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Toward a Healthy Urban Living Environment: Assessing 15-Minute Green-Blue Space Accessibility

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Abstract: Exposure to green-blue space has been shown to be associated with better physical and mental health outcomes. The advent of COVID-19 has underlined the importance for people to have access to green-blue spaces in proximity to their residences due to pandemic-related restrictions on activity space. The implementation of the 15-min concept, which advocates that people should be able to reach locations of essential functions like green-blue spaces within 15 min of active travel, can bring green-blue spaces nearer to where people live. Nonetheless, there is still a lack of understanding of the social and spatial (in)equality in 15-min green-blue space accessibility by active travel in cities seeking to embrace the concept, such as Hong Kong. This study explores 15-min green-blue space accessibility by walking and cycling in Hong Kong to reveal the distribution of disadvantaged neighborhoods. The results show that neighborhoods in Kowloon's districts are the most disadvantaged in accessing green-blue spaces within 15 min of active travel. Our study provides policymakers with valuable insights and knowledge conducive to formulating policies aimed at reducing inequality in 15-min accessibility.

Keywords: 15-min city; green-blue space; accessibility; Hong Kong

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1. Introduction

Both green space and blue space (hereafter "green-blue space") have been commonly found to exert beneficial impacts on human health and well-being [1]. Exposure to such spaces has been found to be associated with lower risks for various physical health issues such as obesity, Type 2 diabetes, cardiovascular diseases, respiratory diseases [2–4] and mental health issues such as anxiety, depression and mood disorders [5–7].

The advent of COVID-19 has highlighted the importance of having nearby green-blue spaces since various lockdown policies aimed at curbing the spread of COVID-19 have restricted individual activity space to locations near their residences. Although the lockdown measures have been relatively effective in mitigating the spread of COVID-19, they have also been found to be significantly associated with higher levels of stress and mental disorders [8]. The adverse mental health impact of COVID-19 has been disproportionately felt by socially disadvantaged groups such as low-income people [9,10]. Meanwhile, recent studies have observed that green-blue spaces may help relieve mental health issues such as stress, depression and anxiety during COVID-19 [11–13]. Although green-blue spaces can provide various health benefits before and during the COVID-19 pandemic, their spatial accessibility has not been equally distributed [14–16]. This means that people living in different geographic areas do not enjoy the same level of health benefits from green-blue space.

As a solution to the unequal geographic distribution of resources key to essential urban functions such as green-blue space, the 15-min city concept has swiftly gained popularity in cities around the world, such as Paris, Utrecht, Shanghai and Portland. This concept was initially proposed by Moreno (2016) [17], who advocates that the locations of six essential urban functions (i.e., living, working, commerce, healthcare, education and entertainment) should be reachable within 15 min of active travel (i.e., walking and cycling). The attainment of those essential urban functions depends on configuring the urban built landscape in a way that ensures the ease of reaching locations or spaces that are critical for achieving an urban life of high quality for all urban residents [18]. Therefore, it is important to identify the locations or spaces capable of performing essential urban functions and ensure that people can reach those locations or spaces within 15 min.

Green-blue spaces provide venues and facilities where people can safely exercise, socially interact with each other and host various outdoor entertainment events [19,20]. It can fulfill essential living and entertainment functions. Existing literature has also commonly considered green-blue space as possessing aesthetic, recreational and health benefits for urban residents [21–23]. These benefits constitute key aspects of the living and entertainment functions of an urban environment. Despite the key functions fulfilled by green-blue space as well as the increasing popularity and adoption of the 15-min city concept, little is known to date about the spatial distribution of green-blue space accessibility in 15 min across different urban neighborhoods.

This study seeks to investigate green-blue space accessibility, which specifically refers to the ease of reaching locations of green-blue space within 15 min of walking or cycling. We aim to provide insights into 15-min green-blue space accessibility by active travel to enable policymakers to better identify the gaps in the distribution of green-blue space resources and formulate intervention measures aimed at mitigating the social inequalities in reaching green-blue spaces by active travel.

