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EVALUATING SERVICE FUNCTIONS OF URBAN GREEN SPACE: A CASE STUDY IN KOWLOON, HONG KONG

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ABSTRACT

Nowadays, urban green space plays an important role in providing service functions for residents from the adjacent neighborhoods. Especially under the hyper-dense circumstances in Hong Kong, urban green space offers multiple functions for citizens, such as evacuation functions, traffic carrying capacity, and entertainment functions. This paper aims to evaluate the urban green space functions by using evaluating indicators for the neighborhood parks, and by analyzing data with ArcGIS 10 in order to obtain accurate data and evaluation results. This is achieved by analyzing the influencing factors for improving the service functions of urban green space, in order to provide technical and data support for planners and governments in elaborating and making full use of the urban green space service functions in the coming years

Keywords: urban green space; green space index; evacuation ability index; service population index; accessibility.

1. INTRODUCTION

Urban green spaces or open spaces play a critical role in sustaining urban natural environments and the social systems that use these spaces [1,2]. Urban green spaces are indispensable bridges between humans and nature as they are the primary pre-servers of biodiversity in cities [3]. There are many functions for the urban green space, such as the eco function, recreation function and providing seismic refuge for evacuation [4].

There are many studies that research the function of the green space and its distribution based on GIS [5]. In 2008 a study shows how a GIS-based network analysis in conjunction with statistical analysis of socio-economic data can be used to analyze the equity of access to community goods and services [6]. The accessibility and equity indexes are effective to appraise the structure of urban green space [7,8]. Zhang Lulu combined above indexes with the evacuation function and created complete system for assessing the urban green space in Shanghai, China [9]. The function of urban green areas needs the scientific evaluation during the rapid development of green areas building in China [10].

The purpose of the neighborhood park is to provide an attractive neighborhood setting and a place for passive recreation for people of all ages [11, 12]. The type of neighborhood influences to a great extent the particular need for neighborhood park space in relation to playground acreage (Table 1). Population density is a significant factor in determining needed neighborhood park space [13]. Several studies recommend that more space should be provided in multifamily, namely high population density neighborhoods [14].

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 1: The neighborhood parks standard [15]

	Min. Acreage Per 1,000 Pop.	Min. Area	Area for Best Results	Age Group Served	Population Served	Service Radius	Min. Area Necessary
A.P.H.A. **One or two family**	3.5 for 5,000; 1.5 for 1,000	1.5 to 3.5		1,000 to 5,000			1 1/2 to 2 acres
A.P.H.A. **Multifamily**	6.0 for 5,000; 2 for 1,000	2.0 to 6.0					
National Recreation Assoc.	1 acre	Not applicable 1/2 to 25 range	All	4,000 to 6,000	Central	Easy walking distance (1/2 mile)	
Local Planning Admin.	1 acre	1/2 to 2 when part of playground; 7 if by itself	All	4,000 to 7,000	Central; In connection with playground	Easy walking distance (1/2 mile)	
Athletic Institute		10	All		Central; Small if connected to a school	Walking distance	
Recreation & the Town Plan (Conn.)	1 acre	Varies with population density	All		Central; Small if connected to a school	Walking distance	7 acres if not adjoining playground or field

The related technologies and ideas of remote sensing and geographic information system, combined with the existing evaluation index system, are put forward to measure the urban public green space, namely urban public green space accessibility index [16], service population index [17], evacuating ability index, and green space basic conditions index, which can better reflect the function of urban public green space.

2. STUDY AREA AND DATA

2.1 Study Area

Desirable features for the neighborhood park include: open lawn area; trees and shrubbery; tables and benches for quiet games; walks and shade areas; ornamental pool, fountain, or sundial; play apparatus for children (optional); shelter building with game room, storage, and toilet facilities; multi-purpose, all weather court area; spray basin or wading pool [15,18]. According to the above standards and requirements, five parks in the study area were selected as shown in Figure 1.

Promenade Park is a seaside park located in the Kowloon Waterfront Bay, a place that can enjoy Victoria Harbour view freely. With a total length of about 250 meters, the park is connected to Tsim Sha Tsui waterfront garden extension part and has three entrances. It provides rubber runways which attract a lot of evening joggers. Ko Shan Road Park is located in Ko Shan Road, Hung Hom, Kowloon, and it is famous for its Ko Shan Theatre. The site is formerly an abandoned stone pit, redesigned in 1982 into a park with a football field, playground and other facilities.

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Impact Factor: 5.164
CODEN: IJESS7

Hutchison Park locates in the large part of the public park areas in Kowloon. Adjacent to the private residence, it is a classical Chinese garden with natural design. The park contains ponds, walking trails and other landscape facilities.

