AI-Augmented Medical Research on Spatial Distribution and Accessibility of Public Sports Venues in Shanghai Through GIS Visualization Technology

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Abstract. Participation in sports activities plays a vital role in improving the health status of urban residents. As the main places for urban residents to participate in sports activities, the number and distribution of public sports venues have an essential impact on residents' participation in sports activities. Taking Shanghai, one of the most economically developed cities in China, as the research area, this paper makes an in-depth investigation and analysis of residential areas and public sports venues in Shanghai and studies the distribution of public sports venues in residential areas in Shanghai by using G.I.S. visualization technology, mean center, standard deviation ellipse, kernel density analysis, and other indicators. The results show that: 1. The distribution density of public sports venues in the seven urban areas of Shanghai is high, while the distribution density in the suburbs is low. When the central urban area extends to the suburbs, the change of distribution density decreases "cliff-like." The distribution in the suburbs is unbalanced, and the distribution density in the remote areas is smaller. The spatial distribution of public sports venues in Shanghai is unstable. 2. The 15-minute walking accessibility of the seven central urban areas in Shanghai is achievable, while the 15-minute walking accessibility of the suburbs is poor. Suggestions: 1. Turn the construction of public sports service facilities in central urban areas to stock optimization and strengthen the construction of public transportation networks in central urban areas and suburbs. 2. To promote urban renewal, urban fringe areas and suburban core areas with convenient transportation can be selected as crucial construction areas. 3. Encourage the opening of school sports venues to fill the gap in public sports venues in Shanghai.

Keywords: public sports place; G.I.S.; Shanghai Municipality; AI-Augmented Medical Research.
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1 INTRODUCTION

China's urbanization process has accelerated over the past 40 years of reform and opening up [31], with the urban population increasing from 172.5 million in 1978 to 901.99 million in 2021. With the continuous expansion of cities and the continuous improvement of the economic level, people's demand for sports activities is increasing. More and more people are taking part in sports [35]. Previous studies have found that sports can reduce people's body fat percentage [14],[9], improve human immunity [21], and have a significant effect on enhancing chronic diseases [6]. In addition, sports can also reduce people's negative emotions [11], [7]. Many studies have shown that active participation in sports has many beneficial effects on people's bodies and minds, and sufficient sports places are essential for people to participate in sports.

Public sports venues are the main places for urban residents to carry out various sports and participate in improving the health status of urban residents [23]. According to the statistics of China's National Health and Health Commission, in 2021, the proportion of people who regularly participate in sports activities in China will reach 37.2%[20], and the participation rate will increase yearly. With the increase in the number of people participating in sports activities, people's demand for public sports venues is also rising significantly. However, the number of public sports venues in China still needs to grow compared with the United States and Japan [10]. Studies have found that lack of exercise space is one of the critical obstacles to participating in sports activities [8]. Lee et al. concluded that the number of public sports facilities is negatively correlated with the obesity rate in the local community and positively associated with the physical activity rate. The lack of public sports facilities leads to insufficient exercise in the community [17]. Jin et al. applied KNHANES V-3 data from the Korean Center for Disease Control and Prevention to conduct a comparative analysis of L.I.S.A. analysis and spatial regression, and the results showed that the density and number of public sports facilities in South Korea were negatively correlated with B.M.I. [5]. According to Wang's survey, the number of people over 20 years old who participate in sports activities has declined by 10% due to lack of exercise space [10]. Shengping et al. believe that the distribution of sports facilities affects the internationalization of tourist cities and the number of tourist groups, and the uneven distribution of public sports facilities will affect the physical exercise of tourists [30]. Many previous studies have shown that the distribution of public sports facilities significantly impacts urban sports activities.

As China's most economically developed city, Shanghai has a large population density and more public sports venues. The distribution of public sports venues in Shanghai is essential and significant for constructing public sports venues in other cities in China. Haohuai et al. investigated the community sports facilities in Anshan Xincun, Shanghai. They found that the number of public sports facilities positively correlates with the frequency of sports activities for older people [19]. Zhan et al. studied the operation mechanism of public sports venues in the central urban area of Shanghai using literature, questionnaire surveys, and interviews. They found problems in the operation mechanism of public sports venues [26]. Sun et al. explored the distribution of community sports venues in Shanghai from 1982 to 2019, and the results showed that the community fitness venues in Shanghai presented an evolution pattern of "urbanization, suburbanization, and re-urbanization" [12]. Previous studies on public sports venues in Shanghai were mainly carried out using questionnaires or data consulting. In contrast, research on public sports venues in Shanghai using Geographic Information System (G.I.S.) visualization technology was rare. The G.I.S. visualization technology can observe the distribution of public sports places in Shanghai more intuitively and scientifically.

G.I.S. visualization is a technology formed by combining geographic informatics and scientific computation visualization. To be processed by the computer, the geospatial information must be converted into digital information and stored in the computer. This digital information is recognizable to the computer, but it is not identifiable to the human eye. It can have practical value only when this digital information is converted into human-recognizable map graphics. G.I.S. visualization content is mainly manifested in three aspects. First is the visualization of map data; its primary meaning is the screen display of map data. According to digital map data's classification and grading characteristics, the corresponding shape, size, color, and other visual variables are selected to represent a readable map by all or sub-elements. Second, G.I.S. visualization, the use of a variety of mathematical models, all kinds of statistical data, experimental data, observation data, and geographical survey data for grading processing, and then selecting the appropriate visual variables in the form of thematic maps, such as grading statistical maps, zoning statistical maps, histograms, etc. Third, the visual representation of spatial analysis results. An essential function of G.I.S. is spatial analysis, including network analysis, buffer analysis, superposition analysis, etc., and the analysis results are often described as thematic maps.

