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Modeling Elderly Accessibility to Urban Green Space in High Density Cities: A Case Study of Hong Kong

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Abstract

Hong Kong is an ageing society. According to the World Health Organization, an estimated 22% of its residents will be 65 years old or above by the year 2030. Physical activities provide an important way for older people to stay healthy. Green space is recognized as an important environmental setting for physical activity. Therefore, improving elderly accessibility to green space is useful in promoting more physical activity among them. The aim of this study is to modeling and assessing the elderly accessibility to urban green spaces in Hong Kong, by (1) modeling urban green spaces available for elderly people using the landscape fragmentation index (LFI) of green space patches, and (2) accessibility analysis in terms of both distance and time for elderly people to get urban green space patches. As a result, regions with LFI from high to low and accessibility from good to poor are Kowloon, Hong Kong Island, and New Territories. Kowloon has the highest LFI and accessibility. However, it is limited by small size green space patches which may not be in good quality and attractive for elder people. New Territories, due to its large number of available lands, has the largest proportion of big size green space patches. However, they are limited by their poor accessibility. Based on these evidences, we would suggest the prior improvement (1) in Kowloon is to have more green spaces with larger sizes, (2) in New Territories is to increase the green space accessibility either by improving the walking routes or building more small to median size green space patches that can well cover the whole region.

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Keywords: Urban green space; Accessibility anaysis; Elderly; High density cities; Hong Kong

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1. Introduction

Hong Kong, a typical high density city in Asia, is an ageing society with increasing life expectancy for men and women. In Hong Kong, men have the longest while women have the second longest life expectancy in the world[1]. An estimated 22% of its residents will be 60 years old or above by the year 2030, according to the World Health Organization. It is widely documented that the living environment plays an important role in promoting or inhibiting physical activity, which is crucial for older people to stay healthy[2]. In particular, green space has been recognized as one of the most important behavior settings for physical activity of elderly people[3].

Urban green space provides a wide range of benefits in sustaining urban natural environments and the social systems that use these spaces. The benefits include improving air quality, reducing urban heating island effects, and making urban environments more preferable. Moreover, exposure to green spaces promotes physical activities and enhances mental health and psychological state of elderly people[4,5]. However, to achieve these benefits, urban green spaces must be accessible to the public, as accessibility is the key to effective social and ecological functioning of cities[6]. The role of accessibility of urban green space is especially important for elderly people in high density city since they are the age group who will beneficial the most from their living environment[1].

In this study, we aim to model and assess the elderly accessibility to urban green spaces in Hong Kong, by (1) modeling urban green spaces available for elderly people using the landscape fragmentation index of green space patches, and (2) accessibility analysis in terms of both distance and time for elderly people to get urban green space patches. Based on the results, some suggestions on planning and design of urban green spaces in Hong Kong are provided.

2. Background

2.1. High density living environment in Hong Kong

Hong Kong is an example of a high density city, including a total of more than 7 million residents and a total land and sea area of 2,754 km^2. Strictly limited by urban policies for land use planning in Hong Kong[7], the sprawl of built-up areas, new towns and metropolitan area (272 km^2) account for about 25% of the total areas (1,104 km^2). As a result of high density and very limited open spaces, high degree of fragmentation, less green space in some areas, week accessibility and connectivity are the major problems of green spaces in high density areas in Hong Kong. As shown in Table 1, the total green park area distributed in 18 council districts in Hong Kong is 22.7 km^2, in which New Territories has the largest green park area (14.9 km^2) and Kowloon the smallest (3.6 km^2). The result of green park area per elderly person shows that, Kowloon and Hong Kong Island has lower value because of their higher density of residential and business area compared to New Territories. As a solution, enhancing the accessibility through public transportation systems and walking lanes to urban green spaces is one of the most cost effective approaches to enable connections between residents and natural environment[8].

2.2. Aging population in Hong Kong

Hong Kong consists of 18 communities named District Council districts for local administrative purpose. The demographic and socioeconomic profiles vary across these districts[1]. Based on statistics on "*Domestic Households, the Thematic Report on Older Persons"* and "*Domestic Households with Older Persons"*, the projection of total domestic household number with older persons can be obtained. Table 1 shows the population distribution and corresponding basic statistics of green park area, both of which are the basic datasets in the following green space accessibility analysis. The population proportion of age group at 65 and above in most council districts are more than 10%, especially the areas in the Hong Kong Island and Kowloon, the proportion is nearly or more than 15%.