Hoi Sham Park is located in To Kwa Wan Hill Road, Kowloon, was officially opened in 1972. It contains a sea pavilion, two football fields and a children's playground. Karaoke machines are also included, which brings entertainment, but causes noise problems as well.

Ho Man Tin Park is located in Chung Yee ST, Kowloon, adjacent to Ho Man Tin stadium. It has multiple fitness equipment, two basketball courts, a football field and a jogging path.

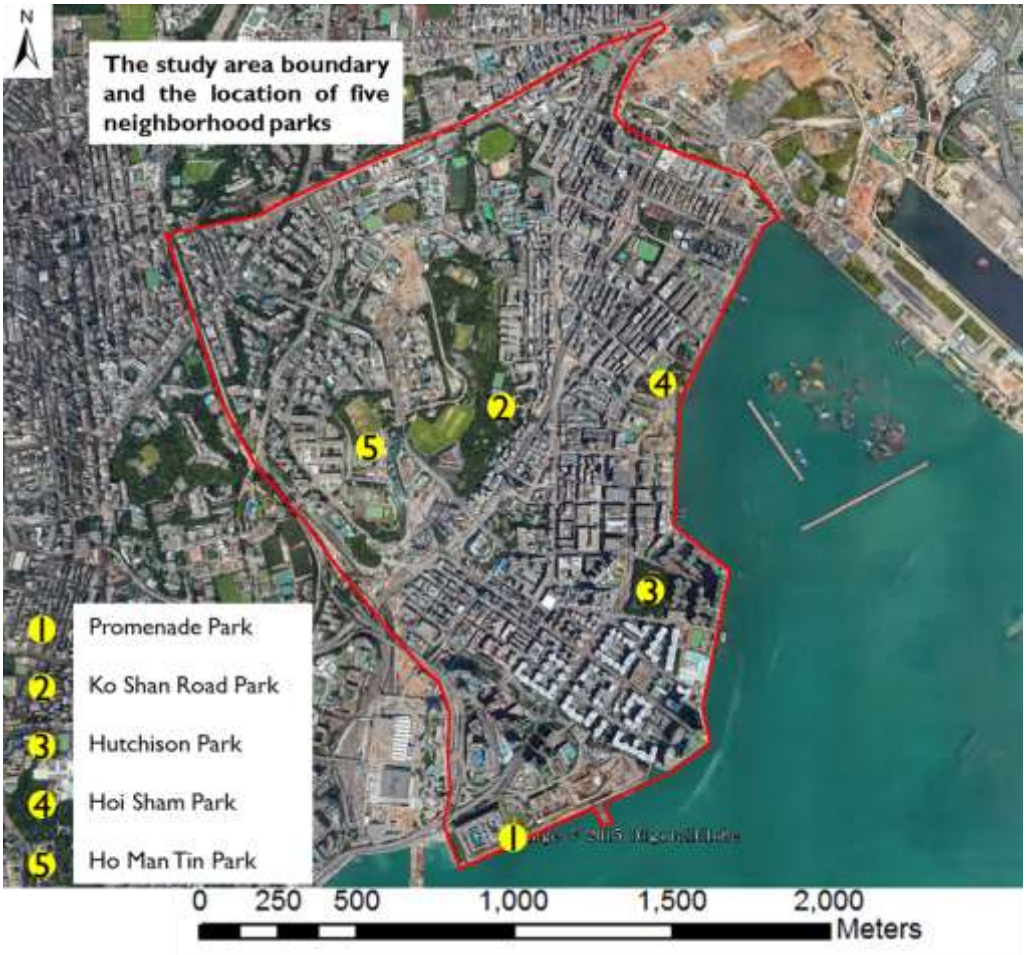

Figure 1: The study area boundary and the location of five neighborhood parks.

2.2 Data Collection

The study area of Kowloon is the largest and the most densely residential population area in Hong Kong. The total area of the study is approximately 4.29 km² and the population was 302,865 in 2011 [19]. There are five neighborhood parks in this area. The locations and areas of these parks can be found in Google Map. There are 172 communities in total, according to the 2011 census of Hong Kong, and the points with population attributes are used to substitute the communities (Figure 3). The sources and numbers of the collected data are shown in Table 2.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 2: Data types and sources

Data types	Sources	Numbers
Communities population	Centamap (2011 population census)	172 communities
Roads and blocks	Open Street Map	All the road in the study area
Parks	Google map	5 community parks

Figure 2 shows the data preparation process from original data to attaching attribute data that includes population numbers and parks. Figure 3 shows the final result of the data preparation.

Figure 2. Data processing.