15-minute accessibility refers to the maximum walking range within 15 minutes of a residential area, which can directly reflect the accessibility of living facilities. Scholars at home and abroad have conducted various studies on urban services by applying 15-minute accessibility in many fields. Xiujin et al. evaluated the number of people participating in sports activities, the commuting time to the nearest sports facility, and the level of physical activity among 3926 respondents. The results showed that the longer it took Chinese residents to commute to the nearest sports facility, the lower people's willingness to participate in sports activities [25]. Li et al. studied more than 1000 communities in Baoding City and studied the spatial distribution and 15-minute accessibility of public service facilities. The results showed that the distribution of public service facilities was uneven, and the accessibility was poor [22]. Based on 2018 Autonavi road network data of Point of Interests (P.O.I.) and Open Street Map (O.S.M.), Wu et al. analyzed the accessibility in 15 minutes, and the results showed that the spatial layout of living service facilities and shopping service facilities needed to be optimized [3]. Many previous studies have shown that 15-minute accessibility is an essential index for evaluating the rationality of various places' layouts and positively affects the optimization of multiple places' layouts. The 15-minute walking accessibility of public sports venues in Shanghai has important guiding significance for the spatial construction layout of sports venues in Shanghai. However, relevant studies are rare.

Given this, this study will address the following questions. 1. Is the spatial layout of public sports venues in Shanghai balanced and reasonable? 2. What is the accessibility of public sports venues within a 15-minute walk in Shanghai?

2 SOURCES OF DATA AND METHODOLOGY OF THE STUDY

2.1 The Area of the Study

Figure 1 shows the location map of Shanghai's administrative districts. Shanghai is located in the Yangtze River Delta region in the east of China, at the estuary of the Yangtze River and the East China Sea; it is bordered by Jiangsu and Zhejiang and is located at 120. 52, -122. 12, E, and 30. 40, -31. 53, N. The total area of Shanghai is 6340.5km^2, with a resident population of 24,870,900 people at the end of 2021; the Shanghai Municipality is a first-tier city in China, an international metropolis, and China's economic, financial, trade, education, and science and technology center, Shanghai's stadium construction is one of the most complete cities in China, Shanghai contains a total of 16 administrative districts, seven central urban areas (Huangpu, Xuhui, Changning, Jing'an, Putuo District, Hongkou, Yangpu), and nine suburban districts (Pudong, Minhang, Baoshan, Jiading, Jinshan, Songjiang, Qingpu, Fengxian, Chongming), the administrative map of this study is the national This map was downloaded from the official website of the National Geographic Information Catalog Resource System (N.G.I.C.R.S.) and finally processed by G.I.S. software and mapping software. The purpose of applying this map in this study is to visualize the location of the administrative districts of Shanghai.

Figure 1: Map of Shanghai.

2.2 Data Sources and Processing

2.2.1 Data of Residential Areas

This study used Python software to obtain information on each residential area on the Shanghai Anjuke website. After removing the error values, invalid values, and duplicated data, the total number of residential regions was 27,532, the total number of buildings was 570,029, and the number of housing households was 781,035. The correlation coefficient between the number of residential areas and the resident population of Shanghai's various administrative districts was 0.78, indicating that the residential areas reflected the spatial distribution of the actual resident population. The residential area referred to in this paper is the city with relatively concentrated residential buildings (Ref. The purpose of collecting data on residential areas in this paper is to study the relationship between public sports venues and population distribution and to analyze whether the distribution of public sports venues is even and reasonable.

2.2.2 Data on Public Sports Venues

Public sports venues refer to general welfare stadiums where the public carries out sports activities such as sports competitions, training, and fitness recreation, including various stadiums, comprehensive gymnasiums, and swimming pools [4]. In this study, the sports and leisure services data were obtained through the application programming interface (API) of Goldmap, using Python to request and receive (CVS) format. In this study, a total of 6,463 public sports venues and 3,703 school sports venues were collected, keyword searches were carried out in an Excel sheet, and the vast amount of data was screened, de-duplicated, corrected and spatial matching after collecting the data to conduct a visualization study of public sports venues, as shown in Table 1.

Public sports venues	*Parse*	*Quantity*
Multi-purpose gymnasiums	*Public sports venues are constructed by sponsoring the Public Welfare Fund of the Chinese Sports Lottery of the General Administration of Sport of China. They are mainly indoor sports venues combined with*	*364*

	comprehensive, multi-purpose indoor ones that serve public sports and fitness programs.	
Climbing gym, yoga studio, martial arts studio, Taekwondo studio, skating rink, Thai boxing studio	*All sorts of niche sports venues*	*2897*
Indoor/outdoor natatoriums	*Outdoor open water venues or indoor artificial swimming venues*	*443*
Ball sports venues	*All ball sports venues, both with and without fences and lightning.*	*2759*
School gymnasiums	*All sports venues in schools*	*3703*

Table 1: Parse and quantity of public sports venues.

2.2.3 Data for Transport

In this study, the data of bus stops and metro stations were obtained through Goldmap Application Programming Interface (API) [28], [13], requested and received (CVS) using Python, changed the Excel format to xls format, and finally processed the data. In this paper, the purpose of collecting traffic data is to study 15-minute accessibility to public sports venues.

