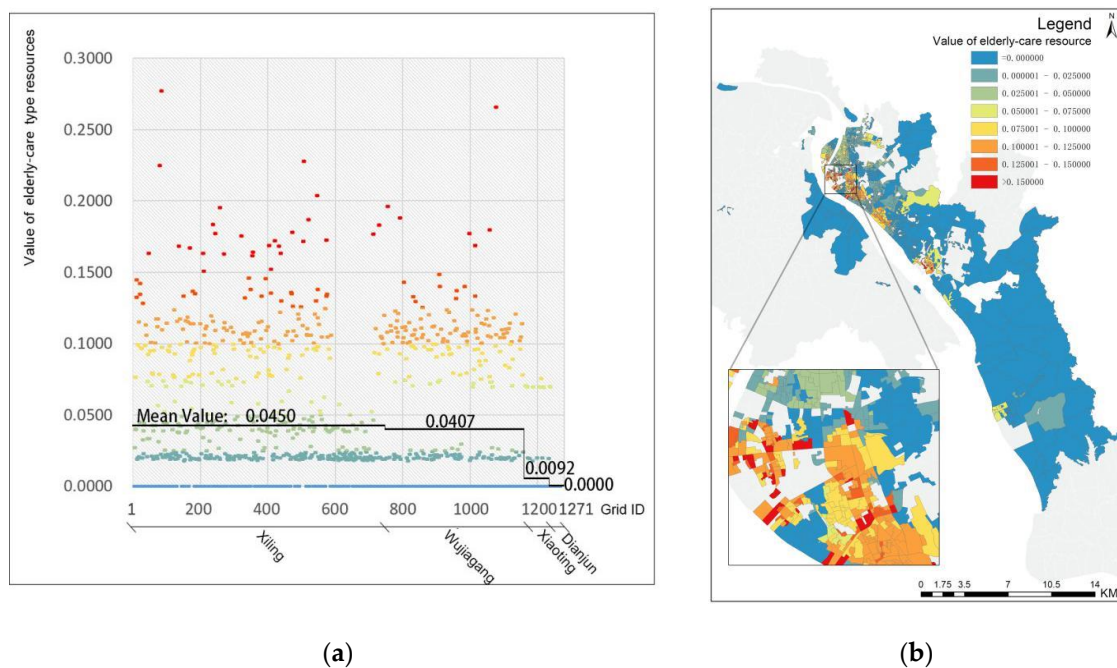

(**a**) (**b**)

Figure 9. The evaluation result of elderly-care resources. (**a**) Value range; (**b**) Spatial distribution.

4.3. Case Analysis

We selected three grids with significant value differences for comparative analysis (Table 6). The values of the three health service resource levels were 0.718745, 0.118223, and 0.020898, respectively.

Grid A had the highest value, and it was located in the Xiling district. Residents shared a wide variety of health service resources within a 15-min walk (Figure 10a), and there were many choices for residents. The number of resources was high, and there were only 16 residents, according to the data provided. Therefore, the per-capita value was large, resulting in a significantly higher final

value. In comparison, grid A had sufficient allocation of public health service resources, so it attracted commercial elements that could gather and enrich the types of resources.
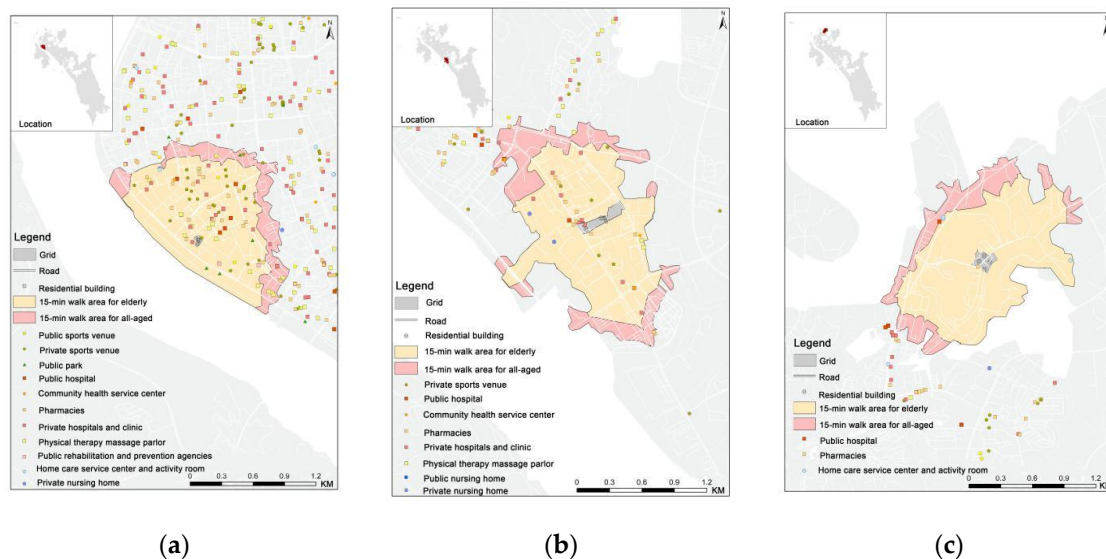
Figure 10. Fifteen-minute resource availability. (**a**) Grid A; (**b**) Grid B; (**c**) Grid C.

