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GIS-Based Urban Green Spaces Accessibility Analysis from the View of Transportation: a Case Study of Hong Kong

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Public green spaces have gradually proved to be a key element in promoting sustainable urban development. Green spaces are both the most important natural landscape of a city and provide accessible green spaces for activities that meet the recreational needs of urban residents. If parks are convenient and accessible to residents, they can increase the probability of residents participating in outdoor physical activity, improve their physical and mental health, and alleviate their potential physical and mental fatigue. This study proposes an evaluation method for urban green space accessibility with the aim of improving residents' well-being. Taking Hong Kong Special Administrative Region (SAR), China as an example, the study analyzes the impact of transportation on urban green space accessibility. The methodologies are network analysis and kernel density analysis based on the ArcGIS software analysis platform. Research shows the walking time of urban parks is almost maintained within 14 min in Hong Kong, but the North District with higher green spaces resources have lower accessibility. In this context, this study makes recommendations for policymakers from the perspective of transportation and road system construction based on results. One of the study recommended conclusions is to reduce the number of dead-end roads in the city, develop urban slow-moving road systems such as walking and bicycling, and establish good transportation conditions to improve the accessibility of parks.

1. Introduction

Majority of the world's population is migrating to cities, especially in developing countries promoted the urbanization process. World Bank reported more than half of the world's population currently lives in cities, and predicted the urban population is expected to account for two-thirds of the total urban population by 2050. The acceleration of urbanization leads to the occupation of green space in cities, directly leads to the high fragmentation degree of urban green space, which in turn leads to many social environment and residential life problems. Urban green space, defined as open areas designated in land use planning for parks and other "green spaces" (e.g., plants, water features and other kinds of natural habitats) (Palliwoda and Priess, 2021), which are gradually proved to be one of the key elements in promoting sustainable urban development. As the most important component of the urban natural landscape, green space provides significant ecological services for urban residents, such as regulating the local microclimate, improving air quality, managing rainwater and floods (Paudel and States, 2023).

Urban green public space can also meet the needs of urban residents by creating and maintaining public spaces and natural environments for social interaction, healthy interpersonal interactions and social equity are promoted (Pasanen et al., 2023). In addition, the probability of people participating in outdoor physical activity increases if parkland is easily accessible to residents (Kondo et al., 2018). At the same time, it can provide residents with activity or exercise space to improve their physical and mental health and alleviate their potential physical and mental fatigue (Wolch et al., 2014).Studies have found that in areas where public green space is not easily accessible in cities, people's obesity rate and death risk are correspondingly higher(Semeraro et al., 2021). Urban green space accessibility also can contribute to carbon emission reduction. Green land vegetation can play a role in CO_2 sequestration and thus play a role in climate change mitigation. Comparing carbon sink estimates with total urban CO_2 emissions benefits municipalities for appropriate green space planning to increasing carbon sinks while reducing CO_2 emissions. Given the importance of urban green space, a systematic

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and comprehensive understanding of the accessibility of urban green space in the process of rapid urbanization can help to formulate appropriate green policies that benefit residents.

Hong Kong is one of an emblematical cities in the world with largest population density and limited space, and following the compact development model requires the concentration of floor space and comprehensive allocation of urban functions in the city center. BBC mentioned that public green space accounts for 40 % of total land use in Hong Kong, much higher than in London or New York. However, deeper research shows that the majority of citizens live on less than a quarter of Hong Kong's land, yet Hong Kong's largest parks are located in less densely populated areas, with some Hong Kong residents taking an average of one hour to reach a major country park. Civic Exchange Charity research report showed that compared to other cities, Hong Kong has very little outdoor recreation space available to the public, only about 2.7 m^2 per resident; Singapore, which is smaller than Hong Kong, has 7.4 m^2 of urban public space per capita.