2.3 Research Method

2.3.1 The Mean Center

In this study, we utilized the mean center method provided by the G.I.S. platform to analyze the spatial distribution of public sports venues in urban areas. The P.S.V. barycenters, or central points, were identified by calculating the coordinates of mean centers to identify the most densely populated areas[28]. The following equations determine the mean centers:

$$x_t = \frac{\sum_{i=1}^{n} s_{ti} \times x_i}{\sum_{i=1}^{n} s_{ti}} \quad (1)$$

$$y_t = \frac{\sum_{i=1}^{n} s_{ti} \times y_i}{\sum_{i=1}^{n} s_{ti}} \quad (2)$$

Where (x_t、y_t) denotes the barycentric coordinates in the t year, (x_i, y_i) represents the barycentric coordinates of the i-th secondary planar unit, and s_{ti} is the property value of the unit in the t year.

2.3.2 Standard Deviational Ellipse

Initially proposed by Lefever in 1926, the standard deviational ellipse (S.D.E.) is a crucial technique for examining spatial distributions and characteristics of elements (points). Technical abbreviations will be explained upon initial use. S.D.E. consists of the standard deviation of the major and minor axes and the rotation angle. The semi-major axis represents the primary distributional direction of spatial elements, while the semi-minor axis indicates the distributional direction of a few elements. The degree of dispersion of spatial points or elements is represented by the ratio of the semi-major axis to the semi-minor axis. A value closer to 1 indicates a more significant dispersion, while a smaller value denotes a greater degree of distinct distributional direction [28], [13]. To analyze the directional trend and degree of dispersion of public sports venues, this paper utilized the S.D.E. provided by the G.I.S. platform. The equations used to obtain the major and minor axes of the ellipse are as follows:

$$\mathrm{SDE_X} = \sqrt{\frac{\sum_{i=1}^{n} \tilde{x}_i^2}{n}} \tag{3}$$

$$\mathrm{SDE_y} = \sqrt{\frac{\sum_{i=1}^{n} \tilde{y}_i^2}{n}} \tag{4}$$

Where (S .D.E.X., $\mathrm{SDE_y}$) denote elliptic variances, with semi-major and minor axes respectively being the maximum and minimum variances; $\mathrm{SDE_X}$and $\mathrm{SDE_y}$respectively marks the axial lengths along the x- and y-axis of the S.D.E.; $\tilde{x_i} = \widetilde{X_{ti}} - \tilde{x_t}$, $\tilde{y_i} = \widetilde{Y_{ti}} - \tilde{y_t}$, $\widetilde{X_{ti}}$and$\widetilde{Y_{ti}}$respectively denote the x- and y-coordinate of the i-th grid unit in the t-th year; and ($\tilde{x_t}$, $\tilde{y_t}$)denotes the x- and y-coordinate of the barycenter in the t-th year. ($\tilde{x_i}$, $\tilde{y_i}$) is the location coordinates of the P.O.I.s in the distribution of sports venues.

2.3.3 Kernel Density

Kernel density estimation is a frequently employed approach for accurately representing the density distribution of point data within a specific range. This method allows for the visualization of the relative concentration of point data and is commonly utilized to describe the distribution of spatial point data[18], [2]. The kernel density analytical tool, available through the G.I.S. platform, was utilized to analyze data from residential areas and sports venues to create a spatial visualization of their aggregation characteristics. The equation for this process is as follows:

$$\int \mathrm{h(x)} = \frac{1}{\mathrm{nh^d}} \sum_{i=1}^{n} \mathrm{K}\left(\frac{\mathrm{x - x_i}}{\mathrm{h}}\right) \tag{5}$$

$\left(\frac{\mathrm{Kx - x_i}}{\mathrm{h}}\right)$. The kernel function takes $\mathrm{k}\left(\frac{\mathrm{x - x_i}}{\mathrm{h}}\right)$, typically using a symmetric single-peak probability density function. The bandwidth, h, is a free parameter determining the smoothness degree. D represents the data dimension, and n represents the number of points i within the bandwidth scope.

2.3.4 Data Analysis Based on the Buffer

The study used the G.I.S. platform's buffer analysis feature to examine the 15-minute walking accessibility to subway stations, bus stops, and residential areas[1]. The buffer zone $\mathrm{B_i}$ of the object $\mathrm{O_i}$ is defined as:

$$\mathrm{B_i}=\{\mathrm{x}: \mathrm{d}(\mathrm{x}, \mathrm{O_i}) \le \mathrm{R}\}(\text{d is the minimum Euclidian distance}) \tag{6}$$

The typical walking speed for an individual ranges from 60 to 100 meters per minute. This investigation supposes that an average person can cover a distance of 1,000 meters in 15 minutes on foot, which also serves as a suitable service radius for most public venues. Consequently, the radius of the buffer zone R is established as 1,000 meters.

3 RESEARCH RESULTS

3.1 Spatial Distribution Characteristics of Residential Areas

Figure 2 is a map of the proportion of residential districts in each administrative district of Shanghai to the total number of residential districts in the city. Jing'an, Xuhui, Huangpu, Yangpu, Changning, Hongkou, and Putuo districts have more residential districts. In contrast, Baoshan District, Jiading, Songjiang, Fengxian, Qingpu, Jinshan, and Chongming Districts have fewer residential districts, and what is more remarkable is the Pudong New District and Minhang District, which are in the seven periphery of the central urban areas, which account for a high percentage of the number of residential districts due to the large size of the region, the geographical location of the administrative districts and the size of the administrative districts affect the number of residential districts.