By using the data provided by different government departments, we seek to shed light on the distribution status of 15-min accessibility to green-blue space based on the enhanced two-step floating catchment area (2SFCA) method. The results from this research can reveal the disadvantaged neighborhoods, which helps policymakers formulate intervention measures conducive to the alleviation of the disadvantages.

2. Data and Methodology

2.1. Study Area

Our study selects Hong Kong, which is a densely populated Asian metropolis bordering mainland China in the north, as the study area. Hong Kong is currently on the steering committee of the C40 Cities Climate Leadership Group (C40 Cities), which is a major international organization aimed at increasing the well-being of urban residents around the world. The C40 Cities is a main advocate for the 15-min city concept and many of its member cities have incorporated this concept into their urban development plans. This concept is also in line with the objective of enhancing livability in a compact high-density city in the Hong Kong 2030+ report published by the Hong Kong Government. This makes Hong Kong a suitable study area for examining 15-min green-blue space accessibility.

Hong Kong, with a population of more than 7.6 million as of 2022, consists of three regions that are further divided into 18 administrative districts as shown in Figure 1.

Among the three regions, the land area of the New Territories alone accounts for more than 85% of the total land area and is the least densely populated region in Hong Kong. The much smaller Kowloon and Hong Kong Island, which have experienced earlier urban development than the New Territories, have high densities of residential and commercial buildings.

In terms of sociodemographic characteristics, the districts in Hong Kong Island generally have a higher median monthly household income when compared to districts in Kowloon and the New Territories as illustrated in Table 1. Further, the districts (except Kwai Tsing) in the New Territories have a much lower population density compared to the districts in Kowloon and Hong Kong Island.

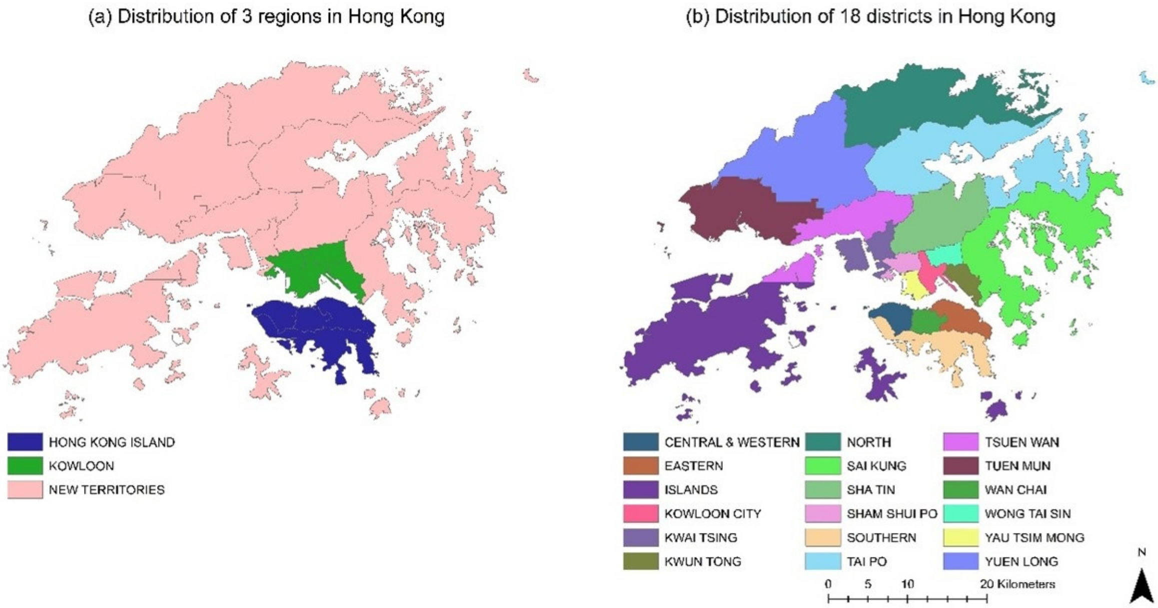

Figure 1. Distribution of the (**a**) three regions and (**b**) 18 districts in Hong Kong.

Table 1. Population density and median monthly household income of the 18 districts.