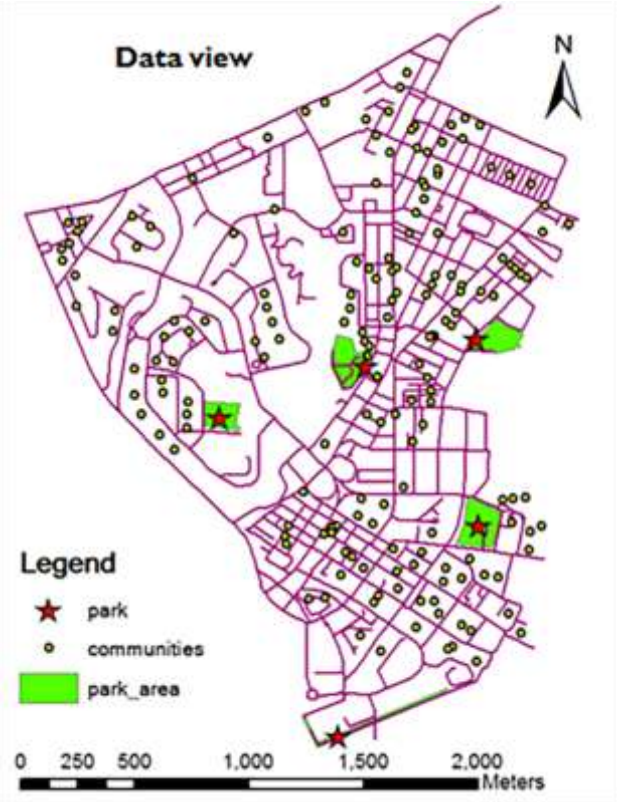

Figure 3: Data view

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

3. METHODS

3.1 Constructing the Road Network Module

Network analysis is a useful tool in analyzing water distribution, stream flows, and traffic flows, whereby centers, links, nodes, and impedance are key elements in that analysis [19].

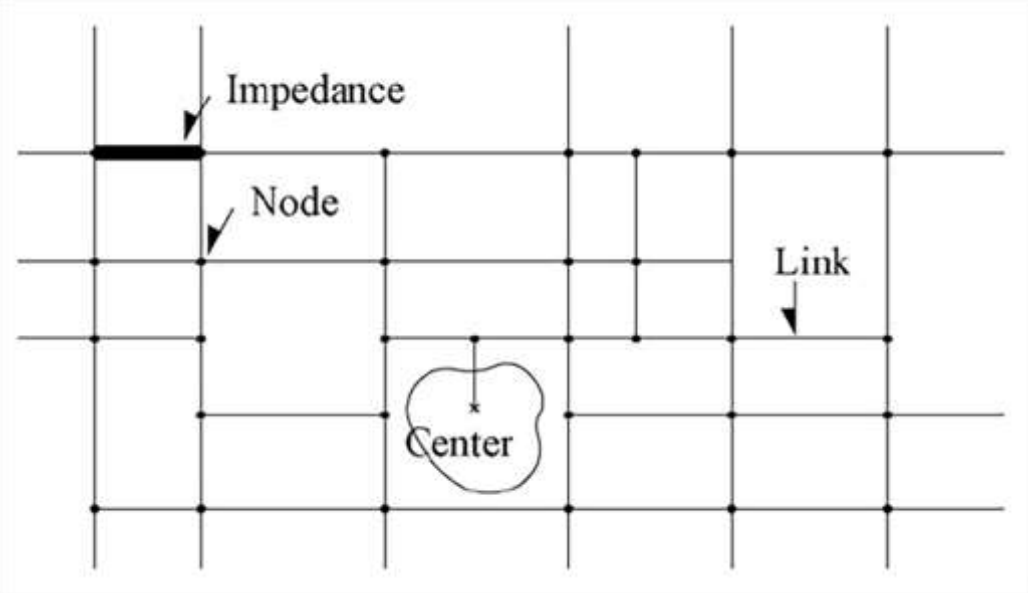

Figure 4: Elements of network analysis [20]

The road data to construct the simple road network are taking into account the pedestrian factors [21]. In this research, centers are defined as the central locations for residential population to use or distribute resources, which are viewed as the neighborhood parks. Links are pedestrian roads that connect the communities to the parks. Nodes are intersections of the links. In a more complex situation the nodes impedance can be set which refers to barriers that prevent people along the links. There are many kinds of impedance such as crosswalks, overpasses and underpasses. Normal walking speed is considered to be 1 m/s upslope and 1.5 m/s downslope in transportation engineering. In this study, the walking speed was set as 1.25 m/s. Finally the network analysis can be used to calculate the walking time from a community point to a neighborhood park and provide the boundaries of service areas of neighborhood parks where residents can reach them within a certain amount of walking time through actual roads. Figure 5 shows the result of the road network module and the attribute that contains the length and walking time.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Figure 5: Road network module.