Table 1. Population, Proportion and Density by District Council.

ID No.	Council District	Population Number (*All Age Group*)	Population Number (*Age Group 65+*)	Population Density *%* (*number/km*^{2})	Population Proportion *%* (*Age Group 65+*)	Green Park Area (*km*^{2})	Green Park per Elder Person (m^2/person)
Hong Kong Island		1,268,112	173,731	15,915	13.7	4.1	3.2
HK01	Central &Western	250,064	31,008	20,102	12.4	0.5	2.1
HK02	Wan Chai	155,196	22,503	15,788	14.5	0.5	3.2
HK03	Eastern	587,690	82,864	31,664	14.1	1.0	1.7
HK04	Southern	275,162	37,147	7,083	13.5	2.1	7.6
Kowloon		2,019,533	321,106	43,033	15.9	3.6	1.8
KLN01	Yau Tsim Mong	280,548	37,313	40,136	13.3	0.7	2.3
KLN02	Sham Shui Po	365,540	61,045	39,095	16.7	0.7	1.9
KLN03	Kowloon City	362,501	52,200	36,178	14.4	0.8	2.2
KLN04	Wong Tai Sin	423,521	75,387	45,540	17.8	0.7	1.7
KLN05	Kwun Tong	587,423	93,988	52,123	16.0	0.8	1.3
New Territories		3,573,635	357,363	22,421	10.0	14.9	4.2
NT01	Kwai Tsing	523,300	72,739	4,679	13.9	0.6	1.2
NT02	Tsuen Wan	288,728	33,234	6,057	11.5	0.5	1.8
NT03	Tuen Mun	502,035	44,179	3,858	8.8	0.9	1.8
NT04	Yuen Long	534,192	44,338	2,055	8.3	1.6	2.9
NT05	North	280,730	28,354	2,156	10.1	2.3	8.3
NT06	Tai Po	293,542	27,887	8,842	9.5	1.0	3.3
NT07	Sha Tin	607,544	62,577	3,135	10.3	1.3	2.1
NT08	Sai Kung	406,442	33,328	783	8.2	3.8	9.3
NT09	Islands	137,122	12,067	3,748	8.8	3.0	21.6
Land Total		6,861,280	850,799	6,352	12.4	22.7	3.3
Marine Total		3,066	133	--	3.7	--	--
Whole Territory Total		6,864,346	851,179	6,352	12.4	22.7	3.3

2.3. Planning guideline for green space accessibility

According to the recommendations from Accessible Natural Greenspace Standard (ANGSt)[9], any resident, regardless of where they live, should have an accessible green space that is: (1) at least 2 ha in size, and (2) no more than 300 m (or a 5 min walk) from their living house. Moreover, ANGSt recommends that every resident should have access to at least: (1) one accessible 20 ha site within 2 km from their home, (2) one accessible 100 ha site within 5 km from their home, (3) one accessible 500 ha site within 10 km from their home, and (4) a minimum of 1 ha of statutory Local Nature Reserve per thousand residents[10,11]. However, these standards are difficult to apply to high density cities, like Hong Kong because of their extreme limited lands. Hong Kong Planning Standards and Guidelines (HKPSG) suggests that urban open spaces should be located within short walking distance from the residents, preferably within a radius of not more than about 500 m and should be located close to major transport routes and interchanges. Both ANGSt and HKPSG emphasize the importance of green space accessibility, especially for elderly people in high density city. These guidelines underlie the development of the combined social network analysis and GIS approach to study accessibility of public green spaces for elderly in high density cities[8,12].

3. Method

3.1. Data collection

- Road Network in Hong Kong

Hong Kong has the most heavily used roads in the world. According to the statistical analysis based on the GIS transportation data base, there were over 720,000 vehicles on 2,100 kilometers of roads, in which 442 km on Hong Kong Island, 465 km in Kowloon and 1,193 km in the New Territories. Moreover, there are 15 major road tunnels, 1,332 flyovers and bridges as well as 1,216 footbridges and subways to keep people and goods on the move[13].

- Green Space in Hong Kong

In this study, the green space refers to urban green parks that are openly accessible by the public. The green space data are shown in Figure 1. These green space patches are separated into 7 different categories according to their areas. An analysis of these green space patches is presented in Section 4.1.