Grid B was located in the Wujiagang district, and its proximity to the district-level commercial center granted it sufficient public service facilities and attracted commercial elements (Figure 10b). However, compared with grid A, there were fewer health service resources and types of resources that residents could use within a 15-min walk. Meanwhile, grid B had the largest population. Therefore, resource demand exceeded supply, and per-capita resource evaluation value was extremely low, which resulted in the relatively low final value.

Grid C was located near the new industrial park in the northwest of the Xiling district. The number and types of health service resources were scarce compared with the other two grids (Figure 10c), and the large population lead to very few per-capita resources. Since it took more than 15-min to walk from the grid buildings to the district-level center, and the area was still under development, it was less attractive to commercial resources; thus, the allocation of health service resources was still lacking.

4.4. Analysis of Influencing Factors and Forming Mechanisms

4.4.1. Geographical and Historical Factors

Natural geographical conditions are the basic conditions for the formation of the spatial pattern of health service resources in Yichang. The topography of Yichang is complex, with only a few plains, whereas the height of the terrain varies greatly. The current urban construction is concentrated in the plains area at the boundary of the middle and upper reaches of the Yangtze River, presenting the characteristics of a banded cluster. Following the founding of modern China, the earliest land construction area in Yichang was the present-day Xiling, Wujiagang, and Dianjun districts. Continued industrial construction and supporting residential investment during the planned economy period made it a relatively mature area for the development of health service resources. Thus, the basic skeleton of the current spatial pattern of health service resources in Yichang was formed. Although the Xiaoting district was established in 1995, its regional development, population, and related supporting resources are still in the stage of construction and development, so the comprehensive value of health service resources was at a low level in our research.

4.4.2. Policy Factor

At present, most cities in China, including Yichang, are limited by the scale of economic development. Lands for private goods and public goods are in accordance with the Standard for Urban Residential Area Planning and Design, the Standard for Urban Public Service Facilities Planning, and other normative documents, which have provisions on facility configuration for the 1000-person indicator and the service radius. Therefore, the Xiling and Wujiagang districts, where the population is concentrated, have become the core area for the distribution of health service resources. The remoteness of the residential buildings in the Xiaoting and Dianjun districts are due to low population density and dispersed residential buildings, which have made it difficult to meet configuration standards and have resulted in incomplete service resource coverage.

4.4.3. Economic Agglomeration Factor

The foundation of productivity layout drives the strategic positioning of spatial development in different regions of the city and establishes the spatial distribution characteristics of differentiated health service resources. As a gathering place of economic elements, the Xiling and Wujiagang districts are densely populated and have high consumption power, attracting a continuous inflow of labor and capital; thus, they have become the core gathering areas for various commercial health service resources. In comparison, the economic structure of the Dianjun and Xiaoting districts is relatively simple, consisting of a large number of tertiary industries and a small number of primary industries. Their lower population density, lower concentration of commercial elements, and lower regional development level compared to the Xiling and Wujiagang district also affected the level of health service resources in our research.

4.5. The Innovation of the Research

Compared with several known comprehensive evaluation methods for multiple types of facilities (Table 7), the research has the following innovations.

(1) The innovation of a comprehensive evaluation method for multiple types of facilities. Most of the existing researches focus on the improvement of the evaluation method of a certain type of facilities, but the comprehensive evaluation for multiple types of facilities remains scarce. Such kind of method innovation is expected. In the above table, we compared our research with other evaluation research for multiple types of facilities, and proposed that the innovation of the research method lies in: (a) It is an easy-to-operate and easy-to-understand method for rapid evaluation of multiple types of facilities; (b) It is an integration of an accessibility evaluation method (the average distance to a set of providers method) and a comprehensive evaluation method.