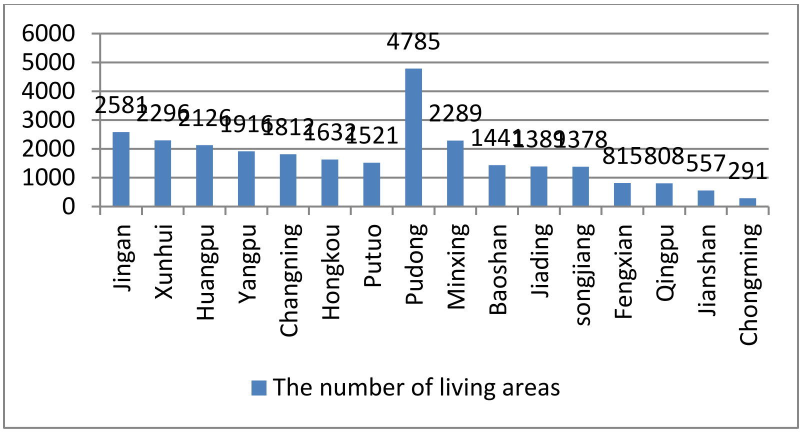

Figure 2: The ratio of residential areas in each administrative area to the total number of residential areas in Shanghai.

As shown in Figure 3, the distribution map of Shanghai's residential districts shows that in addition to Chongming District, the remaining 15 administrative districts are relatively sparse in the west, dense in the east, light in the south, and thick in the north, with Chongming District having the lowest density of residential districts. There is a massive gap between the distribution density of the central city and the suburbs, and the distribution of the city's residential areas appears to be a "cliff" phenomenon; from the core area outward, the distribution of the number of residential areas is not declining gently, but rather a drastic reduction in the scope of the transition area is not significant.

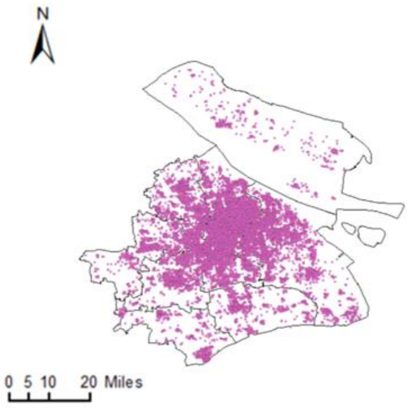

Figure 3: The distribution of residential areas in Shanghai.

As shown in Figure 4, the distribution of the density of the core of Shanghai's residential areas, it can be seen that in the seven central urban areas of Shanghai, the formation of a very high density of the "core," which fully demonstrates a high degree of aggregation of residential areas in the central urban areas. In contrast, the density of the suburbs is lower. The distribution of residential areas in the suburbs is uneven in the Songjiang District, Fengxian District, Jinshan District, Jiading District, and other suburbs within the scope of the formation of the size of the core of the small areas are also formed, which are usually located in the administrative centers of the districts, due to the merger of Nanhui and Pudong, the formation of Pudong New Area of the more than two clusters of the center of the towns and streets of the districts to form a much smaller cluster of areas.

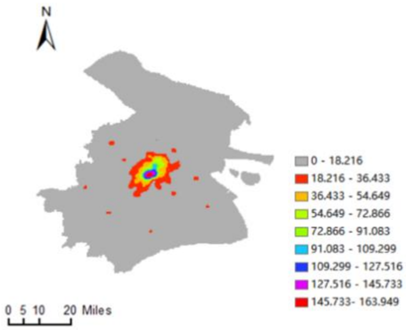

Figure 4: The kernel density distribution of residential areas in Shanghai.

3.2 Spatial Distribution Characteristics of Public Sports Venues

Figure 5 shows a map of the distribution of sports venues in Shanghai. The figure lists the total number of public sports venues in the city in each administrative district of Shanghai, Baoshan District, Jiading District, Songjiang District, Pudong New District has the most significant number of stadiums, Jing'an District, Xuhui District, Huangpu District, Yangpu District, Changning District, Putuo District is more, while Fengxian District, Qingpu District, Jinshan District, and Chongming District have fewer stadiums; the Pudong New District has the largest area, the number of stadiums is more, and the number of stadiums in Minhang District is more.

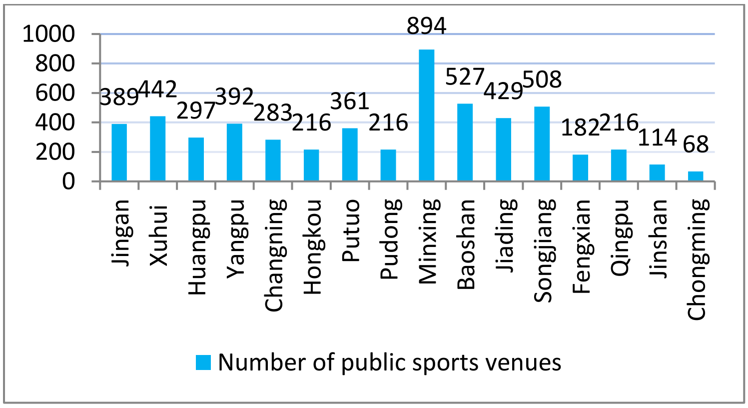

Figure 5: The distribution of sports venues in Shanghai.

Figure 6 shows the distribution of public sports venues in Shanghai. Jing'an District, Xuhui District, Huangpu District, Yangpu District, Changning District, Hongkou District, and Putuo District, the seven central urban districts of Shanghai, have a high density of distribution of stadiums in the core area. In contrast, the suburban Baoshan District, Jiading District, Songjiang District, Fengxian District, Qingpu District, Jinshan District, and Chongming District have a low-density distribution of residential areas. There is a significant gap in the distribution of stadiums in the central urban areas of Shanghai and the suburban districts, with a relatively sparse distribution in the west and a reasonably dense distribution in the east. relatively sparse in the south and relatively thick in the north.