3.2 Use of OD Analysis to Evaluate the Traffic Accessibility

Accessibility is a quantitative expression of the desire and ability of residents to overcome the distance, travel time and cost to arrive at a service facility or activity place [22]. If the accessibility is good, it shows that the green space has great potential for residents, that is, the service function is strong, and vice versa [23].
There are many kinds of calculation methods, such as buffer zone analysis, minimum distance, travel cost, and gravity index (Table 3).

Table 3: Main methods for measuring accessibility

Method	Brief Description
Buffer zone	Calculate the number of urban green spaces within a certain point or area within a certain radius or the number of certain elements (such as residential area) within a certain range of the urban green space.
Minimum distance	Calculate the linear distance (Euclidean distance) of a point to the nearest urban green space.
Travel cost	Calculate the time or the cost (usually time and money) from a point or area to urban green space.
Gravity index	It is based on the theory of universal gravitation between the material, so the index not only considers the impact of distance, but also considers the impact of the city's own size or other characteristics.

This paper adopted the travel cost of time method to calculate the accessibility of these five parks. The traffic accessibility was evaluated based on average walking time from the communities to nearest green space with the help of OD analysis in network analysis.

Accessibility evaluation is based on the previous road network database. With the GIS software of network analysis module [24], select original point and destination point, the corresponding shortest path will be produced. The shortest path algorithm is based on Dijkstra algorithm.

3.3 Establishment of the neighborhood parks service population indices

The service population of parks is an important index in green space evaluation. Considering the need of the surrounding residents, five 4-ring buffers are created along the road traffic network based on average walking

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

time of 5, 10, 20, 30 minutes from the centers (parks). The area of different service radius is obtained using the service area analysis module of ArcGIS. Finally, the number of people covered by each area is calculated.

The results obtained for the five parks will be compared with each other, and recommendations will be given. For instance, if there are blind service areas of green space, the analysis of possible causes may contribute to the improvement of green space, road network and residential distribution.

3.4 On-site survey

The on-site survey was conducted on 13th November 2015 by the group of three members, for two purposes, firstly to select samples to test the actual shortest walking time calculated by GIS OD analysis and secondly the group members scored the basic conditions of the five parks individually to evaluate the basic condition indices.

3.5 Expert grading method

A qualitative method to describe quantitative situation is done by selecting several evaluation projects according to the specific requirements of the evaluation, then based on evaluation criteria several representative experts give their scores by virtue of their own experience.

3.6 Weight calculation

The method of calculating the index value by weighting is the weight calculation method. Statistics suggest that it is more scientific and accurate that weights can be given in order to take into account the importance of each item. Thus, this paper aims to apply the weight calculation method for the calculation of the overall scores based on a weighted combination of the four functions' sub scores.

4. RESULTS

4.1 Accessibility of the Neighborhood Park

4.1.1 Operation process

The operation process consists of building a new OD cost matrix and loading the community points as the origins and the park points as the destinations. Solving the process brings the results as shown in the Figure 6.

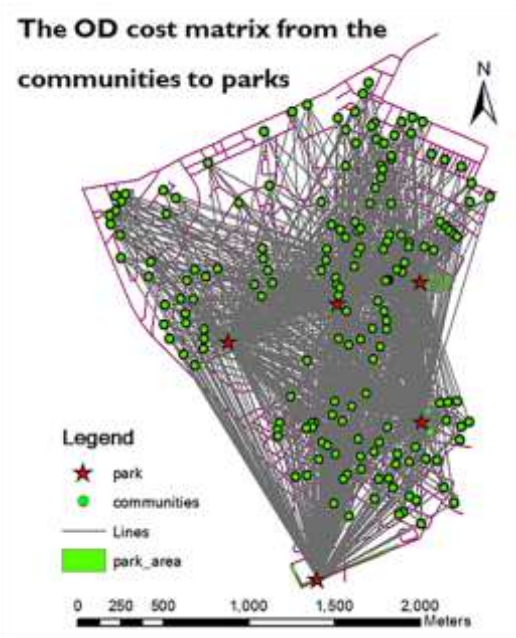

Figure 6: The OD cost matrix from the communities to parks.

The shortest time from the communities to the park is between 0.5 minutes to 47 minutes. The time is divided into five classes according to the distance from communities to parks. (Table 4)

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 4: Main methods for measuring accessibility

The shortest time	Scores
0-5 min	5
5-10 min	4
10-20 min	3
20-30 min	2
＞30 min	1

4.1.2 Results

The final score of these five parks (Table 5) is calculated with the help of Excel. It can be seen that the Ko Shan Road that lies in the center of the study area gets the highest score, while the Promenade Park that is located in the border of the study area gets the lowest score.