(2) Application of fine-grained data in the evaluation of multiple types of facilities. Community population and resource data are usually only available at the scale of the administrative region, it is very difficult to perform further fine-scaled spatial distribution equilibrium evaluation studies. Such kinds of activities are highly expected for precise urban planning and management. The grid-scale data of Yichang is more refined than traditional statistical data that are at the scale of the administrative regions, which have overcome the shortcomings such as coarse statistical granularity and insufficient accuracy. The significance of the fine-grained data in our empirical research includes: (a) Accurately simulates the distribution of population and the availability of facilities, and the calculated results of supply and demand are more in line with actual conditions; (b) POI data enables private facilities to be included in the evaluation, which has greatly enriched the content of health service resource evaluations.

(3) Redefinition of health service resources. The importance of health-related service resources for public health has been recognized; however, there is no unified definition of health service resources, and some existing related definitions lack systemicity. Therefore, from the perspective of a healthy city, the research takes the demand of people of different ages and different physiological

states into consideration, and then redefines and reclassifies health service resources. It has some significance for healthy city policymakers (this part has been removed from the introduction, and emphasized as a section).

4.6. Limitation and Future Outlook of the Research

Limited by the available data and the starting point for rapid evaluation, the residents' willingness and preference to walk were not considered in the spatial analysis. Therefore, the demands for health service resources were decided by the population size and distribution, which might be different from the actual demands. Moreover, due to the different types of resources selected, it was difficult to obtain information, such as facility size and service radius, and it has not been able to describe it uniformly. Although the above factors were not included in the accessibility evaluation of the research, they were important for the systematic and comprehensive evaluation of health service resource distribution. Besides, in the research, a 15-min walking distance is used as a single impedance for accessibility evaluation. Whether or not other impedance elements should be considered in the research is a direction worth discussing and further exploring in the future. Furthermore, the methods adopted in this paper are mainly based on objective data for calculation analysis and evaluation. Therefore, sample data integrity requirements are relatively high for empirical studies.

With the development of smart city construction and the enhancement of data support, in the future, we might be able to adjust and improve the analysis process according to the expanding needs and carry out a more comprehensive and systematic evaluation. For example, with processed resident demand survey data, pedestrian perspective data, land use data, and environment characteristic data, we might be able to optimize impedance and attractiveness factors; with experts and public opinions collected, we might be able to adjust evaluation indicators. Hence, a more comprehensive health service resource evaluation indicator system might be created. The evaluation method might also provide a reference for horizontally comparing the level of health service resources between cities.

Table 7. Comparison among researches related to the evaluation of multiple types of facilities.

Researches for Comprehensive Evaluation of Multiple Types of Facilities	Introduction to Research Methods	Empirical Case Study	Innovation Points/Features	Shortcomings
Our research	A method that integrates the average distance to a set of providers method with the comprehensive evaluation method. The quantity ratio, the richness ratio, and the per capita number of health service resources within a 15-min walking distance of the residential buildings were taken as the basic indicators of the evaluation, and the weight value of the indicators was obtained via the entropy weight method.	(1) Research object: Three types of health service facilities in Yichang city (including public and private services) (2) Data source: Fine-grained government community grid data (population), Social big data (facilities). It is estimated that each community grid has about 200 households.	(1) Provides a rapid evaluation method that is easy-to-operate and easy-to-understand; (2) Creates a method that integrates the average distance to a set of providers method with the comprehensive evaluation method; (3) At the community grid level, accurately simulate the accessibility of facilities, and the calculated results of supply and demand conditions are more in line with actual conditions; (4) Private services are considered in the evaluation as well; (5) Adopts an objective weight determination method: Entropy weight method.	(1) Sample data integrity requirements are relatively high in empirical studies; (2) In lack of subjective evaluation content in the comprehensive evaluation.
An accessibility-based integrated measure of relative spatial equity in urban public facilities [53]	The research created integrated equity indices for the analysis of the relative equity status of facility distributions. The public service spatial equity level is calculated comprehensively from the perspectives of spatial separation, public service radius, facility preference (subjective evaluation survey).	(1) Research object: Twelve types of public service facilities in Rende (2) Data source: Survey data (facility preference), government data (facilities) (3) Scale: Coarse-grained. It is estimated that each town has about 1000 households.	(1) Creates integrated equity indices for the analysis of the relative equity status; combines objective and subjective evaluation; (2) Combines multiple indices to measure equity, and considers the preferences of facilities through subjective survey evaluation.	(1) The role of facility accessibility evaluation is weakened and abstracted; (2) Involving complex formulas and statistical methods, which are difficult to calculate and understand; (3) It is necessary to obtain facility preference data in combination with questionnaire surveys, and the workload is large.