Kwak et al. (2024) through a comprehensive analysis of transportation, environment, health, spatial restructuring, and economic aspects using the Seoul Green Transportation Zone as a research case, the effectiveness of travel demand management (TDM) in reducing greenhouse gas emissions and promoting urban sustainable development has been demonstrated. Jeong et al. (2023) A specially tailored algorithm for personal mobility has been proposed, and an effective path combining personal mobility characteristics has been proposed as an alternative to traditional transportation to improve the accessibility of metropolitan railways in metropolitan areas. In this study, aims to adopt the network analysis module method and kernel density analysis method of ArcGIS to explore the accessibility of urban green space by taking Hong Kong as a case study, and provides references for urban public green spaces design and its optimal layout in urban planning from a transportation perspective, so that more urban residents can enjoy urban green space resources more conveniently.

2. Methodology

2.1 Simple buffer method

A buffer zone is established at the centre of the park, with the maximum service distance as the radius, in order to facilitate the easy reach of the park by people within the buffer zone (Kun et al., 2012). Conversely, buffer zone are unable to enjoy the park services, either in the form of a point buffer and a surface buffer.

This approach employs a straight line to measure the service radius, which fails to account for the heterogeneity of the urban landscape and the existence of natural and man-made landscape barriers to park accessibility (Oh and Jeong, 2007). As a result, the service area of the park is often overstated and accessibility overestimated. Furthermore, this approach assumes that all urban park boundaries are park access points, in reality, not all boundary points are accessible. Consequently, this approach tends to overestimate urban parks accessibility.

2.2 Cost-weighted distance method

The cost-weighted distance method is based on a raster data classification of the urban landscape and employs a shortest path search algorithm to calculate the cumulative resistance (distance, time, cost, etc.) to reach the park in order to evaluate the accessibility of urban parks (Larbi et al., 2018).

The fundamental tenet of the cost-weighted distance method is the classification of the urban landscape, followed by the assignment of varying relative crossing resistances, which are then employed to calculate the cumulative resistance of each point to the park (Gill et al., 2019). However, it still in the theoretical stage about the resistance understanding of citizens in the process of entering the park. (Suleiman et al., 2015). This is because there are only two situations in the process of reaching a certain point: traversable and non-traversable. The method provides a relative resistance to the classification spaces, which is challenging to accurately reflect the actual situation.

2.3 Network analysis module method

The network analysis method may be regarded as a vector version of the cost-weighted distance method based on the road network or the buffer method. The method integrates the barriers to entry into the park, and calculates the coverage of urban parks at a certain resistance value based on a road network according to a certain mode of transportation (Comber, et al., 2008). This method more accurately reflects the process of citizens entering the park in the actual way, and overcomes the obstacles in the process of measuring straight-line distance, which cannot identify the accessibility and the resistance measurement error caused by the cost-weighted distance method (Ahmed, et al., 2017). Network analysis extension module is an important extension module in ArcGIS desktop. The module can create and edit network dataset for traffic network, and also be performed based on the network dataset. It mainly includes the following types of analysis and processing: finding the optimal path, finding the service area, finding the nearest facilities, creating origin-destination cost matrix, and solving the problem of vehicle driving route (path planning).

This study employs topology analysis based on the Hong Kong road network data downloaded from Open Street Map (OSM) and imported into GIS. The corrected road network data is then used to establish a database and a network data set. The latter is employed to construct network analysis, which is then used to calculate the service area function in the network analysis module. The starting point is entered into Hong Kong City Park SHP, and the interval is set at 5 min. The results are then exported as an image, with the layout, scale, north arrow and legend being imported and the image being exported.