Table 5: The index of accessibility

Park	Accessibility Index
Promenade Park	1.70
Ko Shan Road Park	3.14
Hutchison Park	2.40
Hoi Sham Park	2.94
Ho Man Tin Park	2.18

4.1.3 Results testing

Five parks and five communities were chosen to test the operation results in an on-site survey. The on-site survey route is shown in Figure 7.

Figure 7: The on-site survey route.

The actual time used from communities to a park was recorded and compared to the predicted time using the network analysis in GIS (Table 6), using the following formula

$$a = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(T_p - T_a)^2} \quad (1)$$

The deviation of the predicted time from the actual time is 1.25 minutes.
The numerical results show that the calculation results of the model are close to that of the testing. The numerical results show that the calculation results of the model are close to that of the testing.

Table 6: The comparison between the module and reality

Number	Route	Predicted Time	Actual Time
1-2	KC0257-HMT	28′24″	32′
2-3	HMT-KC0231	14′20″	13′46″
3-4	KC0231-KSR	14′20″	14′40″
4-5	KSR-KC0049	7′24″	10′
5-6	KC0049-HS	4′48″	4′20″
6-7	HS-KC0063	7′54″	8′46″
7-8	KC0063-Hu	12′30″	13′
8-9	Hu-KC0226	10′20″	10′57″
9-10	KC0226-Pro	9′12″	6′55″

4.1.4 Discussions

In the downtown area between the point 1 and point 2 there are five traffic lights and each takes almost one minute. Also, the crowd and the narrow pedestrian streets are another factor that results in the actual time being longer than predicted time. From point 4 to point 5 we encountered the blocked road due to the construction of

the subway. From point 9 to point 10 there are several entrances to the Promenade Park. We reached the nearest entrance in almost 7 minutes.

In conclusion, traffic light, the crowd, pedestrian conditions and road conditions can affect the actual time. Also, walking velocity may change due to the road slope and individual differences. Park with more than one entrance in different directions can improve the accessibility.

4.2 Service Population Analysis

4.2.1 Operation process

Firstly, the Road Network Analyst is created as the basis of service population analysis, and the park layer including five parts of green space was also needed (Figure 8).

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

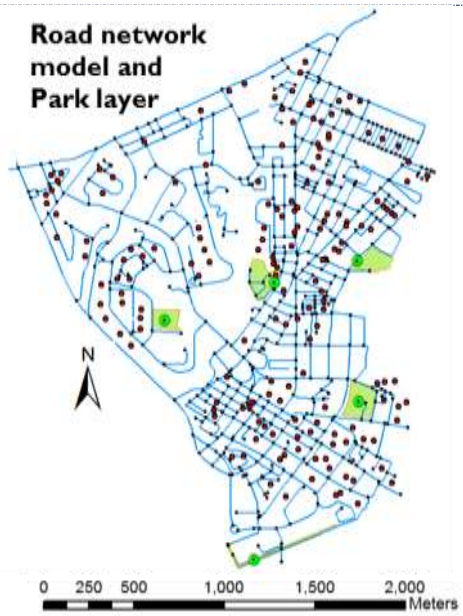

Figure 8: Road network model and Park layer

Next, five service areas are created and the location of facilities is defined in accordance with the elements of parks. "Parks" layer is chosen when loading position to ensure that the buffers take the five parks as the centers. Five four-ring buffers are created (Figures 9) respectively along the road traffic network, based on average walking time of 5, 10, 20, and 30 minutes from the centers.

The Table 7 shows the total covered population within a certain walking time distance from a park. The final service population index is graded (Table 6) based on the scoring standard (Table 8).

Table 7: Population in different walking time radius of neighborhood parks (unit: person)

Name	< 5 min	< 10 min	< 20 min	< 30 min
Promenade Park	0	7443	76861	120480
Ko Shan Road Park	17513	71279	240565	302865
Hutchison Park	1907	46176	118577	241148
Hoi Sham Park	29950	73184	188298	289505
Ho Man Tin Park	5422	22325	86255	238052

Table 8. Scoring standard

Score	< 5 min	< 10 min	< 20 min	< 30 min
1	5000	10000	50000	100000
2	10000	20000	100000	150000
3	15000	30000	150000	200000
4	20000	50000	200000	250000
5	> 20000	> 50000	> 200000	> 250000

4.2.2 Results

The sort of service population index is "Ko Shan Road Park = Hoi Sham Park > Hutchison Park > Ho Man Tin Park > Promenade Park".