Table 7. *Cont.*

Researches for Comprehensive Evaluation of Multiple Types of Facilities	Introduction to Research Methods	Empirical Case Study	Innovation Points/Features	Shortcomings
A GIS-Based Integrated Approach to Measure the Spatial Equity of Community Facilities of Bangladesh [54]	An integrated spatial index for public facilities is developed in the research. The public service spatial equity level is calculated comprehensively from the perspectives of the number of facilities, the scale of facilities, the nearest distance from the community center to available facilities, facility preferences (subjective evaluation), and the overall pattern of spatial connections, and also, the research uses AHP analysis to determine facility weights.	(1) Research object: Six types of public service facilities in Bangladesh (2) Data source: Unspecified (3) Scale: Coarse-grained, sub-district level data (population and facilities). It is estimated that each sub-district has tens of thousands of households.	(1) Creates integrated equity indices for the analysis of the relative equity status; combines objective and subjective evaluation; (2) Uses AHP analysis to determine the weight of different facilities; (3) The differences in facility size are considered.	(1) The role of facility accessibility evaluation is weakened and abstracted; (2) Involving complex formulas and statistical methods, which are difficult to calculate and understand; (3) Coarse-grained data is used in empirical research; therefore, the final results are displayed at the national level, and the reference value for policymakers is to be discussed.
Evaluating urban public facilities of Shenzhen by application of open source data [55]	The research creates an evaluation method combining subjective and objective evaluations. First, performs a subjective evaluation of the online questionnaire on the attention and satisfaction of public service facilities, combined with an objective evaluation of facility density and the number of facilities per capita, and also, using Delphi method to determine weights of different facilities.	(1) Research object: Ten types of public service facilities in Shenzhen city (2) Data source: Coarse-grained census data, social big data (facilities) (3) Scale: Coarse-grained, district-level population data; average population data on a grid scale of 1 * 1 km was obtained through mathematical processing. It is estimated that each grid has several thousand households.	(1) Provide a comprehensive evaluation method combining objective and subjective evaluation; (2) In the evaluation, the Delphi method was used to consider the weight of different facilities.	(1) The role of facility accessibility evaluation is weakened and abstracted; (2) It is necessary to obtain facility preference data in combination with questionnaire surveys, and the workload is large. (3) Grid-scale population is calculated data rather than actual statistical data, which may lead to inaccurate results.

5. Conclusions

We used social big data to obtain the POI data of the resources. With the help of GIS tools and mathematical statistics tools, a comprehensive, fine-grained evaluation of the health service resources level was made. It showed the development of the integration of government data and social big data in the field of healthy city research. It can be of reference value for the evaluation of urban health levels and the formulation of healthy city development policy. Besides, the resource evaluation of both public goods and private goods was a breakthrough that further enriches the connotation of health service resources and can be used to achieve more scientific and systematic measurements of health service resource levels. Moreover, the evaluation results of the health service resources can be used by city planning departments in formulating regional development and facility designation policies. The lower resource level areas should have the priority in allocating new public facilities, and should also be supplemented by commercial resources that may be attracted by local infrastructure and employment.

This research aimed to show an approach for precise rapid evaluation of the distribution of health service resources based on refined geographic information spatial data, which can be of significance for the current quantitative healthy cities research in China and other countries. Future related research should consider deepening the connotation of health service resources, scientifically formulating resource evaluation indicators, and improving accessibility evaluation methods. These are also the directions we will make efforts in future.

References

1. What Is a Healthy City? Available online: http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/who-european-healthy-cities-network/what-is-a-healthy-city (accessed on 1 May 2019).
2. Barton, H.; Grant, M. Urban Planning for Healthy Cities: A Review of the Progress of the European Healthy Cities Programme. *J. Urban Health* **2013**, *90*, 129–141. [CrossRef] [PubMed]
3. Northridge, M.E.; Sclar, E.D.; Biswas, P. Sorting out the connections between the built environment and health—A conceptual framework for navigating pathways and planning healthy cities. *J. Urban Health* **2003**, *80*, 556–568. [CrossRef] [PubMed]
4. Duhl, L.J.; Sanchez, A.K. Healthy Cities and the City Planning Process: A Background Document on Links between Health and Urban Planning. Available online: https://apps.who.int/iris/bitstream/handle/10665/108252/E67843.pdf?sequence=1&isAllowed=y (accessed on 1 May 2019).
5. Northridge, M.E.; Sclar, E. A Joint Urban Planning and Public Health Framework: Contributions to Health Impact Assessment. *Am. J. Public Health* **2003**, *93*, 118–121. [CrossRef] [PubMed]
6. Barton, H.; Grant, M.; Mitcham, C.; Tsourou, C. Healthy Urban Planning in European Cities. *Health Promot. Int.* **2009**, *24*, i91–i99. [CrossRef] [PubMed]
7. Wang, H.; Xie, J.; Sheng, J. *Annual Report on Healthy City Construction in China*; Social Sciences Academic Press: Beijing, China, 2016; ISBN 978-7-5201-1523-0.
8. Chen, P.; Li, F.; Harmer, P. Healthy China 2030: Moving from blueprint to action with a new focus on public health. *Lancet Public Health* **2019**, *4*, e447. [CrossRef]
9. Forsyth, A.; Schively Slotterback, C.; Krizek, K. Health Impact Assessment (HIA) for Planners: What Tools Are Useful? *J. Plan. Lit.* **2010**, *24*, 231–245. [CrossRef]