Regions	Districts	Population Density (per km^2)	Median Monthly Household Income
New Territories	North	2310	$21,500
	Tai Po	2233	$26,200
	Sha Tin	9602	$26,800
	Sai Kung	3563	$31,500
	Tsuen Wan	5149	$29,200
	Kwai Tsing	22,307	$21,200
	Yuen Long	4435	$22,800
	Tuen Mun	5894	$22,500
	Islands	886	$28,900
Kowloon	Wong Tai Sin	45,711	$22,000
	Kowloon City	41,802	$26,900
	Kwun Tong	57,530	$20,800
	Sham Shui Po	43,381	$20,600
	Yau Tsim Mong	49,046	$25,800
Hong Kong Island	Central and Western	19,391	$39,500
	Wan Chai	17,137	$40,000
	Eastern	30,861	$31,300
	Southern	7080	$30,700
Overall		6777	$25,200

To better illustrate the fine-grained sociodemographic distribution in Hong Kong, Figure 2 is produced.

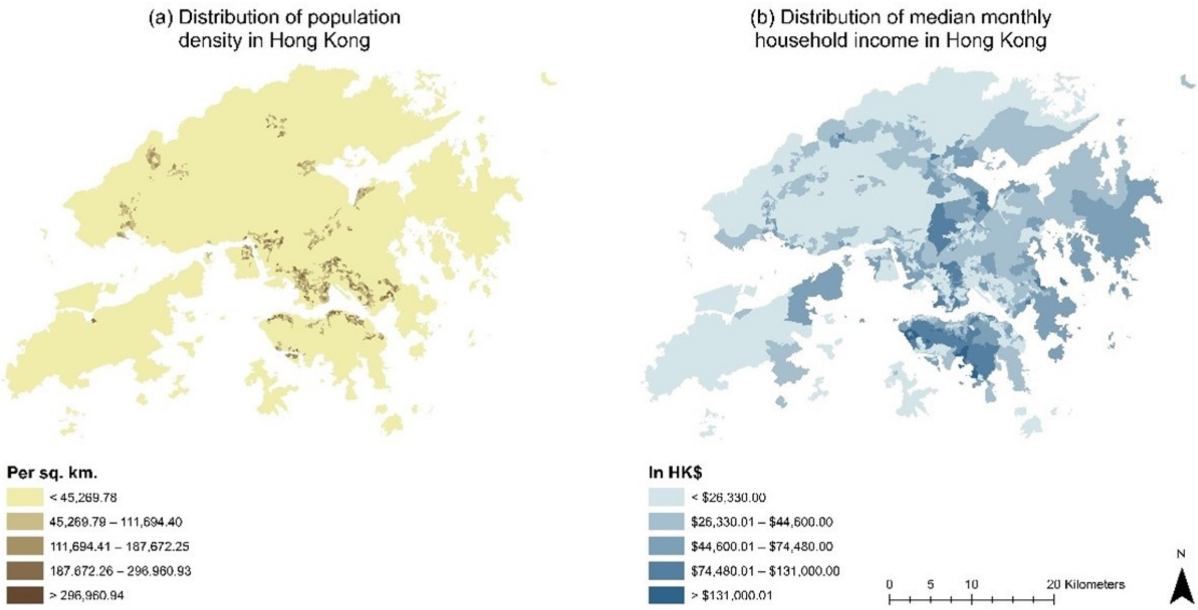

Figure 2. Distribution of (**a**) population density and (**b**) median monthly household income in Hong Kong.

As shown in Figure 2, the most densely populated districts in Hong Kong are distributed in Kowloon and along the northern coast of Hong Kong Island. There are also some population centers distributed around the New Territories, which consist of the new towns built between the 1960s and the 1990s to accommodate the swiftly increasing population in Hong Kong at that time.