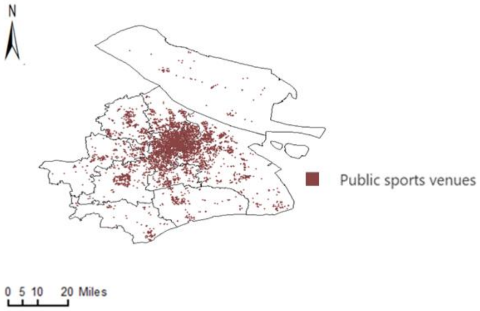

Figure 6: The locations of PSVs in Shanghai.

As shown in Figure 7, the mean center and standard deviation ellipse of public sports venues in Shanghai, it can be seen that the center of the density of public sports venues in Shanghai is located at the intersection of Jing'an, Xuhui, Huangpu, Yangpu, Changning, Hongkou and Putuo districts in the central city. The coordinates of the mean center are [121. 4,; 31. 2,], the seven central urban areas of Shanghai, Jing'an, Xuhui, Huangpu, Yangpu, Changning, Hongkou, and Putuo districts, the core area of the city, have a high density of distribution of stadiums. In contrast, the suburban districts of Baoshan District, Jiading, Songjiang, Fengxian, Qingpu, Jinshan, and Chongming districts have a low density of distribution of stadiums and the standard deviation ellipse of the city of Shanghai's circle is not elliptical, close to circular, the ratio of the long axis to the short axis is close to 1:1.1, indicating that the spatial layout of sports venues in the east-west direction and north-south direction is not significantly different from the density of the four directions of the southeast, west, north and west is not particularly large, for the aggregation of distribution type, the degree of dispersion is not large.

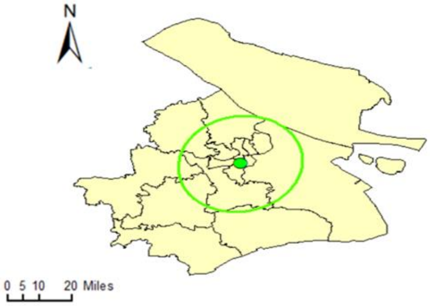

Figure 7: The mean centers and SDEs of PSVs in Shanghai.

Figure 8 shows the nuclear density distribution of public sports venues in Shanghai. It can be seen that Shanghai's seven central urban areas form a very high density of the core area, which fully demonstrates that the public sports venues in the seven major metropolitan areas are highly agglomerated. In contrast, the density in the suburbs is significantly lower, and the distribution of sports venues within the suburbs is not balanced in the Songjiang District, Fengxian District, Jinshan

District, Jiading District, and other suburban areas within the scope of the formation of the size of the different many of the small core area.

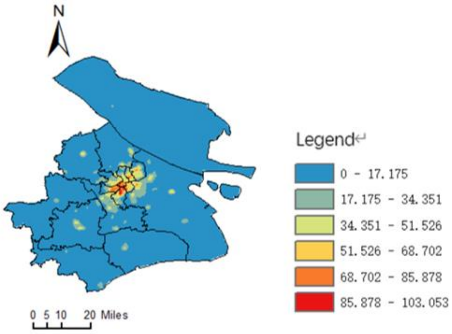

Figure 8: The distribution of kernel density of PSVs in Shanghai.

3.3 Spatial Distribution and Walking Accessibility of School Stadiums

As shown in Figure 9, the spatial distribution of school sports venues in Shanghai, it can be seen that the distribution density of sports venues is significant in the core area of the seven central urban areas of Shanghai, namely Jing'an District, Xuhui District, Huangpu District, Yangpu District, Changning District, Hongkou District, and Putuo District. The distribution density is small in the residential areas of the suburban districts, Baoshan District, Jiading District, Songjiang District, Fengxian District, Qingpu District, Jinshan District, and Chongming District, and there is a significant difference in the distribution density of sports venues in the seven central urban areas and suburban districts of Shanghai. There is a large gap between the density distribution of sports venues in Shanghai's seven central and suburban neighborhoods, and school sports venues are more evenly distributed than public sports venues in the suburbs, covering the entire suburban area.

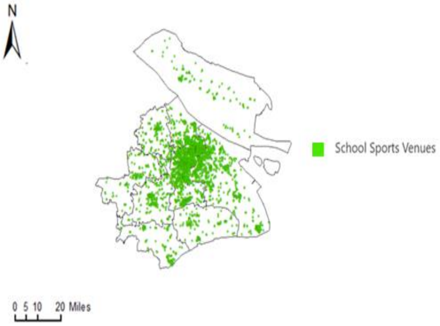

Figure 9: The spatial distribution of school sports venues in Shanghai.

As shown in Figure 10, the spatial distribution of school and public sports venues in Shanghai shows that school sports venues fill the gaps of public sports venues in the suburbs. There are ample vacancies for public sports venues in Fengxian District, Jinshan District, Qingpu District, Songjiang District, and especially in the northern part of Chongming District.

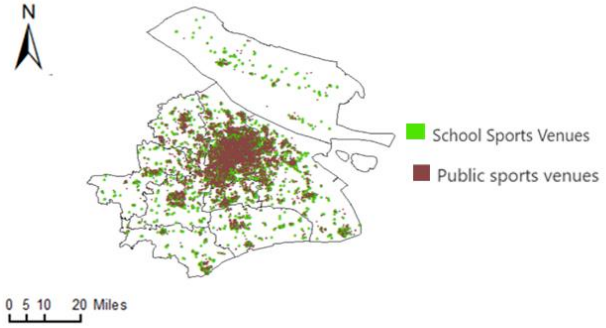

Figure 10: The spatial distribution of school sports venues and PSVs in Shanghai.