10. Slotterback, C.S.; Forsyth, A.; Krizek, K.J.; Johnson, A.; Pennucci, A. Testing Three Health Impact Assessment Tools in Planning: A Process Evaluation. *Environ. Impact Assess.* **2011**, *31*, 144–153. [CrossRef]

11. London Healthy Urban Development Unit. Healthy Urban Planning Checklist London. 2013. Available online: https://www.healthyurbandevelopment.nhs.uk/wp-content/uploads/2014/04/Healthy-Urban-Planning-Checklist-March-2014.pdf (accessed on 1 May 2019).

12. Lee, K.K. Developing and implementing the Active Design Guidelines in New York City. *Health Place* **2012**, *18*, 5–7. [CrossRef]

13. Shen, Q. Location characteristics of inner-city neighborhoods and employment accessibility of low-wage workers. *Environ. Plan. B Plan. Des.* **1998**, *25*, 345–365. [CrossRef]

14. Wang, F.; Minor, W.W. Where the Jobs Are: Employment Access and Crime Patterns in Cleveland. *Ann. Assoc. Am. Geogr.* **2002**, *92*, 435–450. [CrossRef]

15. Luo, W.; Wang, F. Measures of Spatial Accessibility to Health Care in a GIS Environment: Synthesis and a Case Study in the Chicago Region. *Environ. Plan. B Plan. Des.* **2003**, *30*, 865–884. [CrossRef]

16. Langford, M.; Higgs, G.; Radcliffe, J.; White, S. Urban population distribution models and service accessibility estimation. *Comput. Environ. Urban Syst.* **2008**, *32*, 66–80. [CrossRef]

17. Farhan, B.; Murray, A.T. Siting park-and-ride facilities using a multi-objective spatial optimization model. *Comput. Oper. Res.* **2008**, *35*, 445–456. [CrossRef]

18. Alçada-Almeida, L.; Coutinho-Rodrigues, J.; Current, J. A multiobjective modeling approach to locating incinerators. *Socio Econ. Plan. Sci.* **2009**, *43*, 111–120. [CrossRef]

19. Hansen, W.G. How Accessibility Shapes Land Use. *J. Am. Inst. Plan.* **1959**, *2*, 73–76. [CrossRef]

20. Handy, S.L. Accessibility- vs. Mobility-Enhancing Strategies for Addressing Automobile Dependence in the U.S. Available online: https://escholarship.org/uc/item/5kn4s4pb (accessed on 29 October 2019).

21. Handy, S.L. Planning for Accessibility. In *Theory and in Practice*; Emerald Group Publishing Limited: Bingley, UK, 2005; pp. 131–147. [CrossRef]

22. Ingram, D.R. The concept of accessibility: A search for an operational form. *Reg. Stud.* **1971**, *5*, 101–107. [CrossRef]

23. Blecic, I.; Cecchini, A.; Congiu, T.; Pazzola, M.; Trunfio, G.A. A Design and Planning Support System for Walkability and Pedestrian Accessibility. In *International Conference on Computational Science and Its Applications*; Springer: Berlin, Germany, 2013; pp. 284–293. [CrossRef]

24. Apparicio, P.; Abdelmajid, M.; Riva, M.; Shearmur, R. Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues. *Int. J. Health Geogr.* **2008**, *7*, 7. [CrossRef]

25. Corazza, M.; Favaretto, N. A Methodology to Evaluate Accessibility to Bus Stops as a Contribution to Improve Sustainability in Urban Mobility. *Sustainability* **2019**, *11*, 803. [CrossRef]

26. Litman, T.A. Measuring transportation: Traffic, mobility and accessibility. *ITE J.* **2003**, *73*, 28–32.

27. Wachs, M.; Kumagai, T.G. Physical accessibility as a social indicator. *Socio Econ. Plan. Sci.* **1973**, *7*, 437–456. [CrossRef]

28. Kwan, M.; Murray, A.T.; O'Kelly, M.E.; Tiefelsdorf, M. Recent advances in accessibility research: Representation, methodology and applications. *J. Geogr. Syst.* **2003**, *5*, 129–138. [CrossRef]

29. Geurs, K.T.; Ritsema, V.E.J. Accessibility Measures: Review and Applications. Evaluation of Accessibility Impacts of Land-Use Transportation Scenarios, and Related Social and Economic Impact. 2001. Available online: https://rivm.openrepository.com/handle/10029/259808 (accessed on 29 October 2019).