2.2. Data Source

The datasets used in this study are collected from a variety of government departments in Hong Kong and are at the Large Street Block Group (LSBG) level. The LSBG is the smallest census unit where census data are provided in the study area [24,25]. Specifically, sociodemographic data including information on the population, population density and median monthly household income are collected from the 2016 Population By-Census of Hong Kong, which is the latest by-census where census data at all unit levels (including the smallest LSBG census unit) have been released. Furthermore, the 2020 green space and blue space data are provided by the Planning Department, which defines green space as including woodland, shrubland, grassland, country parks, open and recreation space; and blue space as including beaches, the harbor, rivers, streams, wetlands, artificial lakes and reservoirs, marine parks and reserves. Finally, the 2020 road network data are obtained from the Transport Department.

2.3. Methodology

Our study measures 15-min green-blue space accessibility as the supply of green-blue space discounted by the population demand and travel friction within 15 min of walking and cycling. To calculate 15-min green-blue space accessibility, we use the enhanced 2SFCA method that incorporates the distance decay effect into the measurement. The enhanced 2SFCA method is chosen because of its advantages in terms of its (1) integration of the distance decay function; (2) consideration of both supply and demand for resources (i.e., green-blue space in this study) compared to the more traditional gravity-based and cumulative opportunity measures [26,27]. By resorting to the enhanced 2SFCA method, the measurement of accessibility is implemented in the following two steps:

Step 1: For each LSBG j, we find LSBG o whose centroid is within the 15-min active travel distance buffer from the centroid of LSBG j and calculate the green-blue space area-to-population ratio L_j within the buffer from the centroid of LSBG j. Step 1 is operationalized based on Equation (1):

$$L_j = \frac{C_j}{\sum_{o \in \{d_{oj} \leq S\}} P_o \times EXP\left(\frac{-d_{oj}}{\mu}\right)} \tag{1}$$

where L_j is the ratio of the area of green and blue space to the population for LSBG j; C_j is the area of both green and blue space in LSBG j; P_o is the total population in LSBG o whose centroid is within the travel distance threshold from the centroid of LSBG j; d_{oj} is the distance between the centroids of LSBG o and LSBG j; and S is the walking distance (i.e., 1.25 km) or cycling distance (i.e., 3.75 km) covered within 15 min based on the average walking speed of 5 km/h or the average cycling speed of 15 km/h used by past studies [28–30]. Note that there are two green-blue space area-to-population ratios (L_j) and accessibility measures, one for walking and one for cycling. μ is the Gaussian distance decay function parameter.

Step 2: For each LSBG i, find all LSBGs whose centroids are within the 15-min active travel distance buffer from the centroid of LSBG i and sum up the green-blue space area-to-population ratios calculated from Step 1, L_j, at these LSBGs. Step 2 is operationalized based on Equation (2):

$$A_i = \sum_{j \in \{d_{ij} \leq S\}} L_j \tag{2}$$

where A_i is the 15-min green-blue space accessibility for LSBG i; and d_{ij} is the distance between the centroids of LSBG i and LSBG j.

After obtaining the 15-min green-blue space accessibility by walking and cycling (differentiated by different values of S in Equation (1) as described above), we proceed to reveal the LSBGs with lower-than-median accessibility and consider these LSBGs as being disadvantaged in accessing green-blue space. Then, we calculate the percentage of LSBGs with lower-than-median accessibility by walking and cycling in each district, as shown by Equation (3):

$$P_b = \frac{M_b}{L_b} \tag{3}$$

where P_b is the percentage of LSBGs with lower-than-median accessibility by walking and cycling in district b; M_b is the number of LSBGs in district b whose accessibility is lower than the median accessibility of the entire Hong Kong by walking and cycling; and L_b is the total number of LSBGs in district b.

Finally, we rank the districts by the percentage of LSBGs with lower-than-median accessibility by walking and cycling and determine the districts that are more disadvantaged in accessing green-blue space.

3. Results

Based on Equations (1) and (2), we obtain the results of 15-min green-blue space accessibility in the study area by walking and cycling, which are visualized in Figure 3.