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 9: Service population index

Name	Average Score
Promenade Park	1.5
Ko Shan Road Park	4.75
Hutchison Park	3
Hoi Sham Park	4.75
Ho Man Tin Park	2.75

4.2.3. Discussions

According to the results of the study (Figure 9), three main factors influence the final score: 1) Location: Ko Shan Road is located in the central area and it is surrounded by communities, so compared with Promenade which is near the sea, the service population of Ko Shan Road is larger; 2) Road network density: the road network density of Hoi Sham and Ko Shan Road is obviously higher than Promenade and Ho Man Tin, so the corresponding purple areas differ in size; and 3) Population density: the number of communities close to Hutchison, Ko Shan Road and Hoi Sham are more than the other two, so their service area is larger.

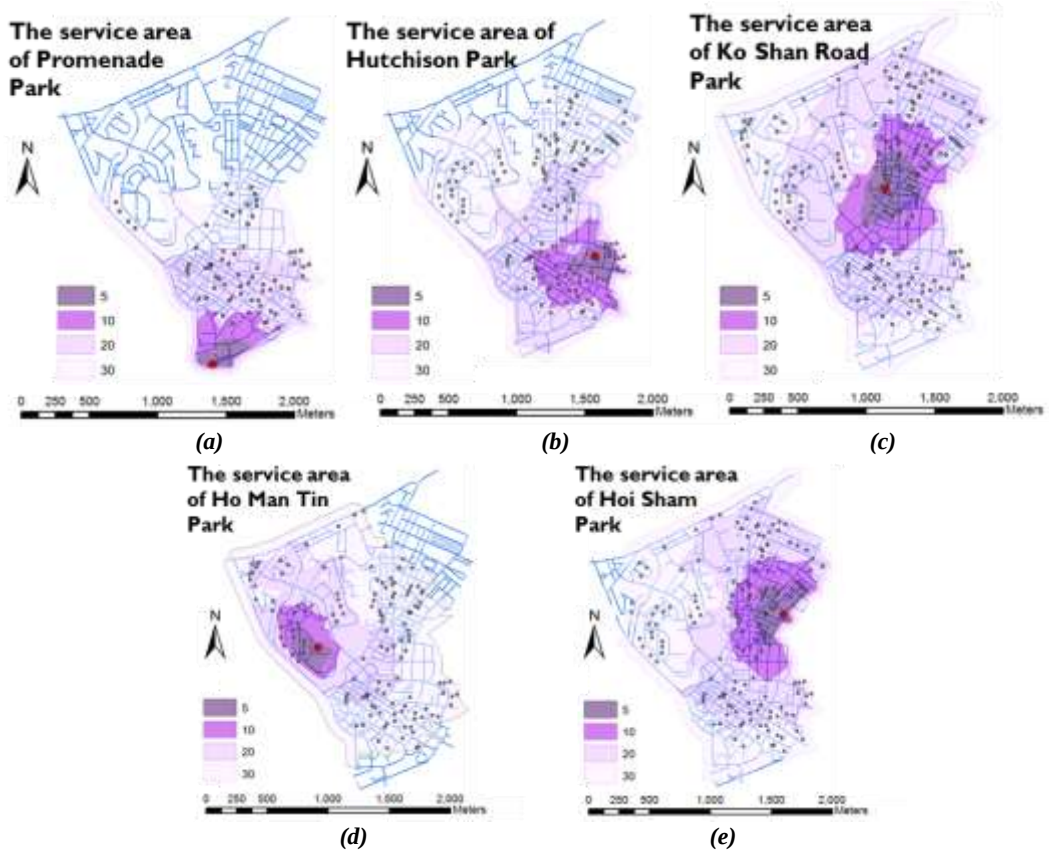

Figure 9: The service area of each park: (a) Promenade Park; (b) Hutchison Park; (c) Ko Shan Road Park; (d) Ho Man Tin Park; (e) Hoi Sham Park.

Table 10: Population and communities in 5 min and 10 min walking time radius of neighborhood parks

	< 5 min		< 10 min	
Name	**Communities**	**Population**	**Communities**	**Population**
Promenade Park	0	0	3	7443
Ko Shan Road Park	12	17513	44	71279
Hutchison Park	1	1907	26	46176

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Hoi Sham Park	18	29950	45	73184
Ho Man Tin Park	3	5422	13	22325

Figure 10 shows two parts of blind area; the main reason may be the separation by mountain for the upper one. For the improvement of the other one, new parks should be constructed and the surrounding road network density should be improved to meet the needs of residents.