2.4 Kernel density analysis method

The kernel density analysis method in GIS can be applied to point, line and area feature classes in order to calculate the density of point, line or area features in the vicinity of each output raster cell. This type of analysis is applicable to a surface with a smooth topography, the surface value is highest at the location of the point and gradually decreases with increasing distance from the point, until it reduces to zero within the search radius distance (Mohaymany et al., 2013). The density of each output raster cell is the sum of the values of all kernel surfaces superimposed at the centre of the raster cell. Kernel density analysis can be applied to a variety of scenarios, and this study employs it to calculate the distribution density of the park. The process begins with selecting the kernel density tool, inputting the requisite elements, and then selecting the park SHP. In order to facilitate a more detailed analysis of the relationship between park distribution and traffic, the park density grid was set to 30 % transparency in GIS, and the subway stations were adjusted to eye-catching colours. The coordinate system employed is consistent with that of the park SHP, and the processing range is consistent with the Hong Kong Administrative Region. Furthermore, the range of grid analysis is also consistent with the boundary of Hong Kong.

3. Results and Analysis

3.1 Urban Green Spaces Distribution in Hong Kong

Hong Kong is characterised by a high mountainous topography, with a relatively low level of flat land. The majority of the land area is submerged by the sea. Figure 1 illustrates that the majority of Hong Kong is mountainous, includes 20.5 % of forest land and 49.8 % of grassland and shrubs. The majority of Hong Kong's urban parks are situated within the built-up areas of the city, including the Eastern District, Wanchai District, Central and Western District, Kwun Tong District, Kowloon City District, Yau Tsim Mong District, and so forth. Among these districts, Kwun Tong District and Kowloon City District exhibit the highest park density.

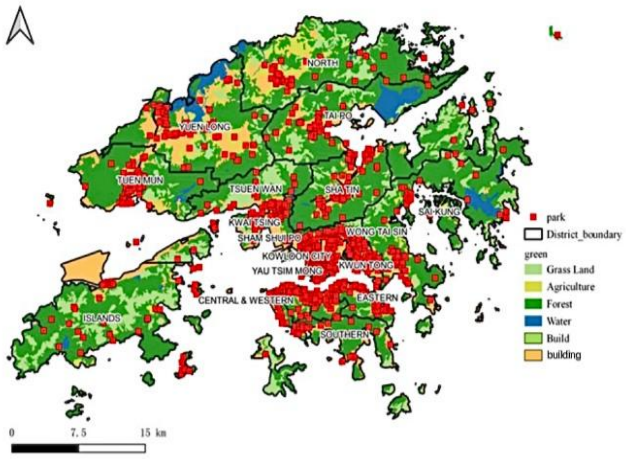

Figure 1: Distribution of Green Space and Urban Parks in Hong Kong

3.2 Transportation and Accessibility

Hong Kong has constructed and manages hundreds of parks of varying sizes, which are strategically located within the urban fabric. These parks serve as convenient rest spaces for citizens, offering a valuable public amenity. To analyse the distribution of urban parks and subway stations, a density analysis was conducted using the kernel density method. Figure 2(a) shows a clear distribution between the density of urban parks and the distribution of subway stations. This indicates that the greater the population density of an area, the greater the availability of public transportation options. Figure 2(b) indicates the road network in Hong Kong. The

accessibility of green space resources is contingent upon the accessibility of transportation networks, which means residents living in proximity to subway stations have higher green space accessibility. Nevertheless, there is a greater availability of green space resources in areas with limited transportation infrastructure, such as the North District. The distribution of green space resources is skewed towards local residents, which consequently results in residents of other areas being unable to access these resources effectively.

(a) (b)