Figure 3 shows that the districts in the New Territories generally have better 15-min green-blue space accessibility by both walking and cycling than the districts in Kowloon and on Hong Kong Island. This may be explained by the fact that large parts of the New Territories are occupied by country parks and conservation areas, which generally provide good exposure to green-blue space for residents living there. Further, as Figure 3 also shows, the values of walking and cycling accessibility are different in most LSBGs. Since cycling can help people reach green-blue spaces in a greater catchment area (when compared to walking), the supply of green-blue space increases when the travel mode is cycling. Nonetheless, the demand for the supply of green-blue space also increases when the travel mode is cycling because the size of the population also increases as the size of the catchment area increases. To better illustrate the difference in 15-min green-blue space accessibility between walking and cycling, we proceed to produce Figure 4. The accessibility score difference, as shown in Figure 4, is obtained by subtracting the green-blue space accessibility score by walking from the green-blue space accessibility score by cycling.

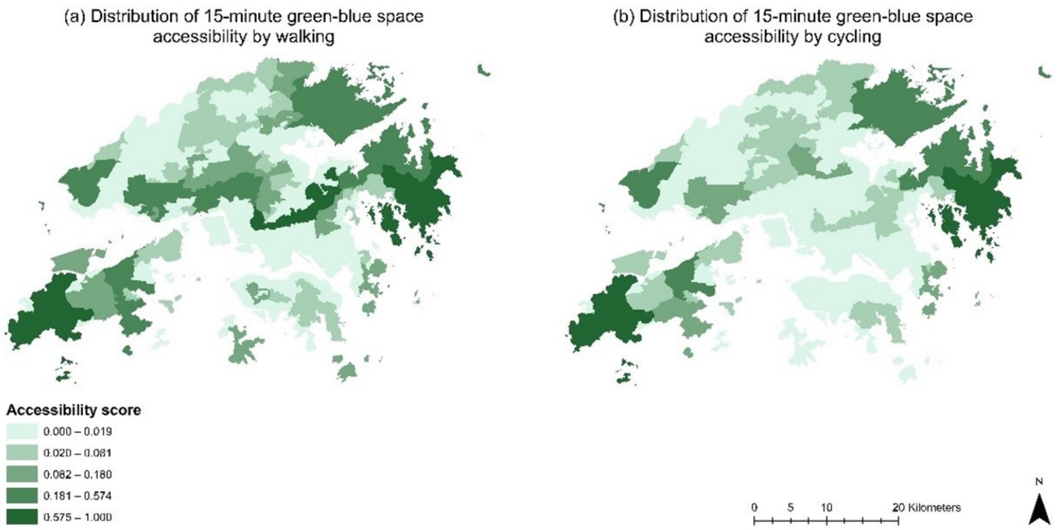

Figure 3. Distribution of 15-min green-blue space accessibility by (**a**) walking and (**b**) cycling.

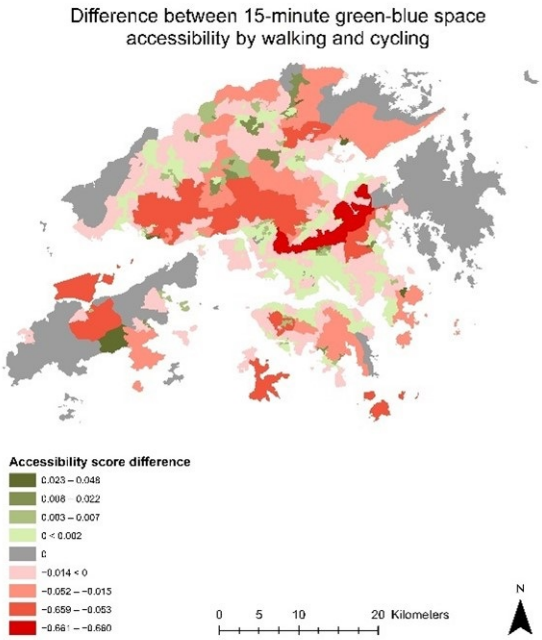

Figure 4. Difference between 15-min green-blue space accessibility by walking and cycling.