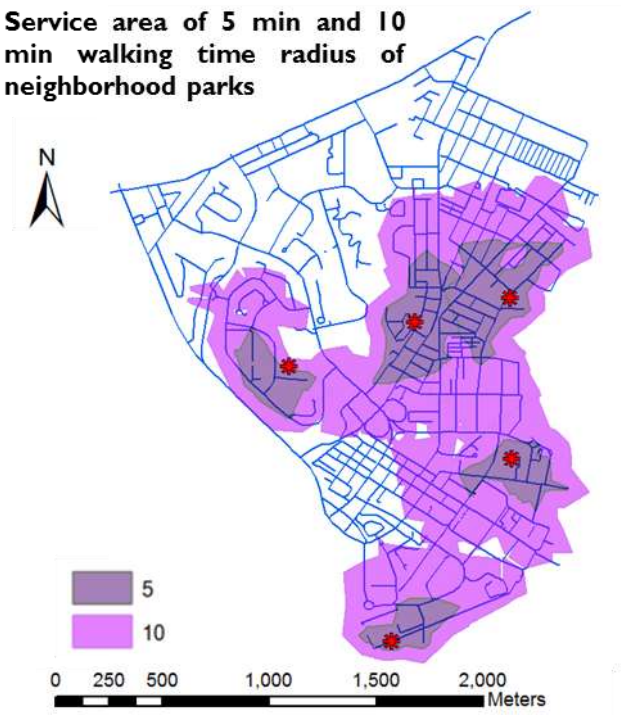

Figure 10: Service area of 5 min and 10 min walking time radius of neighborhood parks.

4.3 Evacuating Ability Index

Evacuation ability reflects the ability of urban public green space in emergency and disaster alleviation [25]. When the disaster occurs, the larger the area of urban public green space is, the more population it contains. And the walking time to the public green space is also an important factor. The less time it requires, the greater chance is that people will survive [26]. In order to better evaluate the ability of the urban public green space, we introduce the general gravity model of the space interaction model. Considering that the evacuation ability and park area are in the direct ratio, and the time to reach the park is inversely proportional to the evacuation ability, the formula below was used to calculate the evacuation index.

Index=Area/Time

(Index represents the evacuation ability index. Area represents the park area. Time represents for the shortest walking time from communities to parks.)

The evacuation ability index is calculated by using the five parks' area divided by the walking times from the 172 residential areas separately by using the above formula.

From the distribution and the numeric size of the index, five levels are set to grade each park (Table 11). Then, each park's average score is calculated and sorted from high to low (Table 12).

Table 11: Scoring standard

INDEX	**>5000**	**2000-5000**	**1000-2000**	**500-1000**	**<500**
SCORE	5	4	3	2	1

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 13 shows that Hoi Sham Park reaches the highest score of 4.13 and Promenade Park has the lowest score of 1.46. The higher the score, the better the evacuation ability is. In conclusion, the evacuation ability from great to poor is Hoi Sham Park, Ko Shan Road Park, Hutchison Park, Ho Man Tin Park and Promenade Park.

Table 12: Evacuation ability index

Name	Evacuation Ability Index
Hoi Sham Park	4.13
Ko Shan Road Park	3.50
Hutchison Park	3.12
Ho Man Tin Park	2.03
Promenade Park	1.46

From the perspective of emergency disaster prevention, public green space evacuation capacity should be increased, along with the increase of population; otherwise, when the district has a larger population, the shortage of shelters, facilities and other goods would be caused. So far, the layout and scale of public green space in this area still need to be further adjusted.

4.4 Green Space Basic Conditions Index

To better evaluate the green space basic condition, the on-site survey method was adopted. This on-site survey is not only convenient to investigate the green space basic conditions, but also provides a way in examining the actual walking time from residential areas to the parks [27]. Under this consideration, ten spots were chosen to be the object destinations, five of which are parks and five are communities. One community connects to a park, and then links to another community. The order of the route is Royal Peninsula, Ho Man Tin Park, Ho Man Tin Estate, Ko Shan Road Park, To Kwa Wan Building, Hoi Sham Park, Hung Hom Garden, Hutchison Park, Willow Mansions and Promenade Park.

After careful observation during the process, five green spaces have their own characters. Ho Man Tin Park is relatively small, but equipped with a variety of facilities like football court, basketball court, running path exercising facilities and a playing area. Ko Shan Road Park has plenty of facilities with large areas, but the venue is not open enough, and the large numbers of footsteps are not suitable for the elderly and children. Promenade Park provides simple activities just for runners and walkers, but coastal environment is extremely

comfortable. Hoi Sham Park is extremely rich with activities. The elderly gather together to play chess and cards while many people sing on the square using the karaoke equipment. Hutchison Park is a traditional Chinese style park with good scenery and quiet environment.

From the Table 13, it can be easily seen that Hoi Sham Park reaches the highest score of 4.00 and Ko Shan Road has the lowest score of 2.73. The higher the score, the better green space basic conditions it has. In conclusion, the green space basic conditions from great to poor are Hoi Sham Park, Hutchison Park, Promenade Park, Ho Man Tin Park and Ko Shan Road Park.