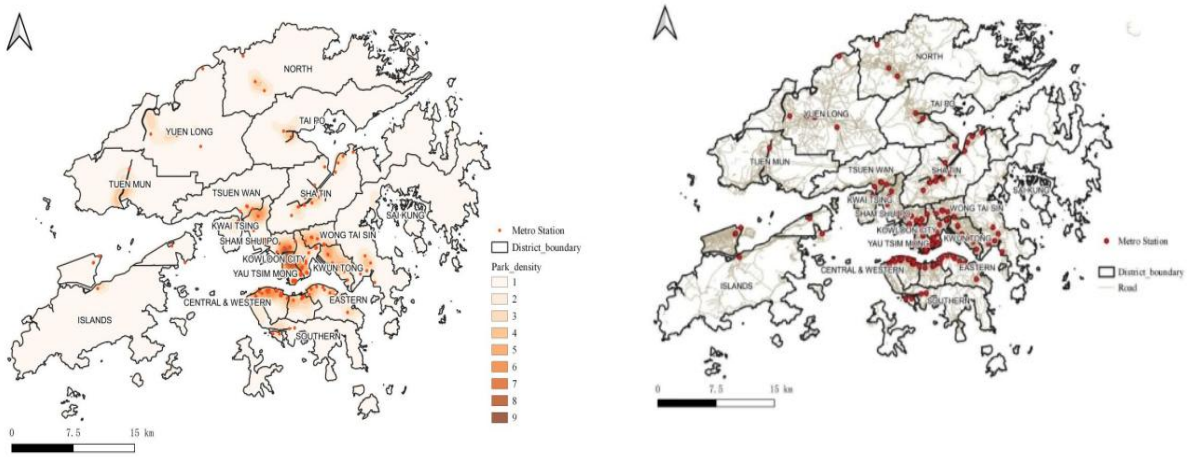

Figure 2: (a) Superposition of Urban Park Density and Subway Station (b) Road Network

In order to obtain a map of accessibility to green spaces, the study involved downloading Hong Kong road data from OSM website. This data was then used to establish a personal geographic database, which was subsequently imported into the personal geographic database. Finally, a topology was created to repair the road network data. Subsequently, a network dataset was established based on the repair data, loaded into GIS, and the network analysis tool was opened. The new service area module was then selected, and park data was input at the location of the facility point. The impedance values in the layer properties were set to 5, 8, 11, 14, 17, 20, 23, 26 and 29. After on-site exploration, it takes about 5 min to travel from the concentrated green spaces (Victoria Bay) in Hong Kong to the nearest city park, while the subway travel time to the relatively distant green spaces (Northern Districts) is about 30 min. In this study, 5 was chosen as the first value, increasing by 3 until the last value of 29, ensuring that the impedance values are set within 30.

Through using the network analysis method, Figure 3 indicates that the accessibility of urban parks tends to diverge from Victoria Bay to the surrounding areas.

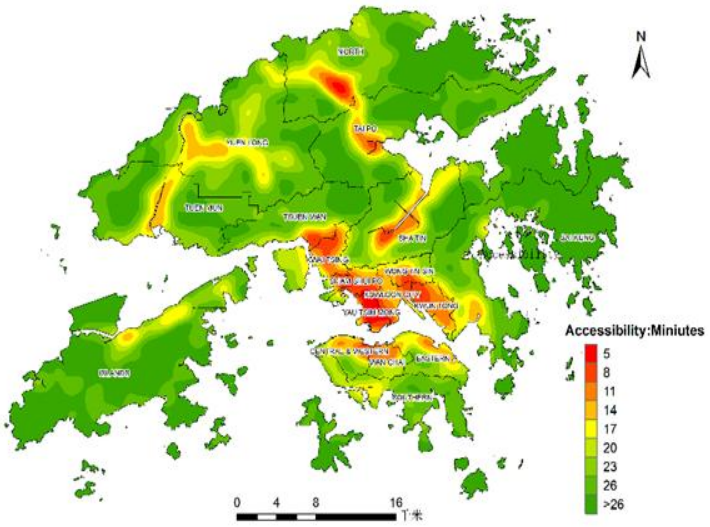

Figure 3: Accessibility map of Hong Kong Park Green Space

In areas with well-developed transportation infrastructure, the accessibility of urban parks is high, allowing more people to enjoy green resources. Currently, a total of 23 country parks, 15 special areas, four marine parks and one marine reserve account for more than 38 % of Hong Kong's total land area. However, reserve green space cannot be included in the scope of urban green space due to its protection status. The only accessible urban green space is a small number of parks located within the urban area. The good accessibility of parks in the urban area since the implementation of urban planning and green space conservation policies can be attributed to the increase in the amount of green spaces around densely populated areas. The urban development in Hong Kong is extremely concentrated, with a small usable land area and an extremely concentrated distribution of parks. The walking time of urban parks is almost maintained within 14 min, with the exception of the conservation of green space. However, although the country parks have better resource conditions, most of them deviate from the urban areas (in the North District). Although the population density in the North District is not as high as in the city center, according to population data released by the Hong Kong government, there are currently 305,000 people living in there. For these residents, the lack of convenient transportation options results in a relatively high time requirement for commuters to reach urban parks, which in turn contributes to a below-average level of accessibility.