30. Guagliardo, M.F. Spatial accessibility of primary care: Concepts, methods and challenges. *Int. J. Health Geogr.* **2004**, *3*, 3. [CrossRef]

31. Makuc, D.M.; Haglund, B.; Ingram, D.D.; Kleinman, J.C.; Feldman, J.J. The Use of Health Service Areas for Measuring Provider Availability. *J. Rural Health* **1991**, *7*, 347–356. [CrossRef]

32. McGrail, M.R.; Humphreys, J.S. Measuring spatial accessibility to primary care in rural areas: Improving the effectiveness of the two-step floating catchment area method. *Appl. Geogr.* **2009**, *29*, 533–541. [CrossRef]

33. Grohmann, S.; Urošević, D.; Carrizosa, E.; Mladenović, N. Solving multifacility Huff location models on networks using metaheuristic and exact approaches. *Comput. Oper. Res.* **2017**, *78*, 537–546. [CrossRef]

34. Huff, D.L. A Probabilistic Analysis of Shopping Center Trade Areas. *Land Econ.* **1963**, *39*, 81. [CrossRef]

35. Spencer, J.; Angeles, G. Kernel density estimation as a technique for assessing availability of health services in Nicaragua. *Health Serv. Outcomes Res. Methodol.* **2007**, *7*, 145–157. [CrossRef]

36.　Cervero, R.; Duncan, M. Walking, Bicycling, and Urban Landscapes: Evidence from the San Francisco Bay Area. *Am. J. Public Health* **2003**, *93*, 1478–1483. [CrossRef]

37.　Blecic, I.; Cecchini, A.; Congiu, T.; Fancello, G.; Trunfio, G.A. Evaluating walkability: A capability-wise planning and design support system. *Int. J. Geogr. Inf. Sci.* **2015**, *29*, 1350–1374. [CrossRef]

38.　Kwan, M. Space-Time and Integral Measures of Individual Accessibility: A Comparative Analysis Using a Point-based Framework. *Geogr. Anal.* **1998**, *30*, 191–216. [CrossRef]

39.　Agbenyo, F.; Marshall Nunbogu, A.; Dongzagla, A. Accessibility mapping of health facilities in rural Ghana. *J. Transp. Health* **2017**, *6*, 73–83. [CrossRef]

40.　Neutens, T.; Delafontaine, M.; Schwanen, T.; Weghe, N.V.D. The relationship between opening hours and accessibility of public service delivery. *J. Transp. Geogr.* **2012**, *25*, 128–140. [CrossRef]

41.　Gu, X.; Tao, S.; Dai, B. Spatial accessibility of country parks in Shanghai, China. *Urban For. Urban Green.* **2017**, *27*, 373–382. [CrossRef]

42.　Yu, K.; Duan, T.; Li, D.; Peng, J. Landscape Accessibility as Measurement of the Function of Urban Green System. *City Plan. Rev.* **1999**, *23*, 8–11.

43.　Li, P.; Lu, Y. Review and Prospection of Accessibility Research. *Prog. Geogr.* **2005**, *24*, 69–78.

44.　Song, Z.; Yan, T.; Ge, Y. Spatial Equilibrium Allocation of Urban Large Public General Hospitals Based on the Welfare Maximization Principle: A Case Study of Nanjing, China. *Sustainability* **2018**, *10*, 3024. [CrossRef]

45.　Cheng, G.; Zeng, X.; Duan, L.; Lu, X.; Sun, H.; Jiang, T.; Li, Y. Spatial difference analysis for accessibility to high level hospitals based on travel time in Shenzhen, China. *Habitat. Int.* **2016**, *53*, 485–494. [CrossRef]

46.　Shen, S.G.; Wang, H.; Fei, W.J.; Fu, X. Urban Park Green Space System Planning Based on Accessibility Method—A Case of Luancheng City in China. *Appl. Mech. Mater.* **2012**, *209*, 331–336. [CrossRef]

47.　Wu, H.; Tseng, M. Evaluating Disparities in Elderly Community Care Resources: Using a Geographic Accessibility and Inequality Index. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1353. [CrossRef]

48.　Steiniger, S.; Poorazizi, M.E.; Scott, D.R.; Fuentes, C.; Crespo, R. Can we use OpenStreetMap POIs for the Evaluation of Urban Accessibility? *Int. Conf. Gisci. Short Pap. Proc.* **2016**, *1*. [CrossRef]

49.　Steiniger, S.; Poorazizi, E.; Fuentes, C.; Rojas, C.; Hunter, A. WalkYourPlace—Building a Web-based Platform for Urban Accessibility Analysis (breakout presentation). *J. Transp. Health* **2017**, *7*, S59–S60. [CrossRef]

50.　Peng, H.; Xiong, H.; Tian, J. Urban Area Pedestrian Accessibility Study Based on Big Data. *J. Chongqing Univ. Technol.* **2019**, *33*, 111–117.