As illustrated in Figure 4, the green-colored LSBGs are the ones where cycling-based accessibility is higher than walking-based accessibility; the red-colored LSBGs are the ones where cycling-based accessibility is lower than walking-based accessibility; and the grey LSBGs are the ones where there is no difference between cycling- and walking-based accessibility. It can be seen that in the districts in Kowloon and the northern strip of Hong Kong Island, people have higher levels of cycling-based green-blue space accessibility when compared to walking-based accessibility. This may be explained by the fact that the amount of green-blue space in the larger cycling-based catchment areas (when compared to walking-based catchment areas) increases more than the population (demand) for the LSBGs in Kowloon and the northern strip of Hong Kong Island. In other words, the increase in green-blue space supply due to the larger catchment areas is more conducive to the accessibility improvement in the LSBGs of Kowloon and the northern strip of Hong Kong Island where the population demand is already very high but the green-blue space is very limited.

Meanwhile, in the districts in the New Territories and the Southern District of Hong Kong Island, people have lower levels of cycling-based green-blue space accessibility when compared to walking-based accessibility. This may be explained by the fact that the amount of green-blue space in the larger cycling-based catchment areas (when compared to walking-based catchment areas) increases less than the population (demand) for the LSBGs in the New Territories and the Southern District of Hong Kong Island. Note that although the red-colored LSBGs account for 56.68% of the total land area in Hong Kong, they only contain 17.91% of the total population in Hong Kong. This is because large parts of the red-colored LSBGs are occupied by country parks and nature reserves that already have very good green-blue space coverage but a small population. In this context, the larger cycling-based catchment areas could mean that the population living in the neighboring highly urbanized and densely populated LSBGs gets included as part of the demand for the green-blue space supply, while the additional highly urbanized LSBGs only bring in slightly more green-blue space.

In terms of the number of LSBGs where there is a difference between cycling- and walking-based 15-min green-blue space accessibility, our results indicate that among all 1622 LSBGs in Hong Kong, cycling-based accessibility is higher than walking-based accessibility in 1273 (78.48%) LSBGs, walking-based accessibility is higher than cycling-based accessibility in 320 (19.73%) LSBGs, and there is no difference between cycling- and walking-based accessibility in 29 (1.79%) LSBGs. This indicates that the larger catchment areas (activity space) brought about by cycling would help most LSBGs in Hong Kong improve their 15-min green-blue space accessibility.

After examining the difference in 15-min green-blue space accessibility by walking and cycling, we proceed to produce Figure 5 to illustrate the spatial distribution of the LSBGs with lower-than-median accessibility by walking and cycling, respectively.

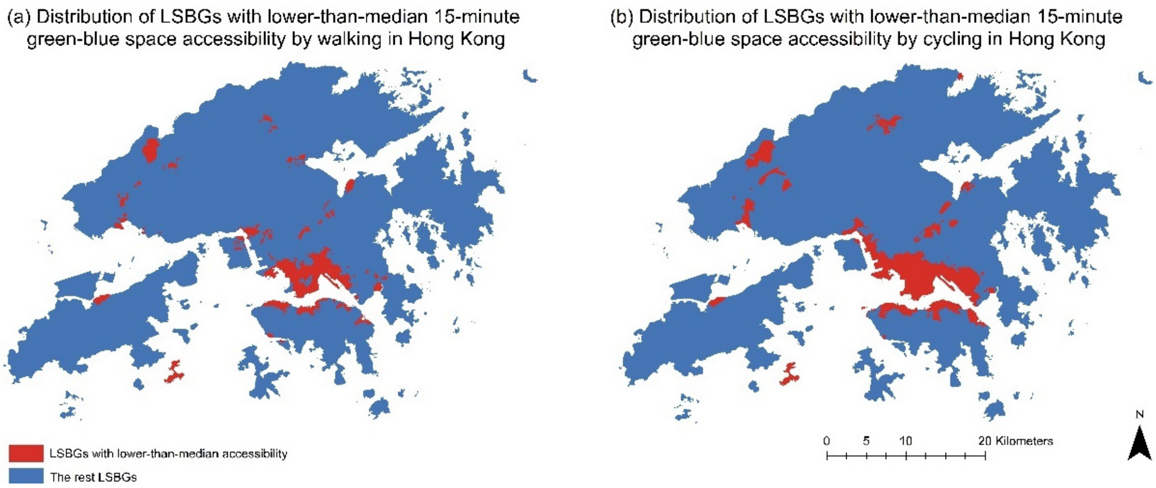

Figure 5. Distribution of LSBGs with lower-than-median 15-min green-blue space accessibility by (**a**) walking and (**b**) cycling in Hong Kong.