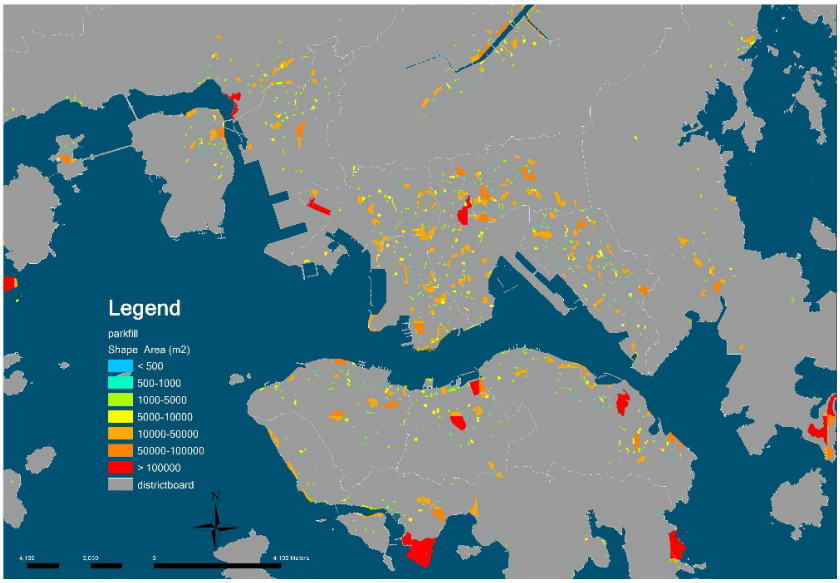

Fig. 1. The distribution of the urban green parks of different scales in Hong Kong.

3.2. Data analysis

ArcGIS Network analysis, which provides network-based spatial analysis tools for solving complex routing problems, is used in this study. It has been successfully used in analyzing water distribution, stream flows, and traffic flows, in which centers, links, nodes, and impedance are key elements in that analysis, and is often concerned with determining the supply and demand of some resource[14]. The access points for urban green space patches were manually digitized using 1:50,000 scale raster data and were placed inside the green spaces as shown in Figure 1. Similar to previous study[9], nodes to represent the supply (access points to the green spaces) and the demand (the locations of the output areas) were inserted into the line network prior to running the network analysis.

4. Results

4.1. Distribution and Fragmentation of Urban Green Space in Hong Kong

A statistical description and landscape fragmentation index of the green space and the datasets used for constructing the green space layers are shown in Table 2. There are in total 2,935 green space patches in Hong Kong, in which more than 50% green space patches are smaller than 0.01 km^2. The density of green space patch is 22.9 patches per km^2 in Hong Kong. More than half of the green space patches are smaller than 1000 m^2. The non-edge-based landscape metric, patch-based landscape fragmentation index (LFI), have been used for quantifying landscape fragmentation[15]. The LFI is defined as $(N-1)/A$, where N is the number of patches in the landscape and A is the average patch size. The LFI is generally an effective tool for measuring landscape fragmentation[16]. The smaller area of green space patches, the higher of the landscape fragmentation index. The LFI result from high to low shows that Kowloon > Hong Kong Island > New Territories, according to the percentage of VI (500-1000 m^2) and VII (<500

m^2) green space patches. Overall, the total degree of landscape fragmentation and green space patch density are high in Hong Kong, and the pattern of green space is mainly characterized by small in size and scattered in spatial distribution, and therefore lacking of good connections. From these results from Hong Kong, we can gain some insights on problems of the urban green spaces planning and design in other high-density areas in the world., moreover, these results also shed light on the issues of connectivity and accessibility of urban green spaces, which are significant indexes for improving urban green spaces and promoting the benefits of urban green spaces for the elderly.

Table 2. Statistics and landscape fragmentation index (LFI) for the green space patches in different scale in Hong Kong.

	Green Space Patches							Total	Green Space Patch Density (per km^2)
	I >100000 m^2	II 50000-100000 m^2	III 10000-50000 m^2	IV 5000-10000 m^2	V 1000-5000 m^2	VI 500-1000 m^2	VII <500 m^2		
Number	32	37	287	207	894	748	730	2935	22.9
Percentage	1.1 %	1.3 %	9.8 %	7.05 %	30.5%	25.5 %	24.9 %	100 %	--
Average Area (m^2)	310735	69851	22511	7013	2194	692	297	7809	--
LFI	0.0001	0.0005	0.01	0.03	0.41	1.08	2.45	0.38	--