As shown in Figure 11, which shows the distribution of 15-minute walking buffer zones and

public sports venues in Shanghai, it can be seen that the seven central urban districts of Shanghai, Jing'an, Xuhui, Huangpu, Yangpu, Changning, Hongkou, and Putuo districts have vital 15-minute walking accessibility. The Jiading, Baoshan, and eastern parts of the Qingpu districts, the northern part of the Pudong district, and the Minhang district are densely inhabited. The coverage rate of the residential area of 1,000 meters is close to 100%. Still, the density of public sports venues could be more evenly distributed, with some vacancies. In contrast, Songjiang, Fengxian, Jinshan, Chongming, and Pudong districts are sparsely populated, with similarly low densities of public sports venues.

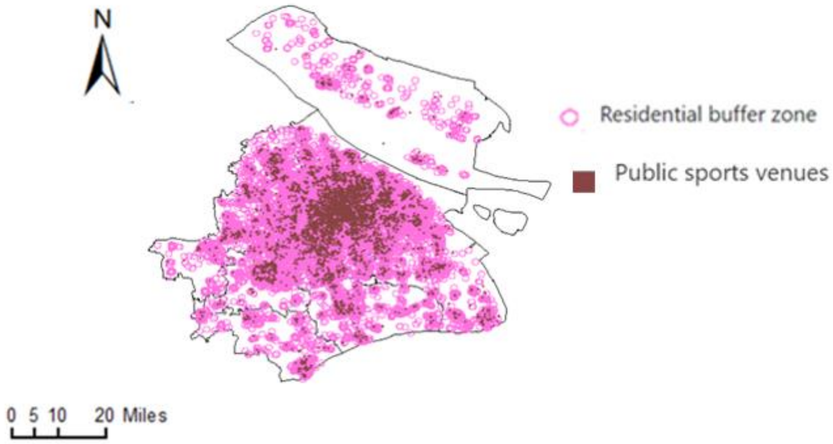

Figure 11: The distribution of 15-minute walking buffer zones and PSVs in Shanghai.

Figure 12 shows the distribution of 15-minute walking buffer zones and public sports venues in Shanghai. It can be seen that school sports venues fill some of the gaps in public sports venues, with sparse public sports venues in Chongming District, the western side of Qingpu District, the central part of Jinshan District, and the eastern part of Fengxian District, where school sports venues fill the gaps and bring some residential areas to the 15-minute walking distance level.

Figure 12: The distribution of 15-minute walking buffer zones and PSVs.

3.4 Spatial Distribution and Accessibility of Public Transport

As shown in Figure 13, the spatial distribution of highways and metro entrances in Shanghai is demonstrated. It can be seen that the distribution of highways in Shanghai is relatively balanced, the difference between suburban and urban areas is minimal, the distribution of the metro is very different, the metro of the seven central urban areas of Shanghai is highly dense, the metro of the metropolitan area is very developed and thick, and the metro of the urban area as the center of the suburb outwardly disperses into a radial shape, Fengxian District, Minhang District, Jiading District, Qingpu District, Baoshan District has only very few one or two metro, Chongming District and Jinshan District have no metro. There is no underground.

Figure 13: The spatial distribution of highways and subway stations.

Figure 14 shows the spatial distribution of bus stops in Shanghai. It can be seen that the seven central districts of Shanghai, Jing'an District, Xuhui District, Huangpu District, Yangpu District, Changning District, Hongkou District, and Putuo District, the core area of the distribution of bus stops in the density of the distribution of bus stops. In contrast, in the suburbs of the Baoshan District, Jiading District, Songjiang District, Fengxian District, QingPu District, Jinshan District, and Chongming District of the distribution of bus stops in the density of the distribution of bus stops is small. The whole of Shanghai presents a pattern of high density in the north and low density in the south, and there are vacancies for bus stops in Fengxian District, Jinshan District, and Qingpu District.

Figure 14: The spatial distribution of bus stops.

Figure 15 shows a map of 15-minute walking buffer zones and metro stations in Shanghai. It can be seen that most of the residential areas in the seven central districts of Shanghai, Jing'an District, Xuhui District, Huangpu District, Yangpu District, Changning District, Hongkou District, and Putuo District, do a 15-minute walk to the metro station. Most suburban residential areas do not have an underground and can not be walked to the metro station within 15 minutes.

Figure 15: The 15-minute walking buffer zones and subway stations in Shanghai.

Figure 16 shows a map of 15-minute walking buffer zones and public stadiums in Shanghai metro stations. It can be seen that public sports venues are densely distributed around metro stations and clustered around metro stations, and there is a close relationship between the location of metro stations and public sports venues; where metro stations are accessible, public sports venues also have good accessibility, and where metro stations are inaccessible in the suburban neighborhoods, there are few public sports venues.

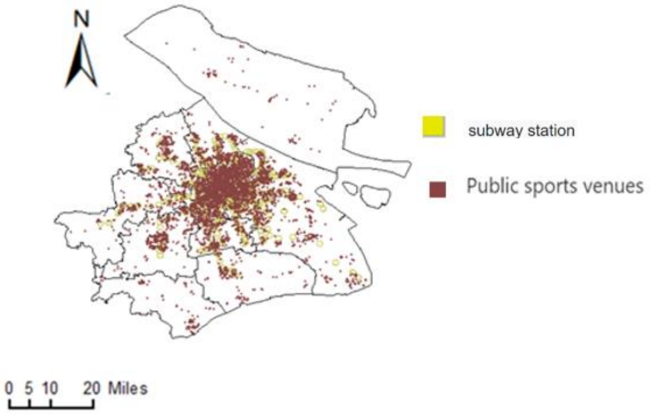

Figure 16: The 15-minute walking buffer zones of subway stations and PSVs in Shanghai.