As shown in Figure 5, LSBGs marked in red color have lower-than-median accessibility and are considered as being disadvantaged in terms of accessing green-blue space within 15 min of walking and cycling. As shown in Figure 5a, most walking-based disadvantaged LSBGs are concentrated in the districts of Kowloon. In addition, there are large pockets of walking-based disadvantaged LSBGs in the districts along the northern part of Hong Kong Island (i.e., Central & Western, Wan Chai, Eastern) and in the new towns of some districts (i.e., Kwai Tsing, Tsuen Wan) spreading around the New Territories. In addition, Figure 5b shows that most cycling-based disadvantaged LSBGs are again concentrated in the districts of Kowloon and the northern districts (Central & Western, Eastern) of Hong Kong Island. In the New Territories, large pockets of cycling-based disadvantaged LSBGs can be found in the district of Sha Tin. This indicates that the extent of cycling-based disadvantaged LSBGs appears to be larger than the extent of walking-based disadvantaged LSBGs. Regardless of the mode of active travel, most disadvantaged LSBGs are found in Kowloon and the northern part of Hong Kong Island where the amount of green-blue space is low due to early and advanced residential and commercial development.

To better reveal the disadvantaged districts in terms of 15-min green-blue space accessibility, we aggregate the LSBGs with lower-than-median accessibility to the district level by walking and cycling separately. Based on the results obtained from Equation (3), we produce Tables 2 and 3 to show each district's percentage of LSBGs with lower-than-median accessibility by walking and cycling respectively.

Table 2. Percentage of LSBGs with lower-than-median accessibility by walking.

District Name	% of LSBGs with Lower-Than-Median Accessibility by Walking
Yau Tsim Mong	97.78%
Kowloon City	91.79%
Sham Shui Po	72.50%
Wong Tai Sin	70.59%
Central & Western	61.76%
Wan Chai	56.41%
Kwun Tong	55.00%
Eastern	52.29%
Kwai Tsing	45.76%
Tsuen Wan	41.07%
Sha Tin	30.48%
Yuen Long	28.99%
Islands	27.59%
Tuen Mun	23.46%
Tai Po	18.99%
Sai Kung	14.49%
Southern	12.28%
North	11.39%

As shown in Table 2, the top four districts with the highest percentage of LSBGs with lower-than-median accessibility by walking belong to Kowloon: Yau Tsim Mong (97.78%), Kowloon City (91.79%), Sham Shui Po (72.50%) and Wong Tai Sin (70.59%). In addition, except for the Southern District, all the districts on Hong Kong Island have higher percentages of LSBGs with lower-than-median accessibility by walking than all the districts in the New Territories. Overall, the results in Table 2 show that the districts in the New Territories generally fare better than the districts in Kowloon and on Hong Kong Island.

As indicated in Table 3, the top four districts with the highest percentage of LSBGs with lower-than-median accessibility by cycling once again belong to Kowloon: Yau Tsim Mong (100.00%), Sham Shui Po (100.00%), Kowloon City (97.01%) and Kwun Tong (93.75%). The Wong Tai Sin (19.12%) district in Kowloon as well as the Southern (1.75%) district and Wan Chai (17.95%) district on Hong Kong Island fare much better than their same-region counterparts in terms of the percentage of LSBGs with lower-than-median accessibility by cycling. The cycling accessibilities of Wong Tai Sin and Wan Chai are much higher than their walking accessibility. The districts in the New Territories generally still enjoy good cycling accessibility. Overall, the results in Table 3 show that (1) the districts in the New Territories still fare better than the districts in Kowloon and on Hong Kong Island;

(2) but some districts in Kowloon and on Hong Kong Island witness substantially higher cycling-based accessibility when compared to walking-based accessibility.