51.　Fang, J.; Dai, D.; Zhou, Q. Pedestrian Accessibility Evaluation of Nanshan District in Shenzhen Based on POI—Transportation—Population. *Urban. Archit.* **2019**, *5*, 37–41.

52.　Yue, Y.; Zhuang, Y.; Yeh, A.G.O.; Xie, J.; Ma, C.; Li, Q. Measurements of POI-based mixed use and their relationships with neighbourhood vibrancy. *Int. J. Geogr. Inf. Sci.* **2016**, *31*, 658–675. [CrossRef]

53.　Tsou, K.W.; Hung, Y.; Chang, Y. An accessibility-based integrated measure of relative spatial equity in urban public facilities. *Cities* **2005**, *22*, 424–435. [CrossRef]

54.　Rahman, M.; Nigar Neema, M. A GIS Based Integrated Approach to Measure the Spatial Equity of Community Facilities of Bangladesh. *Aims Geosci.* **2015**, *1*, 21–40. [CrossRef]

55.　Zhao, M.; Xu, G.; Li, Y. Evaluating urban public facilities of Shenzhen by application of open source data. *Geo-Spat. Inf. Sci.* **2016**, *19*, 1–11. [CrossRef]

56.　Zou, Z.; Yun, Y.; Sun, J. Entropy method for determination of weight of evaluating indicators in fuzzy synthetic evaluation for water quality assessment. *J. Environ. Sci. China* **2006**, *18*, 1020–1023. [CrossRef]

57.　Feng, S.; Xu, L.D. Decision support for fuzzy comprehensive evaluation of urban development. *Fuzzy Sets Syst.* **1999**, *105*, 1–12. [CrossRef]

58.　Chen, M.; Dadao, L.U.; Zha, L. The comprehensive evaluation of China's urbanization and effects on resources and environment. *J. Geogr. Sci.* **2010**, 17–30. [CrossRef]

59.　Wang, Y.; Wang, X.; Guan, F. The Beneficial Evaluation of the Healthy City Construction in China. *Iran J. Public Health* **2017**, *46*, 843–847. [PubMed]

60.　Zhou, Z.; Zhang, X.; Dong, W. Fuzzy Comprehensive Evaluation for Safety Guarantee System of Reclaimed Water Quality. *Procedia Environ. Sci.* **2013**, *18*, 227–235. [CrossRef]

61.　Chen, J.F.; Hsieh, H.N.; Do, Q.H. Evaluating teaching performance based on fuzzy AHP and comprehensive evaluation approach. *Appl. Soft Comput.* **2015**, *28*. [CrossRef]

62.　Yichang Was Shortlisted for the First Batch of "Healthy Cities" Pilots in China. Available online: http://www.hubei.gov.cn/zwgk/szsmlm/shzqb/201611/t20161114_916898.shtml (accessed on 1 May 2019).

63. Yang, J.; Siri, J.G.; Remais, J.V.; Cheng, Q.; Zhang, H.; Chan, K.K.Y.; Sun, Z.; Zhao, Y.; Cong, N.; Li, X. The Tsinghua—Lancet Commission on Healthy Cities in China: Unlocking the power of cities for a healthy China. *Lancet* **2018**, *5*, 238. [CrossRef]

64. Jiang, Y.; Zhen, F.; Sun, H. Spatial Characteristics of Urban Health Resources at Block Scale—A Case Study of Central Urban Area of Nanjing. *Econ. Geogr.* **2018**, *1*, 85–94.

65. Wang, G.; Li, X. Research on the Transformation and Upgrading of Public Health Service of the China's Urban Community. *Hubei Sports Sci.* **2016**, *35*, 283–286.

66. Ding, G.; Huang, Y.; Zeng, K. Discussions on Health Impact Assessment and Its Application in Urban Community: Case Study of San Francisco's Eastern Neighborhoods Community. 2018. Available online: http://kns.cnki.net/kcms/detail/11.5583.tu.20180723.1102.001.html (accessed on 1 May 2019).