4.2. Accessibility Analysis of Urban Green Space in Hong Kong

Based on the road networks and green space patches of Hong Kong, this study implemented the accessibility analysis based on two different metrics, (1) in terms of distance by increasing the radius of buffer region around green spaces from 0m-5000m, including 6 categories (0-100m, 100-300m, 300-500m, 500-1000m, 1000-3000m and 3000-5000m), and (2) in terms of walking time by assuming an average walking speed of elderly, 0.88m/s[17,18]. The accessibility maps are shown in Figure 2 and Figure 3, respectively, for distance and walking time. The spatial pattern of these accessibility data well correspond to the spatial distribution of green space patches shown in Figure 1. We can see from the maps that the accessibilities to green space patches are very non-uniform. In some areas with high population density, such as Kowloon, the accessibility distance can be as high as 1000-3000m, which is about 20-60 min walking time for elderly to get the closest green patch. This distance is far beyond the recommendations from planning guidelines for green space accessibility as described in Section 2.3.

Table 3 shows the basic statistics of area coverage and the area ratio from the accessibility analysis based 6 categories of distances and walking time for elderly to get to urban green space patches in Hong Kong. As expected, longer distance requires longer travel time, and covers a larger area. Less than 10% of the area are within accessibility of 500m to green space patches, and the largest portion (43.1%) of the area has accessibility between 1000m and 3000m. A more detail results from accessibility analysis can be found in Table 4, which shows the ratios of accessibility area averaged over the 18 council districts in Hong Kong that can reach green spaces in 5 different elderly walking times and distances. From Table 4, we can see that the percentages of both 0-100m and 100-300m distance to urban green patches in the 18 council districts are very low, most below 5%. For the distance 300-500m, the proportion has increasing to 10%-30% for both Hong Kong Island and Kowloon, however, most of New Territories still less than 5%. From Table 4, we can see that, for the elder residents, (1) the result of green space accessibility from good to poor level is '*Kowloon > Hong Kong Island > New Territories',* which has the same trend of the LFI of the green space patches; (2) compared with Hong Kong Island and Kowloon Districts, according to different categories, there are appearing better accessibility in Kowloon District during the short travel time '*0-20 min*' and more accessible in Hong Kong Island District in longer travel time '*20-60 min*'; Overall, the accessibility to green space patches in Hong Kong Island and Kowloon is better than New Territories.

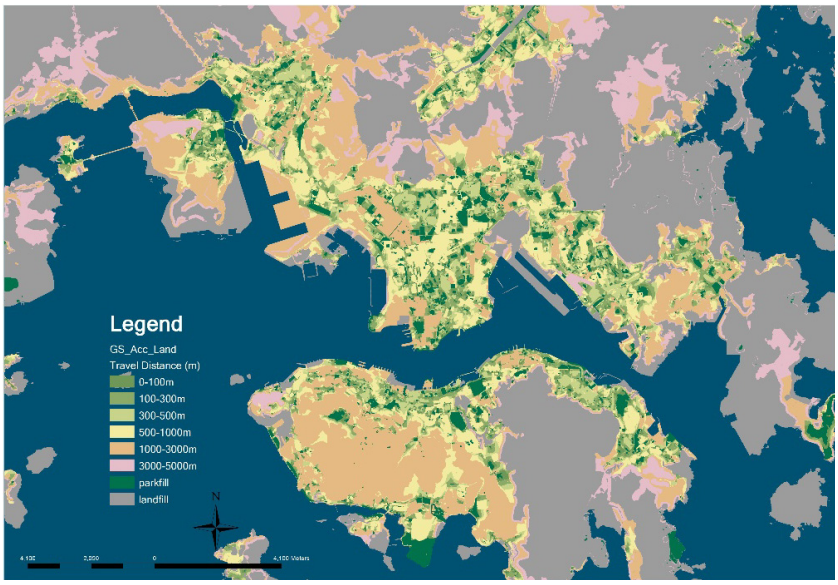

Fig. 2. Accessibility analysis of urban green space patches in terms of walking distance, by increasing the radius of buffer region around green space patches from 0m-5000m, including 6 categories (0-100m, 100-300m, 300-500m, 500-1000m, 1000-3000m and 3000-5000m).