3.3 Suggestions

The accessibility of green space in some locations is severely limited, and the park is unable to fulfil its potential and benefit a greater number of people. Field In Trust Agency stressed the importance of ‘locating park’. If the park easy for locals and visitors to find and enter or not, and whether the road to the park is suitable for both pedestrians and vehicles, as well as if the park can be reached by foot from the home or office. Travel time, economic cost, and urban traffic conditions are all factors that affect the accessibility of the park and the willingness of people. It is recommended that the government implement measures to enhance the construction of transportation infrastructure, facilitating the convenient travel of individuals and enabling the full realization of the health benefits associated with green spaces. Furthermore, the availability of alternative pedestrian routes is constrained by the prevalence of high-grade roads, which often necessitates a circuitous route to reach the park, reducing the accessibility of green space within the park. In this context, it is imperative to prioritize the construction of infrastructure that facilitates the safe crossing of high-grade roads by residents. Secondly, policymakers could implement measures to reduce the number of dead ends and dead roads, actively develop urban slow-moving road systems such as walking and bicycles, and construct effective traffic conditions,enhancing the accessibility of the park. Furthermore, the establishment of green spaces within areas with developed transportation infrastructure, such as bus stations or subway stations, would facilitate greater accessibility to green space resources for a larger number of individuals.

4. Conclusions

In the construction process of park green spaces, it is necessary to comprehensively consider the population density and the actual land use nature of the surrounding environment. Different types of park green spaces have different accessibility requirements for different service groups. The accessibility improvement of urban green spaces with relatively small scale and fewer serving populations mainly lies in the improvement of local road accessibility and the satisfaction of the needs of medium density residents. However, large parks, such as country parks, theoretically have a larger service radius and serve a larger number of people. The road section where they are located needs to have good global accessibility, and the overall requirements for the park are relatively high. Excessive numbers and dense distribution of parks can affect the urban construction process to a certain extent, and the actual service efficiency of park green spaces will also be affected. In such densely populated and high demand areas, it is necessary to build urban comprehensive green spaces with higher quality and more comprehensive functions. This not only effectively coordinates the balance between various functional land uses, but also alleviates the land shortage situation and achieves supply-demand matching.

The objective of this study is to utilize GIS technology and related software to investigate the impact of the subway on the accessibility of urban green space. This will be achieved by employing network analysis and kernel density analysis, with Hong Kong serving as a case study. The research findings demonstrate that it is possible to evaluate and analyse the accessibility of park green space based on ArcGIS, in conjunction with network analysis and kernel density analysis. The findings of this study have the potential to inform the optimal allocation of green space in Hong Kong parks.

This study differs from previous research on green space accessibility in that it considers and analyses the effects of park green space layout and road network on accessibility in a comprehensive manner. Nevertheless, while this study has made significant progress, there is still room for improvement. First, in the real world, parks are polygonal. However, this study simplified the form of parks as ‘points’. If the polygon is assumed to be a point during analysis, errors may occur, and more detailed consideration of the features. Therefore, assumptions

of the data for spatial analysis is needed in the future. The other is due to the limitations of the data, it does not consider the differences in residents' choice of transportation mode and the differences in the service capacity of different types of park green space. These are areas that require further research. In the subsequent study, the CO_2 reduction model based on the temperature cooling curve and spatial accessibility network analysis can be used to evaluate CO_2 reduction potential of urban green space to further clarify the relationship between green space accessibility and CO_2 emissions.

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