4.5 Results

A comprehensive evaluation of neighborhood parks is conducted considering the functions of parks. Instead of doing questionnaires about the weight selection by residents of urban areas, a group discussion was used on the communication process due to a number of factors. Accessibility index, service population index, evacuation ability index and green space basic conditions index are attributed to the different weights: 0.3, 0.3, 0.2, and 0.2.

Table13: The service function score of the five neighborhood parks

Score	Accessibility Index	Service Population Index	Evacuation Ability Index	Green Space Basic Conditions Index	Overall Score
Promenade Park	1.70	1.50	1.46	3.60	1.972
Ko Shan Road Park	3.14	4.75	3.50	2.73	3.617
Hutchison Park	2.40	3.00	3.12	3.67	2.978

ISSN: 2277-9655
Impact Factor: 5.164
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Hoi Sham Park	2.94	4.75	4.13	4.00	3.933
Ho Man Tin Park	2.18	2.75	2.03	3.33	2.551

The final results show that in the selected neighborhood parks the service function of Hoi Sham Park and Ko Shan Road Park is strong (Table 13). This is mainly because these two parks are located in the center of the communities, the traffic accessibility is good, the surrounding residential population density is high, the area can cover more people, and the green space area is large. However, the Promenade Park has low traffic accessibility and service area can accommodate a small population due to its coastal location and commercial land use, which results in poor service function.

5. DISCUSSIONS

One of the advantages of neighborhood parks with higher scores is the location. Ko Shan Road Park and Hutchison Park are close to many communities and are well connected, which have the highest accessibility and service population score. For neighborhood parks, location should be avoided in marginalized area, in order to serve and accommodate more residents. Promenade Park, due to the particularity of its location, offshore and surrounded by high-end community or hotel business, is located far from community areas which results in relatively low levels of accessibility and service population, and these lead their functions to be urban parks and landscape parks.

In addition to being a place for recreation and entertainment, urban neighborhood parks also serve as evacuation sites when disasters occur. From the perspective of park functions, in order to assess its evacuation capability, this study briefly selected time and space as two important indicators to score the parks. According to the evaluation result, there is a great difference in the score between parks. And this result has certain significance for the rational allocation of emergency space in the future.

The spatial quality is usually evaluated and felt by the user experience. According to the field observation and investigation, the study finds that a park which is environmentally friendly, well-equipped and rich in activities can be described as an excellent park. For instance, Hoi Sham Park and Ko Shan Road Park have basically the same ratings in terms of accessibility and service population. Among them, in the case of overall atmosphere, Hoi Sham Park is full of vitality, which attracting a large number of people. While as for Ko Shan Road Park, it has insufficient supporting facilities, and the walking environment is not very friendly as well, with too many

stairs and steps, and limited the barrier-free design. Thus, its overall vitality is much less than that of Hoi Sham Park. Therefore, in addition to the geographical location and the accessibility of traffic around the park, the park's facilities and environment should be paid to more attention and this is a place where the park needs special attention in its development, construction and operation.

6. CONCLUSIONS

6.1 Solutions for Improvements

In this paper, according to the evaluation results of the service functions of urban green space, certain conclusions are defined as:

1) Urban public green space may work much better if distributed in high residents population density area, which can not only meet the needs of the residents' daily recreation activities, but also can improve the evacuation ability of the park;

2) The design of urban public green space should be positioned as open or semi open design, and the number of the entrance for the parks should be increased, which creates convenience for residents to enter. Also, as a part of the urban traffic system, neighborhood parks may serve as a tool for eliminating the burden of urban road traffic system and provide convenience of accessibility for commuting;

3) The increase of the density of urban pedestrian paths and improvement of walking environment may highly improve the accessibility of neighborhood parks;

4) New green spaces should be built to meet the needs of the residents that live in the area which is more than 10 minutes' walk away from the existing parks.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

6.2 Effects of the Evaluation of Urban Green Space on Sustainable Urban Planning

Urban green space system planning has become an important part of urban planning [28], which can not only provide daily leisure and entertainment space for the residents, but also have important service functions, such as evacuation function and so on. During the planning process, the area, accessibility, entrance number and landscape ornamental value should be taken into serious consideration. Due to Hong Kong's high density community environment, the public function of green space carries more heavy weight [29]. To make the urban green space maximize its effectiveness, the land ratio, layout and greening effects should be considered within reasonable planning.

6.3 Limitations

More complex elements should be considered in building road network model, such as increasing obstacles and shortcuts to make the simulation more accurate.

In the road network, the neighborhood parks and communities are marked by points, which lead to the lack of fully consideration of the relationship between the gate of neighborhood park and road network.

In this practice, the evaluation system may be imperfect; other green space ability index should be considered as well.

The main research object of this practice is a part of residential area and urban neighborhood parks in Kowloon. The influences of green space outside the study area have not been considered.

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