67. HRSA HRSA Strategic Plan FY 2019–2022. Available online: https://www.hrsa.gov/about/strategic-plan/index.html (accessed on 1 May 2019).

68. HRSA Public Health Resources. Available online: https://www.hrsa.gov/get-health-care/resources/index.html (accessed on 1 May 2019).

69. Smiley, M.J.; Diez Roux, A.V.; Brines, S.J.; Brown, D.G.; Evenson, K.R.; Rodriguez, D.A. A spatial analysis of health-related resources in three diverse metropolitan areas. *Health Place* **2010**, *16*, 885–892. [CrossRef]

70. Pearce, J.; Witten, K.; Hiscock, R.; Blakely, T. Are socially disadvantaged neighbourhoods deprived of health-related community resources? *Int. J. Epidemiol.* **2007**, *36*, 348–355. [CrossRef]

71. Bedimo-Rung, A.L.; Mowen, A.J.; Cohen, D.A. The significance of parks to physical activity and public health. *Am. J. Prev. Med.* **2005**, *28*, 159–168. [CrossRef]

72. Penedo, F.J.; Dahn, J.R. Exercise and well-being: A review of mental and physical health benefits associated with physical activity. *Curr. Opin. Psychiatr.* **2005**, *18*, 189–193. [CrossRef]

73. Koohsari, M.J.; Badland, H.; Giles-Corti, B. (Re)Designing the Built Environment to Support Physical Activity: Bringing Public Health Back into Urban Design and Planning. *Cities* **2013**, *35*, 294–298. [CrossRef]

74. Kane, R.L.; Rockwood, T.; Hyer, K.; Desjardins, K.; Brassard, A.; Gessert, C.; Kane, R. Rating the Importance of Nursing Home Residents' Quality of Life. *J. Am. Geriatr. Soc.* **2005**, *53*, 2076–2082. [CrossRef]

75. Koren, M.J. Person-Centered Care for Nursing Home Residents: The Culture-Change Movement. *Health Aff.* **2010**, *29*, 312–317. [CrossRef] [PubMed]

76. Giles-Corti, B.; Knuiman, M.; Timperio, A.; Van Niel, K.; Pikora, T.J.; Bull, F.C.L.; Shilton, T.; Bulsara, M. Evaluation of the implementation of a state government community design policy aimed at increasing local walking: Design issues and baseline results from RESIDE, Perth Western Australia. *Prev. Med.* **2008**, *46*, 54. [CrossRef]

77. Christian, H.; Knuiman, M.; Bull, F.; Timperio, A.; Giles-Corti, B. A New Urban Planning Code's Impact on Walking: The Residential Environments Project. *Am. J. Public Health* **2013**, *103*. [CrossRef]

78. Colabianchi, N.; Dowda, M.; Pfeiffer, K.A.; Porter, D.E.; Almeida, M.J.C.; Pate, R.R. Towards an understanding of salient neighborhood boundaries: Adolescent reports of an easy walking distance and convenient driving distance. *Int. J. Behav. Nutr. Phys. Act.* **2007**, *4*, 66. [CrossRef]

79. Yu, Y. From Traditional Residential Area Planning to Neighborhood Life Circle Planning. *City Plan. Rev.* **2019**, *43*, 17–22. [CrossRef]

80. Li, M. The Planning Strategies of a 15-minute Community Life Circle Based on Behaviors of Residents. *Urban Plan. Forum* **2017**, *1*, 111–118.

81. Zhang, T.; Yu, P.; Luo, S.; Wang, H.; Liu, Y.; Huang, B.; Yang, Y.; Zeng, X.; Zeng, P. Gait speed as on indicator for vigorous elders in comprehensive geriatrics assessment. *Chin. J. Geriatr.* **2016**, *35*, 656–661. [CrossRef]

82. Sun, Z. Equalization Strategy of Public Facilities Based on Transport Accessibility: A Case Study of Beijing Emergency Medical Facilities. *Mod. Urban Res.* **2018**, *5*, 2–7.

83. Miller, H. Modelling accessibility using space-time prism concepts within geographical information systems. *Int. J. Geogr. Inf. Syst.* **1991**, *5*, 287–301. [CrossRef]

84. Ishikawa, A.; Amagasa, M.; Shiga, T.; Tomizawa, G.; Tatsuta, R.; Mieno, H. The max-min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy Sets Syst.* **1993**, *55*, 241–253. [CrossRef]

85. Saaty, R.W. The analytic hierarchy process—What it is and how it is used. *Math. Model.* **1987**, *9*, 161–176. [CrossRef]
86. Shannon, C.E. Communication theory of secrecy systems. *Bell Syst. Tech. J.* **1949**, *28*, 656–715. [CrossRef]