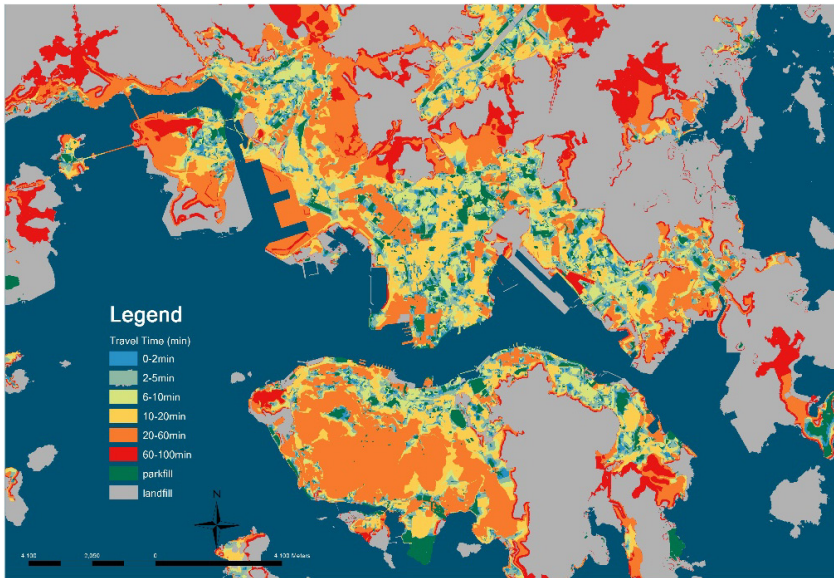

Fig. 3. Accessibility analysis of urban green space patches in terms of walking time, by assuming an average walking speed of elderly, 0.88m/s, including 6 categories (0-2min, 2-5min, 6-10min, 10-20min, 20-60min and 60-100min).

4.3. Suggestions on Planning and Design of Urban Green Space in Hong Kong

From the above results, we can see that (1) Kowloon has the highest LFI and accessibility, due to its largest proportion of small size but well scattered green space patches in the whole region. However, small size green space patches may not be good in good quality and therefore not as attractive as large size urban green space. We would

suggest the prior improvement in Kowloon in to have more green space with larger sizes; (2) New Territories, due to its large number of available lands, has the largest proportion of big size green space patches. However, they are limited by their poor accessibility. We would suggest the prior improvement in this region is to increase the green space accessibility either improving the walking routes or building more small to median size green space patches to cover the whole region.

Table 3. Statistics of area coverage and the area ratio from the accessibility analysis based 6 categories of distances and walking time for elderly.

	Travel Distance (*m*)	Travel Time (*min*)	Area (km^2)	Area Ratio (%)
01	0 - 100	0 - 2	23.7	0.9
02	100 - 300	2 - 5	38.8	1.5
03	300 - 500	6 - 10	100.0	3.9
04	500 - 1000	10 - 20	480.4	18.9
05	1000 - 3000	20 - 60	1093.6	43.1
06	3000 - 5000	60 - 100	798.7	31.5
Total	0 - 5000	0 -100	2535.2	--

Table 4. Ratios of accessibility area from the accessibility analysis averaged over the 18 council districts in Hong Kong in terms of both distance and elderly walking time are shown.

District Council District		Area (km^2)	0-100m (0-2 min) (%)	100-300m (2-5 min) (%)	300-500m (6-10 min) (%)	500-1000m (10-20 min) (%)	1000-3000m (20-60 min) (%)
Hong Kong Island		80.4					
HK 01	Central & Western	12.4	4.8	1.1	10.1	17.1	60.1
HK 02	Wan Chai	9.9	7.1	2.1	14.0	31.0	33.1
HK 03	Eastern	18.7	5.9	0.3	18.2	11.4	11.0
HK 04	Southern	39.4	3.5	1.3	1.2	11.2	21.3
Kowloon		46.8					
KLN 01	Yau Tsim Mong	6.9	12.9	1.8	29.7	28.8	24.1
KLN 02	Sham Shui Po	9.4	8.6	1.0	20.3	26.0	26.0
KLN 03	Kowloon City	10.0	9.5	1.4	19.8	37.8	9.7
KLN 04	Wong Tai Sin	9.3	7.6	1.5	28.2	12.1	16.5
KLN 05	Kwun Tong	11.3	9.1	0.3	34.0	25.2	14.9
New Territories							
NT 01	Kwai Tsing	22.2	4.8	0.7	12.2	23.5	38.3
NT 02	Tsuen Wan	61.0	1.1	1.0	2.5	2.6	8.0
NT 03	Tuen Mun	84.3	1.3	0.2	3.4	4.1	5.2
NT 04	Yuen Long	138.6	13.0	1.9	8.7	42.4	73.5
NT 05	North	136.6	1.9	1.1	3.9	2.2	5.9
NT 06	Tai Po	147.8	0.8	0.1	0.2	4.5	6.9
NT 07	Sha Tin	68.3	2.3	0.4	4.6	11.0	16.2
NT 08	Sai Kung	135.9	1.9	1.3	0.0	0.4	6.5
NT 09	Islands	174.7	0.9	0.4	0.0	0.5	0.1
Whole Territory Total		1096.6					