Figure 17 shows a map of 15-minute walking buffer zones and bus stops in residential areas. It can be seen that public transport is more developed in the residential areas of Shanghai's seven central and nine suburban districts compared to the metro and that several residential areas in the periphery of Chongming District and the southeast of the Pudong New Area are not accessible to bus stops on a 15-minute walk.

Figure 17: The 15-minute walking buffer zones and bus stops in residential areas.

Figure 18 shows a map of Shanghai's residential areas, roads, and public sports venues. It can be seen that where roads are dense in Shanghai, residential areas and sports venues are equally thick. Road transport in Shanghai is also more viscous in the suburbs, especially in Fengxian District, Jinshan District, Jiading District, and the southern part of Pudong New District, where roads are very dense. Still, roads are sparse, and accessibility to public sports venues is poorer in Chongming District.

Figure 18: Highways and PSVs in residential areas of Shanghai.

4 DISCUSSION AND ANALYSIS

4.1 Analysis of the Spatial Distribution of Public Sports Venues

In the overall layout perspective analysis, Shanghai public sports venues layout from the core area to the outside, the distribution of the number is not a gentle decline, there is a "cliff" phenomenon, the scope of the transition zone is small, the distribution of the suburbs is not balanced, in the suburbs near the administrative center of the formation of a small core area, the core of the suburbs and the core of the surrounding areas of public sports venues density is significantly greater than the remote areas. Zhenchao et al. studied the spatial distribution of Shanghai kindergartens, primary schools, and junior high schools. They concluded that the suburbs as a whole show the phenomenon of multiple cores aggregated and unevenly distributed [29], which is the same as the study of public sports venues in this paper. The average centroid of the spatial distribution of public sports venues in Shanghai is located at the junction of seven central urban areas, and the distribution density of the seven central urban areas is large, forming a large core area, while the suburban areas (distribution density is small.) Q.I.U. et al. found that sports parks are dense in the central area of Shanghai, with strong accessibility [33], and Yiling et al. used the point density analysis. The gravity model analysis of the current status of spatial accessibility of public hospitals was assessed. The central district has more quality public healthcare resources. Also, it has a higher level of accessibility [32], and other basic public resources in Shanghai are similar to the distribution of public sports venues in this study.

In the analysis of the discrete degree perspective, the central area of Shanghai is agglomerative distribution, and the suburbs are discrete distribution. Zhenhua et al. studied the demand for ecological and cultural services. They concluded that the spatial agglomeration effect of residents' leisure and tourism is noticeable, mainly concentrated in the city center. In contrast, the spatial distribution of the suburbs is relatively discrete [15], which is the same as the study of public sports venues in this paper, the reason for which may be that the seven central urban areas were developed earlier, and the suburban areas and the central city have higher accessibility levels than the main urban areas. Earlier, the economic gap between the suburbs and the major metropolitan areas needed to be bigger, leading to an uneven distribution of resources.

Analyzed from the perspective of regional distribution, the density distribution of public sports venues in Shanghai shows that the east is dense, the west is sparse, the south is light, and the north is thick. The reason may be that the eastern part of Shanghai, as the core economic development area, has the Oriental Pearl Tower, Jinmao Tower, Shanghai Center Tower, Shanghai World Financial Center, and other centers of Shanghai's economic construction. Still, as the old urban area of Shanghai, it is more densely populated. The nearby Zhangjiang Park is where innovative and entrepreneurial talents gather, gathering many highly educated young people interested in sports (Ref). The northern part of Shanghai is the estuary of the Yangtze River, with many ships, convenient transport, a dense population, and a high demand for public sports venues.

Therefore, it can be concluded that the overall distribution of public sports venues in Shanghai is similar to the distribution of economic development level; the distribution of the seven major urban areas in the center of the city is relatively dense, and the distribution density in the suburbs is sparse, and the distribution density of the center of the town extends to the suburbs when the change of the distribution density of the phenomenon of the "cliff-type" reduction; the distribution of the suburb within the suburb is also uneven, and the distribution density of remote areas is significantly smaller. The distribution is also unstable in each suburb, and the distribution density in remote areas is smaller; the spatial distribution of public sports venues in Shanghai is uneven. The existing land resources in the downtown area of Shanghai have been developed, and the space for re-planning and construction in the downtown area is limited, which makes it challenging to create several large-scale public sports venues. It is suggested that the construction of public sports service facilities in the downtown area is shifted to optimizing the stock and that the edges of the downtown area with convenient traffic be selected as the critical construction areas for the development of public sports venues to disperse the distribution pressure of public sports venues in the downtown area. The pressure on distributing public sports facilities in the central city can be distributed.4.2 Visualization analysis of 15-minute accessibility

4.2 Visual Analysis of 15-Minute Accessibility

The seven central districts of Shanghai can achieve 15-minute walking accessibility to public sports venues. In contrast, the distribution of public sports venues in Jiading District, Baoshan District, the eastern part of Qingpu District, the northern part of Pudong New District, and Minhang District must be balanced. There are some vacancies, and the overall distribution of public sports venues in Songjiang District, Fengxian District, Jinshan District, and Chongming District is relatively small in number. Shanghai's metro and bus layout both show a dense inner and outer, central radial network pattern, suburban metro, and bus accessibility from the center to the extreme extension of the gradual decrease in the nine suburbs of Shanghai's residential metro is tiny, the bus is more developed than the metro, suburban residents through the metro to reach the public stadiums in 15 minutes is difficult to achieve, the outer periphery of the Chongming District and the southeast of Pudong New Area part of the residential area There are very few bus stops, and 15-minute access to public stadiums via bus is difficult to achieve. Compared to other districts, the overall public transport in Chongming District could be more sparse.