Table 3. Percentage of LSBGs with lower-than-median accessibility by cycling.

District Name	% of LSBGs with Lower-Than-Median Accessibility by Cycling
Yau Tsim Mong	100.00%
Sham Shui Po	100.00%
Kowloon City	97.01%
Kwun Tong	93.75%
Eastern	67.97%
Central & Western	56.86%
Sha Tin	40.00%
North	27.85%
Islands	27.59%
Tuen Mun	27.16%
Yuen Long	24.64%
Kwai Tsing	23.73%
Tsuen Wan	23.21%
Wong Tai Sin	19.12%
Wan Chai	17.95%
Sai Kung	8.70%
Southern	1.75%
Tai Po	0.00%

4. Discussion and Conclusions

Given the dearth of studies examining accessibility issues under the 15-min city conceptual framework, this study contributes to the literature by innovatively applying the enhanced 2SFCA method to investigate 15-min green-blue space accessibility by walking and cycling in the context of Hong Kong. As an urban location serving key living and entertainment functions, easy access to green-blue space is important to people's overall health. Our study helps reveal the spatial distribution of the neighborhoods at the smallest census unit that are disadvantaged in terms of 15-min green-blue space accessibility by walking and cycling. It provides insights into the geographic inequality in green-blue space accessibility that needs to be addressed in order for Hong Kong to make significant progress in becoming a 15-min city.

Overall, our results show that LSBGs in most districts in Kowloon are at the most disadvantaged in terms of 15-min green-blue space accessibility by both walking and cycling. Therefore, the Hong Kong Government should consider allocating more resources towards the development of green-blue space in the five districts of Kowloon, including Wong Tai Sin, Kowloon City, Kwun Tong, Sham Shui Po and Yau Tsim Mong. These districts include some of the earliest-developed neighborhoods in Hong Kong such as Yau Ma Tei, Jordan and Mong Kok where the population and building densities are among the highest in the entire world. Therefore, in order to develop more green-blue space for residents living there, the government needs to come up with innovative urban renewal plans such as vertical green-blue space development that has been successfully implemented in other places with similar high-rise and high-density contexts such as Singapore [31,32].

For Hong Kong Island, the Central & Western and Eastern districts have a consistently high percentage of their LSBGs at a disadvantage in terms of 15-min green-blue space accessibility by both walking and cycling. For the district of Wan Chai, although more than half of its LSBGs have lower-than-median accessibility by walking, the percentage dropped to less than 20% when it comes to cycling-based accessibility. This suggests that the government should mostly focus on the Central & Western, Eastern and Wan Chai districts for walking-based improvement of green-blue space accessibility, but should only focus on the Central & Western and Eastern districts for cycling-based improvement of green-blue space accessibility.

For the New Territories, our results show that no districts in the region have more than half of the LSBGs with lower-than-median accessibility by either walking or cycling. Only Kwai Tsing and Tsuen Wan have more than 40% of their LSBGs with lower-than-median accessibility by walking. This shows that the New Territories ranks at the top among all three regions in terms of 15-min green-blue space accessibility performance. The government should focus on the LSBGs in Kowloon and the northern part of Hong Kong Island for improving the overall 15-min green-blue space accessibility in Hong Kong.

Despite the contributions made by this research, some aspects of this study can be improved subject to data availability in the future. First, we have not differentiated the quality and type of green-blue space, which have different recreational values affecting the use frequency and health benefits [33,34]. Second, the quality and type of transport infrastructure, including pedestrian paths and cycling lanes, can also influence people's travel behavior. For example, separated cycling lanes can be more attractive than shared cycling lanes for people when accessing green-blue space even when using shared cycling lanes means shorter travel distances [35,36]. Third, using data on people's daily mobility may improve the accessibility results [37]. These three limitations may be addressed by measuring the perceived accessibility to green-blue space by people and taking into account people's mobility. Further, future studies may also seek to (1) compare perceived 15-min green-blue space accessibility to that based on spatial data alone and (2) reveal the variations between these two types of accessibility results and their associated influencing factors.

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