5. Conclusion

The aim of this study is to modeling and assessing the elderly accessibility to urban green spaces in Hong Kong, by (1) modeling urban green spaces available for elderly people using the landscape fragmentation index (LFI) of green space patches, and (2) accessibility analysis in terms of both distance and time for elderly people to get urban green space patches. As a result, regions with LFI from high to low and accessibility from good to poor are Kowloon, Hong Kong Island, and New Territories. Kowloon has the highest LFI and accessibility. However, it is limited by small size green space patches which may not be in good quality and attractive for elder people. New Territories, due to its large number of available lands, has the largest proportion of big size green space patches. However, they are limited by their poor accessibility. Based on these evidences, we would suggest the prior improvement (1) in Kowloon is to have more green spaces with larger sizes, (2) in New Territories is to increase the green space accessibility either by improving the walking routes or building more small to median size green space patches that can well cover the whole region.

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References

1. Woo, J. (2013). *Aging in Hong Kong: A Comparative Perspective*. New York: Springer Science & Business Media.
2. Cohen-Cline, H., Turkheimer, E., & Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. *Journal of epidemiology and community health, 69*(6), 523-529.
3. Coutts, C., Chapin, T., Horner, M., & Taylor, C. (2013). County-level effects of green space access on physical activity. *Journal of Physical Activity and Health, 10*(2), 232-240.
4. Barbosa, O., Tratalos, J. A., Armsworth, P. R., Davies, R. G., Fuller, R. A., Johnson, P., & Gaston, K. J. (2007). Who benefits from access to green space? A case study from Sheffield, UK. *Landscape and Urban Planning, 83*(2–3), 187-195.
5. Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L. J., Paus, T., & Berman, M. G. (2015). Neighborhood greenspace and health in a large urban center. *Scientific Report, 5*, 11610.
6. Iwarsson, S., & Ståhl, A. (2003). Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. *Disability and rehabilitation, 25*(2), 57-66.
7. Ng, E. (2009). Policies and technical guidelines for urban planning of high-density cities – air ventilation assessment (AVA) of Hong Kong. *Building and Environment, 44*(7), 1478-1488.
8. Chen, J., & Chang, Z. (2015). Rethinking urban green space accessibility: Evaluating and optimizing public transportation system through social network analysis in megacities. *Landscape and Urban Planning, 143*, 150-159.
9. Comber, A., Brunsdon, C., & Green, E. (2008). Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. *Landscape and Urban Planning, 86*(1), 103-114.
10. England, N. (2010). Nature nearby: accessible natural greenspace guidance. *Natural England: Peterborough*.
11. Harrison, C., Burgess, J., Millward, A., & Dawe, G. (1995). Accessible Natural Greenspace in Towns and Cities: A Review of Appropriate Size and Distance Criteria - Guidance for the Preparation of Strategies for Local Sustainability. *English Nature research reports,* 153.
12. Sarkar, C., Webster, C., Pryor, M., Tang, D., Melbourne, S., Zhang, X., & Jianzheng, L. (2015). Exploring associations between urban green, street design and walking: Results from the Greater London boroughs. *Landscape and Urban Planning, 143*, 112-125.
13. Department, H. (2015). Hong Kong Road Network. https://www.hyd.gov.hk/en/road_and_railway/existing/road_network/road.html.
14. Oh, K., & Jeong, S. (2007). Assessing the spatial distribution of urban parks using GIS. *Landscape and Urban Planning, 82*(1–2), 25-32.
15. Turner, M. G. (1990). Spatial and temporal analysis of landscape patterns. *Landscape ecology, 4*(1), 21-30.
16. Zeng, H., & Wu, X. B. (2005). Utilities of edge-based metrics for studying landscape fragmentation. *Computers, Environment and Urban Systems, 29*(2), 159-178.
17. Bendall, M., Bassey, E., & Pearson, M. (1989). Factors affecting walking speed of elderly people. *Age and Ageing, 18*(5), 327-332.
18. Bohannon, R. W. (1997). Comfortable and maximum walking speed of adults aged 20—79 years: reference values and determinants. *Age and Ageing, 26*(1), 15-19.