Therefore, it can be concluded that most of the suburbs in Shanghai have poor 15-minute walking accessibility problems, and the areas are extensive. It is suggested that the construction of rail transit should be considered in the construction of urban suburbs to improve the spatial imbalance of the bus system configuration status quo, to enhance the continuity of the crossroads road network, to increase the conventional bus lines and stations in the suburbs, to improve the accessibility of the bus system in the urban fringe, and at the same time, to strengthen the construction of the central metropolitan area and the public transport network in the suburbs. Make residents' traveling smoother and improve the accessibility to public sports venues.

4.3 Visualization and Analysis of Open School Sports Venues

This study found that there are almost no public sports venues in Chongming District, the west side of Qingpu District, the central part of Jinshan District, and the eastern part of Fengxian District, with underdeveloped bus and metro transport and poor 15-minute walking accessibility, which creates a significant barrier to sports activities. Opening school sports venues can fill some of the vacancies in public sports venues to a certain extent, alleviate the problem of uneven and insufficient distribution of public sports venues in some areas of Shanghai, and improve the coverage of the 15-minute fitness circle in Shanghai. As an essential part of sports venues, opening school sports venues is conducive to increasing the coverage of public sports venues, which several scholars have agreed upon. Zhang L. conducted a study through the questionnaire method and concluded that community sports resources could not satisfy the residents' fitness needs, and 67.4% of the residents hoped that the school sports resources would be opened up to the residents [27]. Peng et al. used the questionnaire survey method and documentation method, and the results showed that opening university sports venues can promote the sustainable development of school sports venues [24]. Yang et al. concluded that the opening of school sports venues has a positive impact on the implementation of the national fitness program [36], and opening school sports venues to provide sports venues for the social population can solve the problem of the shortage of venues for physical activities [37].

Due to the educationally exclusive nature of school stadiums, their opening to the community is limited. Therefore, coordinating the relationship between the "educational exclusivity" and the "public attributes" of school sports venues is the key to improving the social utilization of school sports venues. Open schools can take the following two measures: first, establish and improve the legislation on the management of public sports venues in Shanghai, and implement legalized management of the opening of school sports venues to the public to provide adequate legal protection for the social opening and management of school sports venues. Secondly, the joint construction of public stadiums and schools should be promoted, and the proportion of school stadiums open to public stadiums should be increased. As public stadiums have strong organizational and management capabilities for sports activities, this will reduce the pressure on schools to open their stadiums and facilitate the coordination of arrangements for the use of the stadiums.

5 CONCLUSIONS

This study takes Shanghai City as the study area. It uses data from Shanghai's residential areas and public sports venues based on G.I.S. visualization technology, standard deviation ellipse, the center of mean, and kernel density analysis. The conclusions of the study are as follows. First, the distribution density of the seven major urban areas in the center of Shanghai (Jing'an District, Xuhui District, Huangpu District, Yangpu District, Changning District, Hongkou District, and Putuo District) is significant. In contrast, the distribution density of the suburban areas (Baoshan District, Jiading District, Songjiang District, Fengxian District, Qingpu District, Jinshan District, and Chongming District) is small. The seven major urban areas in the center have formed a large core area, and the distribution of the city's public stadiums appears to have a "cliff-like" pattern outward from the core area. The distribution of public sports venues in the city from the core area to the outside is a phenomenon of "cliff-like" decline; the distribution of the suburbs is also uneven; in the suburbs near the administrative center, the formation of a small core area, the core of the suburbs and the core of the surrounding areas of the density of public sports venues is significantly greater than the remote areas of the city of Shanghai, the phenomenon of the spatial distribution of public sports venues in the city of Shanghai has an imbalance in the distribution of the phenomenon. Secondly, 15-minute walking accessibility is achievable in Shanghai's seven central urban areas. At the same time, the construction of public transport in the suburbs is less, and 15-minute accessibility is poor in most areas of the suburbs. The study recommends the following: 1. The existing land resources in the central urban areas are developed, and the space for re-planning and construction is limited. It is recommended that the construction of public sports service facilities in major urban areas be shifted to stock optimization and the number of public transport in the suburbs be increased. In contrast, the construction of public transport networks between the central urban areas and the suburbs should be strengthened. 2. Promote urban renewal; Shanghai suburban land resources are abundant, the construction cost is lower, can choose the urban fringe with convenient traffic and suburban core area as critical construction area can choose the urban fringe with convenient traffic and suburban core area as the critical construction area. 3. Encourage the opening up of school stadiums, can fill the blank area of the public sports venues in Shanghai, and to a certain extent, can relieve The problem of uneven distribution of public sports venues in Shanghai can be alleviated to a certain extent. The poor accessibility of public sports venues in suburban areas can be improved. Integrating A.I., medical research, and G.I.S. technology offers a powerful approach to uncovering patterns and correlations that may otherwise remain hidden. Through this research, we aim to empower decision-makers with the knowledge needed to create environments that support and encourage physical activity, leading to improved public health outcomes in the dynamic city of Shanghai.

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